DECARB21

Final report

Heating & cooling, mobility, electricity: Scenarios for the decarbonisation of Vienna's energy system by 2040

Commissioned by: WIEN ENERGIE

8 October 2021 (translation: 24 April 2023)

Gerald AUE
Anton BURGER

This Study has been prepared by FTI France S.A.S., trading under Compass Lexecon ("Compass Lexecon"), for Wien Energie GmbH ("Wien Energie") under the terms of the contract between Wien Energie and Compass Lexecon ("Contract").

This study has been prepared solely for Wien Energie and no other party is entitled to rely on it for any purpose. Compass Lexecon accepts no liability or duty of care to any person (other than Wien Energie under the relevant terms of the Contract) for the contents of the Study. Accordingly, Compass Lexecon disclaims any responsibility for the consequences to any person (other than Wien Energie on the basis set out above) acting or refraining from acting in reliance on the Study or for any decision made or not made on the basis of the Study.

The Study contains information obtained or derived from a variety of sources. Compass Lexecon assumes no responsibility for verifying or determining the reliability of these sources or for verifying the information so provided.

Compass Lexecon makes no representations or warranties of any kind (whether express or implied) as to the accuracy or completeness of the Study to any person (other than Wien Energie in accordance with the relevant terms of the Contract).

The Study is based on information available to Compass Lexecon at the time the Study was prepared and does not take into account any new information that comes to our attention after the date of publication of the Study. We assume no responsibility to update the Study or to inform any recipient of the Study of such new information.

Any recipient of this Study (other than Wien Energie) does not acquire any rights in relation to the Study. All copyright and other proprietary rights in the Study remain the property of Compass Lexecon and all rights are reserved.

The views expressed in this Study are those of the named authors and not necessarily the views of Compass Lexecon, its management or parent company or any other Compass Lexecon professionals.

© 2023 FTI France S.A.S. All rights reserved.

Table of Contents

Table of Figures

Glossary

ETS	EU Emissions Trading Scheme
EV	Electric Vehicle
HOB	Heat Only Boilers
CHP	Combined Heat and Power plant (CHP)
PV	Photovoltaics
PtH	Power to Heat

Chapter 1

Executive Summary

THE POLITICAL EFFORTS TO MITIGATE CLIMATE CHANGE ARE INTENSIFIED

Decarbonisation is one of the great challenges of our time. Accordingly, EU heads of state and government have committed to the goal of climate neutrality by 2050.[1] In December 2020, the EU emission reduction target for 2030 was additionally increased, to at least 55% compared to 1990 (instead of 40% before then) (European Commission, 2021a). The Austrian federal government has set itself an even more ambitious target: Austria is to become climate neutral already by 2040.

VIENNA SETS ITSELF NEW AMBITIOUS GOALS

In this context, the Viennese government coalition has agreed the goal of **"Vienna becoming climate neutral by 2040"** (SPÖ & NEOS, 2020). Vienna's decarbonisation target is thus just as ambitious as the targets at the federal level and exceeds the EU requirements.

THE PRESENT STUDY SHEDS LIGHT ON THE EFFECTS OF THE NEW OBJECTIVES ON VIENNA

This study summarises the results of the "DECARB 21" project, which has analysed the effects of the new political decarbonisation guidelines on the Viennese energy system. During the project, the evolvement of the Viennese energy system was modelled. In the scenario **"Climate Neutral 2040"**, the net CO_2 emissions in Vienna are reduced to zero by 2040 – in line with the new political targets. This was realised within the political objectives and the expected targets of the forthcoming Smart City Framework Strategy ("Smart-City-Rahmenstrategie"). The scenario therefore is not a forecast of developments, but rather an illustration of economic effects and a presentation of how the set political goals can be achieved efficiently.

The study analysed the sectors **heating & air conditioning**, **mobility,** and **other energy demand** (cooking, electrical appliances, process heat and 'stationary motors') as well as the resulting **electricity demand** and the possibilities to **cover the electricity demand through production in the Vienna urban area**.

---

[1] Remaining residual emissions must then be offset by processes that remove greenhouse gases from the atmosphere.

In summary, four major changes can be seen by 2040 (Figure 1):

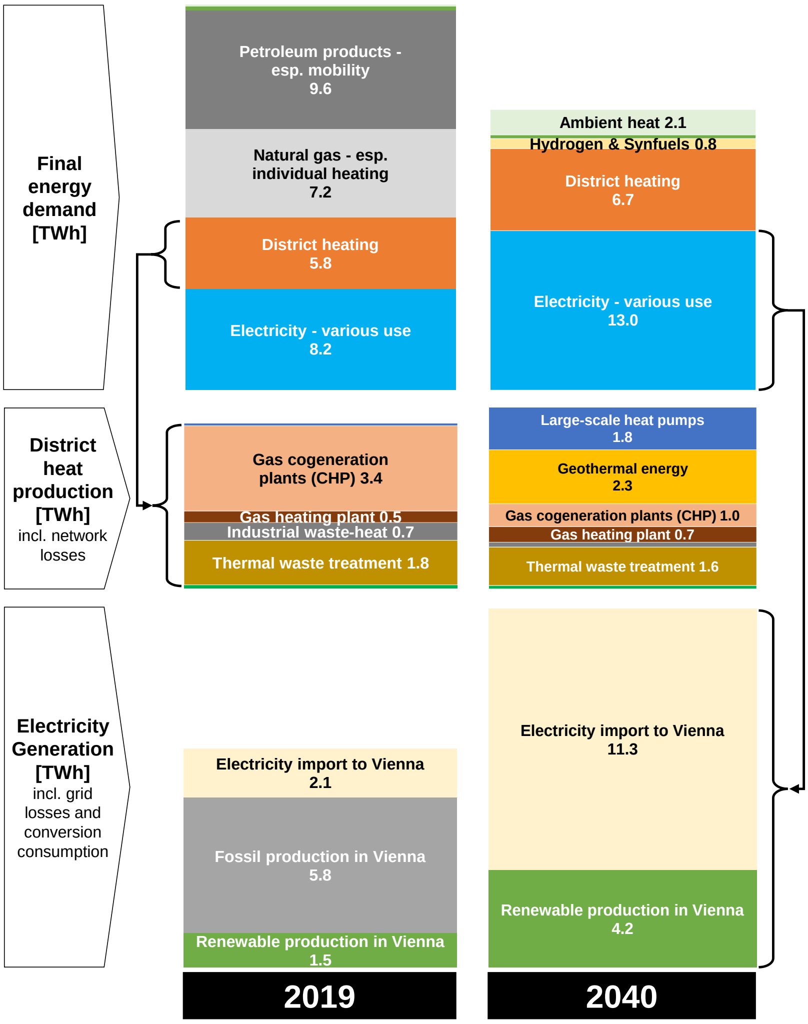
a. In mobility, petroleum products are replaced by electricity

b. For space heating & hot water, natural gas is replaced by district heating and electricity (via heat pumps)

c. Geothermal energy and large-scale heat pumps replace gas-fired CHP as the dominant technology in district heating generation

d. Fossil electricity production in Vienna is replaced by the expansion of renewable generation and electricity imports.

Figure 1: Changes in final energy demand, district heating and electricity generation until 2040



There are **two major changes** in **final energy consumption**:

1. In **mobility**, **petroleum** products are **replaced by electricity**.
2. For **space heating & hot water**, **heating oil and natural gas** are replaced by **district heating and electricity** (heat pumps)

→ This leads to **increasing electricity demand**…

→ … however, also brings **efficiency gains**, which **reduce the overall energy demand**

Likewise, there are **two major changes in district heating and electricity production**:

1. **Heat production** in gas-fired CHPs **decreases** significantly; **geothermal energy and large-scale heat pumps become the dominant technology** for the generation of district heat
2. The **expansions of renewable production and electricity imports replace fossil electricity generation** in Vienna.

Notes: Final energy consumption includes c. 0.4 TWh of biomass and 0.15 TWh of ambient heat in 2019 and c. 0.3 TWh of biomass in 2040 not labelled due to lack of space. The same applies to 0.2 TWh heat from biomass and 0.1 TWh heat from heat pumps in 2019 and c. 0.2 TWh heat from biomass and heat purchases in district heating in 2040. The district heating final energy demand also includes large individual consumers and heat for cooling. Columns for final energy consumption are shown on a smaller scale than those for supply.

Source: Compass Lexecon analysis based on the study assumptions.

THE GREATEST FINANCIAL AND TECHNICAL CHALLENGES AWAIT IN THE HEATING SECTOR

Of all sectors analysed, the **heating sector** (low-temperature heating, i.e., space heating and hot water preparation) requires the largest investments within Vienna to achieve the decarbonisation targets – also for Vienna's heating sector this means climate neutrality by 2040. This will be achieved primarily through extensive changes in heating technologies. The "Climate Neutral 2040" scenario also considers the political objectives of **phasing out the use of natural gas in existing buildings** by 2040 and **without significant use of green gases[2] in individual heating**. Due to thermal renovation and the effects of climate change, the demand for space heating decreases by 18% – despite population growth. The investments necessary for **thermal refurbishment** were estimated at c. **10 billion EUR_{2021} up until 2040** and thus represent the largest single measure considered in terms of costs.

