Potential for efficient heating and cooling

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Summary

According to Article 14 of the Energy Efficiency Directive (Europäisches Parlament und Rat der Europäischen Union, 2012), Member States are required to submit a 'comprehensive assessment of the potential for efficient heating and cooling'. This report presents that comprehensive assessment as well as the associated data and analyses. The report is aligned with the requirements of Article 14(1) of the Energy Efficiency Directive (or Annex VIII according to the Commission Delegated Regulation of 4 March 2019 amending Annexes VIII and IX to Directive 2012/27/EU as regards the content of the comprehensive assessments of the potential for efficient heating and cooling), C(2019) 1616 final (Europäische Kommission, 2019a) as well as the corresponding recommendations of the Commission (Europäische Kommission, 2019b).

In accordance with the Commission's requirements, the structure of the report is as follows: After an introduction in Chapter 1, Chapter 2 (Part 1 according to Annex VIII of the Energy Efficiency Directive) gives an overview of the heating and cooling demand and supply in Austria. Chapter 3 (Part 2 according to Annex VIII) presents the existing targets, strategies and policy measures in this context (Europäisches Parlament and Rat der Europäischen Union, 2012). Chapter 4 analyses the economic potential for efficient heating and cooling supply. Lastly, Chapter 5 summarises potential and planned new strategies and strategic measures to tap the potential for efficient heating and cooling.

The reporting obligation to the European Commission includes, among other things, the regionalised representation of the heat demand and the determination of economic potentials in the period until 2030 as well as 2050. This map material as well as background data for the study are provided within the framework of the Austrian Heatmap. This was already created in 2015 as part of the study 'Assessment of the potential for the use of high-efficiency CHP and efficient district heating and cooling supply' (Büchele et al., 2015) in a first version and is now being updated with the current data as part of this study.

The economic potentials for different variants of efficient heating and cooling supply are strongly dependent on future framework conditions such as energy prices, CO_2 prices, whether external costs are considered, and achievable connection rates for district heating. To account for this, a large number of scenarios were calculated. For these variants, possible district heating regions were also explicitly identified geographically.

The basic assumption of the study is that the goal of (net) climate neutrality in Austria will be achieved between 2030 and 2050. This means that fossil energy sources still play a role in determining the economic potential for 2030, but no longer for 2050. For 2050, it is therefore assumed, among other things, that any demand for gas will be provided from renewable sources.

Under these assumptions, the following key statements can be made:

- The decarbonisation of the heating and cooling supply in Austria is possible, but only under some key assumptions and framework conditions, such as extensive efforts to renovate buildings, parallel decarbonisation of electricity generation and the successful integration of industrial waste (/excess) heat accompanied by the decarbonisation of industry.
- The share of district heating depends above all on the connection rate that can be achieved in the district heating regions, which in turn is strongly related to the spatial energy planning framework conditions. Depending on the achievable connection rate, an economic potential for district heating is calculated from about 20% to over 50%.

Concerning the technology mix of district heating supply, the following statements can be made:

- Under the assumptions made in this study, renewable gas does not prove to be a cost-effective option for decarbonising the sector.
- Biomass continues to represent a significant share of the renewable heat supply, both decentralised and in district heating. It can be observed that in the scenarios with low efficiency increases, the pressure on the use of biomass resources would increase very strongly.
- It can be seen that heat pumps play an essential role not only in decentralised applications, but also in district heating.
- The role of thermal power plants and CHPs in a future renewable electricity system was not the focus of this study. In the sense of high fuel utilisation, heat extraction from existing thermal power plants should definitely be strived for. Until 2050, however, the analyses show that gas-fired CHP plants will only be used with relatively low full load hours.
- Large solar thermal plants can be an economically viable option, although there is a strong dependence on the overall structure of the generation portfolio on the one hand, and on the achievable cost reductions on the other; these in turn scale strongly with the size of the plants.
- The use of large thermal storage systems is shown to contribute significantly to the economic operation of the heating networks. At the same time, there are significant uncertainties regarding the associated costs, which depend not least on the exact location.

Model-based analyses, such as those in this study, are always subject to uncertainties. On the one hand, these result from the possible cost development (including the locally existing site-specific conditions, which can lead to deviations in terms of costs), especially regarding large-scale thermal storage and solar thermal energy and the costs for land required for them, as well as deep geothermal (and the associated risks in the development). On the other hand, there are also uncertainties regarding technological developments and the efficiencies and corresponding technology characteristics that can be expected in the future. Furthermore, it is also evident that the interplay of the various renewable district heating technologies in the portfolio, also with the use of heat storage, is complex and strongly depends on the expected district heating demand. The expected heat demand is in turn strongly dependent on the measures concerning building renovation as well as on the achievable connection rates. Since these factors cannot be predicted in the long term, a continuously adapting planning process is required, both on the part of the heating network operators and on the part of policymakers.

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1 Introduction

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In 2015, TU Wien produced a study in collaboration with e-think and ecofys entitled 'Assessment of the potential for the use of high-efficiency CHP and efficient district heating and cooling supply' (Büchele et al., 2015). The project also encompassed the creation of the Austrian Heatmap, which has been available ever since at www.austrian-heatmap.gv.at. Although the current study is based on that 2015 report, adaptations and in some cases new methodological procedures were required as a result of the alteration and restructuring of the recommendations for carrying out the assessment.

Once again, the map material as well as background data for the study are provided within the framework of the Austrian Heatmap.

2 Overview of the heating and cooling supply in Austria

This chapter provides an overview of heating and cooling demand and the corresponding supply, both in the baseline year and under the various scenarios up to 2030 and 2050. Particular emphasis is placed on describing the current network-based heating supply. The corresponding data (Europäische Kommission, 2019b) can be found in Annex 6.4, in line with the Commission's recommendations.

2.1.1 Heating and cooling demand and supply in Austria

The analysis of useful energy carried out by Statistics Austria (Statistik Austria, 2018a) for the period up to 2018 was evaluated as a basis for describing the useful energy demand for the end-use sectors 'heating' and 'cooling'. To this end, the entire producing sector ('industry'), public and private services and all other economic sectors (both grouped together as 'commercial sector') and private households ('households') were evaluated. In each of these three defined sectors, the areas of useful energy generation that are relevant to the supply of heating and cooling were taken into account ('space heating and air-conditioning systems', 'steam generation' and 'industrial furnaces').

Figure 1 below shows the generation of useful energy for heating and cooling applications in the industry sector in Austria. It is readily apparent that the amount of useful energy generated over recent years for the areas of steam generation and industrial furnaces was around triple that generated for space heating and air-conditioning systems.

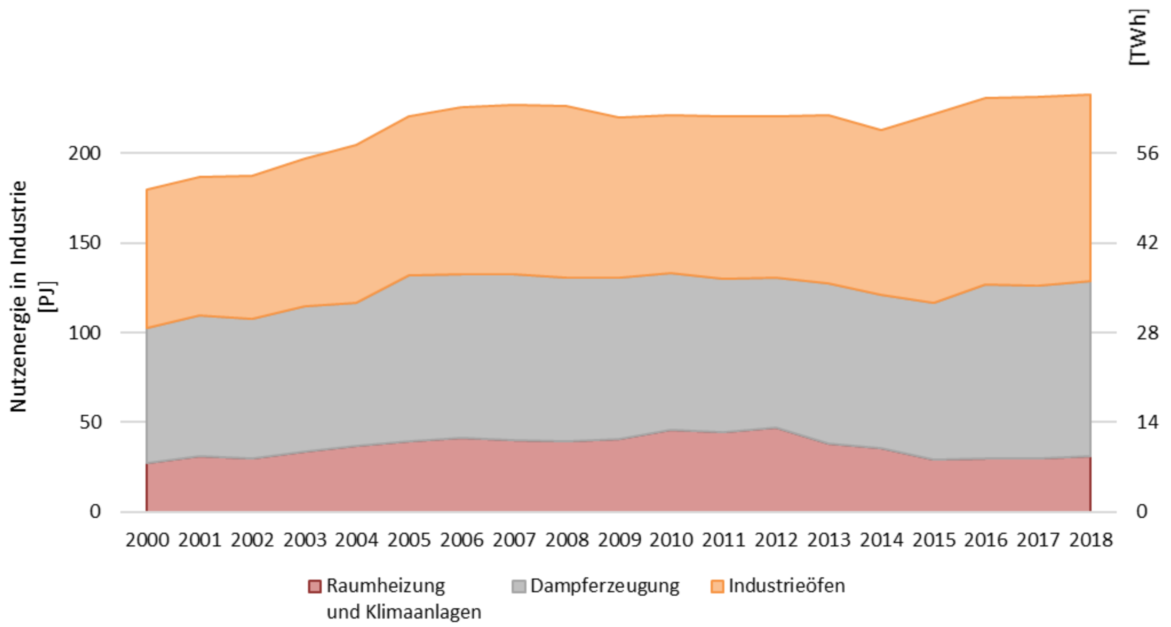

Figure 1: Generation of useful energy for heating and cooling applications in the industry sector in Austria (source: analysis of useful energy in Austria (1993 to 2018), Statistics Austria)

	[TWh]
	Useful energy in industry [PJ]
	Space heating and air-conditioning systems
	Steam generation
	Industrial furnaces

Figure 2 shows the generation of useful energy for heating and cooling applications in the sectors of public and private services and agriculture. By far the largest share is accounted for by space heating and air-conditioning systems. Although industrial furnaces also account for a significant share of useful energy demand in the commercial sector in Austria, steam generation plays a lesser role.

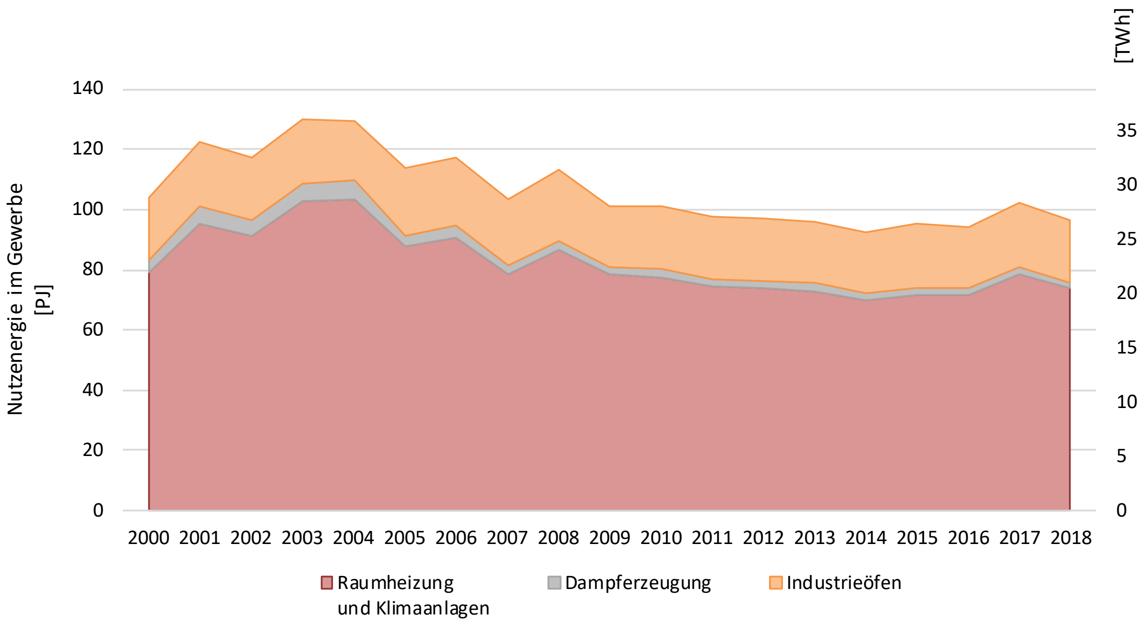

Figure 2: Generation of useful energy for heating and cooling applications in the commercial sector in Austria (source: analysis of useful energy in Austria (1993 to 2018), Statistics Austria)

	[TWh]
	Useful energy in the commercial sector [PJ]
	Space heating and air-conditioning systems
	Steam generation
	Industrial furnaces

Figure 3 shows the generation of useful energy in the heating and cooling sector for Austrian house-holds. Thermal energy is used in this sector for space heating and air-conditioning systems and for cooking purposes (categorised in the useful energy analysis as 'industrial furnaces'). There is no demand for steam by households in Austria.

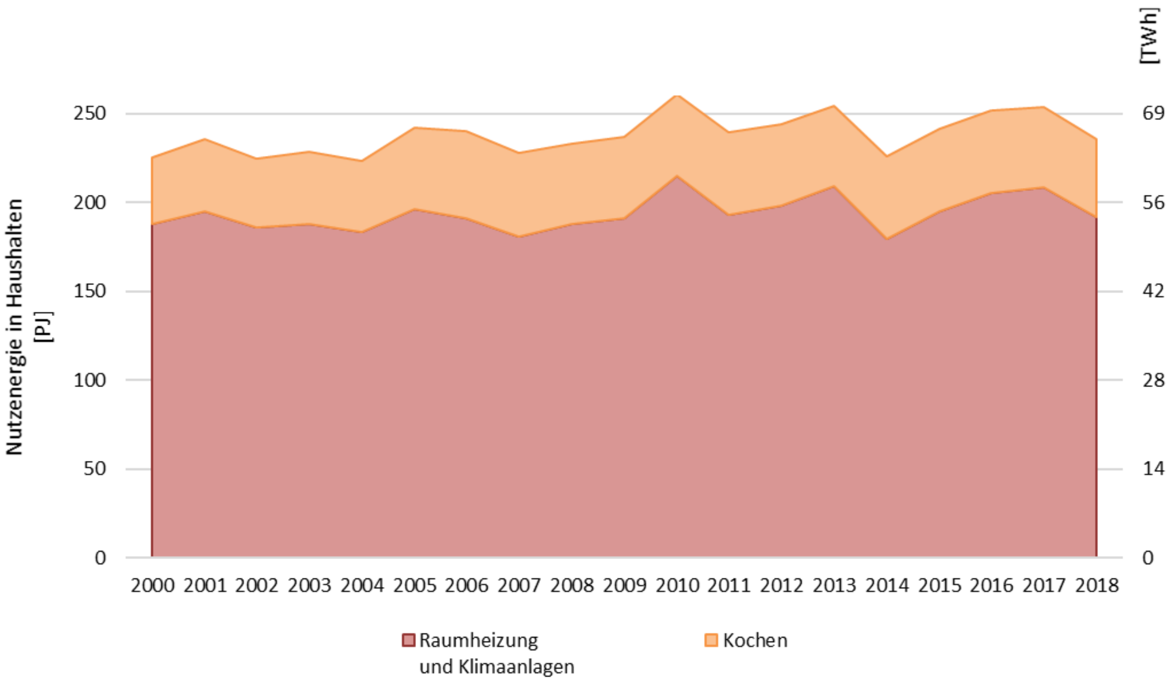

Figure 3: Generation of useful energy for heating and cooling applications in households in Austria (source: analysis of useful energy in Austria (1993 to 2018), Statistics Austria)

	[TWh]
	Useful energy in households [PJ]
	Space heating and air-conditioning systems
	Cooking

With a view to simplifying the reporting process in connection with the comprehensive assessment of the potential for efficient heating and cooling, the European Commission makes available a template and recommends its use (Europäische Kommission, 2020a). When using this template to report on the current heating and cooling supply, a distinction is made between energy provided on-site and energy provided off-site; the data are further broken down into sectors (residential, service, industrial and other sectors). Within each sector, the data are then broken down into fossil fuel sources and renewable energy sources (as well as further distinctions that are explained in the following description and can be seen in Table 1).

Energy provided on-site:

The values for pure heat generators ('heat-only boilers') and for 'other technologies' are taken from the current useful energy analysis by Statistics Austria (Statistik Austria, 2018a). It was assumed that 'high-efficiency CHP' is only used directly in the industrial sector, and plays a negligible role in terms of direct use in the residential, service and other sectors. The values for 'high-efficiency CHP' in the industrial sector were calculated using data taken from the overall energy balance produced by Statistics Austria (Statistik Austria, 2018b). The total energy quantities (according to the overall energy balance) supplied from on-site plants were converted into the corresponding heat quantities on the basis of data from operating statistics regarding the (electrical) efficiency levels of power plants (E-Control, 2019). The values for heat pumps are also taken from the overall energy balance (Statistik Austria, 2018b); the energy quantities included in this connection are equivalent to 'ambient heat etc.' minus 'solar heat' (or in other words 'ambient heat' and 'reaction heat'). The values specified for heat pumps are based on the assumption of an averaged coefficient of performance (COP) for all heat pumps in use (assumption: COP = 3).

Energy provided off-site:

According to the analyses by Moser and Lassacher, (2020), extracted waste heat in Austria amounts to around 1.8 TWh/a. Values for 'high-efficiency CHP' and 'other technologies' are taken from the overall energy balance (Statistik Austria, 2018b), whereby the energy quantities supplied by the energy utilities are included on a proportionate basis according to their sectoral allocation to district heating. The absence of data that could be used as a basis for allocating the fossil fuels or renewable fuels used in each case to different sectors meant that a pro rata distribution was assumed instead. Since there was a similar absence of data regarding the extent to which waste heat is generated using either renewable energies or fossil fuels, the following table makes no distinction in this respect.

Table 1: Current heating and cooling supply, 2018. Reporting based on the European Commission's template (sources: own analyses on the basis of (Statistik Austria, 2018a), (Statistik Austria, 2018b), (E-Control, 2019) and (Moser and Lassacher, 2020))

Energy provided on-site			Unit	Value
Residential sector	Fossil fuel sources	heat-only boilers	GWh/a	26 800
		Other technologies	GWh/a	4 739
		HECHP	GWh/a	0
	Renewable energy sources	heat-only boilers	GWh/a	18 918
		HECHP	GWh/a	0
		Heat pumps	GWh/a	2 636
		Other technologies	GWh/a	4 073
Service sector	Fossil fuel sources	heat-only boilers	GWh/a	5 441
		Other technologies	GWh/a	4 756
		HECHP	GWh/a	0
	Renewable energy sources	heat-only boilers	GWh/a	885
		HECHP	GWh/a	0
		Heat pumps	GWh/a	2 568
		Other technologies	GWh/a	3 564
Industrial sector	Fossil fuel sources	heat-only boilers	GWh/a	36 326
		Other technologies	GWh/a	4 234
		HECHP	GWh/a	889
	Renewable energy sources	heat-only boilers	GWh/a	17 307
		HECHP	GWh/a	898
		Heat pumps	GWh/a	116
		Other technologies	GWh/a	2 489
Other sectors	Fossil fuel sources	heat-only boilers	GWh/a	329
		Other technologies	GWh/a	231
		HECHP	GWh/a	0
	Renewable energy sources	heat-only boilers	GWh/a	1 865
		HECHP	GWh/a	0
		Heat pumps	GWh/a	38
		Other technologies	GWh/a	165

Energy provided off-site				
Residential sector	Fossil fuel sources	HECHP	GWh/a	3 393
		Other technologies	GWh/a	1 249
	Renewable energy sources	HECHP	GWh/a	1 636
		Other technologies	GWh/a	2 865
	Waste heat		GWh/a	813
Service sector	Fossil fuel sources	HECHP	GWh/a	2 865
		Other technologies	GWh/a	1 055
	Renewable energy sources	HECHP	GWh/a	1 382
		Other technologies	GWh/a	2 419
	Waste heat		GWh/a	686
Industrial sector	Fossil fuel sources	HECHP	GWh/a	1 206
		Other technologies	GWh/a	444
	Renewable energy sources	HECHP	GWh/a	582
		Other technologies	GWh/a	1 019
	Waste heat		GWh/a	289
Other sectors	Fossil fuel sources	HECHP	GWh/a	75
		Other technologies	GWh/a	28
	Renewable energy sources	HECHP	GWh/a	36
		Other technologies	GWh/a	64
	Waste heat		GWh/a	18

2.1.2 Network-based supply

This chapter analyses developments to date in the district heating sector in Austria and the existing networks, covering the period up to 2018 where possible. A description is provided of the most important heating supply areas in Austria, broken down by region. The various network structures and relevant parameters are identified and compared. The supply structure in these areas is investigated and outlined (waste incineration, biomass plants, heat-only plants and CHP plants, broken down by energy source).

2.1.2.1 Developments in the district heating sector and current state of play

It is apparent from the data contained in the overall energy balance (Statistik Austria, 2018b) that heating networks have become increasingly important in Austria since the 1970s. District heating generation increased by around 40% in Austria over the period between 2005 and 2018, with an upward tendency overall. A uniform trend can be identified over the period between 2012 and 2018. Average network losses for the entire district heating sector were around 15% between 2005 and 2018. Using the remaining sales volume of around 20 TWh, over 18% of the total heat demand in the 'households' and 'services' sectors could be covered with district heating in 2018. In both the producing sector and the agriculture sector, almost 5% could be covered. Figure 5, which shows the shares of district heating generation accounted for by different energy sources, clearly indicates that generation from CHP plants and heat-only plants using non-renewables was approximately uniform; at the same time, it shows that there was a significant rise in generation from CHP plants and heat-only plants using renewables.

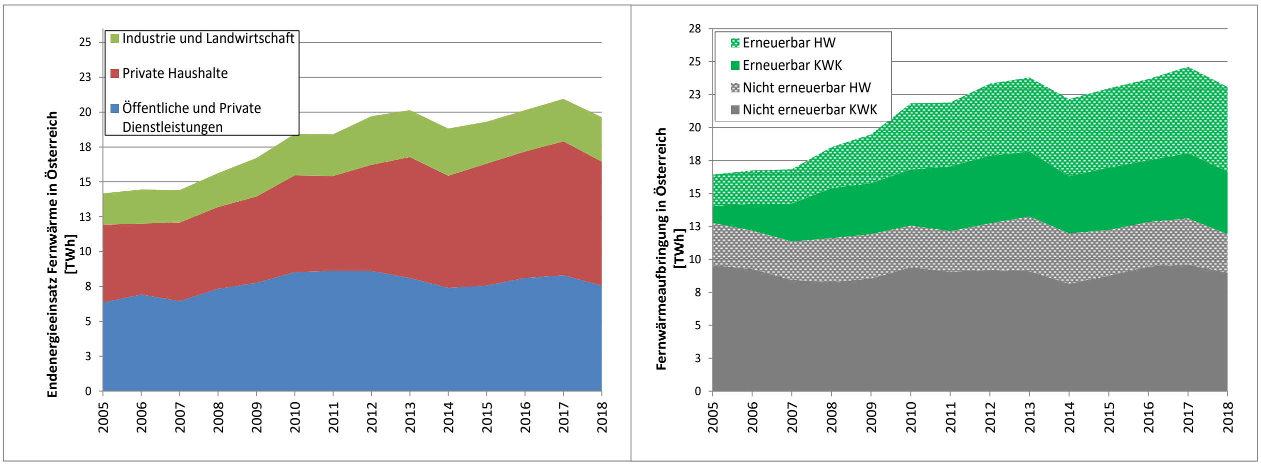

Figure 4: Final energy use and type of generation by the district heating sector in Austria (Statistik Austria, 2018b)

	Final energy use of district heating in Austria [TWh]
	Industry and agriculture
	Private households

	Public and private services
	District heating generation in Austria [TWh]
	Renewable heat-only plants
	Renewable CHP plants
	Non-renewable heat-only plants
	Non-renewable CHP plants

On the generation side, the increase in district heating demand was accounted for almost entirely by the expansion of heat-only plants and CHP plants using renewable energy sources (mainly biomass). In 2018, wood waste accounted for the largest share of biogenic energy sources at over 88%. The overall share of renewable energy sources in district heating generation rose from 22% in 2005 to 48% in 2018. The share of heat generated in CHP plants was consistently between 56% and 67% over this period. Figure 5 shows the shares of district heating generation accounted for by the individual energy sources.

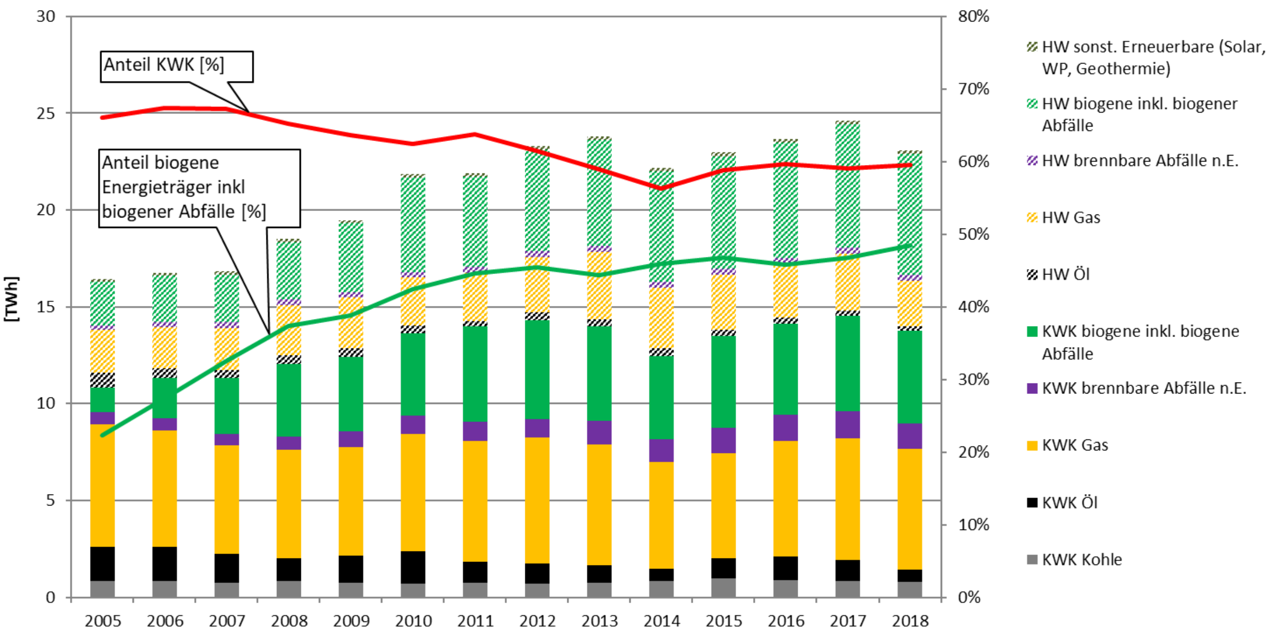

Figure 5: Shares of district heating generation accounted for by different energy sources (Statistik Austria, 2018b)

	Share of CHP [%]
	Share of biogenic energy sources including biogenic waste [%]
	[TWh]
	Heat-only, other renewables (solar, heat pumps, geothermal)

	Heat-only, biogenic, including biogenic waste
	Heat-only, flammable waste, non-renewable
	Heat-only, gas
	Heat-only, oil
	CHP, biogenic, including biogenic waste
	CHP, flammable waste, non-renewable
	CHP, gas
	CHP, oil
	CHP, coal

The current district heating supply situation for private households can be determined from the results of the 'microcensus' household survey (Statistik Austria, 2019). According to the latter, of the almost 4 million primary residences recorded in total in 2019, over 1 million were supplied with district heating. This corresponds to 26.7% of primary residences in Austria. According to the Association of Gas and District Heating Supply Companies (FGW), in 2019 heat was supplied to end customers by district heating supply companies through a network measuring around 5 600 km in total (Fachverband Gas Wärme, 2020).