The **investments required for the change of heating systems up until 2040** have been estimated at c. **6 billion EUR_{2021}.** This considerable investment volume is mainly due to the required significant change in heating systems to achieve the emission target. In the "Climate Neutral 2040" scenario, a complete phase-out of heating oil and gaseous energy sources in individual heating systems is required. In particular, gas boilers for individual flats – widespread in Vienna – are therefore no longer envisaged in the "Climate Neutral 2040" scenario from 2040 onwards. Therefore, a conversion of all existing buildings to central heat supply via heat pumps or district heating was modelled. Due to foreseeable problems with logistics and particulate matter emissions in urban areas, no expansion of biomass use in Vienna was modelled.

In total, **district heating** provides **c. 56% of the heat required in Vienna in 2040** for space heating and hot water (useful energy). **Geothermal energy and large-scale heat pumps** are the **main technologies to produce fully decarbonised district heat**. Together, these two technologies produce about 4 TWh of district heat in 2040 and thus almost 55% of the total production. In line with the expansion of geothermal energy and heat pumps as well as the decommissioning of combined heat and power (CHP) plants reaching the end of their service life, the share of CHP heat in district heating production is decreasing. However, even in **2040, Vienna's CHPs produce almost 1 TWh of district heating** (this corresponds to c. 13% of total production in 2040 – compared to c. 52% of district heating production in CHPs today). It is assumed that **from 2040 onwards only green gases** will be fired in the **CHPs and heating plants** in Vienna. Since remaining unavoidable fossil **CO_2 emissions from district heating production** will be **sequestered in 2040**, **district heating production will be completely CO_2 neutral from 2040 onwards** (just like central electricity production in Vienna's CHP plants). For the required expansion, **investments in the district heating infrastructure** (production and network) were estimated at **c. 2.5 billion EUR_{2021} up until 2040.**

---

[2] "Green gas" in the context of this study includes biomethane, renewable hydrogen and renewable synthetic methane.

ELECTRIFICATION OF MOBILITY IS THE STRONGEST DRIVER OF ELECTRICITY DEMAND UNTIL 2040

Following the political objectives, the complete **decarbonisation of mobility** in Vienna is to be achieved as early as 2040. Also, the proposals of the EU Commission to ban internal combustion engines from 2035 onwards (European Commission, 2021b) point in the same direction. Parallel to this, the current trend towards electromobility is increasingly gaining momentum among consumers. Electric vehicles (EVs) are now competitively priced – not least due to corresponding subsidies and tax breaks (Rauecker, 2021). The main challenge – and the focus of this study with regards to the mobility sector – remains the need for a rapid expansion of the charging infrastructure[3], in order to keep pace with the ramp-up of electric car usage as required for decarbonisation by 2040. The respective support framework is already well-developed and also addresses the need for smarter charging to smoothen demand peaks. However, the legal hurdles to deploying non-public charging points – especially in multi-party buildings – are still considerable (Federal Ministry for Transport, Innovation and Technology , 2019b). Overall, the estimated investments in Vienna's public and private **charging infrastructure** for e-mobility are estimated to reach **c. 1.3 billion EUR$_{2021}$**[4] **up until 2040**. As a result of a successful transition to e-mobility, **Vienna's electricity demand for mobility is** expected to **increase** significantly (in the “Climate Neutral 2040” scenario by **c. 2.7 TWh** by 2040 – this corresponds to approximately one third of Vienna's total current final electricity consumption, making e-mobility the strongest driver of electricity demand by 2040). **Limiting** the associated **electricity peak demand** (e.g., via smart(er) charging) can contribute to making decarbonisation of mobility easier, faster and cheaper to implement. Decarbonisation also results in an increasing demand for electricity in public transport. In addition to the expansion of direct use in the underground, trams and for the electrification of part of the bus fleet, the electricity demand is also increasing, due to the production of hydrogen for use in the public bus fleet.

RISING ELECTRICITY DEMAND AND DECLINING GENERATION INCREASES VIENNA'S “ELECTRICITY IMPORTS”

In total, the decarbonisation measures described above will lead to a significant increase in Vienna's electricity demand by 2040. Starting from today's level (2019) of c. 9.5 TWh, **the electricity demand** in the “Climate Neutral 2040” scenario will **increase by c. 65% by 2040, to 15.5 TWh.**[5]

In the “Climate Neutral 2040” scenario, **Vienna's electricity generation falls by more than 40%** from just under 7.3 TWh in 2019 to just under 4.2 TWh in 2040. However, the decline in

---

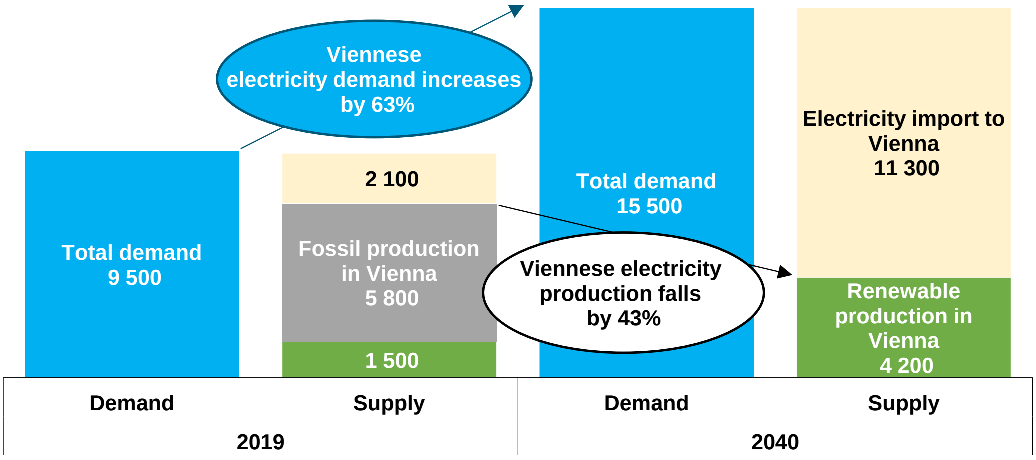
[3] The required electricity distribution grid infrastructure in Vienna was not considered in this study, but grid access fees were taken into account in the estimates.

[4] This value is not reduced by current and any future subsidies for the installation of charging infrastructure.

[5] In addition to electricity for final consumption, there are other electricity needs to be met in the Viennese energy sector. This concerns electricity used for district heating and hydrogen production, other electricity consumption in the energy sector and electricity grid losses.

generation in Vienna's thermal power plants cannot be compensated for by the expansion of photovoltaic (PV) capacities – and the corresponding increase in the production of renewable electricity in Vienna (2040: +1.3 TWh from PV). As a result, the need to "import" electricity from the surrounding areas to Vienna will increase. While in 2019 less than 23% of Vienna's electricity demand (annual balance) could not be covered by production in Vienna, **the electricity import share rises** to **74% in 2040** in the "Climate Neutral 2040" scenario. The re-invested CHP plant thereby, has a considerable share in the remaining electricity production in Vienna in 2040. The required **investments in Vienna's electricity production** (PV installations and a share of the CHP re-investment) up until 2040 were estimated at **c. 1.3 billion EUR$_{2021}$**. With regards to required electricity imports Vienna, however, remains dependent on the success of the Austria-wide efforts to expand renewable generation and their system integration. In this respect Vienna is no exception: **limited potential for renewable electricity production is a general issue of urban areas** (IEA, 2021)**.** On the other hand, decarbonisation leads to the **discontinuation of use of natural gas and fossil fuels** – which until now had to be imported to Vienna from the surrounding area or abroad.

Figure 2: Vienna's electricity demand and its coverage [GWh/a] – "Climate Neutral 2040"

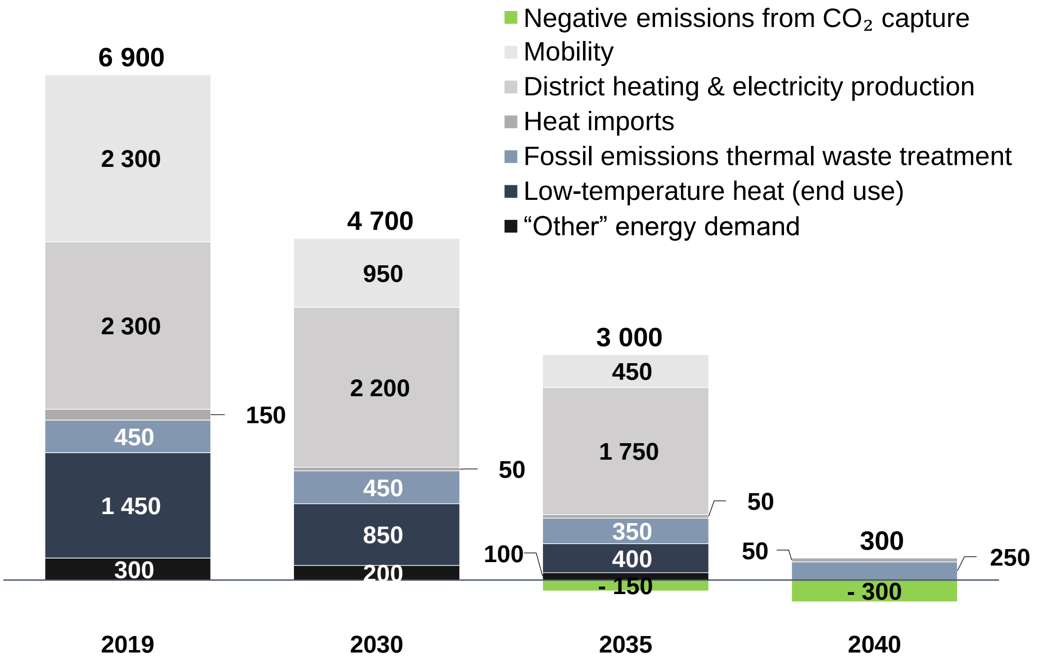


Notes: Results rounded to full 100 GWh
Source: Compass Lexecon analysis based on the study assumptions

CLIMATE NEUTRALITY 2040 REQUIRES EMISSION REDUCTIONS IN ALL SECTORS

Based on the modelled ramp-up of decarbonised technologies for mobility and individual heating, as well as the technical lifetime of the CHP plants and the derived schedule for investments in district heating and electricity production, a large part of emission reductions will be achieved between 2030 and 2040. In 2040, essentially only the fossil emissions from thermal waste utilisation remain. These are offset by sequestering biogenic CO_2 emissions.