Figure 6 shows the allocation of final energy consumption for district heating to the individual Austrian provinces. The network-based heating supply is distributed very differently in the individual provinces. It is apparent that approximately one third of total district heating is sold in Vienna, followed by Upper Austria, Lower Austria and Styria. The lowest sales are recorded for Vorarlberg and Burgenland. These provinces also have the lowest values for sales per inhabitant. The highest sales per capita are recorded for Carinthia and Vienna. District heating supply displays a rising trend in all provinces, however.

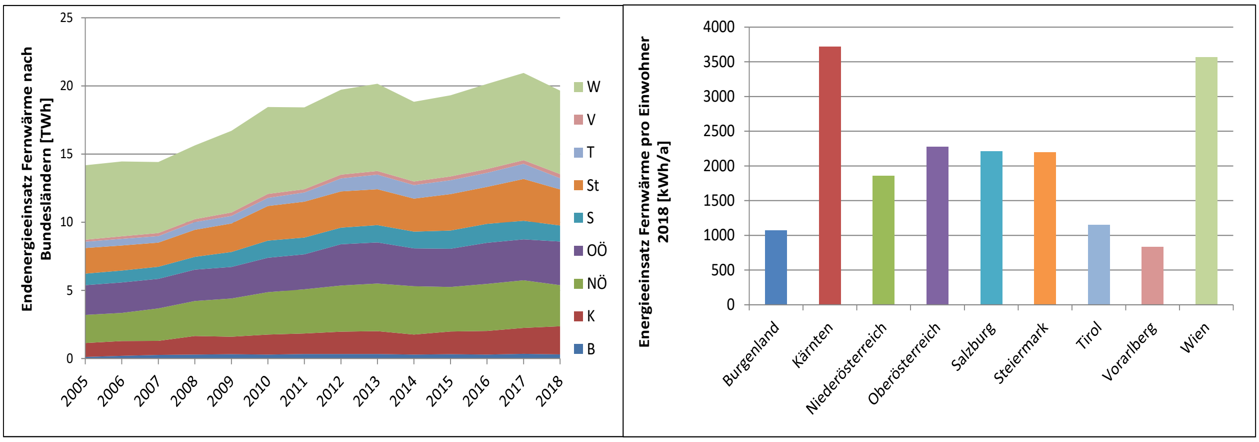

Figure 6: Development and shares of final energy consumption of district heating by province (Statistik Austria, 2018c)

	Final energy use of district heating by province [TWh]
	Vienna

	Vorarlberg Tyrol Styria Salzburg Upper Austria Lower Austria Carinthia Burgenland
	Energy use of district heating per inhabitant in 2018 [kWh/a]
	Burgenland
	Carinthia
	Lower Austria
	Upper Austria
	Salzburg
	Styria
	Tyrol
	Vorarlberg
	Vienna

2.1.2.2 Supply structure of district heating networks (generating plants and companies)

A huge variety of heat sources can be used to supply district heating networks. These range from CHP plants (combined heat and power), heat-only plants and industrial waste heat through to the feed-in of solar or geothermal heat using heat pumps and electric direct heaters. As a basic principle, the following options are used to provide district heating in Austria:

- heat from CHP plants using a wide range of fuels,
- heat from waste incineration plants,
- heat from heat-only plants using a range of fuels,
- industrial waste heat,
- geothermal heat,
- solar thermal heat,
- high-capacity heat pumps.

This wide range of options means that the supply structure of district heating networks varies greatly. In the larger towns and cities, the networks were originally fed primarily using combined heat and power from the CHP plants of the electricity suppliers. Heat from biomass or waste incineration also plays a major role in these large networks, however, and alternative sources such as industrial waste heat or high-capacity heat pumps are also being used with increasing frequency. In addition, boilers are typically required in larger towns or cities to cover peak loads and as a stand-by option. In smaller communities, district heating networks are mostly fed using biomass heat-only plants or biomass CHP plants.

In 2018, 72 thermal power plants using fossil fuels, 472 thermal power plants using biogenic fuels and 23 other thermal power plants (other biogenic, other fuels and mixed) were used in Austria for the primary purpose of generating electricity. Of this total (567 power plants), almost 90% of the installed electrical capacity of around 7.2 GW_{el} was designed as CHP plants (E-Control, 2018).

The 472 power plants using biogenic fuels provide an installed electrical capacity of almost 500 MW_{el}. Most non-CHP plants are biogas-fired micro gas turbines or small gas engines for the purpose of generating electricity. In 2018, the total heat capacity of all CHP plants (fossil and biogenic) was over 8.8 GW_{th}, and almost 32 TWh of heat was generated (E-Control, 2018). Figure 7 shows the changes in thermal and electrical capacity for all fossil and biogenic CHP plants in use over the period since 2005 (E-Control, 2019). It can be seen that the installed thermal and electrical capacities of CHP plants rose steadily until 2011 and have been decreasing slightly ever since. In contrast, the cumulative capacity of non-CHP plants decreased steadily over the period.

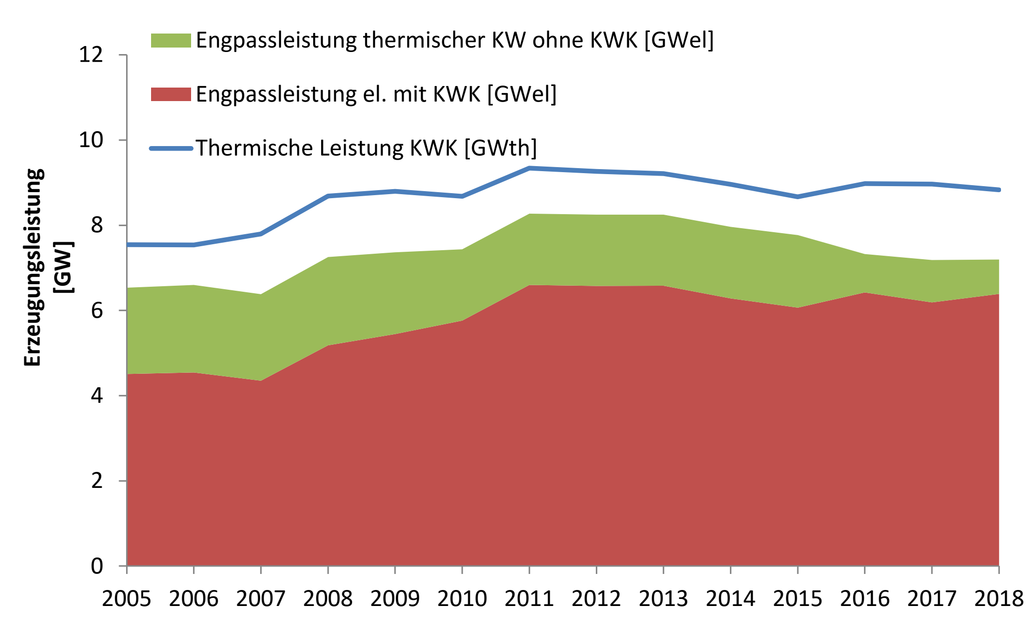

Figure 7: Installed capacity (electrical and thermal) of thermal power plants in Austria (E-Control, 2019)

	Generation capacity [GW]
	Bottleneck capacity of thermal power plants without CHP [GWel]
	Bottleneck capacity of electrical power plants with CHP [GWel]
	Thermal capacity of CHP [GWth]

Large heat-only plants fired with fossil fuels are located almost exclusively in Austria's major cities. The vast majority of all heat-only plants are small-scale plants supplied using biogenic energy sources. According to a biomass heating survey carried out in 2019 (Haneder, 2020), a total of 828 woodchip-fired plants with a heat capacity of over 1 MW_{th} have been installed since 2000. Based on an average capacity of 2.9 MW, this gives a total capacity of almost 2 400 MW_{th}. It can almost always be assumed that plants of this size will be used to feed heat into a local or district heating network. Assuming an average lifetime of around 20 years for these plants, it is likely that 870 plants of this size class are currently installed, with a total capacity of 2 500 MW_{th}.

Austria has 34 incineration and co-incineration plants for the disposal of waste with a capacity of over 2 t/h. Of these 34, 18 belong to industrial undertakings, 8 belong to energy utilities and 8 belong to special municipal or recycling companies (Kellner, 2020). Some already feed heat into district heating networks, in particular the majority of plants belonging to municipal companies and energy utilities. Industrial co-incineration plants are mostly used to generate heat required on-site for certain processes. In addition, Austria has 26 incineration and co-incineration plants with capacities below 2 t/h, which will not be further considered in this document (Kellner, 2020).

Energy-intensive industry is the main source of industrial waste heat in economically usable quantities. If the temperature is still adequately high after the heat has been used on-site and a sufficient flow of heat is available, it is recommended that this cheap source of energy be fed into a nearby district heating network.

A number of large industrial enterprises already feed their waste heat into district heating networks. Particularly in the case of larger networks, this covers part of the base load, since the heat is generated continuously by many different processes. Examples of waste heat feed-ins that have already been implemented include the following:

- CHP heat from OMV Schwechat feeds into the Vienna district heating network,
- Hrachowina and Henkel Austria feed into the Vienna district heating network,
- the Marienhütte steelworks feeds into the Graz district heating network,
- Böhler Edelstahl feeds into the Kapfenberg district heating network,
- voestalpine Stahl Donawitz feeds into the Leoben district heating network,
- the Hofmann Kirchdorf cement works feeds into the Energie AG district heating network in Kirchdorf.

According to the analyses by (Moser and Lassacher, 2020), CHP using waste heat amounts to around 1.8 TWh/a in Austria. The fluctuations that can be observed on a timescale of years must, however, be taken into account in this connection, such as those caused by changes in production. According to data from Kommunalkredit Public Consulting GmbH, CHP using waste heat from plants subsidised since 2011 amounts to just over 0.8 TWh/a (approximate figure) (KPC, 2021). Yet these data only include the publicly subsidised projects that have been systematically recorded from 2011 onwards. This explains the significant deviations between the quantities of waste heat cited in the research; potential annual fluctuations in the quantities actually fed in must also be taken into account in the case of the KPC data. It should also be noted in connection with the calculations carried out within the framework of this study that the waste heat quantities specified above are not restricted to companies within the ETS. The values in Table 4 were based on (Moser and Lassacher 2020).

Geothermal (hydrothermal) uses in Austria are restricted to potential areas in Upper Austria and in Styria. Overall, 12 plants are available for the use of geothermal energy: 8 in the Upper Austrian basin and 4 in the Styrian basin. All of the Upper Austrian and at least two of the Styrian geothermal plants are used to generate district heating (Könighofer et al., 2014a). Upper Austria currently has the highest installed thermal capacity from geothermal sources. Overall, around 70 MW_{th} is provided by seven plants (Lassacher, 2018). Figure 8 shows potential geothermal areas in Austria.

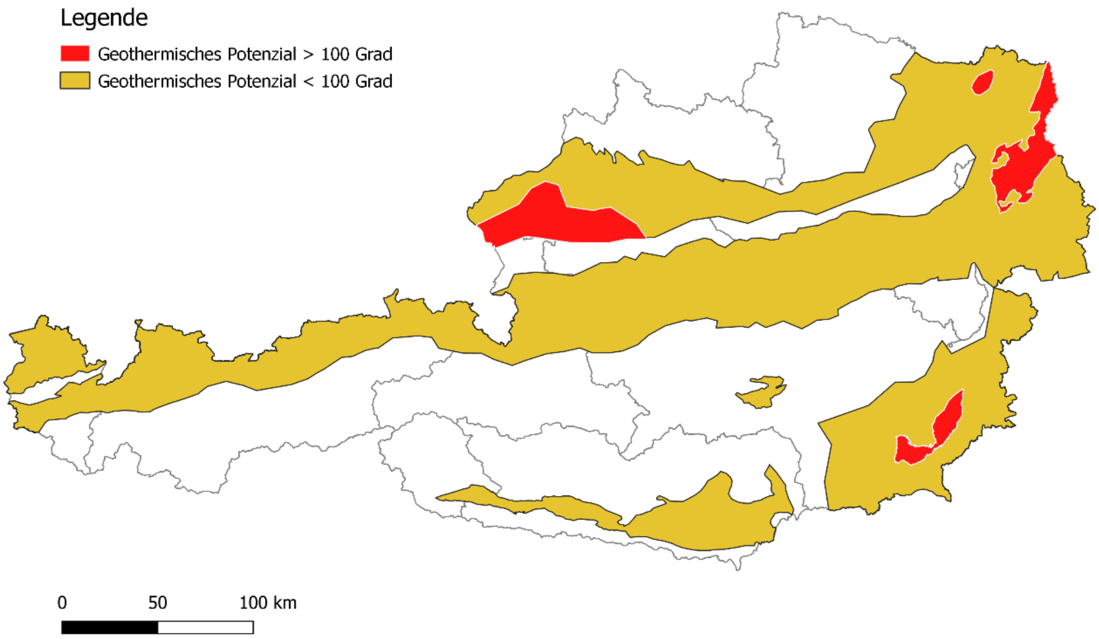

Figure 8: Potential geothermal areas in Austria (source: own illustration on the basis of Austrian Geothermal Association, 2019)

	Key
	Geothermal potential > 100 degrees
	Geothermal potential < 100 degrees

Large-scale solar thermal plants offer an opportunity to use solar energy to produce heat for district heating networks. Given that the majority of heat is produced during the summer months, these plants are particularly suitable for networks in which no cheap supply of heat is available in the summer (e.g. from waste incineration or the use of waste heat). Around 5.05 million square metres of thermal solar collectors were in operation at the end of 2019 in Austria, corresponding to an installed capacity of 3 535 MW_{th}. Average annual market growth in Austria was 7% in 2000 and 2010. The capacity installed each year almost doubled over this period, from 117 MW_{th} to 200 MW_{th}. Market growth has fallen since 2010, however, and a market downturn of 8% was recorded in 2019. 2019 saw a return to the same level of installed capacity figures as in the early 1990s. Almost all of the installed capacity is used by small-scale private consumers to heat water for on-site use (Biermayr et al., 2020). Notwithstanding the contraction of the solar thermal market, which is attributable in particular to the reduction in the price of photovoltaic installations for single-family and multi-family dwellings, an increased number of large-scale solar thermal plants have been built to support district heating networks in recent years. Several large-scale thermal solar plants are currently integrated into urban district heating systems in Austria. The largest of these plants are listed in Table 2 (SDH, 2017).

Table 2: Large-scale solar thermal plants in Austria (SDH, 2017)

Plant	Year	Operator	Location	Surface area [m²]	Capacity [kW_{th}]
District heating plant	2006	S.O.L.I.D., AT	Graz	7 750	5 300
Andritz Waterworks	2009	S.O.L.I.D., AT	Graz	3 860	2 702
Wels	2011	Wels Power Plants, AT	Wels	3 388	2 400
Berliner Ring	2004	S.O.L.I.D., AT	Graz	2 480	1 736
Eibiswald	1997	Nahwärme Eibiswald eGen, AT	Eibiswald	2 450	1 715
Salzburg	2011	Gemeinnützige Salzburger Wohnbaugesellschaft m.b.H., AT	Salzburg	2 150	1 505
AVL List	2017	S.O.L.I.D., AT	Graz	1 584	1 109
Waldmühle Rodaun	2015	Wien Energie, AT	Kaltenleutgeben	1 500	1 050
Perg	2014	Habau, AT	Perg	1 420	1 000
Merkur Arena	2002	S.O.L.I.D., AT	Graz	1 407	985
Loeben	2013	Göss Brewery, AT	Loeben	1 375	963
Villach	2017	Energy Island Landskron, AT	Villach	1 357	950
Gleinstätten	2006	Nahwärme Gleinstätten, AT	Gleinstätten	1 315	921
Bad Mitterndorf	1997	Bio-Solar, AT	Bad Mitterndorf	1 120	784
Lohbach Residences I	1999	Lohbach Residences I, AT	Innsbruck	1 080	756
Sieghartskirchen	2013	Fleischwaren Berger, AT	Sieghartskirchen	1 068	748
Bolaring	2000	Gemeinnützige Salzburger Wohnbaugesellschaft G.m.b.H., AT	Salzburg	1 056	739
Lodenareal	2009	NEUE HEIMAT TIROL, AT	Innsbruck	1 050	735

2.2 Scenarios for heating and cooling demand

Scenarios for changes in space heating and hot water demand are required as a basis for estimating district heating potentials and efficient heating. Renovation measures, new-build projects and demolition activities play an important role in these scenarios. The scenarios used for the purpose of this study were based on the project 'Heat demand by small-scale consumers with reference to the climate targets for 2030 and 2050' in connection with the production of energy scenarios (Krutzler et al., 2017).

A distinction is made between the following two scenarios: the With Existing Measures (WEM) scenario, under which it is assumed that the measures that have already been implemented will remain in force without any alterations, and the Transition scenario, under which a change in final energy demand and final energy use corresponding to a consistent overall reduction in Austria's CO_2 emissions across all sectors of -80% by 2050 compared to 1990 is assumed. The Transition scenario accordingly does not comply with current policies, either those set out in the Austrian Government's present legislative programme or those pursued by the European Union and under the Paris Agreement. Chapter 4, which is based on these scenarios, therefore assumes that the remaining fossil energy sources (mainly natural gas) will be replaced by renewable gases, and that the reduction in energy demand achieved by accelerating the processes of building renovation and efficient new-build construction will be sufficient to achieve complete decarbonisation.

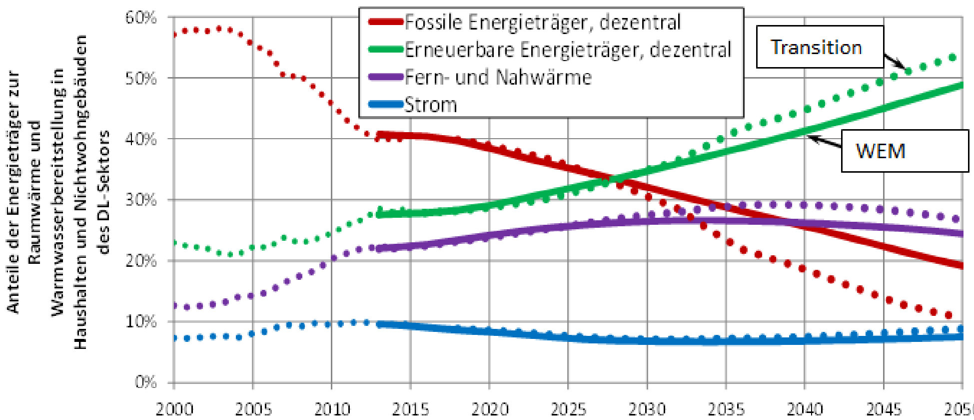

Figure 9: Changes in the share of heating supply to small-scale consumers under the scenarios 'WEM 2017' and 'Transition 2017' accounted for by different groups of energy sources (Müller et al, 2017)

	Share of energy sources for space heating and hot water supply in households and non-residential buildings in the service sector
	Transition
	WEM
	Fossil energy sources, decentralised
	Renewable energy sources, decentralised
	Local and district heating
	Electricity

Useful energy demand for space heating and hot water could be reduced by around 50% under the Transition scenario; the same reduction under the WEM scenario would be only around one third. In Chapter 4, these two scenarios describing changes in useful heat demand are used as a basis for determining the economic potential of different individual decentralised heating systems and of district heating, assuming complete decarbonisation of the sector (achieved between 2030 and 2050).

Further details of scenario setting, policy assumptions, assumed economic parameters and renovation or boiler replacement activities implied under these scenarios can be found in (Krutzler et al., 2017).

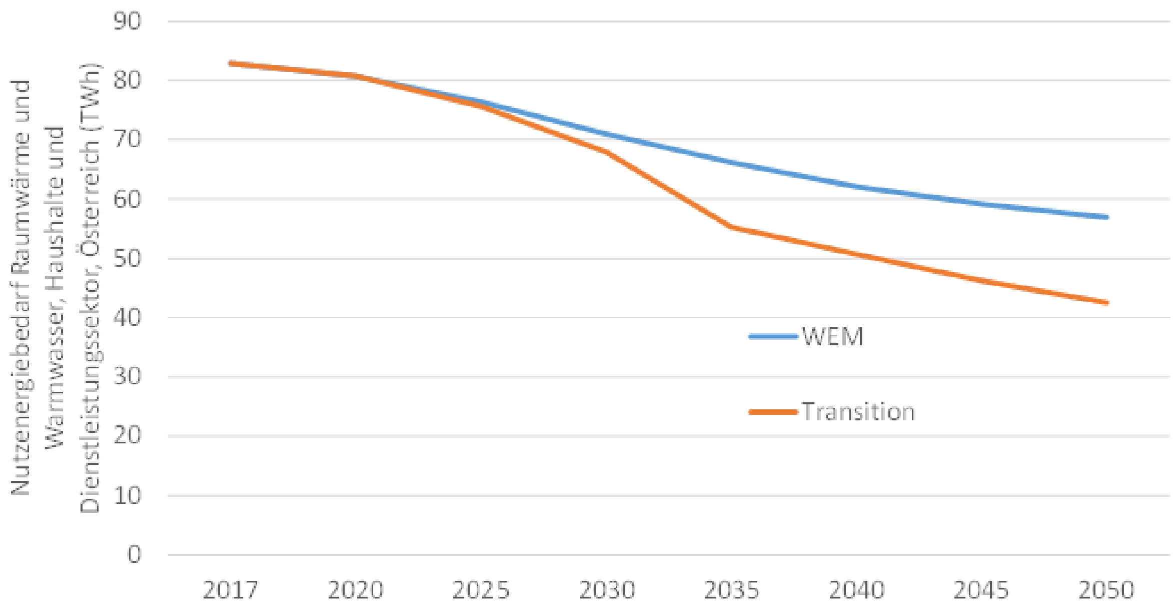

Figure 10: Changes in useful energy demand for space heating and hot water in households and the service sector in Austria under the WEM and Transition scenarios

	Useful energy demand for space heating and hot water, households and the service sector, Austria (TWh)
	WEM
	Transition

In line with the template supplied by the European Commission as referred to above, current and predicted heating and cooling demand is reported using data on final energy demand and useful energy demand.

The analysis of useful energy in Austria published most recently by the Federal Statistical Office (Statistics Austria) (Statistik Austria, 2018a), which describes current final energy consumption on the basis of useful energy categories, was used to determine final energy demand for heating. Total quantities of energy under all the categories of relevance for heat demand, namely 'space heating and air conditioning', 'steam generation' and 'industrial furnaces', in each case for residential buildings (private households), services (public and private services), industry (producing sector overall) and other sectors (agriculture), were taken into account in this connection.

The data on final energy demand for cooling are taken from the results of the Heat Roadmap Europe 4 (Heat Roadmap Europe, 2017). The section entitled 'Shares of type of heat in final heating and cooling by sector' on the 'Aggregation analysis' worksheet was used for residential buildings, services and industry. This section did not contain any data for other sectors (namely agriculture).

Useful energy demand for heating (space heating and hot water) is based on the WEM or Transition scenario described above. Useful energy quantities for the industrial sector were determined on the basis of scenario data from the Austrian Institute of Economic Research (WIFO) (Kratena, 2019); the values shown include only heat energy ('space heating', 'steam generation' and 'industrial furnaces'). The final energy quantities calculated in this source were converted into useful energy on the basis of assumptions concerning efficiency levels (80%).

Process heating and cooling and space cooling are not explicitly included in the further calculations concerning economic district heating potential carried out as part of this project.

Table 3: Current and predicted heating and cooling demand, 2018 and 2017. Reporting in accordance with the European Commission's template (sources: own analyses on the basis of (Statistik Austria, 2018a), (Heat Roadmap Europe, 2017), (Krutzler et al., 2017), (Kratena, 2019))

			Year						
		Unit	2018 (/17)	2025	2030	2035	2040	2045	2050
Heat demand, final energy	Residential sector	GWh/a	65 397						
	Service sector	GWh/a	24 136						
	Industrial sector	GWh/a	65 587						
	Other sectors	GWh/a	2 730						
Cooling demand, final energy	Residential sector	GWh/a	32						
	Service sector	GWh/a	1 821						
	Industrial sector	GWh/a	2 014						
	Other sectors	GWh/a							
Heat demand, useful energy	Residential sector	GWh/a	53 891	51 304	48 944	46 598	44 366	42 510	40 884
	Residential buildings*	GWh/a	53 887	50 791	46 954	40 372	37 127	34 076	31 202
	Service sector	GWh/a	29 000	25 092	22 041	19 596	17 724	16 646	16 050
	Service sector*	GWh/a	29 003	24 821	20 974	14 906	13 589	12 174	11 343
	Industrial sector	GWh/a	52 971	56 351	58 279	61 162	63 934	65 599	67 278
	Other sectors	GWh/a							

*Scenario developments up to 2050 are based on the WEM scenario; the values with an asterisk (*) relate to the Transition scenario. Since only space heating and hot water demand in residential and service buildings are used as a basis for calculating economic potentials in the remainder of this study, both scenarios are only shown for these sectors.