Figure 3: Vienna's CO2 emissions per sector [kt p. a.] – "Climate Neutral 2040"

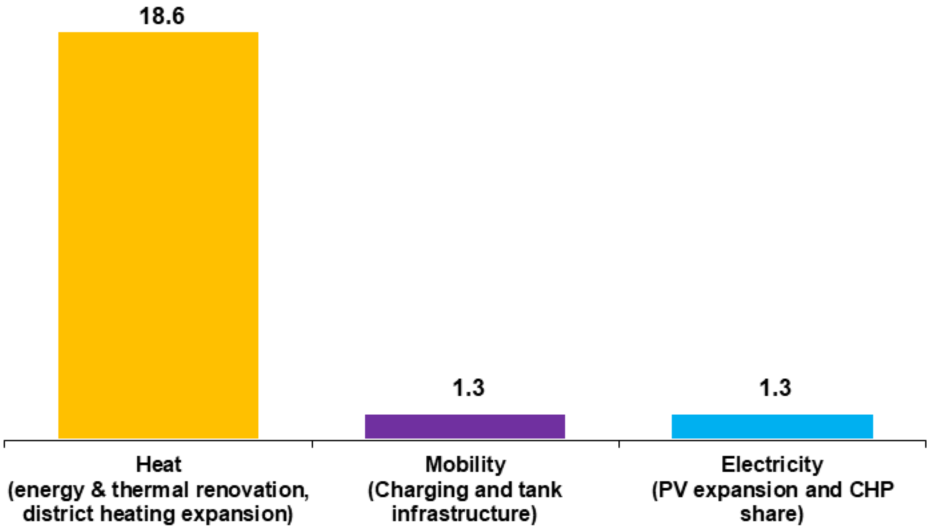


Notes: Results rounded to the nearest 50 kt
On top of the columns: Total emissions before taking into account compensation through sequestration of biogenic emissions.
Totals of rounded values do not always correspond to the rounded sum values.
Source: Compass Lexecon analysis based on Statistics Austria, 2020 (for 2019) and the study assumptions (for 2030-2040).

INVESTMENTS IN DECARBONIZATION FOCUS ON THE HEATING SECTOR

Among the sectors covered by the study, the **largest share of** decarbonisation **investments required in Vienna** by 2040 is required **in the heating sector** (Figure 4). On top of the decarbonisation investments in Vienna, additional **investments in renewable electricity generation** are required **outside of Vienna. Investments in renewable electricity generation** to cover Vienna's demand were estimated by Wien Energie to reach **c. 7.3 billion EUR$_{2021}$** up until 2040**.**

Figure 4: Investments in the Viennese energy system to achieve climate neutrality by 2040 (in the sectors covered by the study, excluding inter alia the electricity grid) [billion EUR$_{2021}$]



Notes: Results rounded to the nearest 100 million EUR$_{2021}$
<u>Heat</u>: Investment in thermal (i.e. insulation) and energetic (i.e. heating systems) refurbishment of the Viennese building stock, investment in district heating production (geothermal plants, heat pumps, re-investment in waste incineration plants, equipping waste incineration plants with CO_2 sequestration and half of the investment in the new CHP plant) and investment in the district heating network.
<u>Mobility</u>: Investment in charging infrastructure for electric cars and hydrogen filling stations
<u>Electricity</u>: Investments in PV installations and the second half of the investment for the new CHP plant
Investment requirements in the electricity grid were not analysed separately, but the necessary grid access fees were included.
Source: Compass Lexecon analysis based on the study assumptions

THE EXTENSIVE INVESTMENTS REQUIRE A TARGETED POLITICAL AND REGULATORY FRAMEWORK

The extensive investments required to decarbonise Vienna by 2040 require a targeted political and regulatory framework conditions. For the evolvements described in the "Climate Neutral 2040" scenario, this concerns particularly:

- the extensive **thermal refurbishments and** the **heating system replacements**;
- the **expansion of the district heating system** and investments in decarbonised production technologies;
- the availability and use of **green gases** in district heating and electricity production;
- the use of **CO_2 capture** for otherwise unavoidable fossil CO_2 emissions;
- the installation of **charging points** for electric cars – especially in non-public areas;
- the expansion of renewable **electricity production** in Vienna and the rest of Austria**.**

DECARBONISATION OF VIENNA AS AN OPPORTUNITY FOR LOCAL BUSINESS AND THE LABOUR MARKET

Overall, considerable efforts and substantial investments are required to achieve the goal of making Vienna climate-neutral by 2040. At the same time, however, these extensive investments also create **opportunities for Vienna's local businesses and Vienna's labour market.**[6] This is particularly true for building renovations, heating replacements, the expansion of district heating and charging infrastructure as well as the expansion of photovoltaic installations on Viennese buildings. All these measures must be carried out in Vienna and require specialised craftsmen and skilled workers.

---

[6] However, corresponding macroeconomic analyses were not the subject of the present study.

Chapter 2

Background and Objective

In 2018, Wien Energie published the first decarbonisation study (Schimmel et al., 2018). Since then, both the federal government and Vienna’s city government – in a changed government coalition – have defined the significantly more ambitious target **“Vienna will be climate neutral by 2040”**.

Against the background of these adjusted political objectives, Compass Lexecon was commissioned by Wien Energie to update its first decarbonisation study. For this purpose, two scenarios – complying with the previous and the new targets for the development of Vienna’s energy system – were to be modelled. Based on these two scenarios, deviations within the individual sectors resulting from changed targets and their energy economic effects were to be presented.

The main work on this study was carried out in spring and summer 2021 – in parallel to the process of updating the Smart City Framework Strategy. As far as possible, planned adjustments to the Smart City Framework Strategy were considered when preparing this study. However, a final version of the Smart City Framework Strategy was not yet available when finalising this study.

Chapter 3

Starting Points

3.1 Final energy demand: Vienna's 2019 final energy demand is dominated by the heating sector

The starting point for all considerations on the decarbonisation of the Viennese energy system is the current[7] Viennese final energy demand (for details see Annex B). In this study, Vienna's final energy consumption is divided into four segments:

- **Heating** (more specifically: low-temperature heating for space heating and hot water)
- **Cooling & air conditioning**
- **Mobility**
- **Other energy needs**[8] – Cooking, electricity for electrical appliances, process heat and "stationary motors" (i.e., motors that are not used for mobility applications)

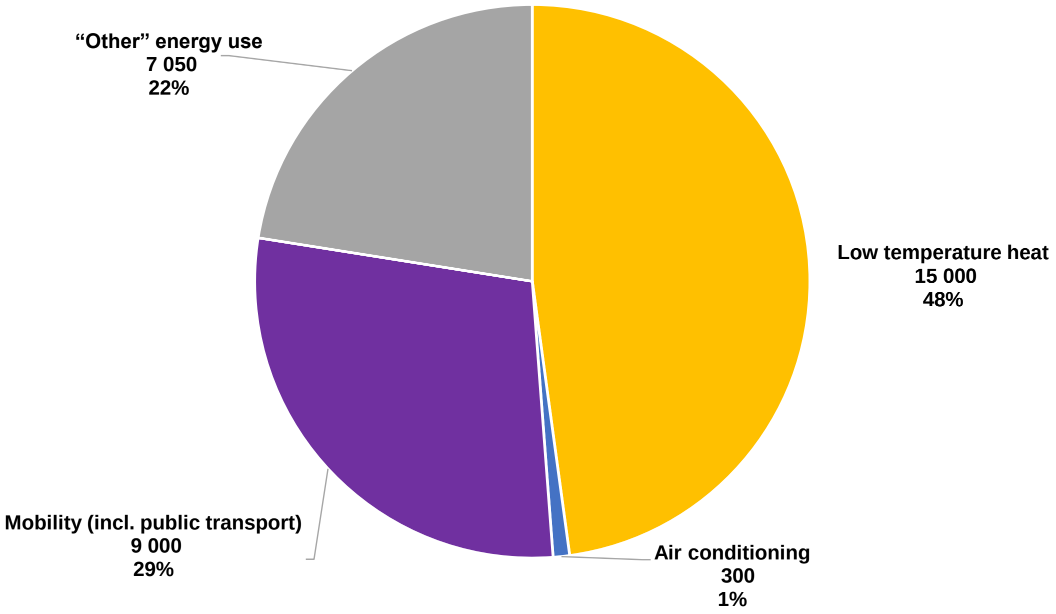
The "heating" sector has by far the largest share of Vienna's final energy demand (Figure 5).

---

[7] The latest available statistical data at the time of the study's preparation is from 2019. Accordingly, 2019 is also the base year for the presentation of the scenario results.

[8] This segment is based on the end-use segmentation also used in the calculations for the Smart City Framework Strategy (Urban Innovation Vienna, 2019). The segment combines several – in comparison to e.g., heat and mobility – relatively inhomogeneous end-use types, which nevertheless have a significant share of the energy demand and are already heavily electrified.

Figure 5: Vienna’s final energy consumption 2019 as starting point of the study [GWh]

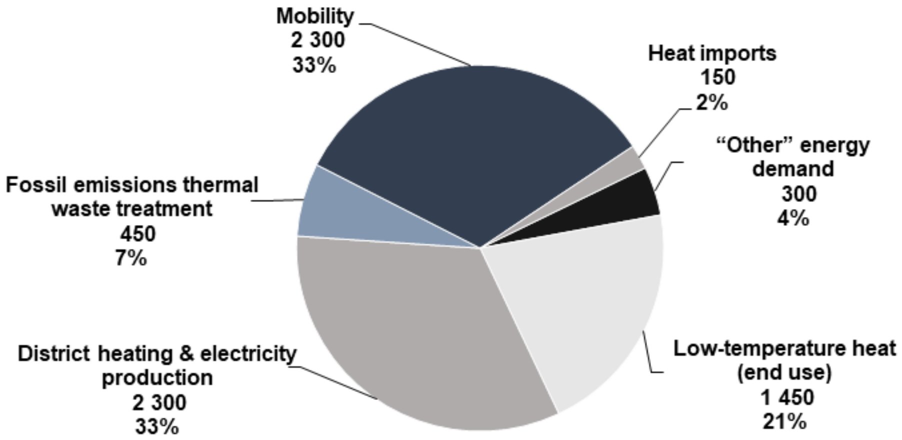


Notes: Figures rounded to the nearest 50 GWh.
Source: Compass Lexecon analysis based on (Statistics Austria, 2020a)

3.2 Emissions: Mobility and centralised electricity & heat production make-up the largest shares

In the areas covered by the study (for details see the Annex B), total emissions of c. **6 900 kt CO_2** were generated in 2019. The final energy demand in mobility and electricity & district heating production account for the largest – almost equal – shares.

Figure 6: Vienna CO_2 emissions 2019 as starting point of the study [kt CO_2]

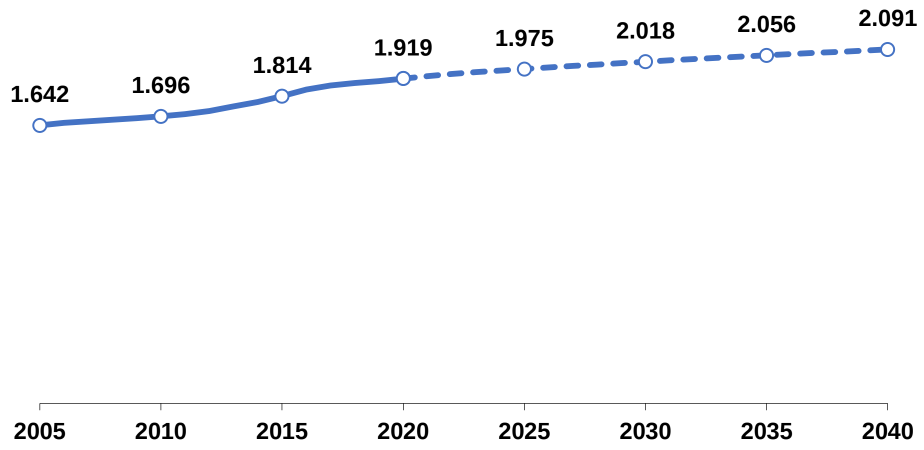


Notes: Numerical values rounded to the nearest 100 kt.
Source: Compass Lexecon analysis based on (Municipal Department 20, 2020), (Statistics Austria, 2020a), (Federal Environment Agency, 2020), (Wien Energie, 2021)

3.3 Population growth: Vienna continues to grow – by c. 10% until 2040

The decarbonisation of Vienna's energy use is taking place against the background of a population that continues to grow strongly. Vienna is currently home to 1.9 million inhabitants, almost 22% of the Austrian population. In the central scenario of its current population forecast, Statistics Austria assumes that Vienna's population will grow by almost 10% by 2040 compared to 2019 (Statistics Austria, 2020c).

Figure 7: Population development in Vienna [million people]



Notes: The development according to the central scenario is shown.
Source: Compass Lexecon based on Statistics Austria, 2020c

Achieving Vienna's climate targets is thus taking place against the backdrop of a significant demand driver: a growing number of consumers of heating, cooling, mobility, and other energy.

3.4 Scenario definition: The study models two scenarios – one based on previous policy objectives and one based on the new policy objectives

Within the scope of the study, two scenarios were modelled for the development of the Vienna energy system until 2040:

- The scenario **"Previous Targets"** is essentially based on the previous political targets for emission reductions (Magistrate of the City of Vienna, 2019)[9];
- The scenario **"Climate Neutral 2040"** is based on the goals of the current Viennese government programme (SPÖ & NEOS, 2020) as well as its expected detailing in the forthcoming update of the Smart City Framework Strategy.

---

[9] Where no targets have yet been defined for 2040, these have been derived from data from given base years.

Table 1 gives an overview of scenario assumptions – further details are provided in Annex A.

Table 1: Overview – Objectives and Measures

Sector	“Previous Targets"	"Climate Neutral 2040"
Overarching target	<u>Target</u>: **Reduction of “local” greenhouse gas emissions** (per capita) by 50% by 2030 and **80% by 2050** compared to 2005	<u>Target</u>: Vienna to become **climate-neutral by 2040**
Heat supply and Air conditioning	• <u>Target 1</u>: **Reduce CO_2 emissions** for space heating, hot water supply and cooling by c. **55% by 2050** compared to 2005 • <u>Target 2</u>: **CO_2 neutrality of district heating production by 2050** • <u>Measures</u>: Thermal refurbishment, expansion of district heating supply	• <u>Target 1</u>: **CO_2 neutrality** of space heating and hot water supply **by 2040** • <u>Target 2</u>: **CO_2 neutrality of district heat production by 2040** • <u>Measures</u>: Thermal refurbishment, expansion of district heating supply, but no use of (green) gas[10] in heating[11]
Mobility	• <u>Target</u>: **CO_2 neutrality** of Viennese mobility **by 2050** • <u>Measures</u>: Expansion of public transport and electromobility	• <u>Target</u>: **CO_2 neutrality** of Viennese mobility **by 2040** • <u>Measures:</u> Same as “Previous Targets” scenario
Other Energy use	• <u>Target</u>: **Reduction of CO_2** emissions from other energy use by c. **50% by 2040** compared to 2005	• <u>Target</u>: **CO_2 neutrality** of other energy use **by 2040**
Power generation in Vienna	• <u>Target</u>: **CO_2 neutrality** of electricity generation in Vienna **by 2050** • <u>Measures</u>: ○ Expansion of PV capacities to 800 MWp in 2030 and 1,300 MWp in 2040 ○ Post-investment of a (green) gas-fired CHP plant within the 2030s	• <u>Target</u>: **CO_2 neutrality** of electricity generation in Vienna **by 2040** • <u>Measures</u>: Same as “Previous Targets” scenario
Thermal waste treatment	(no target for emissions from thermal waste utilisation)	• <u>Target</u>: **CO_2 neutrality** of thermal waste recycling **by 2040**

Source: Compass Lexecon based on (Urban Innovation Vienna, 2019) and in coordination with Wien Energie

---

[10] “Green gas” in the context of this study includes biomethane, hydrogen and synthetic methane.

[11] Individual heating means heat generation via heating installations situated within the respective building – in distinction to district heating with central heat production.

Chapter 4

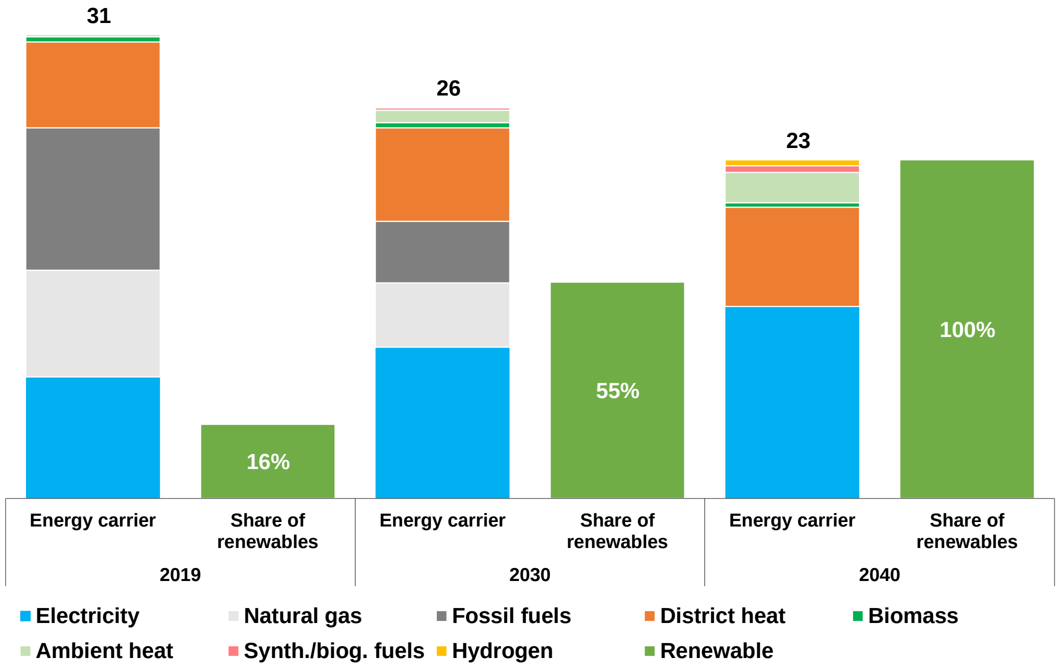
Cross-Sectoral Synopsis

4.1 Final energy demand: Until 2040, final energy demand decreases with both electricity use and renewables share increasing.