2.3 Waste heat: use and potentials

2.3.1 Methodology followed to calculate waste heat potentials

For the purposes of this report, the category of 'industrial waste heat' covers production plants subject to the EU Emissions Trading System. All plants that appear in the EU Emission Trading System (ETS) database (last updated August 2020) (Europäische Kommission, 2020b) are included. This database contains details of emissions for all undertakings covered by the ETS (per year and per plant). The version of the database last updated in August 2020 includes emission time series from 2008 to 2019.

The waste heat potentials of plants of this kind were estimated using different methods within the framework of the project 'Assessment of the potential for the use of high-efficiency CHP and efficient district heating and cooling supply' (Büchele et al., 2015), which was carried out in 2015 as the first report under Article 14 of the Energy Efficiency Directive. On the one hand, the waste heat potentials were determined on the basis of emissions recorded under the ETS (the respective energy input and the associated waste heat were calculated on the basis of plant-specific emissions). On the other hand, the waste heat potential for selected plants was calculated on the basis of the respective production quantities.

The change in emissions per plant across the entire period was used as a starting point for extrapolating the current waste heat potentials on the basis of the 2015 approach (Büchele et al., 2015). The change in average emissions from 2008 to 2011 (basis for calculation of the Austrian Heatmap 2015) compared to average emissions from 2016 to 2019 was used as a basis in this connection. The waste heat potential was re-estimated on the basis of this change. This applies only to plants whose waste heat potential was already estimated in 2015 on the basis of per-plant emissions, however. Where necessary, individual plants whose waste heat has been estimated on the basis of production quantities have been re-assessed for the purpose of this study.

The potential of plants newly added to the ETS was estimated using the module 'User-defined excess heat potentials', which was developed within the framework of the HOTMAPS project, on the basis of individual production quantities. As part of our research, we also investigated whether the plants that were included in the ETS in (Büchele et al., 2015) and now no longer appear in the ETS database continue to exist and whether their waste heat potential is still available. Plants that did not appear in the ETS system in 2015 and do not currently appear in this system were not included (e.g. supermarkets).

2.3.2 Waste heat potentials in Austria

Figure 11 shows the technical waste heat potentials by sector calculated for the purpose of this study. The term 'technical potential' should be understood to mean the waste heat potential which in reality is dependent on development opportunities that are subject to individual technical, economic and regulatory parameters. Since the calculated values are estimates, they should be regarded as indications only, and would need to be re-analysed in detail when implementing uses of waste heat for CHP.

Figure 11 shows that the largest potentials can be found in the chemical industry, the paper industry, the oil-refining sector and the integrated steel mills sector. The term 'integrated steel mills sector' is used to refer to the combination of several different production stages in the manufacturing of steel. The paper industry holds by far the largest potential for waste heat of all the sectors (approximately 5.4 TWh). If the waste heat data are broken down by temperature class, the sectors 'integrated steel mills', 'oil refining' and 'paper industry' each have a waste heat potential of approximately 0.5 TWh > 100 °C. Lower potentials can also be found in the chemical and cement industry and in aluminium production, as well as in the remaining sectors in isolated cases. In the temperature class < 100 °C, the largest potentials can be found in the sectors 'chemical industry' (approximately 1.4 TWh), 'paper industry' (approximately 5 TWh), 'integrated steel mills' (approximately 0.3 TWh) and 'oil refining' (approximately 0.7 TWh). The technical waste heat potential for Austria as a whole is approximately

10.3 TWh, of which 7.7 TWh is accounted for by the temperature class < 100 °C and 2.6 TWh by the temperature class > 100 °C.

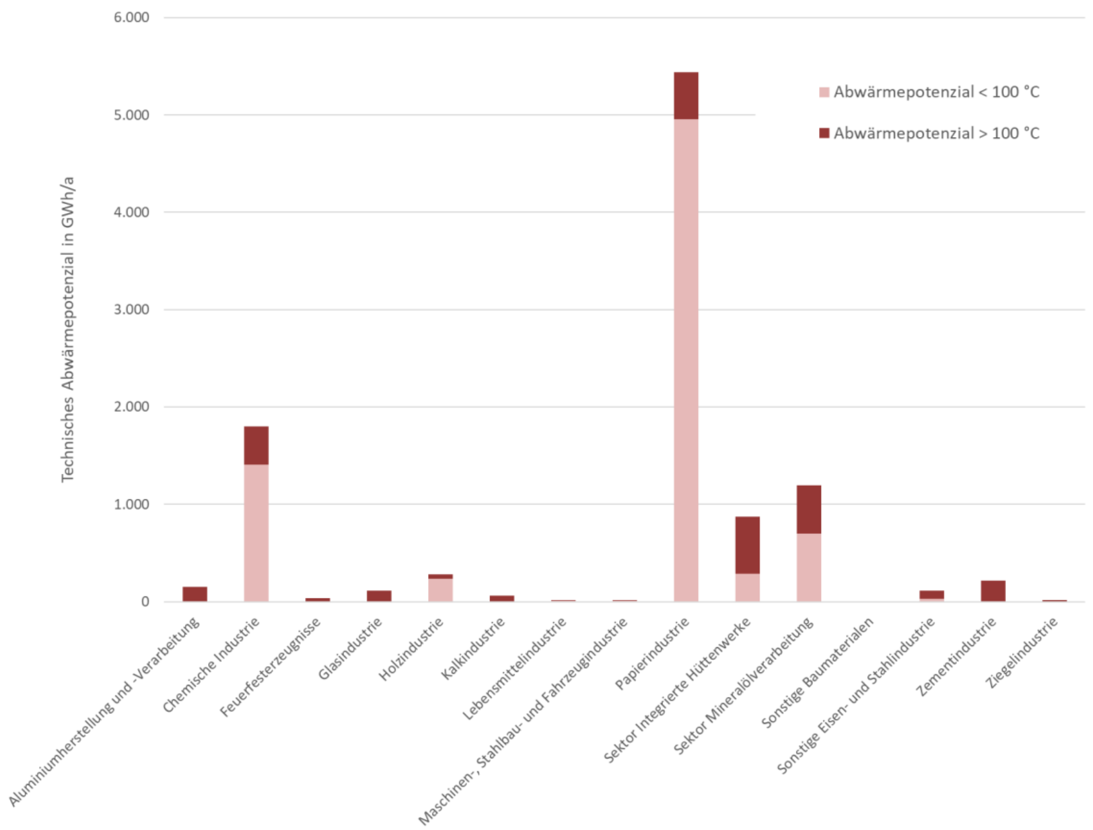

Figure 11: Technical waste heat potential by sector and temperature level (source: own calculations), (Büchele et al., 2015))

	Technical waste heat potential in GWh/a
	Waste heat potential
	Aluminium production and processing
	Chemical industry
	Refractory products
	Glass industry
	Timber industry
	Lime industry
	Foodstuffs industry
	Machinery, steelworks and automotive industry
	Paper industry
	Integrated steel mills sector
	Oil-refining sector

	Other construction materials
	Other iron and steel industry
	Cement industry
	Brick industry

With a view to determining the waste heat available from thermal power plants and renewable energy plants, the amount of electricity they generate each year was calculated on the basis of rated electrical outputs and full load hours (E-Control, 2018). This figure was then used as a basis for estimating the quantities of heat from CHP that could potentially be achieved, assuming that the power plants are operated in heat-driven mode at least some of the time. It was not possible to give detailed consideration to the interactions with the electricity system.

The majority of waste heat from waste incineration plants in Austria is already being used. A detailed analysis of the potential for using additional waste heat was beyond the scope of this study.

Table 4: Waste heat calculated as being additionally available, 2018. Reporting in accordance with the European Commission's template (sources: own analyses and research, inter alia on the basis of (E-Control, 2018), (E-Control, 2019), (Moser and Lassacher, 2020))

	Threshold	Unit	Value
Thermal power plants	50 MW	GWh/a	3 656
Renewable energy plants	20 MW	GWh/a	287
Industrial plants	20 MW	GWh/a	1 806

*The Korneuburg thermal power plant was not included because it is not currently being operated continuously.

2.4 Maps

The maps are based on the Austrian Heatmap. The Austrian Heatmap firstly shows the heating and cooling density for different scenarios and years (2017, 2030, 2050). Secondly, it allows users to display the district heating potentials calculated in Chapter 4 on the basis of various assumptions regarding connection rates and district heating distribution costs and to read off certain key data for these areas.

In a further layer, the Austrian Heatmap provides information on existing heating networks, existing thermal power plants and heat-only plants and industrial waste heat potentials.

3 Objectives, strategies and policy measures

The objectives, strategies and policy measures that currently apply in the area of heating and cooling, in particular district heating and district cooling, are described below on the basis of the integrated National Energy and Climate Plan (Bundesministerium für Nachhaltigkeit und Tourismus, 2019) and the Austrian Government's current legislative programme (Bundeskanzleramt Österreich, 2020).

The following sections of the integrated National Energy and Climate Plan are relevant to the heating/cooling sector:

Measures with an impact on the Dimension *Energy efficiency* until 2030:

- increase in the share of efficient renewable energy sources and district heating/cooling for heating, hot water and cooling, including component activation, active use of hot water storage systems and buildings as storage for load balancing and increased load flexibility,
- transposition of Directive 2012/27/EU in the version of Directive 2018/2002/EU, including measures in the buildings sector,
- doubling of the renovation rate,
- subsidies, regulatory law, identification and gradual abolition of counterproductive incentives and grants,
- phase-out of liquid fossil fuels.

Measures with an impact on the Dimension *Security of energy supply* until 2030:

- investments in district heating network infrastructure,
- 'The focus of support for *heat distribution* includes around 40 projects for feeding waste heat into new or existing local and district heating grids or establishing waste heat distribution grids. These projects make up the majority of renewable energy use in this area of focus',
- regulatory law, market incentives.

Measures with an impact on *decarbonisation*:

- phase-out of liquid fossil fuels: according to the Federal Government's Climate and Energy Strategy (*mission2030*), around half of the 700 000 oil-fired heating systems currently in use (approximate figure) are to be replaced by innovative renewable energy systems or efficient district heating systems (in particular those using renewable energies) by 2030. From 2025 onwards, a further goal will be the switch from existing heating boilers that have an age of over 25 years and that are operated using liquid fossil fuels to renewable energy sources or district heating,
- the necessary infrastructure measures in the areas of district heating and cooling from renewable energies will be assessed in connection with the current drafting process for the *Renewable Expansion Act*. An *Integrated Network Infrastructure Plan* is also being developed at present,
- flexibility through smart network management (e.g. flexible heating networks),
- optimisation of hybrid low-temperature and low-energy networks,
- development of components and systems for heating and cooling supply,

- within the framework of the 2019 renovation policy, and in collaboration with the provinces, the Federal Government offered a funding focus for the phase-out of heating systems based on fossil fuels in the residential construction sector ('Oil phase-out bonus').

The Austrian Government's legislative programme also includes the following points in relation to the heating/cooling sector:

- Production of a heating strategy: the Federal Government, in close collaboration with the provinces, is working on an Austrian heating strategy with the objective of full decarbonisation of the heating market. Among other things, this includes accelerated growth of local and district heating and improved spatial planning parameters for district heating networks,
- Increase of at least 1.5 percentage points per year in the average renewable share of district heating,
- Step-by-step plan for the phase-out of oil and coal in the buildings sector,
    - for new builds (from 2020),
    - for replacement heating systems (from 2021),
    - mandatory replacement of boilers older than 25 years (from 2025),
    - replacement of all boilers by 2035 at the latest,
- By way of analogy to the step-by-step plan for oil and coal, a legislative basis will also be created for the replacement of gas heating systems:
    - new gas boilers / new connections will no longer be permitted in the new-build sector from 2025 onwards,
    - gas networks will no longer be expanded for space heating purposes, with the exception of density increases within existing networks,
- Timetable for the gradual unbundling of heating networks.

Other actions:

- The Austrian Heating and Cooling Network Expansion Act uses investment subsidies to achieve CO_2 savings and increase energy efficiency. The creation of cooling grids is designed to curb the increase in electricity consumption for air-conditioning and to make cost-effective use of existing heat and waste heat potential, particularly on an industrial scale.

4 Analysis of the economic potential for efficient heating

This chapter contains an analysis of the economic potential for efficient heating in Austria. Firstly, the methodology chosen to calculate the economic potentials is described, including any important assumptions and the scenarios and sensitivities analysed. This is followed by a detailed description of the analyses and results for the individual analytical steps, starting with the identification of potentially suitable district heating regions on the basis of the likely distribution costs, the pooling of similar regions into region types, the calculation of heating feed-in costs for potential district heating networks and the estimation of costs for property-specific provision. Finally, the results of the cost comparison of network-based and property-specific provision are outlined, as well as the economic potentials calculated on this basis.

Given that heating accounts for the vast majority of demand in the heating and cooling sector, economic potential is only analysed in respect of the supply of heating.

4.1 Methodology and selected scenarios

This chapter opens with a description of the cost/benefit analysis method used for the study. The methodology used to identify the economic potentials for the provision of heat from district heating or CHP is described, as well as the cost components taken into account in this connection. The methods used to calculate these cost components are also described in detail. This is followed by an overview of the scenario calculations that were carried out with reference to the various cost-related input parameters, including a description of the selected parameters.

4.1.1 Methodology

The economic potential for efficient heating is analysed on the basis of the following four steps:

1. identification of regions in which district heating might potentially be viable, based on likely heating distribution costs according to heating density,
2. pooling of regions with similar characteristics in terms of district heating suitability (previous step) and supply potentials as regards resources and available infrastructure into typical regions (region types),
3. calculation of costs for the provision of heating:
    a. from district heating for different portfolios in the identified region types, under various parameters,
    b. from decentralised provision in various property types, for different technologies and parameters,

4. identification of the economic potential for efficient district heating and CHP based on a comparison of the costs of property-specific provision and the costs of district heating provision in the identified region types. Aggregation of potentials in the region types into Austria-wide potentials.

Figure 12 below provides an overview of the individual steps in this methodology.

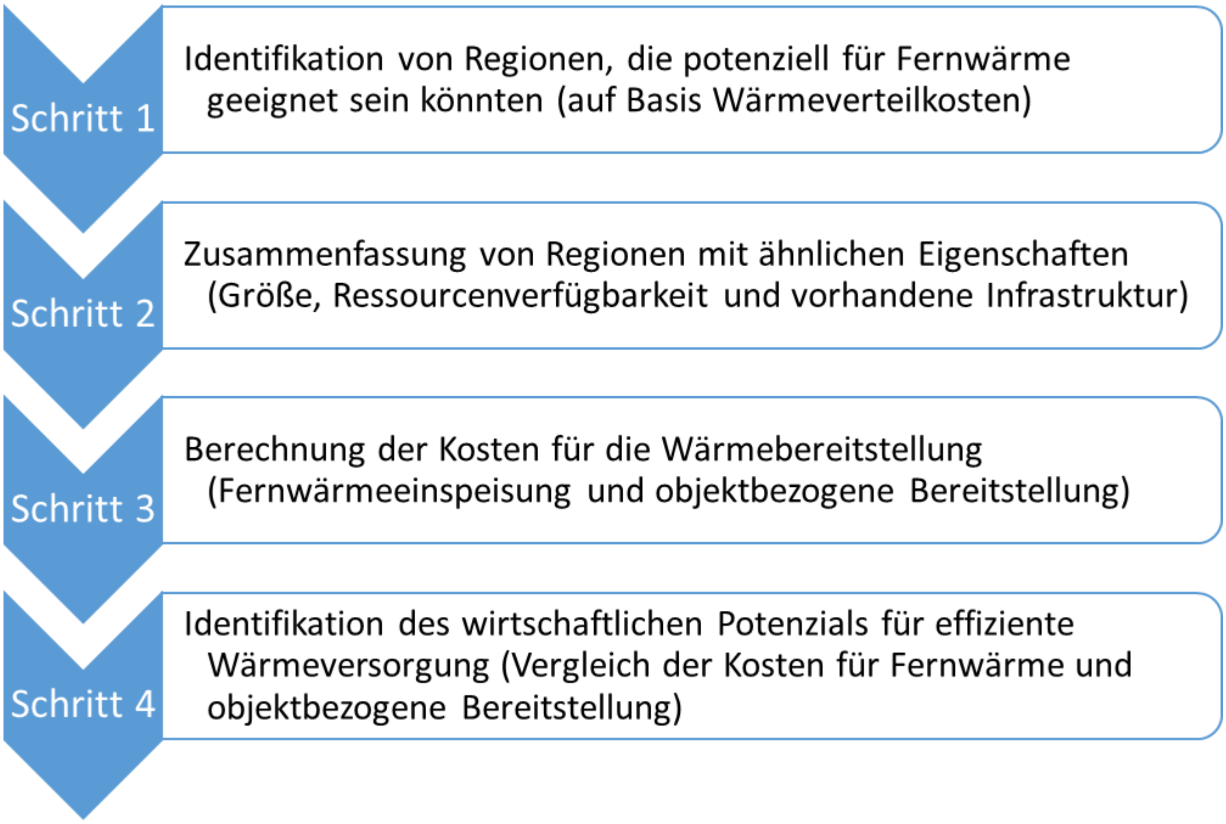

Figure 12: Cost-benefit analysis methodology – step-by-step identification of economic potentials

	Step 1
	Identification of regions where district heating is potentially viable (on the basis of heating distribution costs)
	Step 2
	Pooling of regions with similar characteristics (size, resource availability and existing infrastructure)
	Step 3

	Calculation of the costs of heating provision (district heating feed-in and property-specific provision)
	Step 4
	Identification of the economic potential for efficient heating (comparison of costs for district heating and property-specific provision)

The methodologies and assumptions underlying these four steps are described below.

Step 1: Identification of regions where district heating is potentially viable

In this first step, heating distribution costs are estimated for each hectare in Austria, and average heating distribution costs for contiguous areas are calculated on this basis. This is based on the methodology developed by (Persson und Werner, 2011) and (Fallahnejad et al., 2018). The potential supply of heat through a district heating network and the capital costs incurred in this connection are calculated for each hectare in Austria on the basis of heat demand and development (floor areas). When added together, these indicate the potential heating distribution costs associated with the installation of a district heating network on this hectare. Defined maximum average heating distribution costs are then used to identify contiguous areas where district heating appears potentially viable because the heating distribution costs do not exceed the limit values that have been set.

These calculations are based on the heat demand density maps and development density maps for 2030 and 2050 produced in accordance with the WEM and Transition scenarios (see Chapter 2.2). Other important input variables include the specific capital costs for network installation, the share of heat demand on the relevant hectare that can be covered using district heating (market share), the limit values for the permitted heating distribution costs and the imputed rate of interest. The specific capital costs are taken from (Persson et al., 2019), and the imputed rate of interest is set at 5%. The assumed market shares and the assumed limit values for permitted heating distribution costs are varied in the scenarios in order to investigate their influence on the size of the potential district heating regions.

These calculations result in the identification of areas where district heating is potentially viable under certain assumptions. For each potential district heating area, the calculations also identify the heat demand that could be covered with district heating and the average heating distribution costs that would be incurred in this connection.

Further details of the methodology and the results of this step are outlined in Chapter 4.2.

Step 2: Pooling of regions with similar characteristics into typical regions (region types)

In the second step, the regions where district heating is potentially viable are pooled into regions with similar characteristics in terms of size, availability of resources and existing infrastructure. Initially, the following information is identified for each potential district heating area:

- available potential of industrial waste heat above 100 °C, suitable for direct feed-in to a district heating network using heat exchangers (see Chapter 2.3),

- available potential of industrial waste heat below 100 °C, suitable for direct feed-in to a district heating network using heat pumps (see Chapter 2.3),
- available potential of deep geothermal (Könighofer et al., 2014b),
- size of any river present as a possible source of heat for heat pumps (Umweltbundesamt, 2020),
- availability of gas network infrastructure (Müller et al., 2014) and (Büchele et al., 2015) based on (e-control, 2008),
- presence or otherwise of a district heating network (Büchele et al., 2015).

The four largest district heating regions identified are then separated out from all the other potential regions. They are examined separately in the remainder of the analysis. The cities in question are Vienna, Graz, Linz and Salzburg. All of the other regions are now pooled into six typical regions on the basis of a cluster analysis. The methodology of a minimum 'mathematical distance' between selected parameters is used in this connection. The data previously listed were used as parameters for this analysis.

The results of this step are outlined in Chapter 4.3.

Step 3: Calculation of heating supply costs

The next step involves calculating the heating supply costs. Firstly, the costs of providing heat through district heating systems are calculated; secondly, the costs of providing heat directly in the properties in question are calculated. These costs are then compared against each other for the purpose of identifying the economic potentials for efficient district heating. Figure 13 below contains an overview of the different cost components included in this connection, as well as an overview of the scenarios calculated.

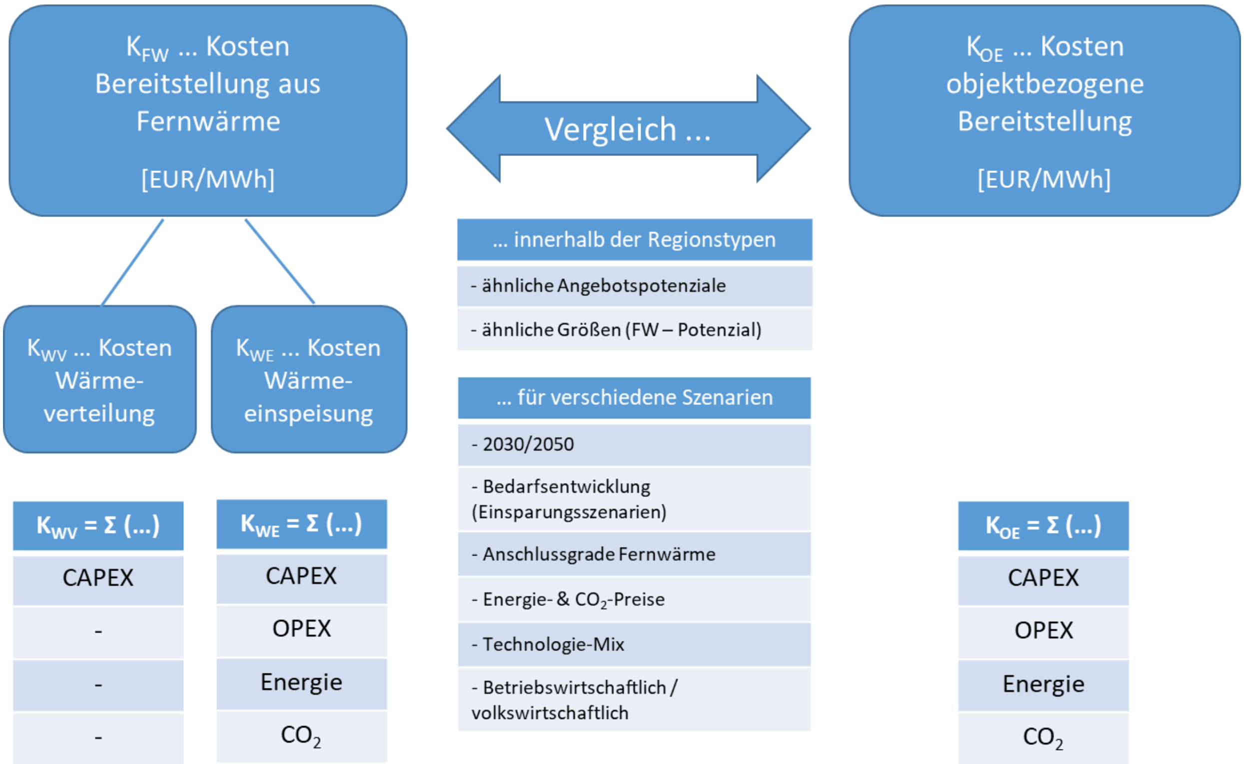

Figure 13: Cost/benefit analysis methodology – overview of cost components and scenarios

	K_{FW} … costs of district heating provision
	K_{WV} … costs of heating distribution
	K_{WE} … costs of heating feed-in
	CAPEX
	OPEX
	Energy
	Comparison
	… within the region types
-	- similar supply potentials
-	- similar sizes (district heating potential)
	… for different scenarios
-	- change in demand (savings scenarios)
-	- connection rates for district heating
-	- energy & CO_2 prices
-	- technology mix
-	- microeconomic/macroeconomic
	K_{OE} … costs of property-specific provision

By way of deviation from the Commission's recommendations concerning the content of the comprehensive assessment of potential (Europäische Kommission, 2019b), LCOH (levelised costs of heat) is used as an indicator instead of capital value. This is because investments in building renovations must be included in any calculations of capital value. Their inclusion was not possible within the framework of this project, since renovation measures were incorporated into the underlying heat demand change scenarios (WEM and Transition) on an aggregated basis rather than on a per-building basis. Since the LCOH represents the capital value with reference to heat quantities, this indicator allows equivalent statements to be made and has no disadvantages compared to capital value.

In terms of district heating supply, both the costs for heating distribution and the costs for heating feed-in are taken into account. The former were already calculated in Step 1 of the cost/benefit analysis for the various regions where district heating is potentially viable. These costs represent the annualised capital costs of the network infrastructure.

The costs of **feeding heat into the potential district heating networks** are now calculated for the typical regions identified in Step 2. This makes it possible to propose and calculate technology portfolios in this step in line with the availability of resources and infrastructures in the relevant regions.

For each typical district heating region, the costs of heating feed-in for various scenarios are now calculated using a dispatch model. This model minimises the ongoing annual costs of using a defined power plant park, taking into account the parameters that change on an hourly basis such as heat demand, supply potential, electricity prices and temperatures in the network and in potential heat sources. The dispatch model used is that developed within the framework of the EU Horizon 2020 project Hotmaps.[1] Among other things, the model makes it possible to take into consideration the dependency of heat pump efficiencies on the changes in temperature that occur throughout the year in heat sources and networks (supply pipe).

A detailed list of the scenarios calculated with reference to technology portfolios and heat demands can be found in Chapter 4.4, together with an outline and description of the results.

The costs of the **property-specific provision of heating** are also calculated using a model developed within the framework of the EU Horizon 2020 project Hotmaps. This model calculates the installed heat provision capacity required for the plant based on the property's annual heat demand, and then the costs of providing this heat using various technologies or combinations of technologies. It also makes it possible to calculate the reference costs of property-specific heat provision by defining the technology (mix) used in the various buildings. Figure 14 illustrates this approach and the parameters and chosen scenarios that are required in this connection.