Vienna's final energy demand will drop significantly by 2040. The main drivers for this are:

- in the mobility sector: electrification with its significantly higher efficiency as well as the change in the modal split[12] with a reduction in motorised private transport
- in the heating sector: thermal refurbishment and the effects of climate change, both of which reduce the demand for space heating

Figure 8: Development of final energy demand [TWh] and the renewable share in Vienna – "Climate Neutral 2040"



Notes: synth. … synthetic, biog.… biological
Source: Compass Lexecon analysis based on Statistics Austria, 2020 (for 2019) and the study assumptions (for 2030 and 2040)

---

[12] I.e., the distribution of mobility needs between different modes of travel and means of transport.

Vienna’s final energy demand is reduced by c. 27% from c. 31 TWh in 2019 to c. 23 TWh in 2040 in the scenario “Climate Neutral 2040” (Figure 8). Due to lower renovation rates and less rapid ramp-up of electromobility, the reduction in the “Previous Targets” scenario amounts to only c. 23% arriving at c. 24 TWh.

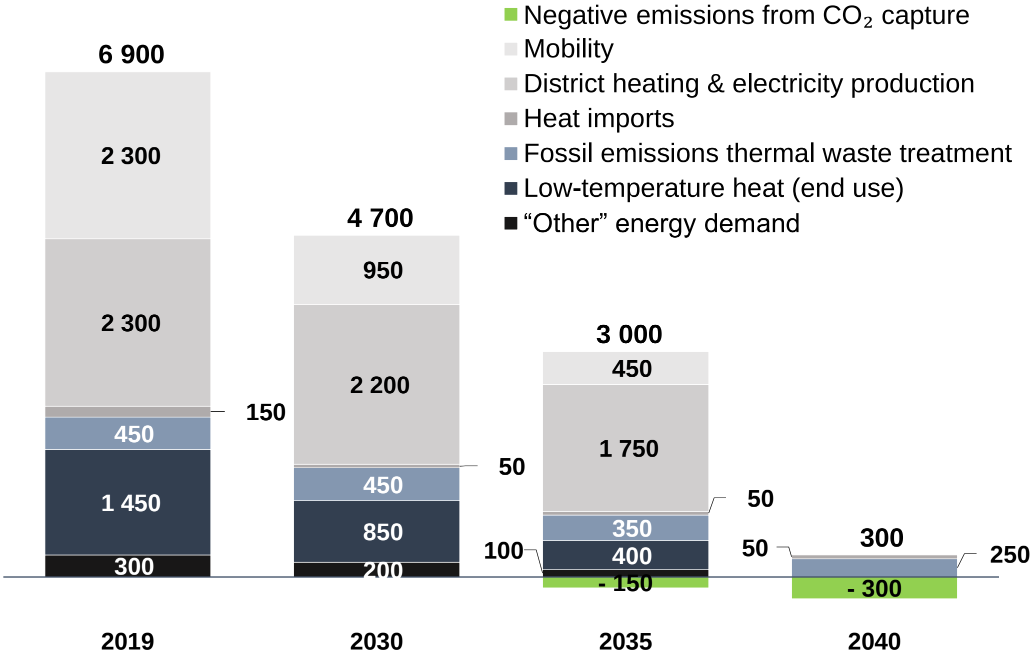
The increased share of renewables is driven by the following developments:

- the expansion of **district heating production from CO₂-neutral sources**
- the expansion of **photovoltaic electricity** generation
- the increasing amounts of **ambient heat** used by heat pumps for individual heating
- the increasing **import of renewable electricity** to Vienna

As a result, the coverage of Vienna’s entire energy demand from renewable generation is achieved in the scenario “Climate Neutral 2040” from 2040 onwards. In the “Previous Targets” scenario, a share of 68% renewables is achieved in 2040.

4.2 Emissions: Accelerated technological changes lead to greater emission reductions in the 2030s than in the 2020s

Figure 9: CO2 emissions in Vienna per sector [kt p.a.] – “Climate Neutral 2040”



Notes: Results rounded to the nearest 50 kt
On top of the columns: Total emissions before taking into account compensation through sequestration of biogenic emissions
Totals of rounded values do not always correspond to rounded totals
Source: Compass Lexecon analysis based on Statistics Austria, 2020 (for 2019) and the study assumptions (for 2030-2040)

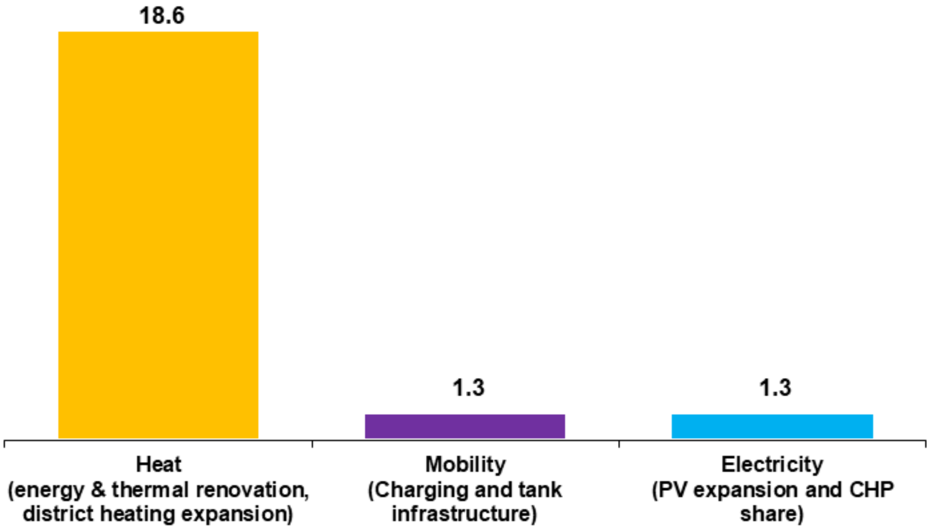
Based on the modelled ramp-up of decarbonised technologies for mobility and individual heating, as well as the technical lifetime of the CHP plants and the derived schedule for investments in district heating and electricity production, a large part of emission reductions will be achieved between 2030 and 2040.

In the scenario “Climate Neutral 2040”, essentially only the fossil emissions from thermal waste utilisation remain in 2040. These are offset by sequestering biogenic CO_2 emissions.

4.3 Investments: The largest share of the investments required in Vienna to achieve climate neutrality is required in the heating sector

By far the largest share of the **investments** to **achieve climate neutrality by 2040** across the sectors covered by the study will be required in the heating sector – primarily through thermal renovations and heating system replacement. In addition, the **investments in renewable electricity production outside of Vienna required** to meet Vienna’s demand by 2040 were estimated by Wien Energie at c. **7.3 billion EUR_{2021}.**

Figure 10: Investments in the Viennese energy system to achieve climate neutrality by 2040 (in the sectors covered by the study, excluding inter alia the electricity grid) [billion EUR_{2021}]



Notes: Results rounded to the nearest 100 million EUR_{2021}
Heat: Investment in thermal (i.e. insulation) and energetic (i.e. heating systems) refurbishment of the Viennese building stock, investment in district heating production (geothermal plants, heat pumps, re-investment in waste incineration plants, equipping waste incineration plants with CO_2 sequestration and half of the investment in the new CHP plant) and investment in the district heating network.
Mobility: Investment in charging infrastructure for electric cars and hydrogen filling stations
Electricity: Investments in PV installations and the second half of the investment for the new CHP plant
Investment requirements in the electricity grid were not analysed separately, but the necessary grid access fees were included.
Source: Compass Lexecon analysis based on the study assumptions.

Chapter 5

Heating, Cooling & Air Conditioning

5.1 Changed framework: The new political goals require a faster and more profound change of Vienna's heat supply

Out of all sectors covered and compared to the Previous Targets, the new Viennese climate policy targets lead to the most extensive need for change in the heating sector.

The previous target was to roughly halve emissions of individual heating by 2050 (Urban Innovation Vienna, 2019). Now, **no more CO_2** is to be **emitted** in the heating sector as early as **2040.** To achieve this goal, a **complete phase-out of natural gas** is required by 2040, **including in existing buildings**. In addition, due to political requirements, **green gases** are **not to be used for individual heating as far as possible** in the future.

As a result, the changed political objectives in the heating sector result in clearly more ambitious decarbonisation target in combination with significantly reduced degrees of freedom with regards to the choice of technology. In the scenario "Climate Neutral 2040" the already envisaged extensive "thermal refurbishment" of existing buildings must therefore be accompanied by "energetic refurbishment" focusing on the replacement of all fossil heating systems (Box 1).

Box 1: Thermal and energetic refurbishments

Thermal refurbishment refers to measures reducing the heating demand of a building. This is done by reducing heat loss through the building envelope. The most important measures include the insulation of the exterior walls, the basement ceiling, and the attic as well as the replacement of windows and, if necessary, exterior doors.

Energetic refurbishment refers to replacing existing heating systems with new, more efficient systems. In addition to changing the heat source itself (e.g., replacing an existing gas boiler with a heat pump), this often also requires modifications to the building's internal heat storage and distribution system.

5.2 Thermal refurbishments: Thermal refurbishment is the measure with the highest investment requirements across all sectors considered

The thermal refurbishment rates considered in the modelling for the two scenarios correspond to the assumptions underlying the Smart City Framework Strategy and its upcoming revision, respectively. In the “Previous Targets” scenario, therefore a ramp-up of the annual refurbishment rate to 2.1% of floor space from 2030 onwards is assumed (Urban Innovation Vienna, 2019). In accordance with the updated approach for the revision of the Smart City Framework Strategy a slightly higher renovation rate (2.4% from 2030 onwards) is assumed for the “Climate Neutral 2040” scenario.[13] In both scenarios, the thermal renovation measures considered are assumed to lead to a reduction in a building’s space heating demand by – on average – 55%.

For the so defined thermal refurbishment of Vienna’s building stock, an **investment need of c. 10 billion EUR$_{2021}$** was estimated for the scenario “Climate Neutral 2040” over the **period up to 2040**.[14] With this sum, thermal refurbishments represent the most investment-intensive decarbonisation measure in Vienna.

Against the background of historical refurbishment rates (Amann et al., 2020), the previous and the new targets seem demanding and will foreseeably lead to challenges. Identified **success factors** lie primarily in the following areas:

- **Information** on individual contributions to climate protection
- **Incentives** for the implementation of the required thermal refurbishment measures – especially in the area of multi-apartment buildings with several owners;
- socially acceptable **cost-bearing** and financing;
- Availability of **skilled labour** to carry out the required comprehensive refurbishment activities.

The necessary investments in thermal refurbishment can, however, also provide impulses for regional value creation and the labour market for skilled workers in Vienna.[15]

---

[13] All the assumptions made can be found in detail in Annex A.

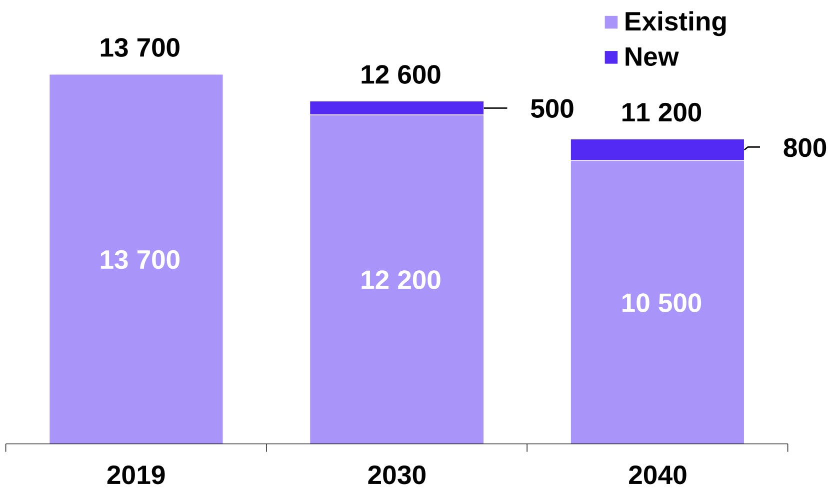
[14] The value is – as with all other investment sums given in this study – an undiscounted sum of the investments.

[15] Corresponding macroeconomic analyses were not the subject of the present study.

5.3 Heading demand: Thermal refurbishments and the effects of climate change reduce heating demand in Vienna by 2040

Despite the projected population growth in Vienna (Statistics Austria, 2020c), a **decreasing demand for low-temperature heat**[16] has been identified until 2040. The main reasons are thermal renovations (see section 5.2) and the effects of climate change itself. Effects of climate warming were taken into account – in accordance with the assumptions for the calculations for the revision of the Smart City Framework Strategy – via an annual reduction of heating degree days[17] of 0.5 percentage points compared to 2019. As a result, these two effects reduce heating demand in existing buildings more than it increases due to population growth and the associated new construction (of houses with high-quality thermal design). The total 2040 heat demand in the "Climate Neutral 2040" scenario is therefore c. 18% lower than today's demand (Figure 11).

Figure 11: Useful energy demand in the heating sector [GWh] – "Climate Neutral 2040"



Notes: Shown is the useful energy demand, i.e., the heat that can be used by the end consumer;
The values are rounded to the nearest 100 GWh;
On top of the columns: Total useful energy demand in the heating sector (excl. largest consumers).
Totals of rounded values do not always correspond to the rounded totals.
"New construction" means buildings constructed from 2022 onwards.
Source: Compass Lexecon analysis based on the study assumptions.

---

[16] This includes space heating and hot water in households and the service sector.

[17] A statistical parameter for estimating heating demand, in which the difference between the standard indoor temperature (20°C) and the daily mean temperature of a day is added up for all days for which the daily mean temperature is below the heating limit temperature (12°C).

5.4 Energetic refurbishments: The decarbonisation of low-temperature heat through heat pumps for individual heating applications and in district heating requires considerable efforts and investments.

The low-temperature heat market in Vienna (space heating and hot water preparation) is currently dominated by (i) gas boilers in individual heating applications and (ii) the use of district heating – each providing c. 40% of the useful energy demand in 2019. The remainder is currently covered by heat pumps, direct electric heating and heating oil – biomass only plays a minor role.

For the low-temperature heating market, the goal of complete **decarbonisation (zero CO_2 emissions) by 2040** is pursued on the basis of the Vienna government programme (SPÖ & NEOS, 2020). In order to achieve this, all fossil energy sources (in 2019 these were 6 270 GWh of natural gas and 650 GWh of heating oil) must be replaced – also in existing buildings – by 2040. In many cases, this requires a heating system replacement (“energetic refurbishment”).

Based on the political guidelines and intentions (Vienna Government Programme and Federal Government Programme (Federal Chancellery Austria, 2020)), the following **heating technologies** that can be used in Vienna in the long term (i.e., also after 2040) were assumed in the "Climate Neutral 2040" scenario:

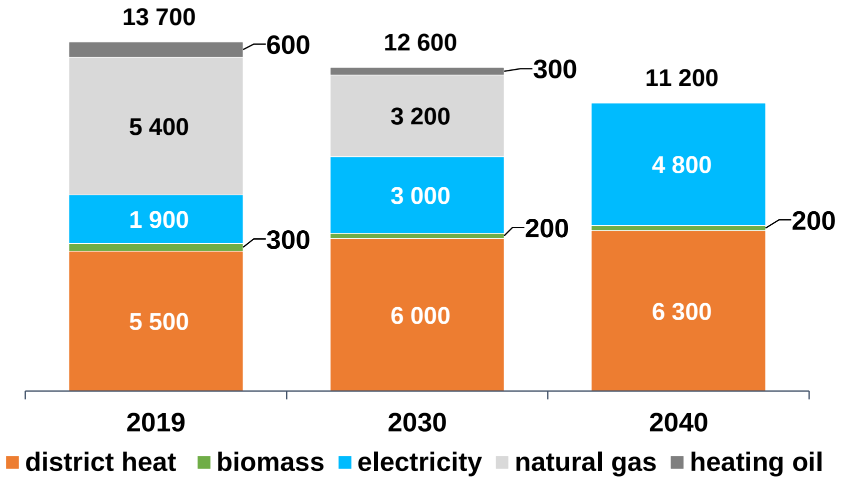
- District heating
- Air-source heat pumps (as house central heating)
- Ground source heat pumps
- Biomass (pellets) boiler

Furthermore, in the “Previous Targets” scenario, gas condensing boilers were also retained in the technology mix. Due to the priority use of **decarbonised gases** for “applications [...] in which their high value is necessary” prescribed for in the federal government programme and the corresponding targets of the Viennese government, the “Climate Neutral 2040” scenario was modelled without the use of green gases in individual heating.

An expansion of biomass use in individual heating was not considered. In addition to the question of sustainable availability, the problems of fuel logistics and particulate matter emissions in urban areas were decisive (Warmuth & Veigl, 2016).

As a result, the **decarbonisation of low-temperature heat** in the scenario “Climate Neutral 2040” is essentially achieved **via heat pumps** for remaining individual heating applications **and district heating** (Figure 12). The development of these two technologies is therefore described in more detail in the following two sections.

Figure 12: Useful energy demand in the heating sector per energy source used [GWh] – “Climate Neutral 2040”



Notes: Shown is the useful energy demand, i.e., the heat that can be used by the end consumer; The values are rounded to the nearest 100 GWh. Totals of rounded values do not always correspond to the rounded totals. The district heating demand shown excludes the largest consumers, district heating for cooling production and network losses, which are nevertheless taken into account when determining and covering the district heating demand (see later).

Source: Compass Lexecon analysis based on the study assumptions.

However, for the use of both heat pumps and district heating as a replacement for the apartment-specific gas boilers typical in Vienna, a prior retrofit to a house central heating (and/or heat distribution) system is generally required (see Box 2).