[1]https://hotmapsdispatch.readthedocs.io/en/latest/

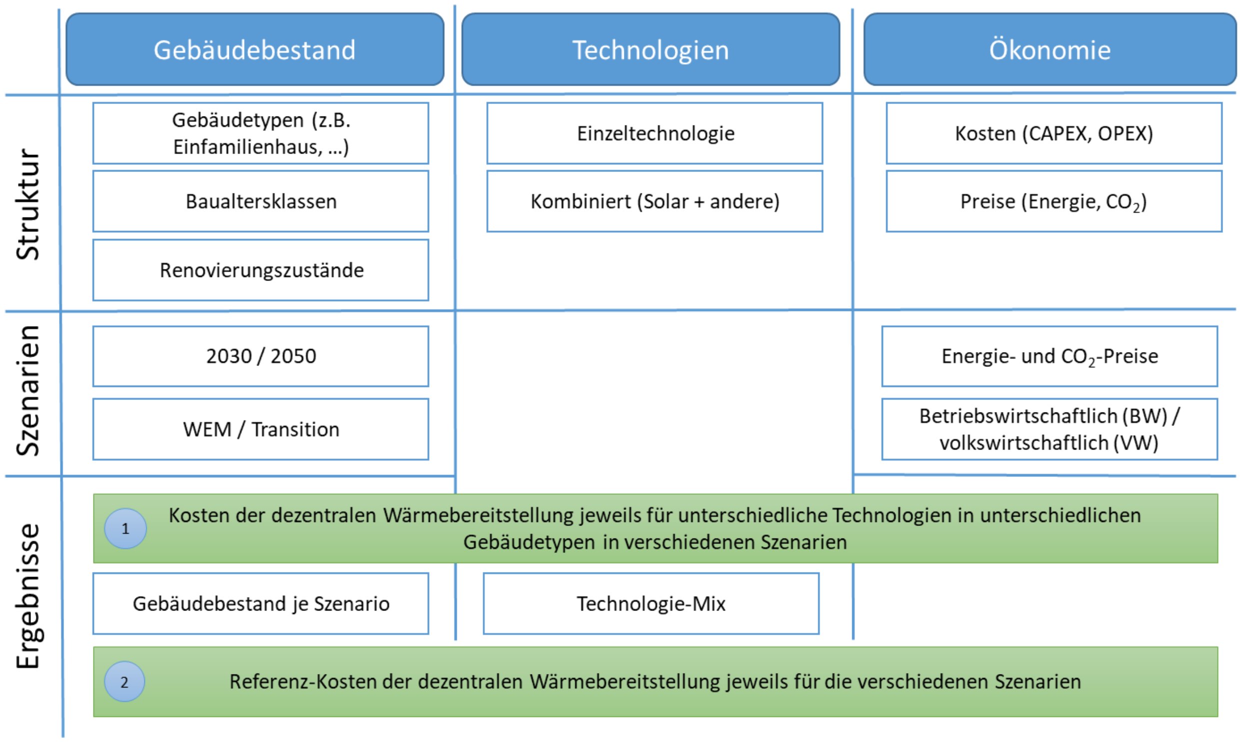

Figure 14: Calculation of costs and scenarios for property-specific provision of heating

	Building stock
	Structure
	Building types (e.g. single-family dwelling)
	Building ages
	Levels of renovation
	Scenarios
	WEM/Transition
	Results
	Costs of distributed heat provision, in each case for different technologies in different building types in different scenarios
	Building stock per scenario
	Reference costs of distributed heat provision, in each case for the different scenarios
	Technologies
	Individual technology
	Combined (solar + others)
	Technology mix

	Economy
	Costs (CAPEX, OPEX)
	Prices (energy, CO_2)
	Energy and CO_2 prices
	Microeconomic/macroeconomic

The costs of property-specific heat provision are calculated for various technologies in different typical buildings (single-family dwellings, multi-family dwellings, office buildings, etc.) from various construction periods (building ages). Consideration is given to the renovation levels of the buildings and the composition of the building stock, as determined on the basis of the scenarios for heat demand development in buildings in accordance with the WEM and Transition scenarios (see also Chapter 2.2 for further details). The calculations are carried out using a module developed within the framework of the Horizon 2020 project Hotmaps.[2] For the purposes of this project, the Hotmaps module is linked to the Invert / EE Lab model so that the central input and output data from the WEM and Transition scenarios can be accessed automatically.

The results of the calculations for property-specific heat provision are shown in Chapter 4.5.

Step 4: Identification of the economic potential for efficient district heating and CHP

The last step involves using the results of the preceding steps to identify the economic potential for the use of district heating and CHP. The economic feasibility of using district heating or property-specific options to cover the demand for heating in each case is then determined by comparing the costs of providing heat using either district heating (heating feed-in + heating distribution) or property-specific options in a region type for a specific set of scenario settings. If the costs of providing heat using district heating in a region type in a certain setting are lower than the costs of providing heat using property-specific options, the total heat demand that can potentially be covered in the cluster using district heating is regarded as the economic potential. The economic potential per technology can then be calculated as the total heat provided using the various technologies in all the areas of the region type. This also includes the economic potential of CHP in district heating. Figure 15 below illustrates this principle.

[2] Calculation Module (CM) – Decentral Heating Supply: https://wiki.hotmaps.eu/en/CM-Decentral-heating-supply

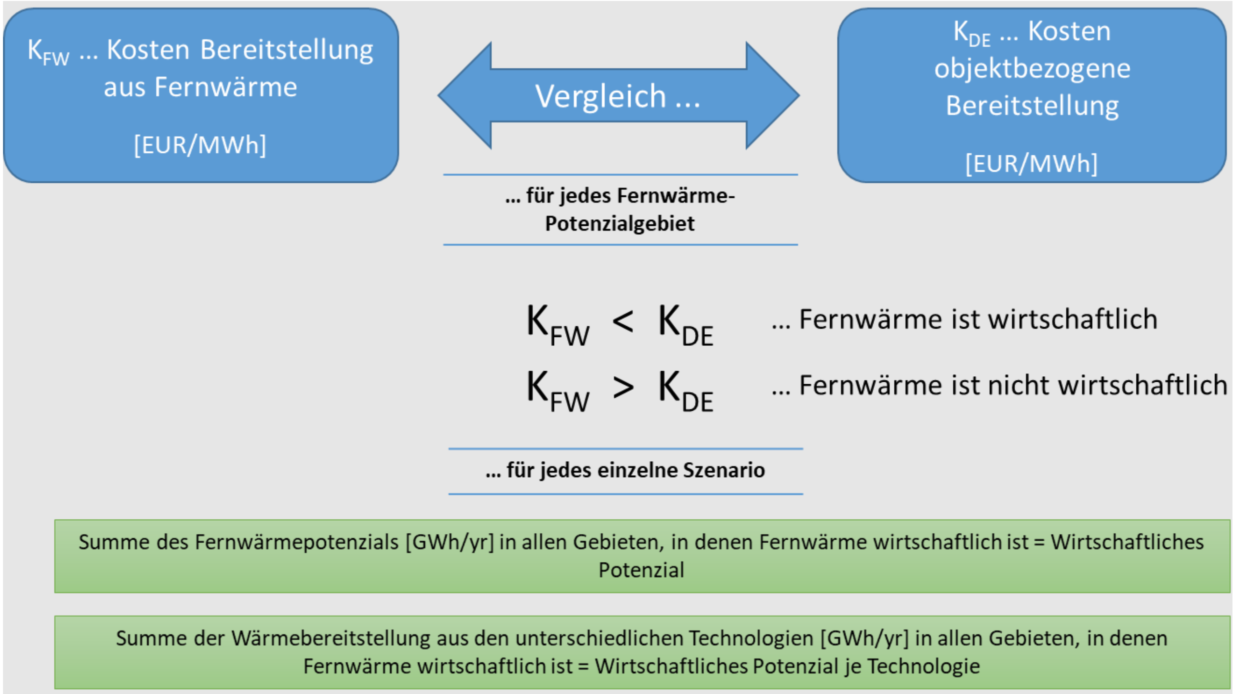

Figure 15: Cost/benefit analysis methodology – identification of economic potential

	K_{FW} … costs of district heating provision
	Comparison …
	K_{DE} … costs of property-specific provision
	…. for each potential district heating area
	… district heating is economically feasible
	… district heating is not economically feasible
	… for each individual scenario
	Total district heating potential [GWh/yr] in all of the areas in which district heating is economically feasible = economic potential
	Total heat provided using the different technologies [GWh/yr] in all of the areas in which district heating is economically feasible = economic potential per technology

The results of this step, and therefore the final results of the cost/benefit analysis, are shown in Chapter 4.6.

4.1.2 Overview of calculated scenarios and key input data

This chapter provides an overview of the scenarios and the parameters varied in this connection under the cost/benefit analysis carried out within the framework of this study, as well as the central input data for the various steps of the cost/benefit analysis as explained in the preceding chapter.

The following tables show the selected scenario variations for the identification of regions where district heating is potentially viable (Table 5), the generation of district heating (Table 6) and the calculation of property-specific heating provision (Table 7).

Table 5: Overview of the selected scenarios for the identification of regions where district heating is potentially viable

Name	Number	Description
Date	2	2030/2050
Changes in heat demand	2	WEM and Transition
Market shares for areas where district heating is potentially viable	2	45% versus 90%
Maximum permitted average heating distribution costs	4	EUR 20, 30, 40 and 50/MWh
Total	**32**	

Table 6: Overview of the selected scenarios for the generation of district heating

Name	Number	Description
Cluster	10	Four specific areas (Vienna, Graz, Linz, Salzburg) Six typical areas (demand/supply potentials) For each cluster: • Temperatures (air, water, heat sources) • Solar radiation • Load profile • Resource availability
Date	2	2030/2050
Economic feasibility	2	Microeconomic/macroeconomic
Heat demand	4	Two demands per date
Energy and CO_2 prices	2	Low versus high prices
Technology portfolios	3	A. BAU: mainly gas B. Alternative 1: Gas with renewables and waste heat C. Alternative 2: Mainly renewables and waste heat, almost no gas

Total	480	

Table 7: Overview of the selected scenarios for calculation of the reference costs of property-specific heating provision

Name	Num-ber	Description
Changes in building stock and demand	2	Composition of the building stock, comprising 20 different building categories for residential and non-residential buildings and 11-13 different building ages per building category. Changes in building stock and demand are taken from the WEM and Transition scenarios. Costs and energy source demands are calculated for individual buildings, with excerpts shown in the results. The costs are weighted in accordance with the composition of the building stock as a basis for calculating the reference costs of property-specific provision.
Date	2	2030/2050
Economic feasibility	2	Microeconomic/macroeconomic
Energy and CO_2 prices	2	Low versus high prices
Technology portfolios (for calculation of the reference costs using property-specific provision)	1	One technology distribution each for the different building types per date and heat demand scenario
Total	**16**	

Additional details regarding the selected input parameter combinations and the results of the scenario calculations for the individual areas/steps can be found in Chapters 4.2, 4.3, 4.4 and 4.5 below. Associated scenario variants for the different areas are then used for the purpose of identifying economic potentials. These are shown in Chapter 4.6.

Central input parameters for the cost/benefit analysis include energy source prices, CO_2 prices, emissions factors and external costs, as well as depreciation periods and interest rates. All the calculations are carried out from two different perspectives:

- **macroeconomic perspective:** taxes are not included, but external costs are taken into account; an interest rate of 2% is used, and the depreciation period corresponds to the technical lifetime of the infrastructures,
- **microeconomic perspective:** taxes and CO_2 prices are taken into account, but external costs are not included; an interest rate of 4% is used, and the depreciation period corresponds to the technical lifetime of the infrastructures.

Table 8 below outlines the central assumptions and data sources for the prices and CO_2 emissions for this study. The following tables show the parameters selected on this basis with reference to the prices, external costs and emissions factors for the various energy sources in the different areas of application (district heating provision, private households and services) for 2030 and 2050.

Table 8: Assumptions and data sources for prices and CO_2 emissions

Energy source	Assumptions	Data sources
Electricity	Hourly wholesale market prices for Austria in the two scenarios based on different assumptions regarding technology priorities and the regulatory framework; both scenarios follow an EU decarbonisation pathway until 2050, with Austria's net emissions at zero by 2030. The two scenarios: joint EU-wide vision versus localised solutions	Calculations using the Enertile model (Fraunhofer ISI, 2020) within the framework of the project (SET-Nav, 2020). A description of the scenarios can be found in (Sensfuß et al., 2019). Feedback from experts and stakeholders
Gas	Share of green gas (synthetic gas and biogas) in the natural gas network of 6% in 2030 and 100% in 2050 In 2030 mainly biomethane in green gas; in 2050 mainly H_2 and PtG. Details of the assumptions regarding green gas can be found in Table 20 in the annex.	(Agora et al., 2018), (Lambert, 2018), (Prognos AG, 2020), (Thrän et al., 2014), (Lux and Pfluger, 2020), (Brändle et al., 2020) Feedback from experts and stakeholders
Oil	Reduction in demand for oil => stable, low prices; oil no longer available for heating (2050)	(SET-Nav, 2020) and (Sensfuß et al., 2019) Feedback from experts and stakeholders
Biomass	Stabilisation of prices under the low-price scenario, moderate price increase under the high-price scenario; Biomass assumed as CO_2-neutral	Own analyses on the basis of (IEA, 2018), (Biermayr et al., 2020) Feedback from experts and stakeholders
Waste	Waste costs EUR 0-5/MWh Specific emissions drop by 20% by 2050	Assumption Feedback from experts and stakeholders
Industrial waste heat	Waste heat costs EUR 5-20/MWh, depending on the quality and price scenario A heat pump is required for low temperatures	Empirical values Feedback from experts and stakeholders
CO_2	Based on the same model and scenario as the electricity prices (2030: EUR 81-120/t; 2050: EUR 183-296/t) External costs of CO_2 emissions: EUR 300/t (only in the macroeconomic calculations)	(Fraunhofer ISI, 2020) within the framework of the project (SET-Nav, 2020). Details can be found in (Sensfuß et al., 2019). Feedback from experts and stakeholders

Table 9: Prices, CO_2 factors and external costs for the different energy sources in 2030

2030										
Energy source	Low prices					High prices				
	Taxes and levies		Emissions factor	CO_2 price	External costs of CO_2	Taxes and levies		Emissions factor	CO_2 price	External costs of CO_2
	without	with				without	with			
	[EUR/MWh]	[EUR/MWh]	[tCO_2/MWh]	[EUR/tCO_2]	[EUR/tCO_2]	[EUR/MWh]	[EUR/MWh]	[tCO_2/MWh]	[EUR/tCO_2]	[EUR/tCO_2]
Use for district heating										
Electricity	56.0	73.0	0.008	81.0	300.0	67.1	84.1	0.012	121.1	300.0
Natural gas	29.6	33.6	0.200	81.0	300.0	38.2	42.2	0.200	121.1	300.0
Synthetic gas / biogas	68.2	72.2	0.002	81.0	300.0	93.2	97.2	0.003	121.1	300.0
Heating oil	48.4	53.4	0.266	81.0	300.0	62.9	68.0	0.266	121.1	300.0
Wood chips	18.6	18.6	-	81.0	300.0	21.7	21.7	-	121.1	300.0
Waste	-	-	0.130	81.0	300.0	5.0	5.0	0.130	121.1	300.0
Industrial waste heat < 100 °C	5.0	5.0	-	81.0	300.0	10.0	10.0	-	121.1	300.0
Industrial waste heat > 100 °C	15.0	15.0	-	81.0	300.0	20.0	20.0	-	121.1	300.0
Use in households										
Electricity	136.5	199.7	0.008	-	300.0	147.6	213.1	0.012	-	300.0
Natural gas	59.6	80.5	0.200	-	300.0	68.2	90.9	0.200	-	300.0
Synthetic gas / biogas	98.2	126.8	0.002	-	300.0	123.2	156.8	0.003	-	300.0
Heating oil	55.7	72.8	0.266	-	300.0	70.2	90.2	0.266	-	300.0
Firewood	31.7	38.0	-	-	300.0	39.2	47.0	-	-	300.0
Pellets	53.3	63.9	-	-	300.0	62.2	74.7	-	-	300.0
Use in services										
Electricity	136.5	166.5	0.008	-	300.0	147.6	177.6	0.012	-	300.0
Natural gas	59.6	67.0	0.200	-	300.0	68.2	75.7	0.200	-	300.0
Synthetic gas / biogas	98.2	105.6	0.002	-	300.0	123.2	130.6	0.003	-	300.0
Heating oil	55.7	60.7	0.266	-	300.0	70.2	75.2	0.266	-	300.0
Wood chips	25.2	25.2	-	-	300.0	31.2	31.2	-	-	300.0
Pellets	53.3	53.3	-	-	300.0	62.2	62.2	-	-	300.0

Table 10: Prices, CO_2 factors and external costs for the different energy sources in 2050

2050										
Energy source	Low prices					High prices				
	Taxes and levies		Emissions factor	CO_2 price	External costs of CO_2	Taxes and levies		Emissions factor	CO_2 price	External costs of CO_2
	without	wit h				without	with			
	[EUR/MWh]	[EUR/MWh]	[tCO_2/MWh]	[EUR/tCO_2]	[EUR/tCO_2]	[EUR/MWh]	[EUR/MWh]	[tCO_2/MWh]	[EUR/tCO_2]	[EUR/tCO_2]
Use for district heating										
Electricity	88.7	105.7	0.002	183.0	300.0	127.5	144.5	0.009	296.0	300.0
Natural gas	31.9	35.9	0.200	183.0	300.0	41.2	45.2	0.200	296.0	300.0
Synthetic gas / biogas	88.7	92.7	0.003	183.0	300.0	128.7	132.7	0.011	296.0	300.0
Heating oil	42.5	47.5	0.266	183.0	300.0	55.3	60.3	0.266	296.0	300.0
Wood chips	17.9	17.9	-	183.0	300.0	28.4	28.4	-	296.0	300.0
Waste	-	-	0.104	183.0	300.0	5.0	5.0	0.104	296.0	300.0
Industrial waste heat < 100 °C	5.0	5.0	-	183.0	300.0	10.0	10.0	-	296.0	300.0
Industrial waste heat > 100 °C	15.0	15.0	-	183.0	300.0	20.0	20.0	-	296.0	300.0
Use in households										
Electricity	169.2	239.1	0.002	-	300.0	207.9	285.5	0.009	-	300.0
Natural gas	61.9	83.2	0.200	-	300.0	71.2	94.5	0.200	-	300.0
Synthetic gas / biogas	118.7	151.4	0.003	-	300.0	158.7	199.4	0.011	-	300.0
Heating oil	49.8	65.7	0.266	-	300.0	62.5	81.0	0.266	-	300.0
Firewood	32.3	38.7	-	-	300.0	51.2	61.4	-	-	300.0
Pellets	51.2	61.5	-	-	300.0	81.3	97.6	-	-	300.0
Use in services										
Electricity	169.2	199.2	0.002	-	300.0	207.9	237.9	0.009	-	300.0
Natural gas	61.9	69.3	0.200	-	300.0	71.2	78.7	0.200	-	300.0
Synthetic gas / biogas	118.7	126.1	0.003	-	300.0	158.7	166.1	0.011	-	300.0
Heating oil	49.8	54.8	0.266	-	300.0	62.5	67.5	0.266	-	300.0
Wood chips	25.6	25.6	-	-	300.0	40.7	40.7	-	-	300.0
Pellets	51.2	51.2	-	-	300.0	81.3	81.3	-	-	300.0

4.2 Regions where district heating is potentially viable on the basis of heating distribution costs

As described in the preceding chapter, regions where district heating is potentially viable are identified on the basis of the anticipated heating distribution costs. The heating distribution costs are calculated on the basis of heating density, development density, investment costs and district heating market shares in potential areas. Areas where district heating is potentially viable are then identified on the basis of a definition of the maximum permitted heating distribution costs in contiguous areas.

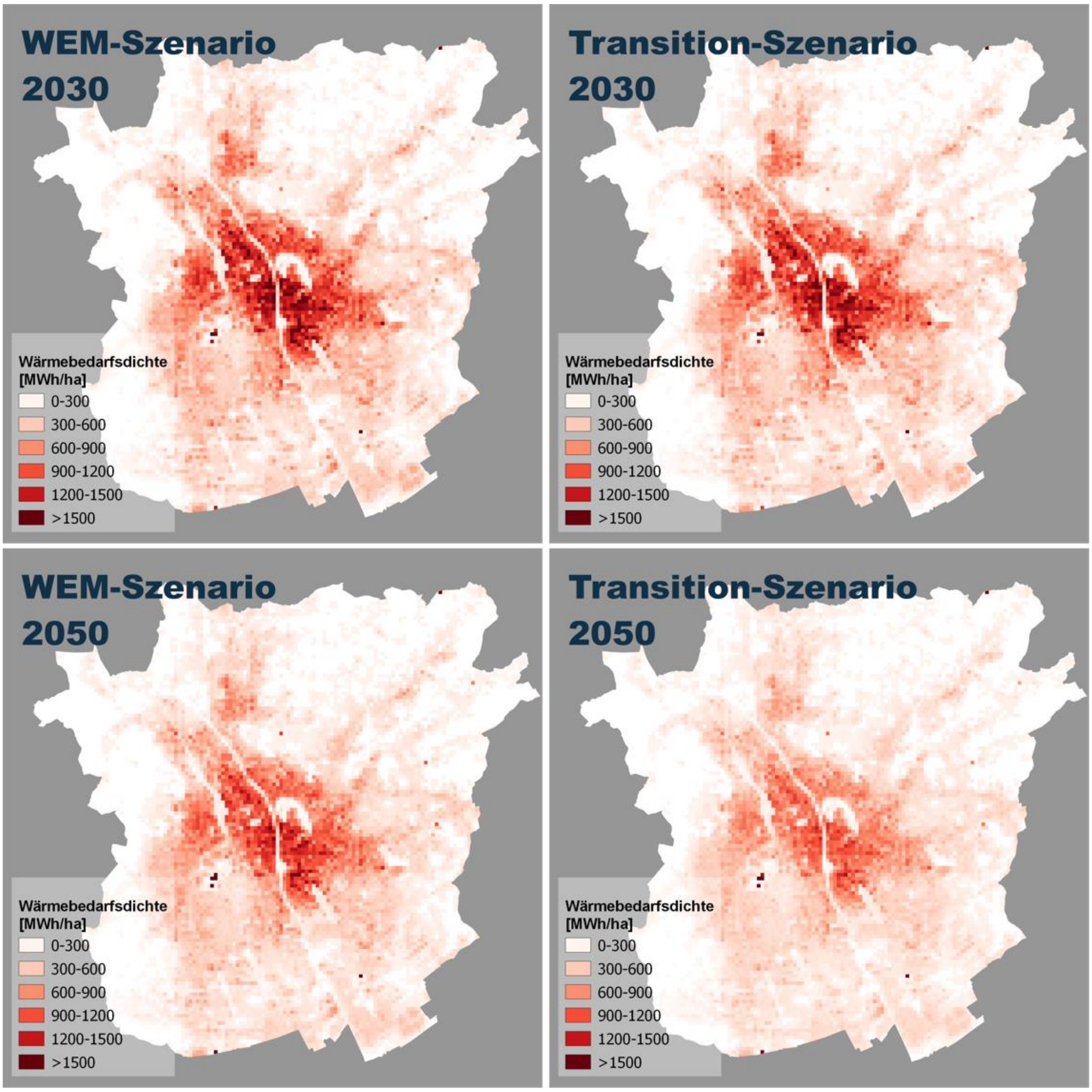

Figure 16: Distribution of heat demand densities in the city of Graz based on the two scenarios for changes in heat demand (WEM & Transition) by 2030 and 2050

	WEM scenario
	Transition scenario

	Heat demand density [MWh/ha]

The calculations are based on the heat demand densities and development densities from the scenarios outlined in Chapter 2.2. Figure 16 shows the heat demand densities in the city of Graz for the two scenarios (WEM and Transition), in each case for 2030 and 2050.

The figure clearly indicates that the heat demand densities differ significantly under the various scenarios and on the different dates. For 2050 in particular, it is readily apparent that demand is reduced more heavily under the Transition scenario than the WEM scenario.

The heating distribution costs are now calculated for each individual hectare. The calculations are carried out using the following formula (aus Persson et al., 2019).

$$C_{d,T} = \frac{C_{1,T} + C_{2,T} \cdot d_a}{n \cdot \frac{Q_T}{L} \cdot \sum_{t=0}^{n} (1+r)^{-t}}$$

$$d_a = 0.0486 \cdot \ln(Q_T/L) + 0.0007 \qquad [m]$$

$$w = A_L/L = \begin{cases} 137.5e + 5 & [m] \quad 0 < e \leq 0.4 \\ 60 & [m] \quad e > 0.4 \end{cases}$$

T Time of investment
Inv_T Annualised district heating distribution network costs per average amount of heat supplied [EUR/GJ]
L Route length [m]
$C_{1,T}$ Construction cost constant [EUR/m], in this case EUR 212/m
$C_{2,T}$ Construction cost factor [EUR/m^2], in this case EUR 4 464/m^2
d_a Average pipe diameter [m]
n Depreciation period, in this case 30 years
Q_T Heat supplied per year [GJ]
Q_T/L Heat supplied per route length [GJ/m]
r Imputed rate of interest, in this case 5%
w Effective width [m]
A_L Area of land, in this case 1 ha

Areas where district heating is potentially viable are now calculated for the following scenarios:

- Changes in demand: WEM versus Transition scenario
- Dates: 2030 and 2050
- Market share of district heating in potential district heating areas: 45% versus 90%
- Maximum permitted average distribution costs: EUR 20, 30, 40 and 50/MWh

In addition to the maximum permitted average distribution costs, a minimum potential of 10 GWh/yr was defined as a further criterion for the viability of district heating in an area.

In total, the variation in the different parameters results in 32 scenario combinations. Figure 17 below shows the resulting calculation of the expansion and localisation of potential district heating areas for the combination involving entirely favourable parameters, i.e. the largest possible expansion of potential district heating areas according to the chosen approach.