Box 2: Replacement of individual gas boilers

Vienna has a considerable number of flats that are heated by individual gas boilers in the respective flat (c. 400,000 flats **(Wimmer & Holzer, 2020)**). Gas boilers are already no longer permitted in new buildings and the vast majority of gas boilers can now be found in Gründerzeit buildings **(Benke, 2017)**.

In individual cases (e.g., attic flats), the use of individual heat pumps is possible as an alternative. In general, however, decarbonisation of the heat supply in residential buildings is associated with a switch to domestic central heating.

The conversion to central heating involves the installation of (i) a central heat source (i.e., a heat pump or district heating sub-station), (ii) a system for domestic hot water preparation and, if necessary, (iii) storage, as well as (iv) the installation of a heat distribution system to the individual flats. As soon as these prerequisites have been met, a gradual conversion is possible by connecting the individual flats to the central heat supply.

When using heat pumps, it may also be necessary to replace the radiators in the flats in order to be able to use the lower flow temperatures. However, a conversion to a central heat supply leads to heat distribution losses in the house, which increase the overall energy demand (unless a thermal refurbishment is carried out at the same time).

The conversion of residential buildings from flat-individual to central heat supply is – apart from exceptions – usually technically feasible and corresponding conversions are also carried out in Vienna in connection with general renovations.

For the scenario “Climate Neutral 2040” **investments** required to **change heating systems** were estimated to c. **6 billion EUR$_{2021}$ until 2040**. While in the “Previous Targets” scenario a phase-out of heating oil and district heating is expanded, the share of natural gas in individual heating is only moderately reduced to achieve the emission reduction. In the “Climate Neutral 2040” scenario, on the other hand, a complete conversion of existing buildings to central heat supply via heat pumps or district heating (if not already the case) is necessary.

Critical **success factors** for the change of heating system in general and the conversion to central heating supply in particular can be identified in the following areas:

- **Information** on individual contributions to climate protection
- **Incentivising** the change of heating system and the conversion to central heating – especially in buildings with owner associations it is foreseeably difficult to reach a consensus without incentives or obligations; in addition, the question arises as to how individual flat owners or tenants can be persuaded to connect to a central heating system.
- Incentives for the implementation of **neighbourhood solutions** using heat pumps jointly for several buildings
- Socially acceptable **cost-bearing and financing**: This is particularly important because the investments required can vary considerably in size depending on the heating situation (both in Vienna and throughout Austria).
- Availability of **skilled workers** (see also the following chapter).

5.5 Individual heating: Decarbonisation through heat pumps in existing buildings is challenging.

Two heat pump technologies for individual heat supply were considered in the scenarios:

- Air-source heat pumps (air-to-water heat pumps) and
- Ground-source heat pumps (brine-to-water heat pump)

In coordination with the Municipal Administration (MA20), heat pump potentials were estimated. In both scenarios, heat pumps are used to a considerable extent in new buildings. Here they are used in about 50% of the buildings and represent the only modelled heating technology besides district heating. With an appropriate design, heat pumps can also be used for temperature reduction or cooling of buildings. In existing buildings, heat pumps replace oil and gas boilers in both scenarios. In the “Previous Targets” scenario, the modelled expansion of district heating and the associated only partial replacement of gas boilers is sufficient to achieve the emission targets. In particular, the use of heat pumps in buildings with flat-individual heating (i.e., as a replacement for gas boilers) can therefore be avoided. In the scenario “Climate Neutral 2040”, on the other hand, the replacement of gas boilers with heat pumps is necessary on a larger scale. Here, even the significantly greater expansion of district heating is not sufficient to supply heat to all buildings currently heated with oil or gas.

In addition to using heat pumps in individual buildings, they can also be used for several buildings at once ("neighbourhood solution") or within the framework of anergy networks (Box 3).

Box 3: Anergy networks

Anergy networks transport water at temperatures between 10 and 20°C. Buildings connected to an anergy network extract low-temperature heat for heating and hot water from the anergy network or transfer heat gained from room temperature control (= temperature reduction) to the anergy network. **Heat pumps** are operated for the energy extraction for heating, while the temperature control is typically carried out without the use of heat pumps. The resulting heat quantities are usually stored temporarily, e.g., in deep boreholes. Commercial and residential buildings can be supplied via an anergy network, particularly in new development areas and in the context of neighbourhood solutions as well as in existing buildings. Anergy networks can be designed as an "island network" or in connection with the district heating network and contribute to decarbonisation in the building sector.

In the scenario "Climate Neutral 2040", the extensive use of heat pumps in individual heating leads to increases in electricity demand in the heating sector from c. 1.8 TWh in 2019 to c. 2.7 TWh in 2040 (Figure 13).[18] This increase corresponds to c. 11% of Vienna's current final electricity consumption. The fact that the electricity demand does not increase more strongly is mainly due to the overall decreasing heating demand (due to renovation and climate change) and the high efficiency of heat pumps compared to other heating technologies (heat utilisation rates[19] around 2 (air-source heat pumps) and >3.5 (ground-source heat pumps)).[20] The lower final energy demand of heat pumps compared to fossil technologies also means that their higher investments can be partly compensated by lower energy costs. Load profiles were developed from the annual electricity demand quantities using standard load profiles; the peak electricity demands estimated in this way increase by c. 250 MWh/h (Figure 14).

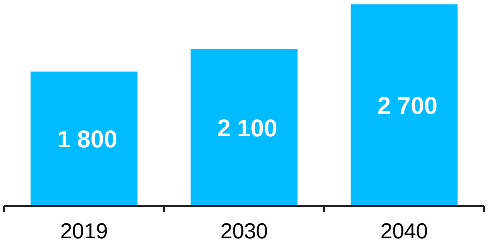
---

[18] No change is assumed for existing direct electric heating.

[19] In contrast to the typically reported annual performance factor for heat pumps, the heat utilisation factor takes into account not only the electricity demand for heat pump operation, but also the demand for the possible use of heating rods. Thus, a direct conversion of heat demand into electricity demand is possible (Prinzing et al., 2019).

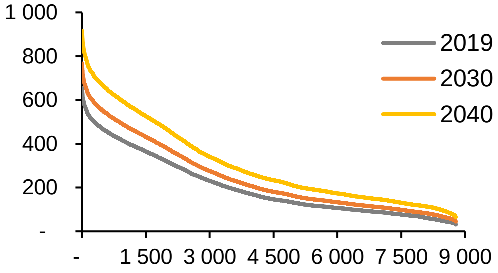
[20] The heat utilisation rates were taken from the EU Technology Pathways (Capros et al., 2019) and take into account efficiency increases up to 2040. In order to obtain conservative estimates, values at the lower end of the reported range were selected in each case. Accordingly, the heat utilisation rates were then also used (simplified) for calculating the peak loads with no further winter mark-up for air-to-water heat pumps.

Figure 13: Annual electricity demand for individual heating [GWh] – "Climate Neutral 2040"



Note: Values rounded to the nearest 50 GWh
Source: Compass Lexecon analysis based on the study assumptions

Figure 14: Duration curve of electricity demand for individual heating [MWh/h] – "Climate Neutral 2040"



Source: Compass Lexecon analysis based on the study assumptions

For the transformation of individual heating through the expanded use of heat pumps, two main challenges were identified, especially in the scenario "Climate Neutral 2040": (i) the required capacities of skilled craftsmen and (ii) the temporal decoupling of thermal and energetic refurbishment.

First, the conversion charted out in the scenario "Climate Neutral 2040" requires considerable **capacities of skilled craftsmen** over a period of less than 15 years. The conversion of existing buildings to heat pump use will foreseeably not begin until the mid/late 2020s (after the legal prerequisites have been created and taking into account corresponding transition periods). To achieve the complete decarbonisation of the heating sector in 2040, the retrofitting of existing buildings must be completed by then. During the peak phase of retrofits (i.e., in the 2030s), approximately 1,500 apartment blocks and non-residential buildings (i.e., excluding single-family houses) will need to be retrofitted to heat pumps per year.[21] This will foreseeably require considerable capacities of skilled craftsmen, but also represents an **opportunity for regional Viennese value creation and the Viennese labour market**.

Second, the complete decarbonisation in the scenario "Climate Neutral 2040" requires the replacement of heating systems ("energetic refurbishment") in fossil-fuel heated existing buildings already by 2040. However, the assumed refurbishment rates do not lead to a complete refurbishment of the building stock by 2040. This results in a **temporal decoupling of energetic and thermal refurbishment**. Since not all buildings currently heated with fossil fuels can be connected to district heating, the accelerated decarbonisation by 2040 will foreseeably require the use of heat pumps in buildings that have not undergone thermal refurbishment. This results in higher investments in heat pumps and their foreseeable oversizing as soon as thermal refurbishment is finally carried out. Although the use of heat pumps in non-thermally retrofitted buildings is not considered ideal, the basic technical feasibility has recently been confirmed for these cases also in the Viennese context – although there may still be difficulties or reasons for exclusion in individual cases (Wimmer & Holzer, 2020). In such cases, either

---

[21] In total, Vienna had just under 60,000 residential buildings with more than three flats and 16,000 non-residential buildings in 2011 (latest building statistics) (Statistics Austria, 2013).

connection to district heating or the exceptional use of biomass should enable the decarbonisation of the heat supply.