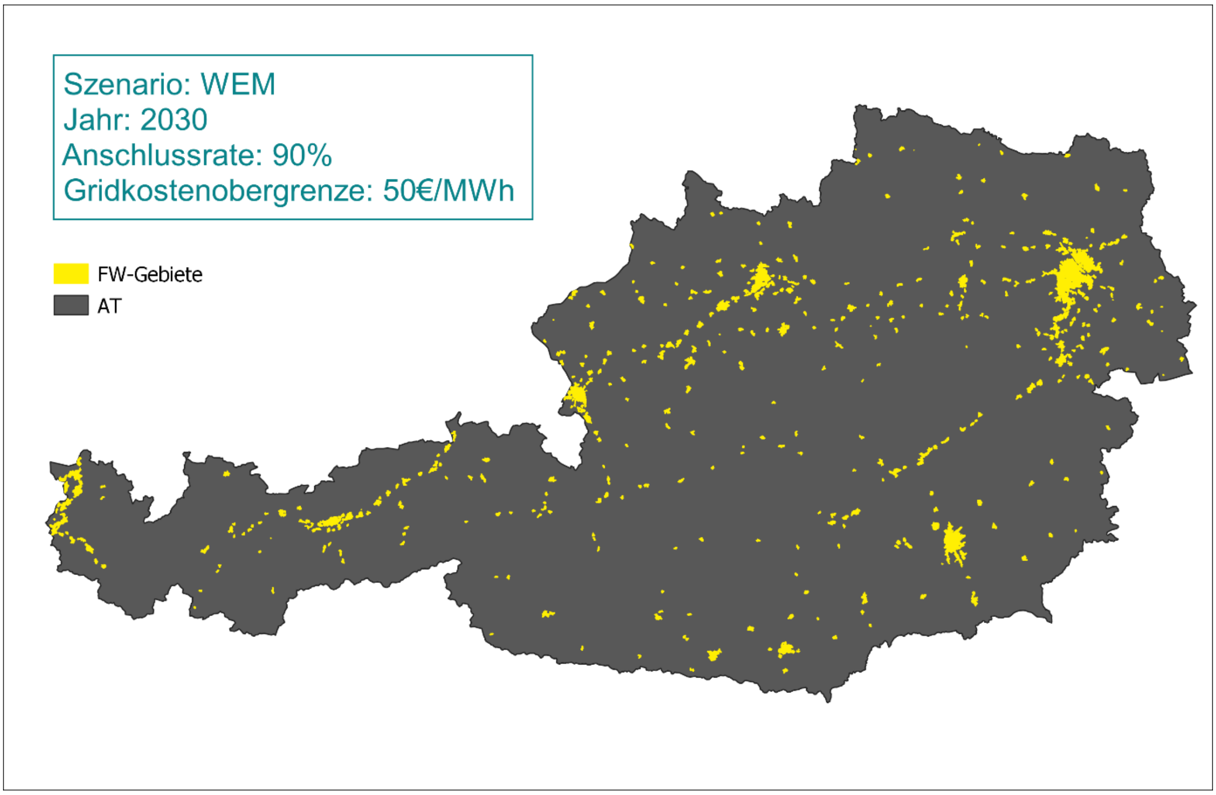

Figure 17: Regions where the use of district heating is potentially viable – scenario with entirely favourable assumptions for 2030 (i.e. the largest possible expansion)

	Scenario: WEM
	Year: 2030
	Connection rate: 90%
	Upper limit for grid costs: EUR 50/MWh
	District heating areas
	AT

Figure 18 below shows the potential district heating area 'Vienna and surroundings'. The area where district heating is potentially viable may be more or less large depending on the scenario combination. The assumed district heating market shares and the maximum permitted heating distribution costs exert a particularly large influence on the result.

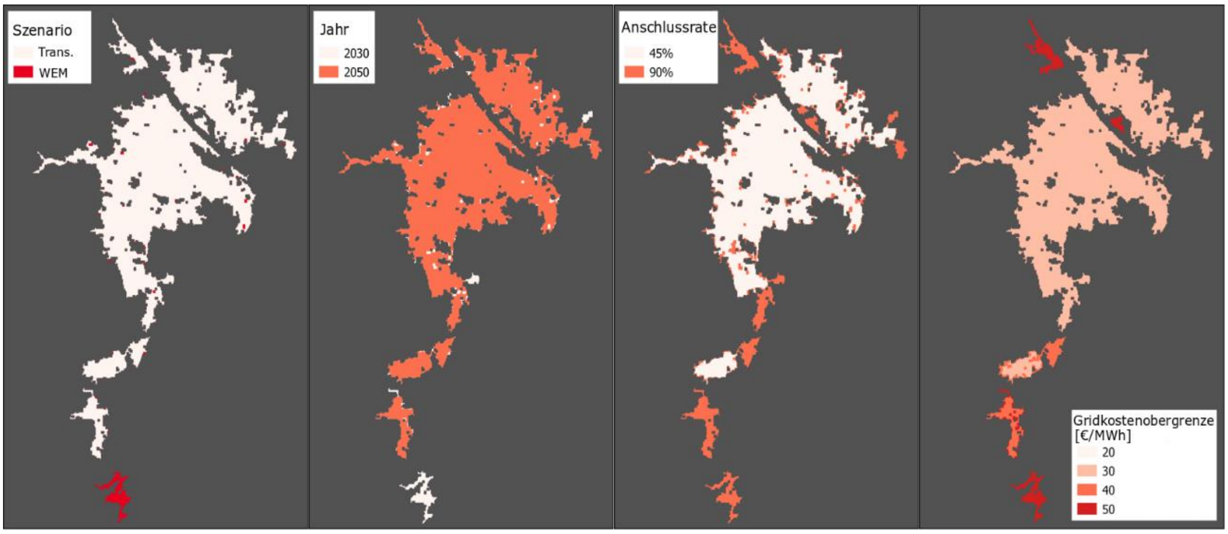

Figure 18: Sensitivity of the expansion of areas where district heating is potentially viable compared to the different scenario parameters (from left to right: changes in demand, date, district heating market share, maximum permitted distribution costs)

	Scenario Transition WEM
	Year
	Connection rate
	Upper limit for grid costs [EUR/MWh]

4.3 Identification of typical district heating regions

Typical regions will now be identified for the regions identified in the preceding step, where district heating is potentially viable. The four largest regions will initially be excluded. They will then be examined individually as part of the further analytical work. These regions are as follows:

- Vienna
- Linz
- Graz
- Salzburg

In the next step, the remaining regions determined in the preceding chapter where district heating is potentially viable on the basis of distribution costs will be linked with the heating generation potentials available in each case with a view to identifying district heating regions with a typical supply structure on this basis. The identified regions where district heating is potentially viable on the basis of distribution costs are not confined within the borders of municipalities; instead, larger or smaller areas may be supplied depending on the scenario and the maximum permitted distribution network costs.

The number of regions (in addition to the four large regions that will be examined individually) where district heating is potentially viable on the basis of distribution costs and the expansion of these regions varies very significantly (between 12 and 442) according to the scenario (changes in demand, district heating market share, year, maximum permitted distribution costs; see also Table 5). The potentials available within the borders of the region in accordance with the expansion inherent in each scenario will be assigned to these potential regions below.

Unique combinations of available resource potentials (typical level of resource potentials) will then be determined from all the potential regions across all scenarios, and these 593 unique combinations of resource potentials will then be divided into six typical regions.

The following heating potential availabilities are used to identify the typical regions:

- availability of high-temperature waste heat over 100 °C, suitable for feeding directly into a district heating network using heat exchangers (see Chapter 2.3),
- availability of low-temperature waste heat below 100 °C, suitable for feeding directly into a district heating network using heat pumps (see Chapter 2.3),
- potential of deep geothermal (Könighofer et al., 2014b),
- size of any river present as a possible source of heat for heat pumps (Umweltbundesamt, 2020),
- availability of gas network infrastructure (Müller et al., 2014) and (Büchele et al., 2015) based on (e-control, 2008)),
- existing district heating network (Büchele et al., 2015).

Figure 19 below shows the distribution of these potentials and availabilities across Austria.

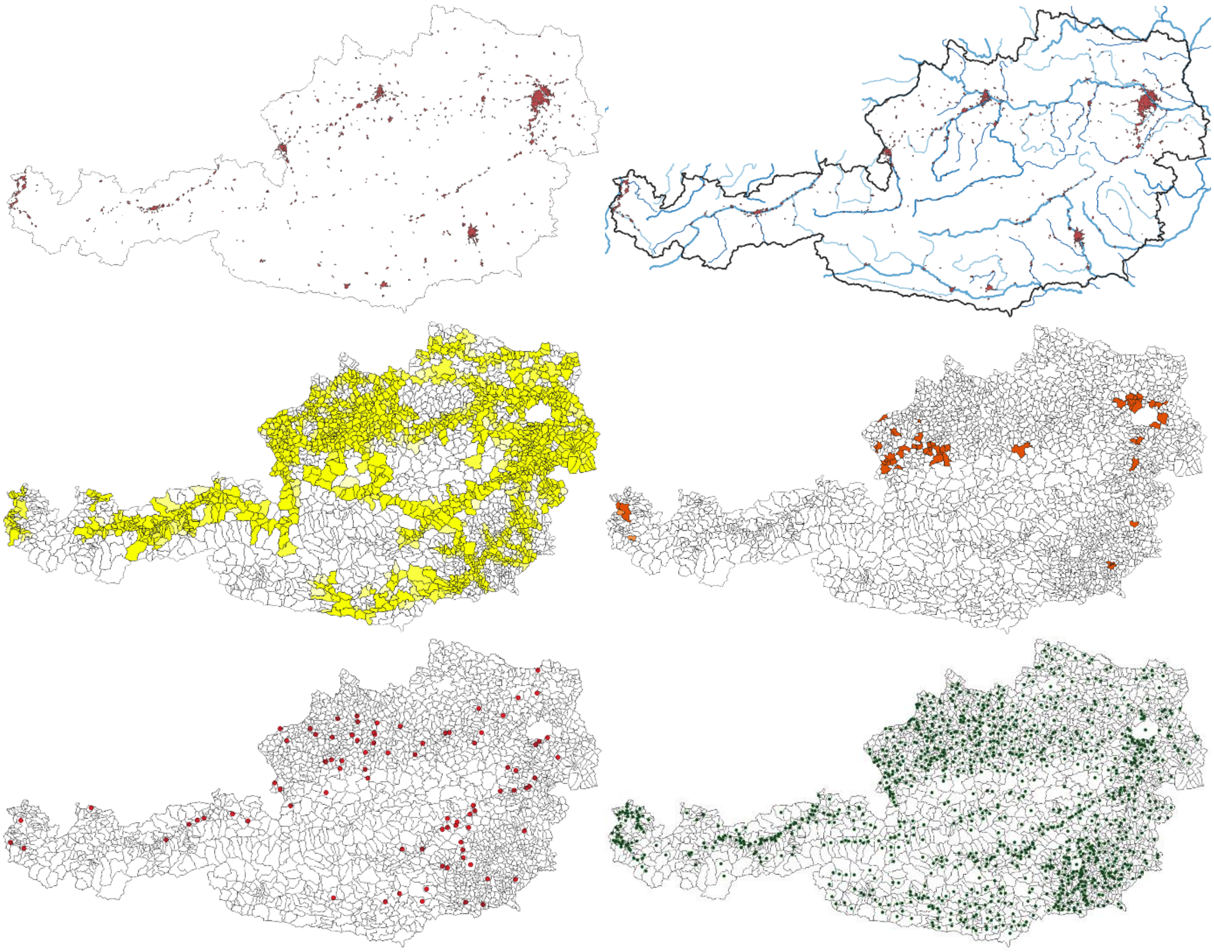

Figure 19: Areas where district heating is potentially viable (top left), rivers (top right), gas network infrastructure (centre left), geothermal potentials (centre right), industrial waste heat potentials (bottom left), existing district heating networks (bottom right) and their distribution across Austria

The assignment of individual regions to the six types, and therefore also the limit values for the assignment, is determined on the basis of an algorithm that pools regions with the minimum 'mathematical distance' between the selected parameters (i.e. regions that are most similar to each other in terms of the existing heating potentials) and groups them on a step-by-step basis. Figure 20 shows the result of this grouping on an exemplary basis. The horizontal line shows the average for categorisation into the six typical regions.

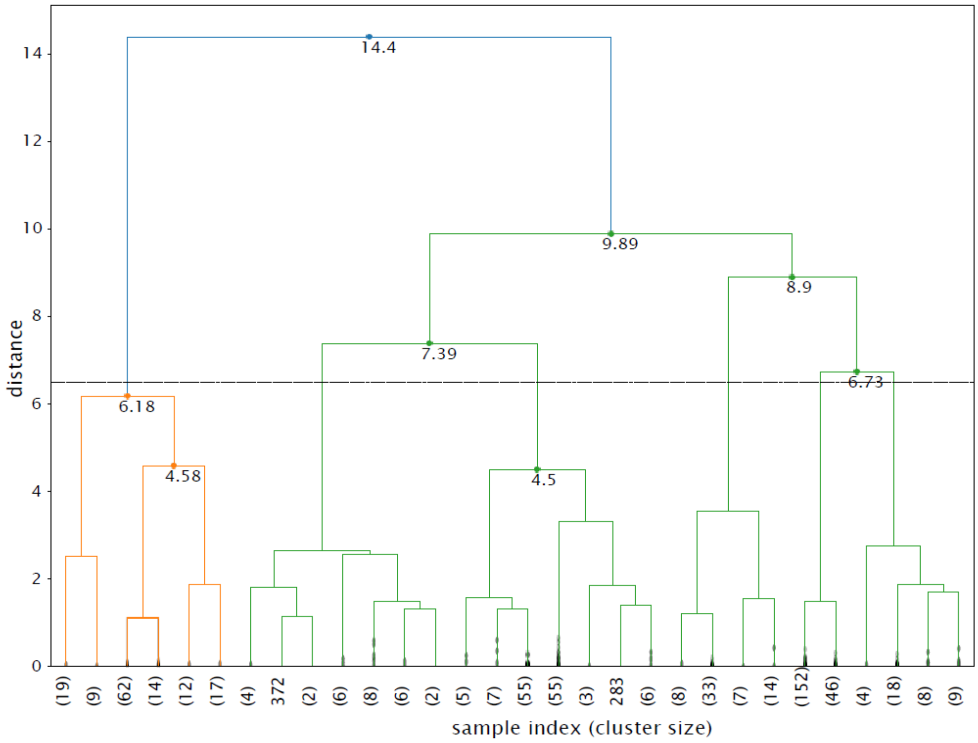

Figure 20: Grouping of all regions where district heating is potentially viable based on their resource availability into varying numbers of different regions – the horizontal line shows the average for categorisation into the six typical regions in this study

Figure 21 shows a graphical depiction of resource availability for all of the regions where district heating is potentially viable (with the exception of the four largest regions, which will be analysed individually). 0 corresponds to no availability of potential or infrastructure; 1 corresponds to availability of infrastructure or a correspondingly high resource potential. The figure reveals that a gas network is present in most of the regions where district heating is potentially viable, and that a district heating network (on a smaller or larger scale) already exists in the majority of the regions. It is also apparent that the various resources tend to be found in different regions. There is typically a lack of industrial waste heat potential and rivers in regions with deep geothermal potential, for example. On the other hand, almost no waste heat or deep geothermal is available in regions with large rivers.

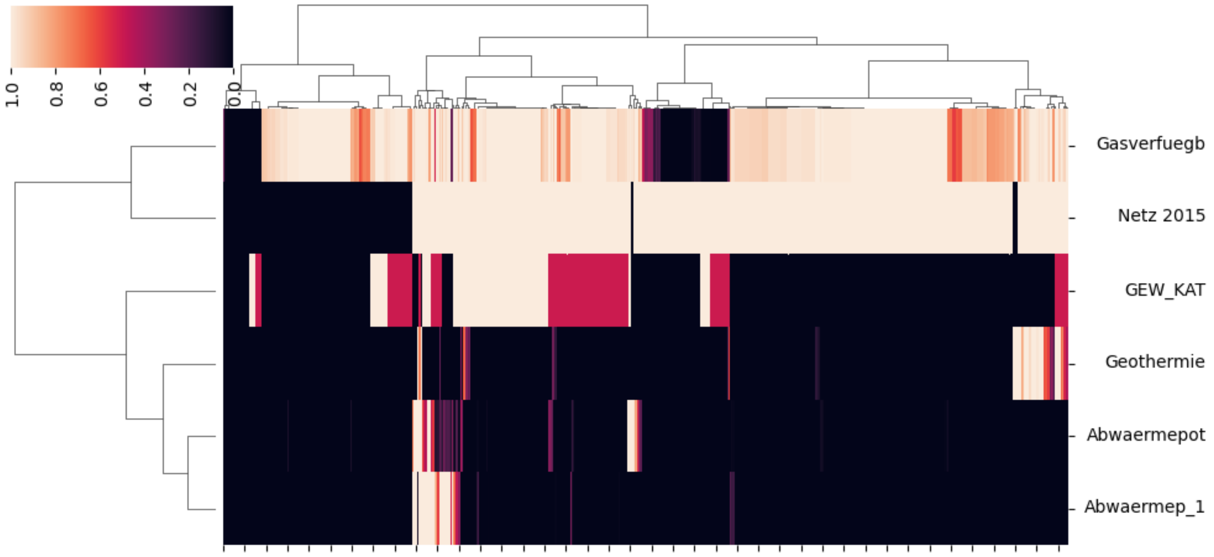

Figure 21: Visualisation of resource availability in the regions where district heating is potentially viable – 0 corresponds to 'No availability' and 1 corresponds to '100% availability of potential'

	Gas availability
	Network 2015
	Hydro_category
	Geothermal
	Waste heat potential
	Waste heat potential_1

The six region types selected for further investigation can be determined on the basis of these characteristics. The following table summarises the characteristics of these regions in qualitative terms.

Table 11: Qualitative presentation of the six identified region types and their characteristics with reference to resource availability

	Existing network	Gas availability	Availability of high-temperature waste heat	Availability of low-temperature waste heat	Geothermal potential	Hydro potential
Type 5: Region without existing network, with gas infrastructure	No	Yes	No	No	No	Low
Type 6: Region with existing network, without gas infrastructure	Yes	No	No	No	No	Low
Type 7: Region with existing network, gas infrastructure and high potential for river source heat pumps	Yes	Yes	No	No	No	High
Type 8: Region with existing network, gas infrastructure and geothermal potential	Yes	Yes	No	No	Yes	No
Type 9: Region with existing network, gas infrastructure and waste heat potential	Yes	Yes	Yes	Yes	No	Low
Type 10: Region with existing network and gas infrastructure	Yes	Yes	No	No	No	No

Table 12 below contains details regarding the number and sizes of regions across the various scenarios. The more favourable a scenario in terms of district heating, the more regions are potentially suitable for its use, and the higher the corresponding values in the table for the number of regions and heat demand. Favourable scenario parameters include high future heat demand, high district heating market shares in district heating areas and high maximum permitted heating distribution costs. The table makes it clear that varying the specified parameters in all region types results in a very broad spectrum in terms of number of regions and heat demand. In order to take account of this broad spectrum of potential heat demands, the calculations carried out on this basis for each region type incorporate the costs of district heating provision for four different district heating demands, for 2030 as well as for 2050. The following assignment of district heating generation costs to identified areas uses the most similar sizes for district heating demands in each case.

Table 12: Number and size of regions for the six identified region types

	Number of regions per scenario (min.-max.) [-]	Heat demand for the regions per scenario (min.-max.) [GWh]	Total heat demand for all the regions per scenario (min.-max.) [GWh]
Type 5: Region without existing network, with gas infrastructure	2-90	10-136	54-1 670
Type 6: Region with existing network, without gas infrastructure	5-195	10-675	290-9 200
Type 7: Region with existing network, gas infrastructure and high potential for river source heat pump	2-66	10-1 100	48-5 200
Type 8: Region with existing network, gas infrastructure and geothermal potential	1-43	10-50	13-750
Type 9: Region with existing network, gas infrastructure and waste heat potential	1-23	10-150	40-990
Type 10: Region with existing network and gas infrastructure	0-24	0-320	0-1 400

4.4 Costs of different district heating supply portfolios in the region types

In accordance with the methodology described in Chapter 4.1, the mode of operation of different district heating supply portfolios was simulated for the (typical) district heating regions identified in Chapter 4.3, firstly in order to identify economically favourable technology portfolios and secondly in order to calculate the costs of generating heat using district heating provision.

The results of two regions are described in more detail in this section. The portfolios for a region with high river source heat pump potential and a region with high waste heat potential are defined, after which exemplary results are discussed.

The following table shows the structural logic of the portfolios for the region with a high river source heat pump potential.

Table 13: Logic and basic assumptions for the creation of district heating generation portfolios for the Cluster 7 example

Cluster 7: Region with existing network, gas infrastructure and high river source heat pump potential				
Portfolio 1				
Brief description	90% gas; remainder covered by river source heat pumps and air source heat pumps			
Demand scenario	**Very small**	**Smal l**	**Me-dium**	**Larg e**
Detailed description (to be read from small to large)	80% gas Remainder covered by air source heat pumps	Large-scale development of air source heat pumps Large-scale development of river source heat pumps (Maximum development of air source heat pumps)	Very large-scale development of gas 80% gas as a result Maximum development of river source heat pumps	Development of gas 90% gas as a result
Portfolio 2				
Brief description	60% gas; remainder covered by river source heat pumps, air source heat pumps, waste water source heat pumps and biomass			
Demand scenario	**Very small**	**Smal l**	**Me-dium**	**Larg e**
Detailed description (to be read from small to large)	60% air source heat pumps 40% gas	Very large-scale development of river source heat pumps Maximum development of air source heat pumps Maximum development of biomass CHP	Very large-scale development of gas Maximum development of river source heat pumps Very large-scale development of waste water source heat pumps	Very large-scale development of gas Small-scale development of waste wa-ter source heat pumps
Portfolio 3				
Brief description	30% gas and 40% river source heat pumps+electric heaters and 15% air source heat pumps; remainder cov-ered by waste water source heat pumps and biomass			
Demand scenario	**Very small**	**Smal l**	**Me-dium**	**Larg e**
Detailed description (to be read from small to large)	90% air source heat pumps Remainder from gas	Large-scale development of air source heat pumps	Very large-scale development of river source heat pumps+electric heaters Large-scale development of waste water source heat pumps Development of biomass CHP and solar thermal Small-scale development of air source heat pumps	Large-scale development of gas Large-scale development of river source heat pumps+electric heaters

			(Maximum development of air source heat pumps, waste water source heat pumps and bio-mass)	

The concrete values for the installed capacities of the individual technologies are defined in the table below (in MW_{th}).

Table 14: Overview of district heating generation portfolios (MW_{th}) for the Cluster 7 example

Demand scenario	040 GWh	150 GWh	400 GWh	750 GWh	040 GWh	150 GWh	400 GWh	750 GWh	040 GWh	150 GWh	400 GWh	750 GWh
District heating generation [MWh]	**40 000**	**150 000**	**400 000**	**750 000**	**40 000**	**150 000**	**400 000**	**750 000**	**40 000**	**150 000**	**400 000**	**750 000**
Peak load [MW]	13.3	49.7	132.6	248.7	13.3	49.7	132.6	248.7	13.3	49.7	132.6	248.7
Minimum load [MW]	0.8	3.0	7.9	14.9	0.8	3.0	7.9	14.9	0.8	3.0	7.9	14.9
Portfolio	Portfolio 1	Portfolio 1	Portfolio 1	Portfolio 1	Portfolio 2	Portfolio 2	Portfolio 2	Portfolio 2	Portfolio 3	Portfolio 3	Portfolio 3	Portfolio 3
Waste incineration plants	-	-	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-	-	-
Waste heat source heat pumps	-	-	-	-	-	-	-	-	-	-	-	-
Waste heat, direct	-	-	-	-	-	-	-	-	-	-	-	-
River source heat pumps	-	15	25	25	-	20	75	75	-	-	75	120
Air source heat pumps	4	25	25	25	9	25	25	25	13	50	60	60
Waste water source heat pumps	-	-	-	-	-	-	20	25	-	-	35	35
Biomass CHP	-	-	-	-	-	10	10	10	-	-	10	10
Biomass heat-only plants	-	-	-	-	-	-	-	-	-	-	-	-
Solar thermal	-	-	-	-	-	-	-	-	-	-	10	10
Electric heaters	-	-	-	-	-	-	-	-	-	-	10	40
Gas turbines	-	-	-	100	-	-	-	65	-	-	-	35
Gas and steam	-	-	-	-	-	-	-	-	-	-	-	-
Gas heat-only plants	10	11	90	124	5	5	45	95	1	1	10	55

Storage	12.8 MW @ 2.7 GWH	48.1 MW @ 10 GWH	128.2 MW @ 26.7 GWH	240.4 MW @ 50 GWH	12.8 MW @ 2.7 GWH	48.1 MW @ 10 GWH	128.2 MW @ 6.7 GWH	240.4 MW @ 50 GWH	12.8 MW @ 2.7 GWH	48.1 MW @ 10 GWH	128.2 MW @ 26.7 GWH	240.4 MW @ 50 GWH
Storage size	33 tm³	123 tm³	330 tm³	617 tm³	33 tm³	123 tm³	330 tm³	617 tm³	33 tm³	123 tm³	330 tm³	617 tm³

The following table shows the structural logic of the portfolios for the region with a high waste heat potential.

Table 15: Logic and basic assumptions for the creation of district heating generation portfolios for the Cluster 9 example

Cluster 9: Region with existing network, gas infrastructure and waste heat potential				
Portfolio 1				
Brief description	75% gas, 20% waste heat and air source heat pumps			
Demand scenario	**Very small**	**Small**	**Me-dium**	**Large**
Detailed description (to be read from small to large)	80% gas Remainder from air source heat pumps	Direct waste heat fully developed Development of waste heat source heat pumps Small-scale development of air source heat pumps (as a result, gas share to 20%)	Large-scale development of gas Maximum development of waste heat source heat pumps	Large-scale development of gas
Portfolio 2				
Brief description	10% gas and 30% waste heat; remainder covered by air source heat pumps, waste water source heat pumps, bio-mass and river source heat pumps+electric heaters			
Demand scenario	**Very small**	**Small**	**Me-dium**	**Large**

Detailed description (to be read from small to large)	10% gas 50% biomass 40% air source heat pumps	Direct waste heat fully developed Development of waste heat source heat pumps	Maximum development of biomass Development of waste heat source heat pumps Large-scale development of air source heat pumps Maximum development of waste water source heat pumps	Large-scale development of waste heat source heat pumps Large-scale development of air source heat pumps Large-scale development of river source heat pumps+electric heaters Small-scale development of gas
Portfolio 3				
Brief description	0% gas, 60% waste heat, 20% air source heat pumps and small amount of waste water and river source heat pumps+electric heaters			
Demand scenario	**Very small**	**Small**	**Me-dium**	**Large**
Detailed description (to be read from small to large)	70% waste heat source heat pumps 30% air source heat pumps	Direct waste heat fully developed Development of waste water source heat pumps	Maximum development of waste water source heat pumps Large-scale development of waste heat source heat pumps Small-scale development of air source heat pumps	Large-scale development of waste heat source heat pumps Large-scale development of air source heat pumps Small-scale development of river source heat pumps

The values defined for the installed capacities of the individual technologies are shown in the table below (in each case in MW_{th}).

Table 16: Overview of district heating generation portfolios (MW_{th}) for the Cluster 9 example

Demand scenario	020 GWh	060 GWh	120 GWh	260 GWh	020 GWh	060 GWh	120 GWh	260 GWh	020 GWh	060 GWh	120 GWh	260 GWh
District heating generation [MWh]	**20 000**	**60 000**	**120 000**	**260 000**	**20 000**	**60 000**	**120 000**	**260 000**	**20 000**	**60 000**	**120 000**	**260 000**
Peak load [MW]	7.1	21.2	42.4	91.9	7.1	21.2	42.4	91.9	7.1	21.2	42.4	91.9

Minimum load [MW]	0.4	1.1	2.1	4.6	0.4	1.1	2.1	4.6	0.4	1.1	2.1	4.6
Portfolio	Portfolio 1	Portfolio 1	Portfolio 1	Portfolio 1	Portfolio 2	Portfolio 2	Portfolio 2	Portfolio 2	Portfolio 3	Portfolio 3	Portfolio 3	Portfolio 3
Waste incineration plants	-	-	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-	-	-
Waste heat source heat pumps	-	4	9	9	-	5	9	19	5	5	16	45
Waste heat, direct	-	9	9	9	-	9	9	9	-	9	9	9
River source heat pumps	-	-	-	-	-	-	-	9	-	-	-	9
Air source heat pumps	2	3	9	9	3	3	9	18	3	3	9	20
Waste water source heat pumps	-	-	-	-	-	-	9	9	-	5	9	9
Biomass CHP	-	-	-	-	4	4	9	9	-	-	-	-
Biomass heat-only plants	-	-	-	-	-	-	-	-	-	-	-	-
Solar thermal	-	-	-	-	-	-	-	-	-	-	-	-
Electric heaters	-	-	-	-	-	-	-	35	-	-	-	-
Gas turbines	-	-	-	28	1	1	1	9	-	-	-	-
Gas and steam	-	-	-	-	-	-	-	-	-	-	-	-
Gas heat-only plants	6	6	19	40	-	-	-	-	-	-	-	-
Storage	6.4 MW @ 1.3 GWH	19.2 MW @ 4 GWH	38.5 MW @ 8 GWH	83.3 MW @ 17.3 GWH	6.4 MW @ 1.3 GWH	19.2 MW @ 4 GWH	38.5 MW @ 8 GWH	83.3 MW @ 17.3 GWH	6.4 MW @ 1.3 GWH	19.2 MW @ 4 GWH	38.5 MW @ 8 GWH	83.3 MW @ 17.3 GWH
Storage size	16 tm^3	49 tm^3	99 tm^3	213 tm^3	16 tm^3	49 tm^3	99 tm^3	213 tm^3	16 tm^3	49 tm^3	99 tm^3	213 tm^3

An excerpt from the result of three generation portfolios based on two district heating demand scenarios for 2030 and 2050 under high-price and low-price parameters and microeconomic and macroeconomic parameters is shown below for the district heating region with high river source heat pump potential. It is apparent that Portfolio 2 has the lowest heating generation costs when moderate district heating demand is assumed, and that Portfolio 3 is most favourable with reference to heat generation costs in the event of high demand.

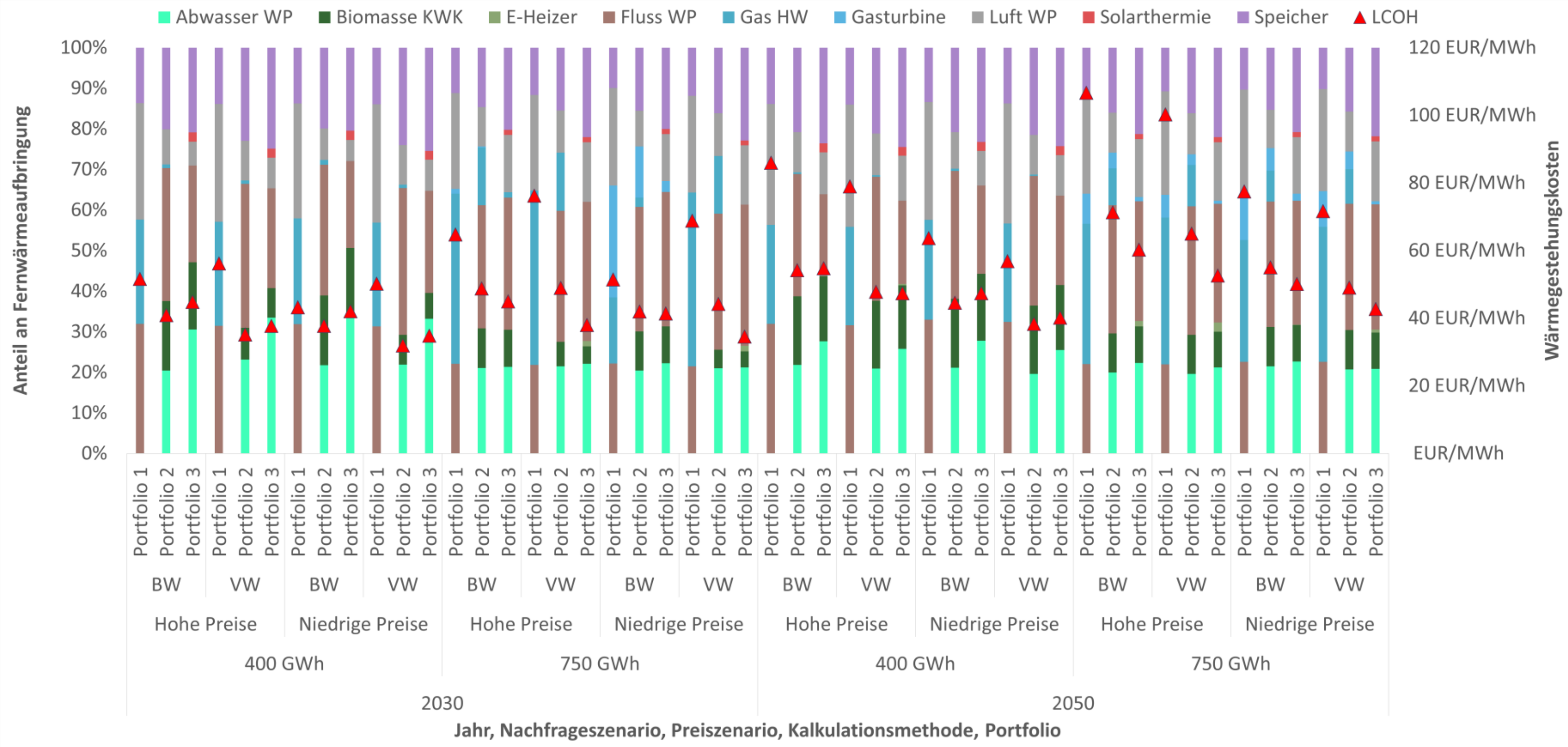

Figure 22: Share of different technologies in district heating generation and the resulting heat generation costs for the Cluster 7 example

	Share of district heating generation
	Heat generation costs
	Year, demand scenario, price scenario, calculation method, portfolio
	Waste water source heat pumps

	Biomass CHP
	Electric heaters
	River source heat pumps
	Gas heat-only plants
	Gas turbines
	Air source heat pumps
	Solar thermal
	Storage
	LCOH
	Portfolio
	High prices
	Low prices
	Microeconomic
	Macroeconomic

The figure below shows an excerpt from the results for the region with high waste heat potential. It shows the share of technologies and district heating generation per portfolio for two demand scenarios, under high-price and low-price and microeconomic and macroeconomic parameters and for 2030 and 2050. It is apparent that Portfolio 3 is the most favourable for the high demand scenario. It is also apparent that it is more economically feasible to expand gas instead of biomass plants for the moderate demand scenario in 2030. This is not the case in 2050, however.

Figure 23: Share of different technologies in district heating generation and the resulting heat generation costs for the Cluster 9 example

	Share of district heating generation
	Heat generation costs
	Year, demand scenario, price scenario, calculation method, portfolio

	Waste heat source heat pumps
	Waste heat, direct
	Waste water source heat pumps
	Biomass CHP
	Electric heaters
	River source heat pumps
	Gas heat-only plants
	Gas turbines
	Air source heat pumps
	Storage
	LCOH
	Portfolio
	High prices
	Low prices
	Microeconomic
	Macroeconomic

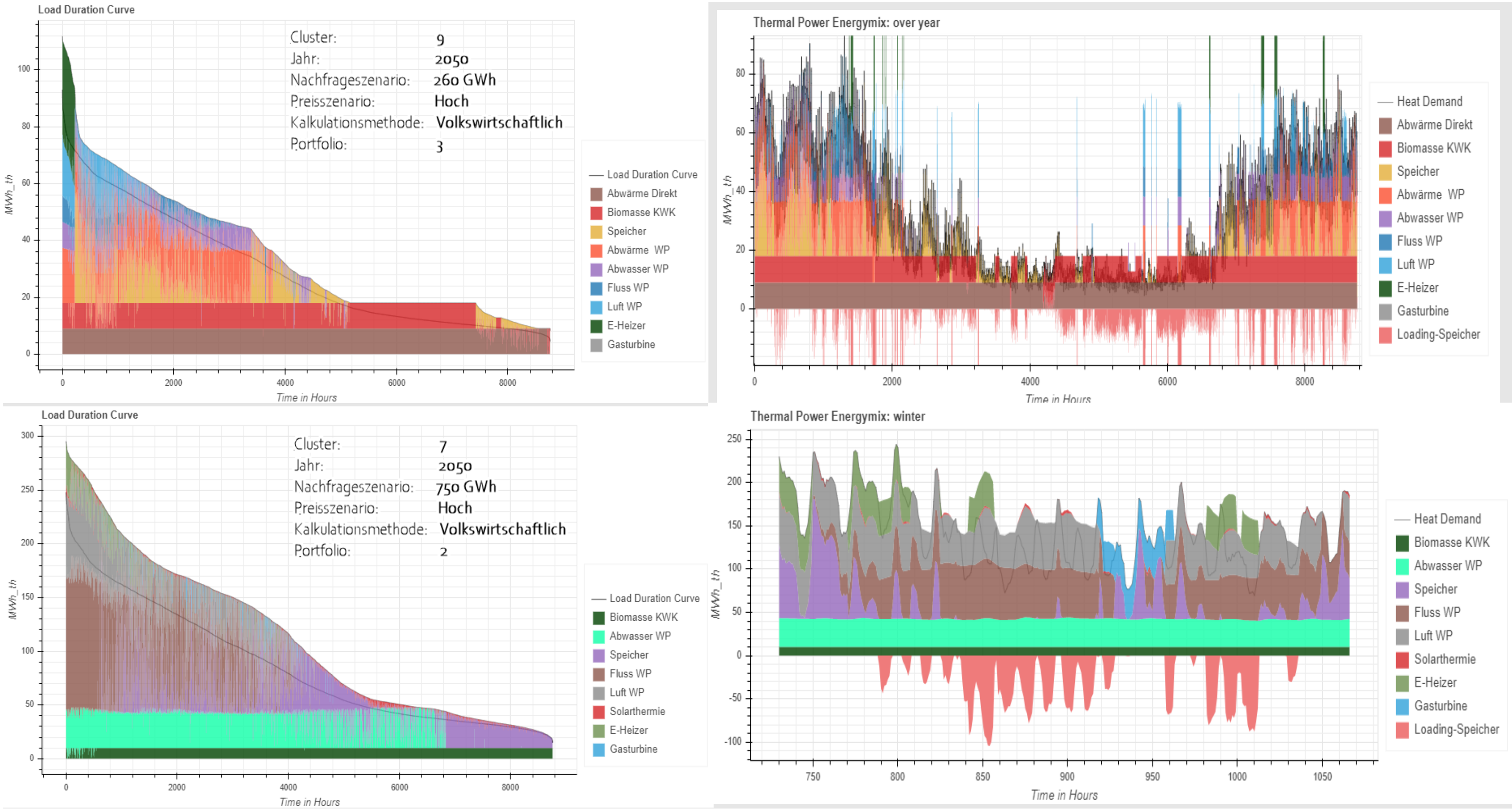

Figure 24: Hourly simulation results for exemplary scenarios from Cluster 7 (below, heating season) and Cluster 9 (above, whole year).

	Cluster
	Year
	Demand scenario
	Price scenario
	Calculation method
	Portfolio
	High
	Macroeconomic

	Waste heat, direct
	Biomass CHP
	Storage
	Waste heat source heat pumps
	Waste water source heat pumps
	River source heat pumps
	Air source heat pumps
	Electric heaters
	Gas turbines
	Loading store
	Solar thermal

With a view to identifying the economic potential, the most favourable portfolio in each case will always be used below as a basis for comparison against decentralised supply.

The costs of generating heat are calculated by minimising the hourly cost of using the technology. Figure 24 shows a selected result. The hourly cost of using the technologies in the two regions investigated can be seen.

Based on these results, the heating distribution costs for each individual region, on the basis of the analyses in Chapter 4.2, are added in each case to the costs of generating district heating in order to obtain the region-specific supply costs for district heating.

4.5 Costs of property-specific heating

In order to calculate the economic potential of district heating, the costs of providing district heating in all of the identified regions where district heating is potentially viable are compared against the reference costs for the property-specific provision of heating. As shown in Chapter 4.1.1, the costs of providing heat directly in the properties/buildings are calculated for various typical buildings, various provision technologies and various scenario variants using the Invert / EE Lab model.[3] For the most part, use is made of existing scenarios and underlying data and assumptions from the project 'Heat demand among small-scale consumers with reference to climate targets for 2030 and 2050' in connection with the production of energy scenarios (Krutzler et al., 2017) (see Chapter 2.2). For both scenarios (WEM and Transition), the following data are used for the analyses shown here for 2030 and 2050: changes in building structure (demolition and new construction of different building types), changes in the thermal properties of these buildings (nature and prevalence of renovation measures in different building types) and the costs and efficiencies of the technologies used to provide the heat. Energy source prices and CO_2 emissions factors are adapted to the assumptions in the relevant investigation (see Table 9 and Table 10). The first step is to calculate the costs of providing heat (levelised costs of heat in EUR/MWh) in all of the different typical buildings using different provision technologies and scenario variants in 2030 and 2050. The following two figures show the results of these calculations for two typical buildings that account for relevant proportions of the Austrian building stock: Figure 25 shows the results for single-family dwellings constructed between 1990 and 1999, and Figure 26 shows the results for office buildings constructed between 1946 and 1969.

[3] https://invert.at/

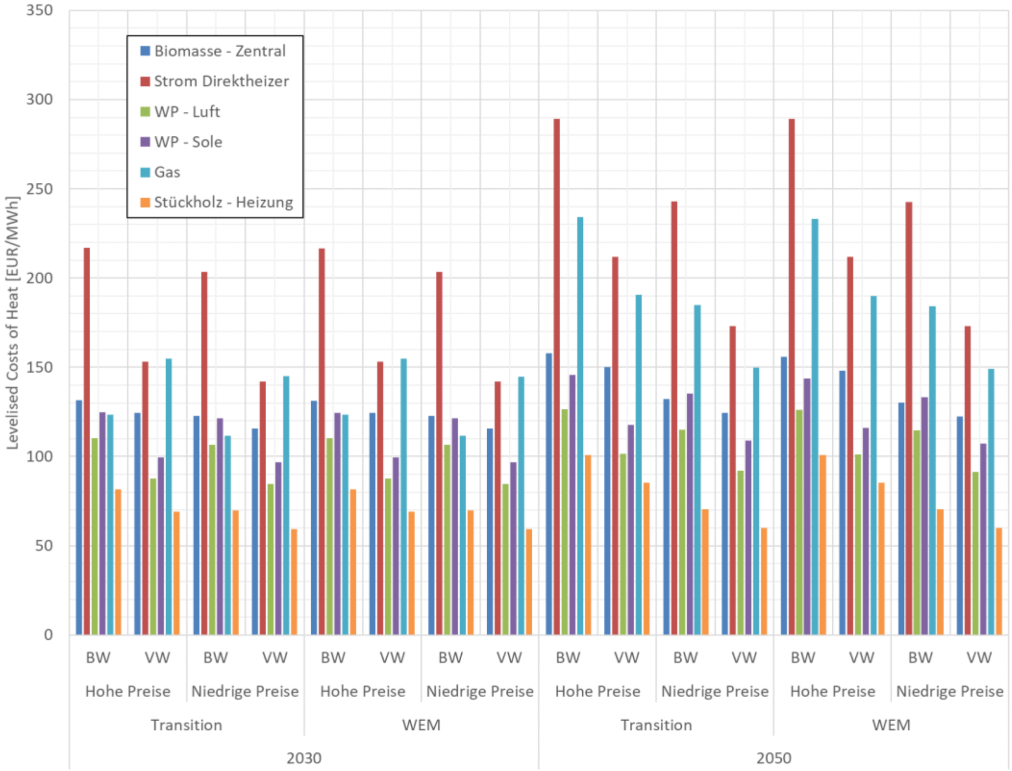

Figure 25: Costs of generating heat (levelised costs of heat (LCOH)) under the various scenarios using different technologies in single-family dwellings constructed between 1990 and 1999

	Biomass – centralised
	Direct electric heaters
	Air source heat pumps
	Brine/water heat pumps
	Gas
	Logs – heating
	High prices
	Low prices

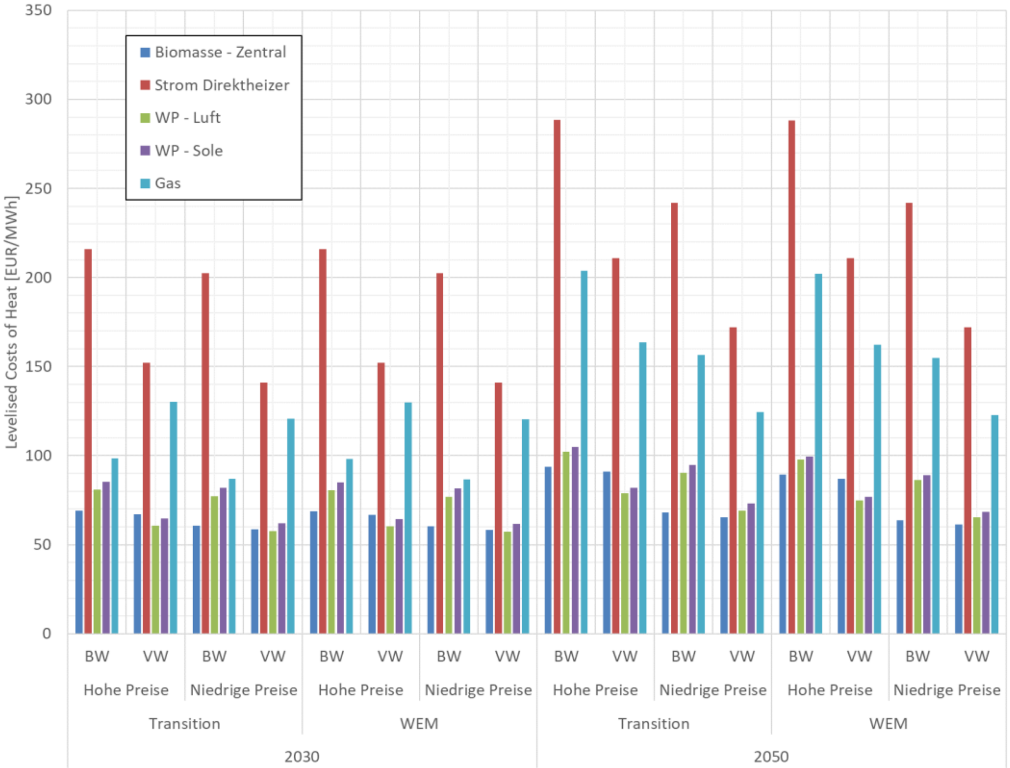

Figure 26: Costs of generating heat (levelised costs of heat (LCOH)) under the various scenarios using different technologies in large office buildings constructed between 1946 and 1969

	Biomass – centralised
	Direct electric heaters
	Air source heat pumps
	Brine/water heat pumps
	Gas
	High prices
	Low prices

The figures show that direct electric heaters represent the most expensive option for providing heat in both single-family dwellings and office buildings. The high energy source prices have an impact in this area. Gas heating systems are the second most expensive option. They are significantly more expensive in all scenarios than the provision of heat using heat pumps or biomass, with the exception of the microeconomic calculations for 2030. The macroeconomic calculations assume that external costs are incurred for CO_2 emissions. In the calculations for 2030, this results in significantly higher LCOHs for the provision of heat from gas compared to the microeconomic calculations. The provision of heat using gas is higher in 2050 because only biogas and synthetic gas will be used by this point. This means that emissions of CO_2 will be almost zero. As a basic principle, the costs are higher in the microeconomic calculations than in the macroeconomic calculations because the latter do not include taxes. The figures also show that the costs associated with the provision of heat using heat pumps are similar to those associated with provision using centralised biomass boilers. Firewood-based heating systems are the cheapest option, but are only feasible in small buildings such as single-family dwellings.

The following step involves calculating the reference costs for the property-specific provision of heat in the various scenarios on the basis of the costs calculated for different technologies in the various typical buildings. The costs of providing heat in all of the typical buildings using all of the various technology variants are weighted according to their occurrence in the respective underlying scenario (WEM or Transition). The distribution of the surface areas of typical buildings is taken directly from the respective scenario and year, and the distribution of the technologies used is slightly adapted for this purpose; since reference costs are to be calculated only for the property-specific provision of heat, the shares of demand covered using district heating for the underlying scenario are divided between the various property-specific technology options. Table 17 below shows the technology distribution used to calculate the reference costs for the different development scenarios and years.

Table 17: Average distribution of the technologies used as a basis for calculating the reference costs for the property-specific provision of heating (based on (Krutzler et al., 2017))

	WEM		Transition	
	2030	2050	2030	2050
Gas	35%	11%	35%	9%
Oil	19%	0%	18%	0%
Firewood*	13%	20%	13%	15%
Biomass – automated	12%	26%	12%	27%
Direct electric heaters	9%	7%	9%	7%
Brine/water heat pumps	8%	19%	8%	21%
Air source heat pumps	5%	18%	5%	22%

*Firewood-based heating systems are only taken into account for single-family dwellings; for all other building types, the share of firewood for automated biomass systems is taken into account

Figure 27 shows the calculated reference costs for the property-specific provision of heat under the various scenarios. This results in LCOHs between EUR 93.5/MWh (WEM, macroeconomic, 2050, low prices) and EUR 143.5/MWh (Transition, microeconomic, 2050, high prices). The reference costs are higher under the macroeconomic scenarios than under the corresponding microeconomic scenarios for 2030, while exactly the opposite is true for 2050. This is because the macroeconomic calculations include the costs of CO_2 emissions, whereas it is assumed in the case of the microeconomic calculations that no CO_2 price is to be paid for property-specific provision. Relevant CO_2 emissions are still generated in connection with the use of gas and oil in 2030, but oil is no longer used by 2050, and even in the gas network only biogas and synthetic gas are used, meaning that CO_2 emissions are almost down to zero. As a basic principle, the reference costs in the macroeconomic calculations are lower because taxes are not included. Substantial differences can be observed between the reference costs for the higher and lower price levels, while the differences between the changes in the WEM and Transition scenarios are significantly lower.

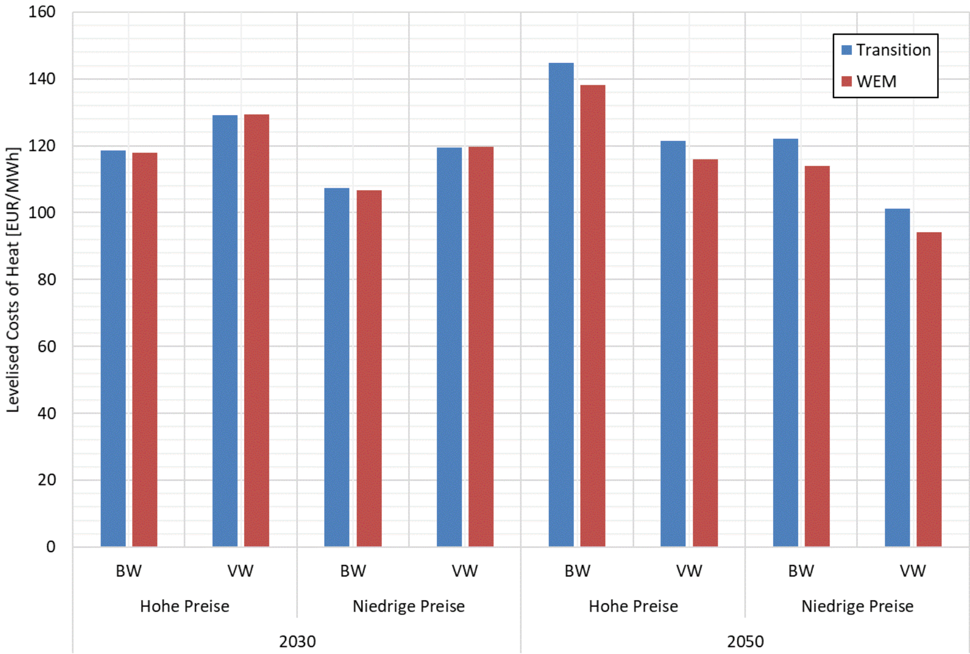

Figure 27: Reference costs for the property-specific provision of heat under the various scenarios

	Transition
	WEM
	Microeconomic
	Macroeconomic
	High prices
	Low prices

4.6 Results of the cost/benefit analysis

A comparison of the costs for network-based provision of district heating against the costs for property-specific provision in the region examined in each case can be used to obtain the economic potential of district heating provision and the resulting economic energy source quantities for district heating.

Figure 28 below shows this comparison of heating generation costs (LCOH) for property-specific provision and district heating provision in the various regions where district heating is potentially viable for various scenario variants in 2030; Figure 29 shows the same for 2050.

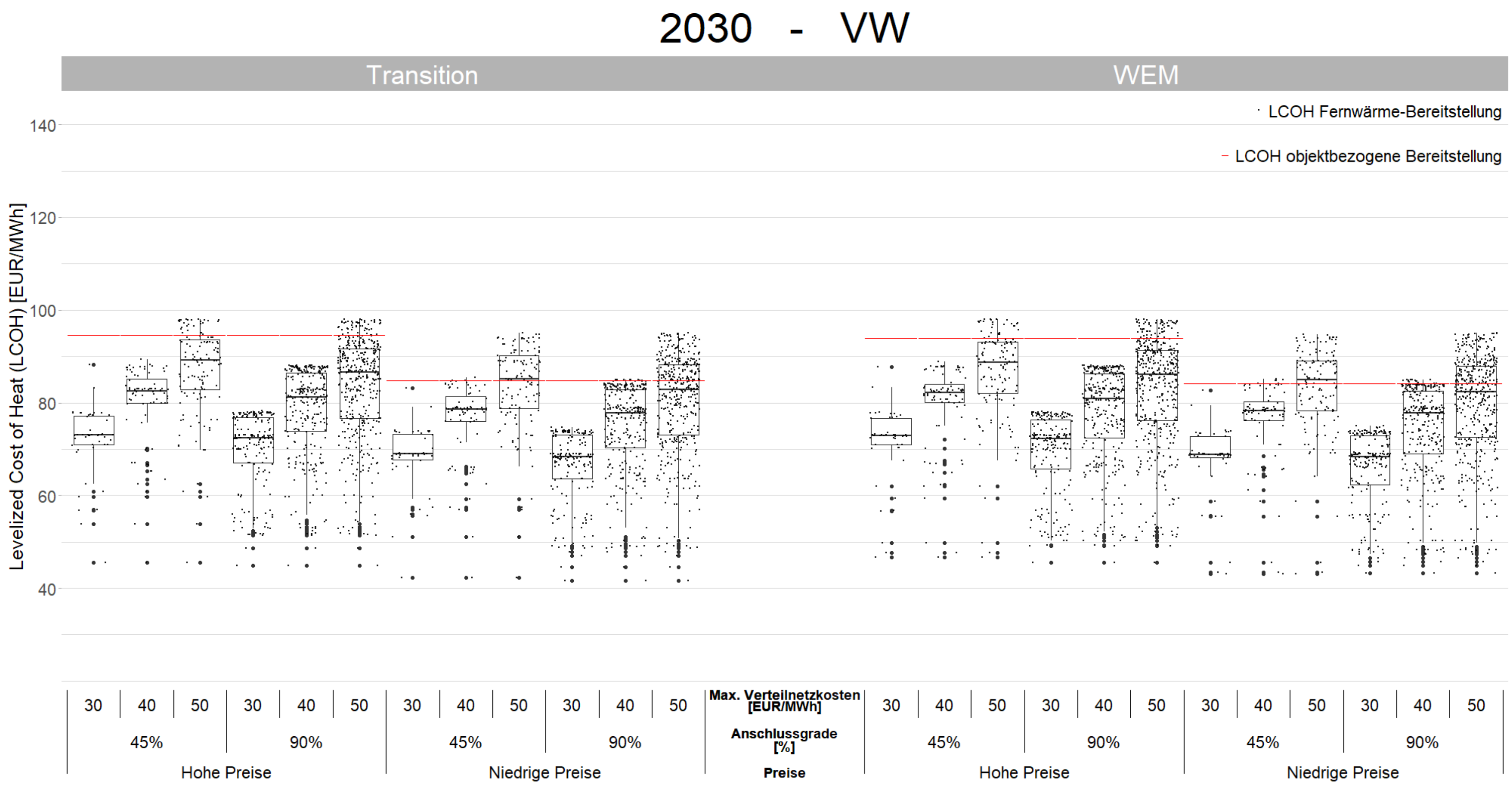

Figure 28: Comparison of the costs (LCOH) of property-specific provision (red line) and the costs (LCOH) of district heating provision (boxplots and scatter plots) for various scenario variants in 2030 – macroeconomic perspective

	2030 – macroeconomic
	Transition
	WEM
	LCOH for district heating provision
	LCOH for property-specific provision
	High prices
	Low prices
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices

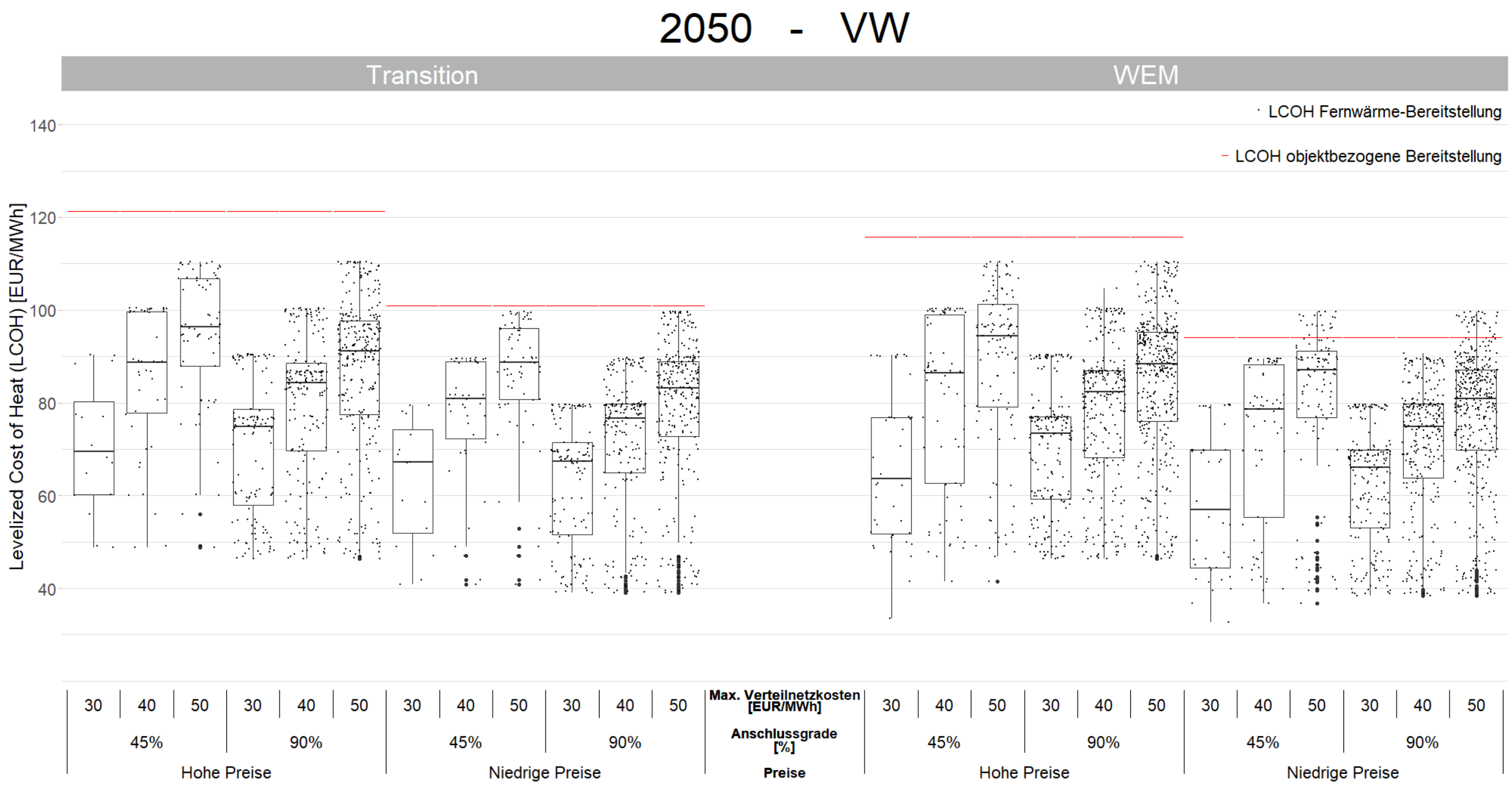

Figure 29: Comparison of the costs (LCOH) of property-specific provision (red line) and the costs (LCOH) of district heating provision (boxplots and scatter plots) for various scenario variants in 2050 – macroeconomic perspective

	2050 – macroeconomic

	Transition
	WEM
	LCOH for district heating provision
	LCOH for property-specific provision
	High prices
	Low prices
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices

It is apparent that district heating exhibits a high level of economic feasibility for the 2050 scenario in the selected scenarios (and therefore also with regard to the underlying regions in which the respective heat generation costs can be achieved), especially if a high energy price level is assumed. It should also be noted in this connection that the mix of decentralised technologies under the WEM or Transition scenarios described above can be assumed to be constant for all calculated variants. Economic feasibility is somewhat lower for 2030 under the specified parameters and assumptions, i.e. there are more regions in which the decentralised technology is cheaper than the supply of heat via heating networks.

The following two figures (Figure 30 and Figure 31) show the non-economic district heating regions in the respective scenario variant.

The following connections are illustrated:

- the larger the maximum permitted distribution network costs in the identification of regions where district heating is potentially viable (Chapter 4.2), the higher the share of these regions that are excluded again in the comparison of the costs of property-specific provision and district heating provision. This is only logical, since increasing the maximum permitted distribution network costs also means significantly increasing the number of regions where district heating is potentially viable.
- More regions are non-economic when prices are low than when prices are high, since prices exert a greater influence over property-specific provision than over provision using district heating; this is because a significant proportion of the costs associated with district heating provision are distribution-related.
- It is apparent that the average size of non-economic areas is significantly below 50 GWh/yr under almost all scenarios in 2050. In 2030, significantly larger areas are also ultimately non-economic under the scenarios with high maximum distribution network costs.

The following figures (Figure 32 and Figure 33) show the economic potential of district heating supply under the different scenarios calculated for 2030 and 2050.

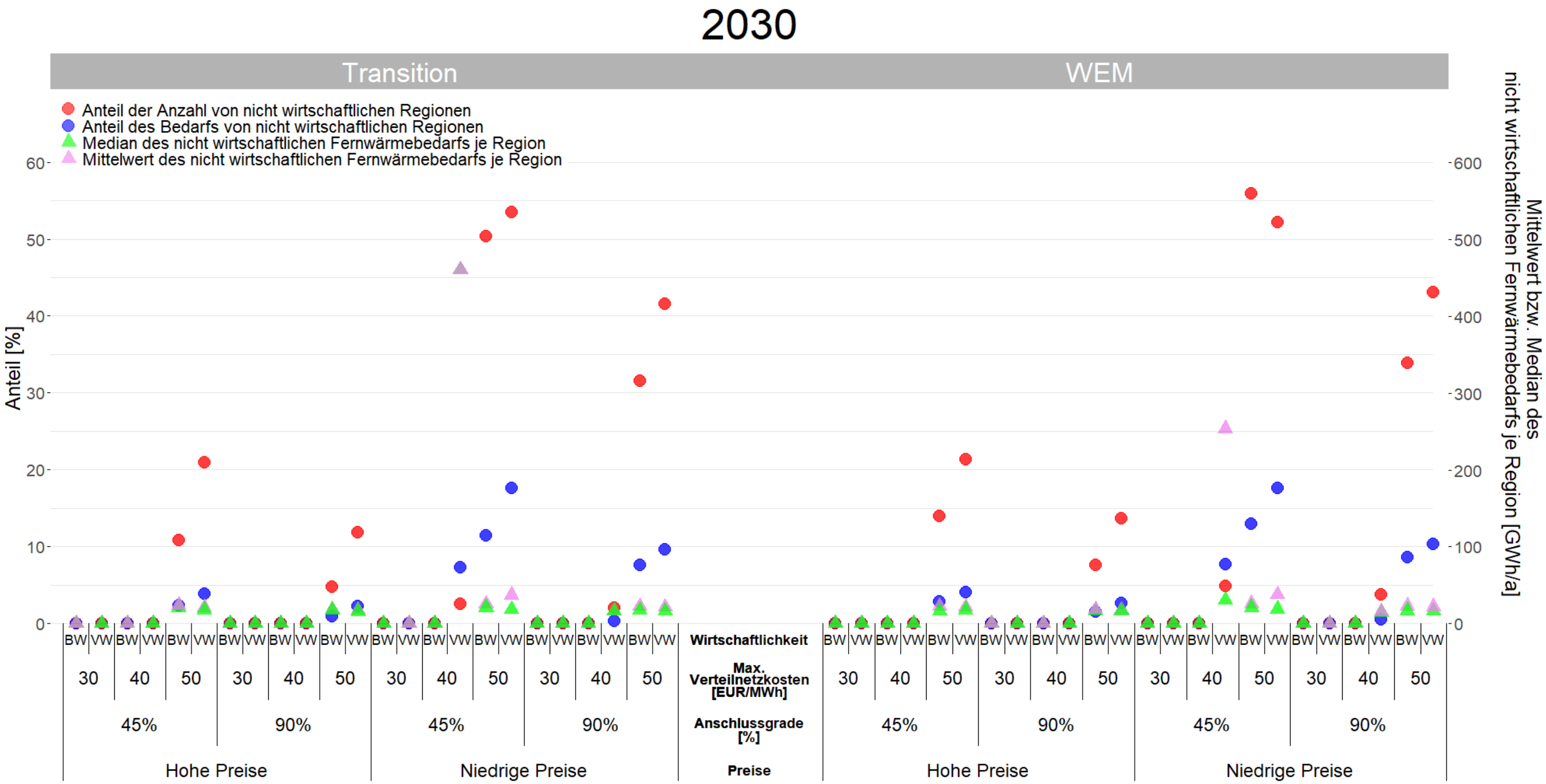

Figure 30: Share of non-economic district heating areas (number and demand) and average size of non-economic areas (median, mean), 2030

	2030

	Transition
	WEM
	Share [%]
	Mean or median of non-economic district heating demand per region [GWh/a]
	Share of number of non-economic regions
	Share of demand of non-economic regions
	Median of non-economic district heating demand per region
	Mean of non-economic district heating demand per region
	High prices
	Low prices
	Economic feasibility
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices

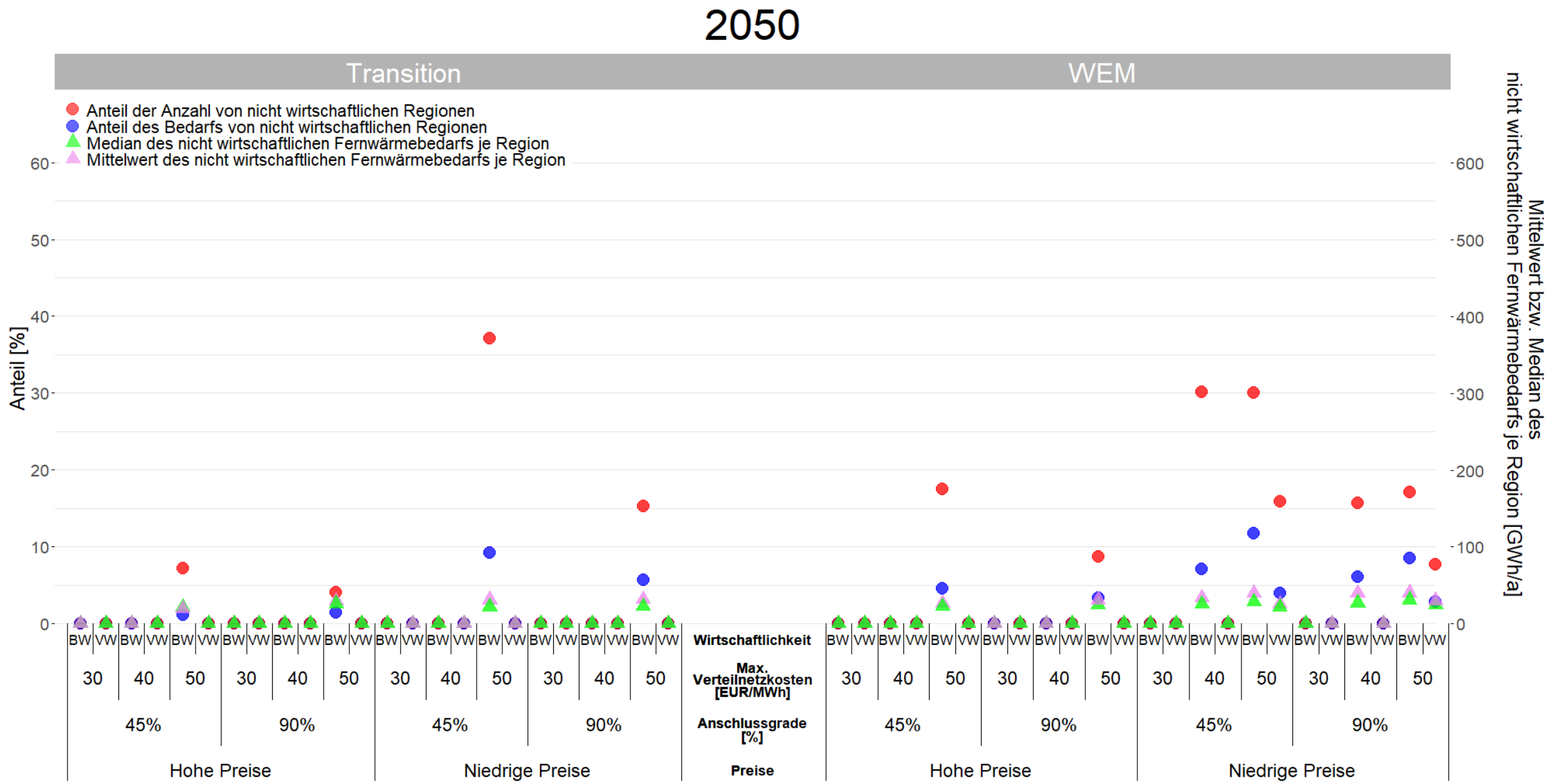

Figure 31: Share of non-economic district heating areas (number and demand) and average size of non-economic areas (median, mean), 2050

	2050
	Transition

	WEM
	Share [%]
	Mean or median of non-economic district heating demand per region [GWh/a]
	Share of number of non-economic regions
	Share of demand of non-economic regions
	Median of non-economic district heating demand per region
	Mean of non-economic district heating demand per region
	High prices
	Low prices
	Economic feasibility
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices

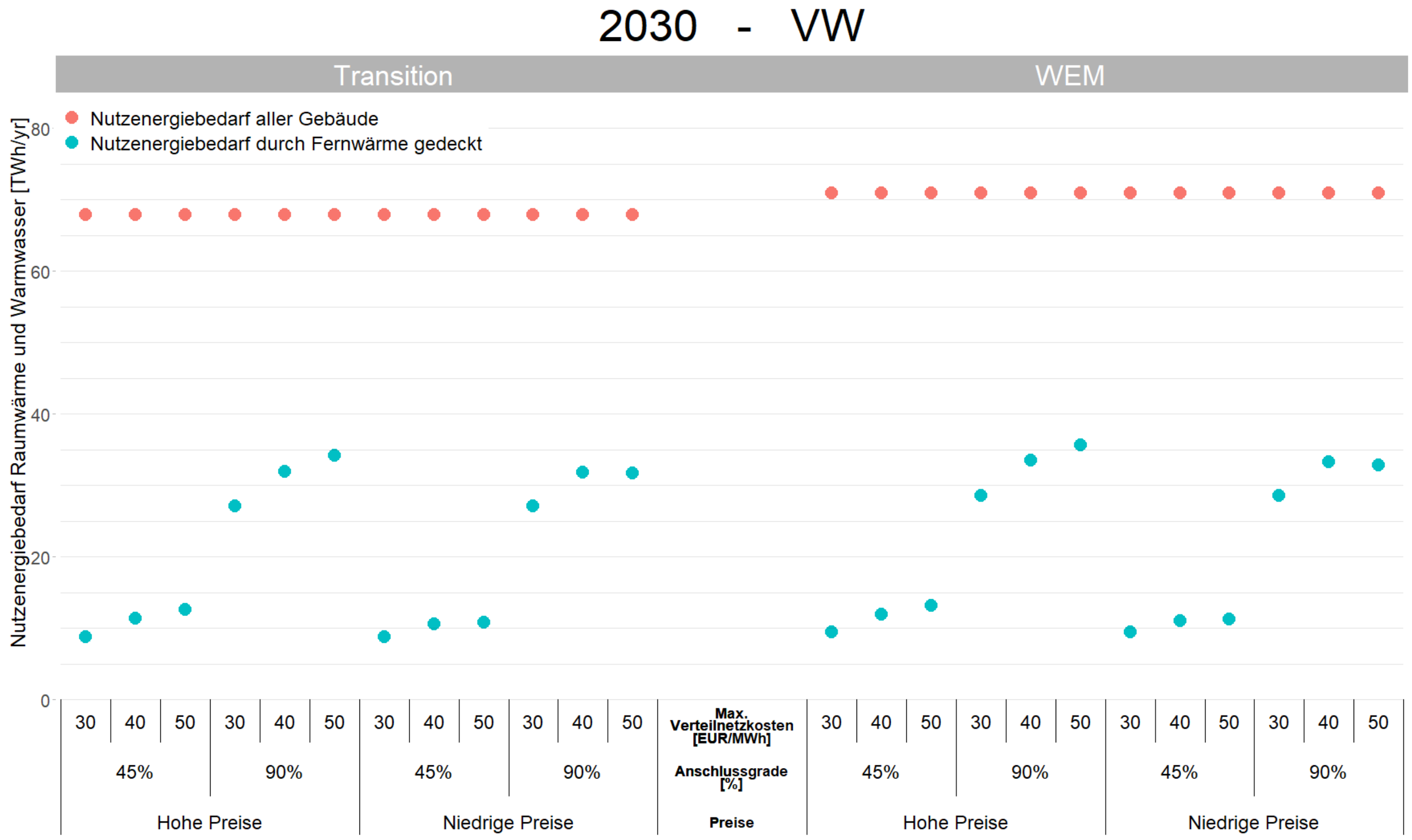

Figure 32: Economic potentials of district heating under the various scenarios calculated, macroeconomic perspective, 2030

	2030 – macroeconomic
	Transition

	WEM
	Useful energy for space heating and hot water [TWh/yr]
	Useful energy demand for all buildings
	Useful energy demand covered by district heating
	High prices
	Low prices
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices

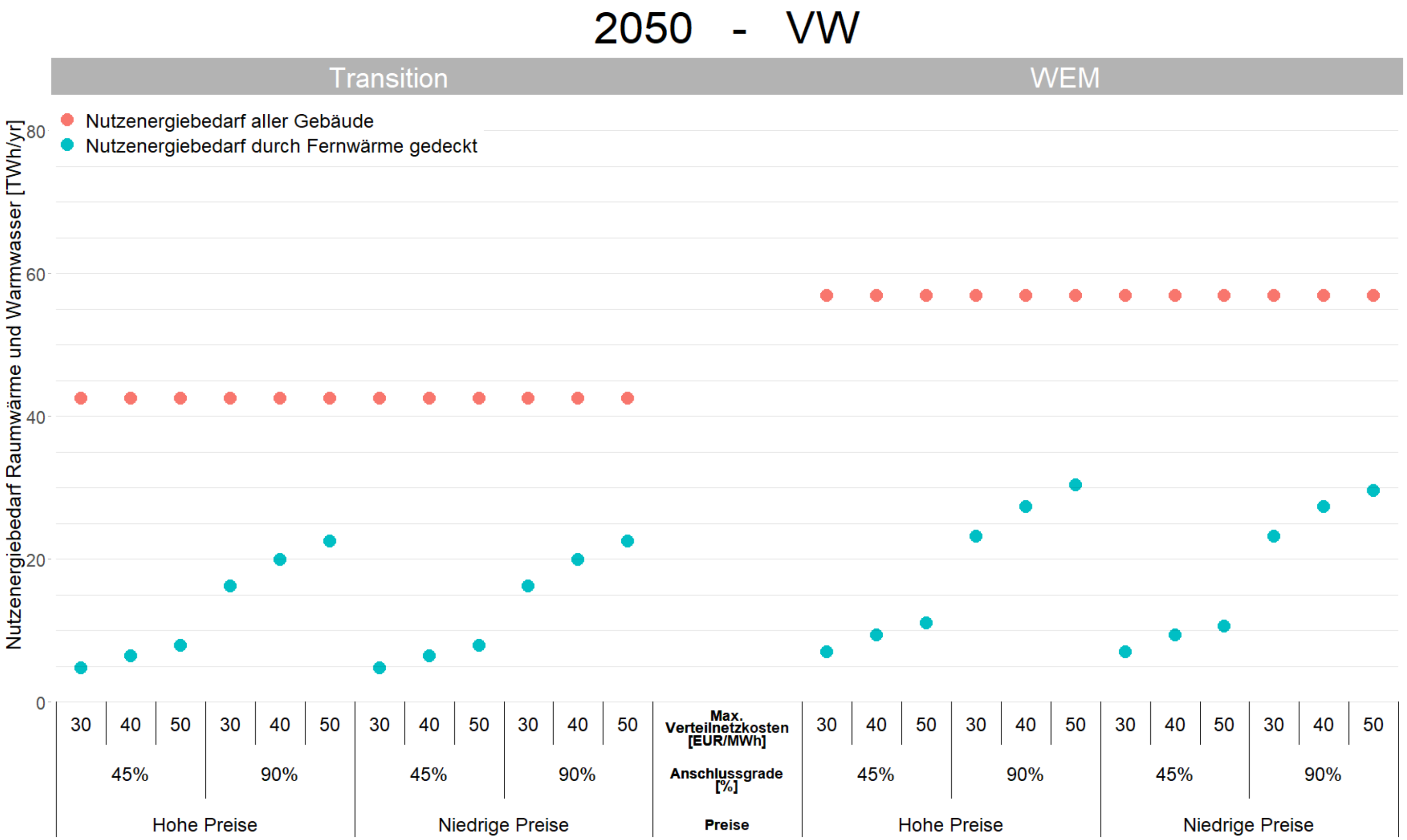

Figure 33: Economic potentials of district heating under the various scenarios calculated, macroeconomic perspective, 2050

	2050 – macroeconomic
	Transition

	WEM
	Useful energy for space heating and hot water [TWh/yr]
	Useful energy demand for all buildings
	Useful energy demand covered by district heating
	High prices
	Low prices
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices

Figure 32 and Figure 33 show that the economic potentials are heavily dependent on the specified connection rates (45% versus 90%). They are also dependent to a relevant extent on the maximum permitted distribution network costs (EUR 30, 40 or 50/MWh). There are also differences between the macroeconomic and microeconomic perspectives, in particular for higher maximum distribution network costs (for Transition only with EUR 50/MWh and low prices, and for WEM also with EUR 40/MWh and low prices); in areas with high distribution network costs, the costs of district heating exceed those of property-specific provision as a result of the VAT charged on total district heating costs. The differences between the price-related assumptions are minimal in terms of their impacts on the economic potential of district heating.

Figure 34 and Figure 35 show the energy source mix for the provision of space heating and hot water under the different scenario variants for 2030 and 2050. The figures show both the energy sources that are used in property-specific provision (crosshatched areas) and the energy sources that are used in district heating. The results of the different scenarios for both years (2030 and 2050) are shown adjacent to each other.

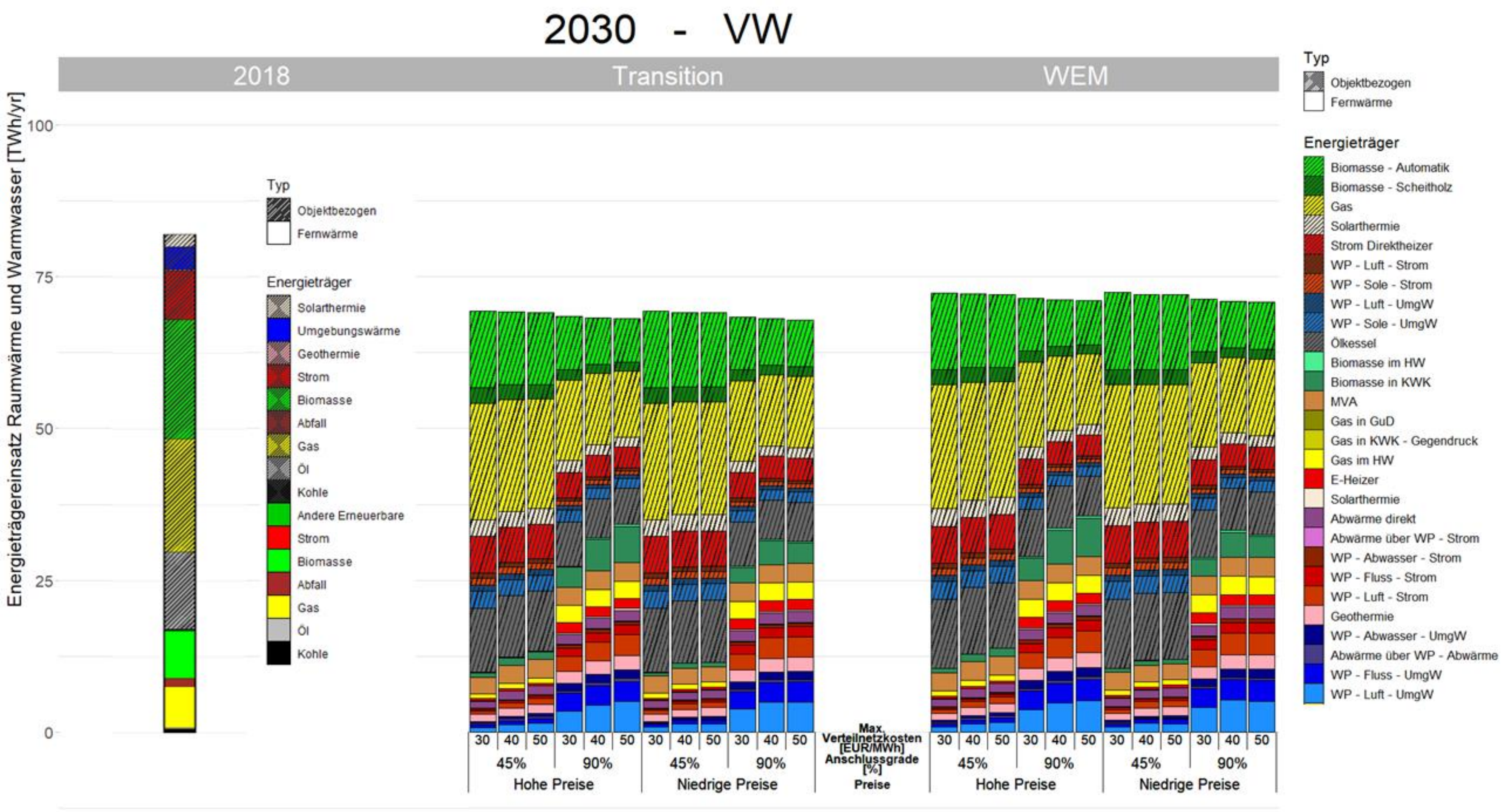

Figure 34: Use of energy sources for the provision of space heating and hot water under the various scenarios for the macroeconomic perspective in 2030

	2030 – macroeconomic
	Use of energy sources for space heating and hot water [TWh/yr]
	Transition
	WEM
	Type
	Property-specific
	District heating
	Energy source
	Solar thermal
	Ambient heat
	Geothermal
	Electricity
	Biomass
	Waste
	Gas
	Oil
	Coal
	Other renewables
	High prices
	Low prices
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices
	Biomass – automated
	Biomass – firewood
	Direct electric heaters
	Air source heat pumps, electricity
	Brine/water heat pumps, electricity
	Air source heat pumps, ambient heat
	Brine/water heat pumps, ambient heat
	Oil-fired boiler
	Biomass in heat-only plants
	Biomass in CHP
	Waste incineration plants
	Gas in gas and steam
	Gas in CHP – back pressure
	Gas in heat-only plants
	Electric heaters

	Waste heat, direct
	Waste heat via heat pump – electricity
	Waste water source heat pumps, electricity
	River source heat pumps, electricity
	Air source heat pumps, electricity
	Geothermal
	Waste water source heat pumps, ambient heat
	Waste heat via heat pump – waste heat
	River source heat pumps, ambient heat
	Air source heat pumps, ambient heat

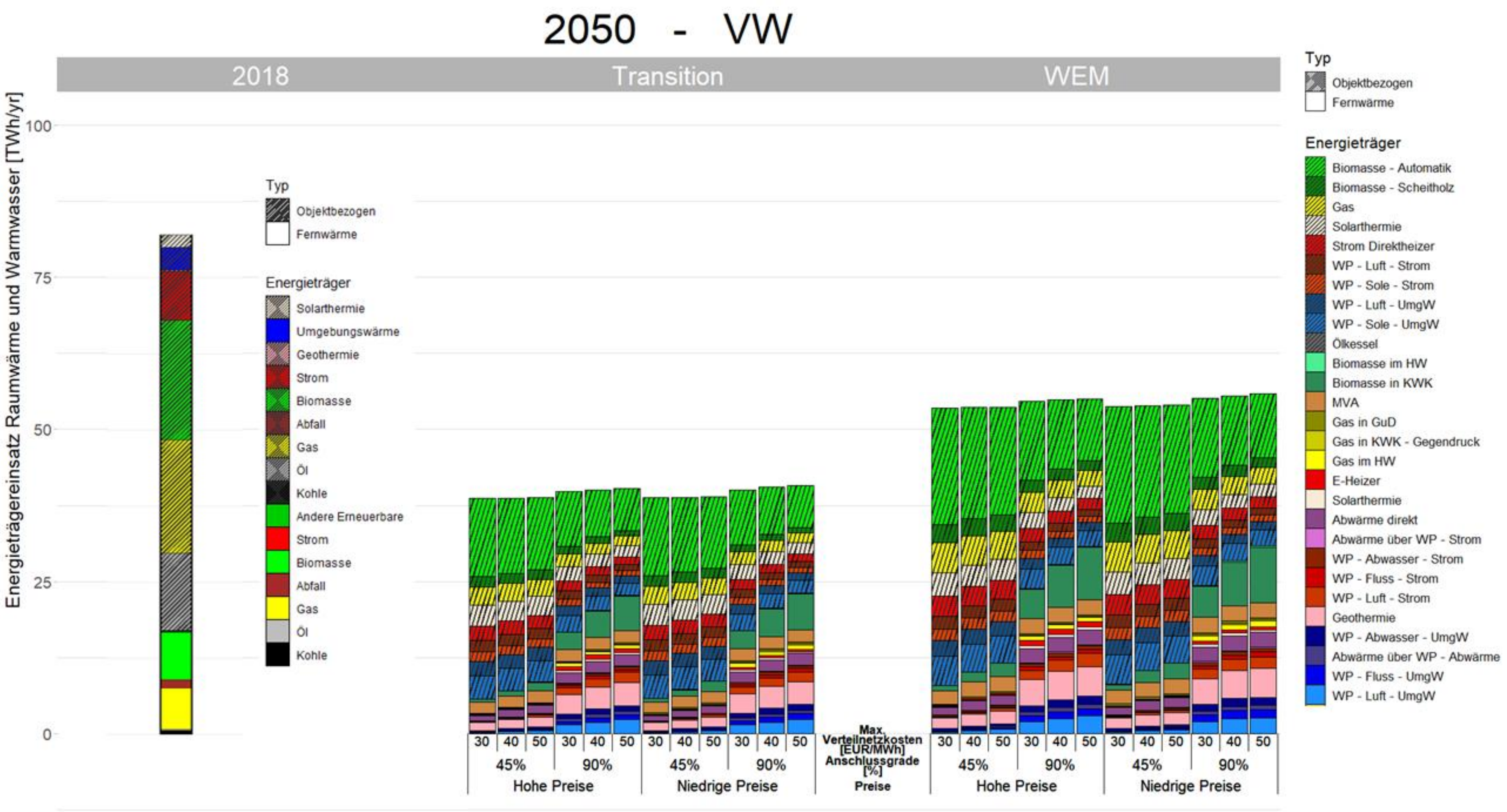

Figure 35: Use of energy sources for the provision of space heating and hot water under the various scenarios for the macroeconomic perspective in 2050

	2030 – macroeconomic
	Use of energy sources for space heating and hot water [TWh/yr]

	Transition
	WEM
	Type
	Property-specific
	District heating
	Energy source
	Solar thermal
	Ambient heat
	Geothermal
	Electricity
	Biomass
	Waste
	Gas
	Oil
	Coal
	Other renewables
	High prices
	Low prices
	Maximum distribution network costs [EUR/MWh]
	Connection rates [%]
	Prices
	Biomass – automated
	Biomass – firewood
	Direct electric heaters
	Air source heat pumps, electricity
	Brine/water heat pumps, electricity
	Air source heat pumps, ambient heat
	Brine/water heat pumps, ambient heat
	Oil-fired boiler
	Biomass in heat-only plants
	Biomass in CHP
	Waste incineration plants
	Gas in gas and steam
	Gas in CHP – back pressure
	Gas in heat-only plants
	Electric heaters
	Waste heat, direct
	Waste heat via heat pump – electricity

	Waste water source heat pumps, electricity
	River source heat pumps, electricity
	Air source heat pumps, electricity
	Geothermal
	Waste water source heat pumps, ambient heat
	Waste heat via heat pump – waste heat
	River source heat pumps, ambient heat
	Air source heat pumps, ambient heat

There are differences in terms of the coverage of heat demand between the WEM and Transition scenarios, resulting from the varying levels of demand. The difference between the 45% and 90% connection rate is more relevant, however. If a higher connection rate can be achieved (e.g. through a stringent energy spatial planning policy), a significantly higher share of heat demand can be covered using district heating. A higher share of geothermal or waste heat use is possible as a result, and the relevance of high-capacity heat pumps also increases.

The models show a slightly higher level of energy use in the scenarios with high shares of district heating. This is a result of distribution losses in the district heating networks. At the same time, however, this higher level of energy use does not imply a lower overall efficiency; on the contrary, a higher overall efficiency of heating is achieved, since in many cases higher proportions of available waste heat, geothermal, waste or river heat potentials can be used. Their use would not be feasible in the case of property-specific provision.

Although there is a clear distinction between the scenarios in terms of centralised and decentralised heating provision, the energy source mix remains relatively constant between the scenarios (connection rates, maximum distribution costs, energy source prices, WEM/Transition). This implies that these parameters do not fundamentally alter the choice of economic portfolios and technologies in the aggregate of all region types across Austria, and that the basic statements therefore demonstrate a certain level of robustness. The uncertainties that nevertheless persist are discussed in the following chapter.

Table 18: Economic potential of the efficient and renewable technologies for heating and cooling identified in the cost/benefit analysis. Reporting in accordance with the European Commission's template (sources: own analyses) – value ranges in line with the scenario variants included in each case

2030	**Transition**		**WEM**	
	Microeconomic	**Macroeconomic**	**Microeconomic**	**Macroeconomic**
	GWh/yr	GWh/yr	GWh/a	GWh/a
Industrial waste heat	1 504-3 206	1 366-2 376	1 704-3 314	1 518-2 407
Industrial waste cooling	-	-	-	-
Waste incineration	2 914-3 493	2 553-3 043	3 193-3 607	2 640-3 143
High-efficiency CHP	1 120-5 463	0-0	1 162-5 661	0-0
Renewable energy sources				
Deep geothermal	1 147-2 417	1 140-2 383	1 187-2 511	1 180-2 477
Biomass	17 059-20 298	13 384-16 758	17 088-20 940	13 693-16 786
Solar thermal	69-142	69-266	72-150	72-279
*Other renewable energies**	935-1 264	865-1 263	995-1 337	916-1 336
Heat pumps	3 927-13 334	4 586-16 465	4 125-13 856	4 838-17 184

2050	**Transition**		**WEM**	
	Microeconomic	**Macroeconomi**	**Microeconomi**	**Macroeconomic**

		c	c	
	GWh/yr	GWh/yr	GWh/a	GWh/a
Industrial waste heat	866-2 610	873-2 598	1 325-3 377	1 325-3 399
Industrial waste cooling				
Waste incineration	1 761-2 098	1 745-1 978	2 287-2 667	2 266-2 501
High-efficiency CHP	262-617	191-446	335-785	244-565
Renewable energy sources				
Deep geothermal	1 376-3 765	1 372-3 784	1 768-4 864	1 762-4 879
Biomass	14 670-17 462	14 514-17 376	21 818-25 988	21 554-25 570
Solar thermal	40-334	45-357	57-443	63-487
*Other renewable energies**	2 621-3 771	2 449-3 475	3 987-5 915	3 691-5 538
Heat pumps	4 389-8 501	4 689-9 050	5 245-10 477	5 656-11 142

*Total renewable gas (including synthetic gas)

4.7 Discussion and conclusions

The purpose of this study is to identify the economic potential for energy-efficient and renewable heating and cooling in compliance with existing energy and climate policy targets, as defined in connection with the regular reporting obligation imposed under Article 14 of the Energy Efficiency Directive. In particular, these targets include the objective of CO_2 neutrality by 2040 which was set by the Austrian Government in its current legislative programme and which results from the Paris Agreement and current developments at EU level, in particular the European Green Deal.

The analytical work did not involve making detailed plans or carrying out detailed analyses with reference to individual heating networks, or issuing concrete recommendations regarding the design of the statutory and political framework for renewables expansion. It also did not involve carrying out feasibility studies with a view to the implementation of specific technologies in individual heating networks, and it was certainly not intended to serve as a basis for investment decisions concerning individual heating networks.

The basic assumption is therefore that the goal of (net) climate neutrality in Austria will be achieved between 2030 and 2050. This means that fossil energy sources still play a role in determining the economic potential for 2030, but no longer for 2050. For 2050, it is therefore assumed, among other things, that any demand for gas will be generated from renewable sources.

Under these assumptions, the following key statements can be made:

- The decarbonisation of the heating and cooling supply in Austria is possible, but only under some key assumptions and framework conditions.
    - These include extensive efforts to renovate buildings, which constitute a basic prerequisite for e.g. an efficient use of heat pumps and moderate resource demand to cover the residual heat demand. Another particularly key point is that building renovations (and the associated reduction in the temperature levels required to provide space heating) also constitute a prerequisite for the further development of fourth-generation heating networks, even though limitations on the scope of this study made it impossible to cover this factor explicitly.
    - Parallel decarbonisation of electricity generation is a further prerequisite for decarbonisation of the space heating and hot water sector. Heat pumps are a highly relevant technology when considering how heat demand could be covered, but require a renewable electricity supply so that they can be categorised as a fully decarbonised option.

  - Successfully integrated industrial waste (excess) heat is a resource that should not be underestimated. The decarbonisation of industry with a view to categorising this heat as renewable is another key pillar of district heating decarbonisation.
- The share of district heating depends above all on the connection rate that can be achieved in the district heating regions. Depending on this, an economic potential for district heating is calculated from about 20% to over 50%.
- Technology mix for district heating:
  - Under the assumptions made in this study regarding the potential composition of renewable gas and the underlying generation costs, renewable gas does not in general prove to be a cost-effective option for decarbonising the sector. Among other things, the costs of renewable gas will depend on the level of demand from various sectors. Since it can be assumed that renewable gas will be harder to substitute for other sectors (e.g. industry) than for the provision of space heating and hot water, for example, a higher level of demand for low-temperature heat also implies higher costs for the use of renewable gas in industry.
  - Biomass continues to represent a significant share of the renewable heat supply, both decentralised and in district heating. It can be observed in particular that in the scenarios with low efficiency increases, the pressure on the use of biomass resources would increase very strongly. The attainability of decarbonisation in these scenarios is therefore more open to question than in scenarios involving higher renovation levels. The amount of biomass resources that will ultimately be available for the heating sector will depend heavily on demand in other sectors such as industry. This issue fell outside the scope of this study, and it was not therefore possible to discuss and analyse it in depth.
  - It can be seen that heat pumps play an essential role not only in decentralised applications, but also in district heating. Their efficiency depends not only on the development of the heat sources available in each specific region, but also on changes in heating network temperatures. Seasonal fluctuations in the temperature of heat sources such as rivers and ambient air were taken into account in connection with the use of heat pumps. In some cases, this means that the use of these technologies during the coldest periods of the year will be substantially reduced, meaning that heat storage will then also play a significant role.
  - The role of thermal power plants and CHPs in a future renewable electricity system was not the focus of this study. In the sense of high fuel utilisation, heat extraction from existing thermal power plants should definitely be strived for. Until 2050, however, the analyses show that gas-fired CHP plants will only be used with relatively low full load hours, based on the assumption that exclusively renewable gas is used.
  - Large solar thermal plants can be an economically viable option, although there is a strong dependence on the overall structure of the generation portfolio on the one hand, and on the achievable costs on the other – and these in turn scale strongly with the size of the plants.
  - The use of large thermal storage systems is shown to contribute significantly to the economic operation of the heating networks. At the same time, there are significant uncertainties regarding the associated costs, which depend not least on the exact location.

Model-based analyses, such as those in this study, are always subject to uncertainties. On the one hand, these result from the possible cost development (including the locally existing site-specific conditions, which can lead to deviations in terms of costs), especially regarding large-scale thermal storage and solar thermal energy and the costs for land required for them, as well as deep geothermal (and the associated risks in the development). On the other hand, there are also uncertainties regarding technological developments and the efficiencies and corresponding technology characteristics that can be expected in the future. Furthermore, it is also evident that the interplay of the various renewable district heating technologies in the portfolio, also with the use of heat storage, is complex and also strongly depends on the expected district heating demand. The expected heat demand is in turn strongly dependent on the measures concerning building renovation as well as on the achievable connection rates. Since these factors cannot be predicted in the long term, a continuously adapting planning process is required, both on the part of the heating network operators and on the part of policy-makers.

As in any model-based analysis, the analysis is subject to certain system limits that have an impact on the results and their validity. It is therefore vitally important to take account of the following factors when interpreting the results:

- There are many obstacles to the feasibility of the scenarios that have been described and the potentials that have been calculated, even if these latter prove to be economically feasible. In particular, these include deadlines that must be met when planning major infrastructure projects. This has been especially problematic in the past when developing waste heat potentials. Development of the potentials that have been identified as economic nevertheless requires the necessary political parameters to be in place, and implementation is unlikely without them.
- The costs for some of the portfolios described are very similar. In keeping with the logic of the selected approach, the cheapest potentials are shown in each case. Nevertheless, uncertainties are still very much present as regards the prioritisation of specific technology portfolios and the mix of renewable and efficient potentials for heating. The fact that renewable gas cannot be classified as a favourable option for decarbonisation of the space heating and hot water sector can be taken as a robust result, however.
- n-1 or n-2 certainties for district heating generation capacities were not fully taken into consideration. Among other things, this also applies to the use of waste heat. The authors believe that this assumption has only a minor impact on the results of the study.
- Existing heating networks were not explicitly taken into account. This can be regarded as a conservative assumption concerning the existing district heating potential.
- The study focused on the heating sector. The role of CHP was therefore also examined from the perspective of the heating sector. The study did not examine the role that will be played by CHP plants in Austria from the perspective of the electricity system in 2030 and 2050.
- The study did not take into account the potential future reduction of temperature levels in heating networks. A reduction of this kind is, however, certainly envisaged, and is promoted and analysed in the relevant studies. In particular, thermal building renovations support a reduction in supply pipe temperatures, which in turn facilitates the feeding-in of low-temperature waste heat or solar thermal. A reduction in temperatures would also have positive impacts on district heating potentials, although quantifying these in detail would exceed the scope of this study.
- The exogenous setting of the different district heating generation portfolios represented a further limitation of the methodological approach in that it restricted the range of solutions. It was, however, possible to achieve a good approximation to reality in this respect by varying the assumptions and consulting a number of undertakings in the district heating sector.
- As already noted, it was assumed for the purpose of this analysis that waste heat should be categorised as CO_2-neutral. This study did not examine the definition of waste heat under the Renewable Energy Directive.

5 Potential new strategies and policy measures

Further to Commission Delegated Regulation (EU) 2019/826, an overview of 'new legislative and non-legislative policy measures (8) to realise the economic potential identified in accordance with [the above]' is provided below.

Since the economic potential of district heating can only be leveraged if the plants are operated in a manner that complies with the climate targets, a higher share of renewable energy or waste heat is required in the district heating or district cooling systems. According to the draft of the Austrian Heating and Cooling Network Expansion Act, parties submitting an application for funding under this Act should therefore be obliged to submit a changeover plan for their existing network in which they explain how they intend to achieve a share of up to 80% renewables in their provision of district heating or district cooling by 2030 (decarbonisation pathway).

As part of this process, applicants should describe the necessary measures and timetable for the changeover and quantify the anticipated greenhouse gas (GHG) savings. The changeover plans should serve as a basis for the gradual renovation of the networks, taking due account of municipal heating plans. It is planned that renewable energy communities for local heating networks will be exempt from this obligation, since these communities are by definition based entirely on renewable energy sources, rendering a decarbonisation pathway unnecessary.

According to the draft of the Austrian Heating and Cooling Network Expansion Act, an ecological criterion should also be used to rank the funding applications that are received. In future, the share of renewables in the energy mix for the district heating or district cooling system will be used as a priority ranking criterion.

6 Annex

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Table 19: Technical and economic data for various district heating generation technologies

Storage	Hourly losses [%[	Charge/discharge capacity [MW]	Charge/discharge efficiency	OPEX fix [EUR/MWh]	Lifetime [a]	Storage density [kWh/m³]	Storage size [m³]	Investment costs [EUR/MWh]
	0.01		**0.97**	**0**	**25**	**81**		**158 279.52 Storage size$^{-0.52}$**

Name	Thermal efficiency	Electrical efficiency	Investment costs (EUR/MW_th)	OPEX fix (EUR/(MW*a))	Lifetime [a]
Waste incineration plants	0.70	0.12	1 800 000	27 000	20
Geothermal heat pumps	15.00	-	820 000	50 000	30
Waste heat source heat pumps	5.50	-	570 000	2 000	25
Waste heat, direct	1.00	-	250 000	7 500	30
River source heat pumps	3.10	-	380 000	4 000	25
Air source heat pumps	2.50	-	760 000	2 000	25
Waste water source heat pumps	3.60	-	380 000	4 000	25
Biomass CHP	0.74	0.11	900 000	45 000	20
Biomass heat-only plants	0.85	-	470 000	14 100	20
Solar thermal	1.00	-	785 000	3 900	20
Electric heaters	0.99	-	180 000	2 000	20
Gas CHP	0.47	0.33	585 000	23 400	25
Gas and steam	0.36	0.45	1 357 000	52 200	25
Gas heat-only plants	0.92	-	100 000	3 700	35

Table 20: Assumptions regarding the composition and the corresponding provisioning costs of green gas in 2030 and 2050 (for sources and further information, see Table 8)

Low prices	2030		2050	
	Share	Costs	Share	Costs
	[%]	[EUR/MWh]	[%]	[EUR/MWh]
PtG	5%	150.0	40%	110.0
H2	15%	80.0	40%	70.0
Biomethane	80%	60.0	20%	80.0

Total		67.5		88.0

High prices	2030		2050	
	Share	Costs	Share	Costs
	[%]	[EUR/MWh]	[%]	[EUR/MWh]
PtG	5%	150.0	40%	170.0
H2	15%	120.0	40%	100.0
Biomethane	80%	80.0	20%	100.0
Total		92.5		128.0