5.6 District heating: geothermal energy and large-scale heat pumps enable the decarbonisation of district heating production

Based on Wien Energie's internal assumptions regarding the maximum number of buildings that can be technically and economically connected to the district heating system, **district heating** reaches a **share of 56% of** Vienna's **total low-temperature heating demand** by 2040 in the "Climate Neutral 2040" scenario.[22] In addition to the connection of new buildings, a considerable **conversion of existing buildings to district heating** was also modelled. After a ramp-up phase until 2027, buildings with a total heating capacity demand of c. 95 MW will be connected to the district heating network each year. The required **annual district heating production thus increases by c. 16%** from almost 6.6 TWh in 2019 **to more than 7.5 TWh in 2040**. In the "Previous Targets" scenario, district heating production only increases by c. 7% to c. 6.9 TWh by 2040. In both scenarios, the progressive refurbishment activity and climate change partly counter-balance demand increases from new connections.

The increasing demand for heat and the progressive ageing of Wien Energie's existing district heating production facilities have resulted in the need to invest in district heating production. Based on today's production portfolio and Wien Energie's current plans for its expansion (including geothermal plants, heat pumps and a new gas-fired **combined heat and power plant (CHP)**, an asset park was developed that meets the requirements for future district heating production at optimal cost. An important constraint was the **completely decarbonised district heating production by 2040**.

The following technologies were considered when selecting new plants:

- **Deep geothermal energy** – Thermal water deposits are tapped through deep boreholes and their heat is made usable for the district heating network (see Box 4).
- **Heat pumps for geothermal plants** – Every geothermal plant planned by Wien Energie will be equipped with a heat pump (see Box 4).
- **Other large heat pumps** – these use industrial and commercial low-temperature waste heat (e.g., from air conditioning systems or cold stores) or waste heat from the flue gases of thermal waste utilisation and increase the temperature level so that it can be fed into the district heating network. Waste heat sources used are usually available all year round, so that the heat pumps can also feed heat into the district heating network in winter.
- **Heat Only Boilers (HOB)** – If necessary and economically optimal, the asset park could also have been expanded to include additional heating plants, in which only green gas

---

[22] Excluding district heating for the largest consumers (e.g., Vienna's general hospital – AKH) and for district cooling.

would be used from 2040 onwards – as it will be in the existing heating plants from then onwards; despite this possibility, new heating plants were ultimately not included in the cost-optimal asset park developed up until 2040, as security of supply can be maintained also with existing heating plants alone.

Box 4: Geothermal energy and heat pumps for district heating in Vienna

Geothermal plants: Wien Energie plans to use thermal water in two formations: the “Aderklaa conglomerate” and the “main dolomite”. The thermal water will be pumped from the geothermal reservoir to the surface. Heat is transferred from the thermal water to the district heating water via heat exchangers. The cooled thermal water is then pumped back into the geothermal reservoir via reinjection pumps. Wien Energie is planning several independent geothermal plants, each with a capacity of about 17 MW_{th}. The first plants are scheduled to go into operation during the 2020s.

Heat pumps in geothermal systems: Wien Energie’s concept for geothermal systems foresees their equipment with heat pumps. The heat pumps have two roles in these setups: On the one hand, they can raise the heat extracted from the thermal water to a higher temperature level in winter. This allows to feed the heat into the district heating network even during peak load periods, when the Vienna district heating network is operated at a higher temperature level (“reheating mode”). On the other hand, the heat pumps can use the residual heat from the district heating return (directly before the geothermal heat exchanger) for the rest of the year and raise this residual heat to the district heating flow temperature. In addition, more heat is extracted from the thermal water (due to the higher temperature spread in the heat exchanger) (“admixing mode”). In both operating modes, the heat pumps can be used all year round for district heating production and have a capacity of typically about 8 MW_{th} per geothermal plant (i.e., per pair of boreholes).

With regards to thermal **waste utilisation**, necessary replacement investments in waste incineration plants (with then slightly smaller heat extraction) and the continued existence of all other current Viennese waste incineration plants were modelled in both scenarios. Assuming an unchanged waste volume and unchanged energy content of the waste – despite a growing population – the thermal waste utilisation plants can continue to produce considerable amounts of district heating in 2040. Part of Vienna’s waste is of biogenic origin and the corresponding emissions from thermal waste utilisation are therefore CO_2-neutral. However, the incineration of the non-biogenic fractions causes fossil emissions. To ensure the CO_2 neutrality of all heat produced, **equipping thermal waste utilisation plants with carbon capture facilities** – and assuming the subsequent use of sequestered CO_2 – was modelled as the only available solution. Dimensioning the carbon capture facilities thereby took into account that CO_2 sequestration is never complete (85% of the CO_2 produced was assumed to be captured from the flue gas stream). However, since a large part of the waste incineration plant emissions (assumed to be 60%) is of biogenic origin, complete capture of the fossil CO_2 emissions can still be achieved. The extent to which carbon capture is used is determined by the need to achieve the emission target at the lowest possible overall cost.

The analyses of carbon capture in Vienna and respective concepts are still in their infancy – also with regards to the role and use of sequestered CO_2 in the context of a circular economy.[23] The assumptions this study was based on therefore represent initial estimates and, in particular with regards to necessary investments, actual figures may deviate significantly from the assumed values.

In addition to heat production plants, **heat storage** facilities (short-term and seasonal storage) were also considered when deriving the future asset portfolio (see Box 5 and Figure 15).

Box 5: Heat Storages

For heat storage systems, a basic distinction is made between short-term storages on the one hand and seasonal storages on the other.

Short-term storage facilities are characterised by relatively high injection and withdrawal rates and comparatively low storage volumes. Thus, these storage facilities have very short cycle times (= time to completely load and unload the storage). Wien Energie has been operating a short-term heat storage facility in the form of a high-pressure water storage tank in Simmering since 2003. It primarily serves to decouple electricity market-driven production in CHP plants from heat demand in the district heating network.

Seasonal storage, on the other hand, has significant storage volumes but is filled at comparatively lower rates over longer periods of time. These storage facilities are typically designed either as earth basin storage facilities (earth basins filled with water and/or another storage medium and insulated from the environment) or as aquifer storage facilities (water-bearing geological formations in which heat can be stored and withdrawn again over longer periods via deep boreholes).

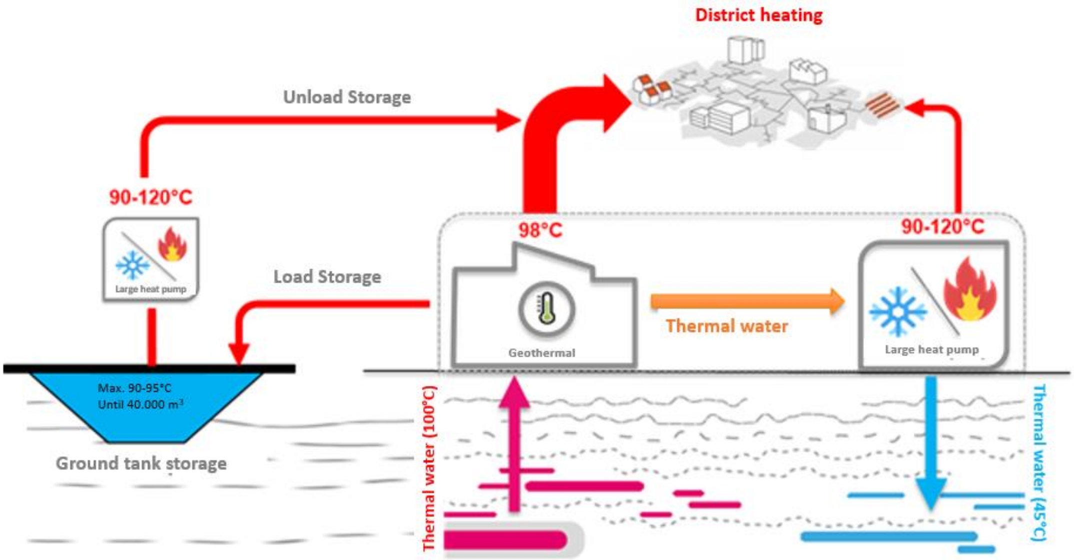
Based on the technologies described, a **cost-optimal development of the asset portfolio** was determined for both scenarios. The production portfolio determined for the scenario "Climate Neutral 2040" includes **significant geothermal capacities** (2040: 290 MW_{th}) and the associated heat **pumps** (2040: 125 MW_{th}) in addition to a **replacement investment in a gas-fired CHP plant** (380 MW_{th}) (exogenously determined). Also, investments in more than 200 MW_{th} other heat pumps and almost 190 GWh of heat storage were found to be optimal by 2040. **Investment volumes of c. 1.7 billion EUR_{2021}** have been estimated for this **district heating production** asset park by 2040.[24] The additional investments required by 2040 for the expansion of the **district heating network** to connect end consumers and geothermal production have been estimated at **c. 750 million EUR_{2021}.**

---

[23] There is a wide range of possible applications for sequestered CO_2, in which either otherwise produced CO_2 is displaced (e.g., in the food industry or as an industrial gas) or fossil raw materials can be replaced (e.g., in the production of basic chemicals such as methanol and ethanol).

[24] This includes the investments in the geothermal plants, the heat pumps, the re-investment in the Flötzersteig waste incineration plant, the equipment of the waste incineration plants with CO_2 sequestration plants and half of the investment in the new CHP plant.

Figure 15: Interplay between geothermal energy and heat storage

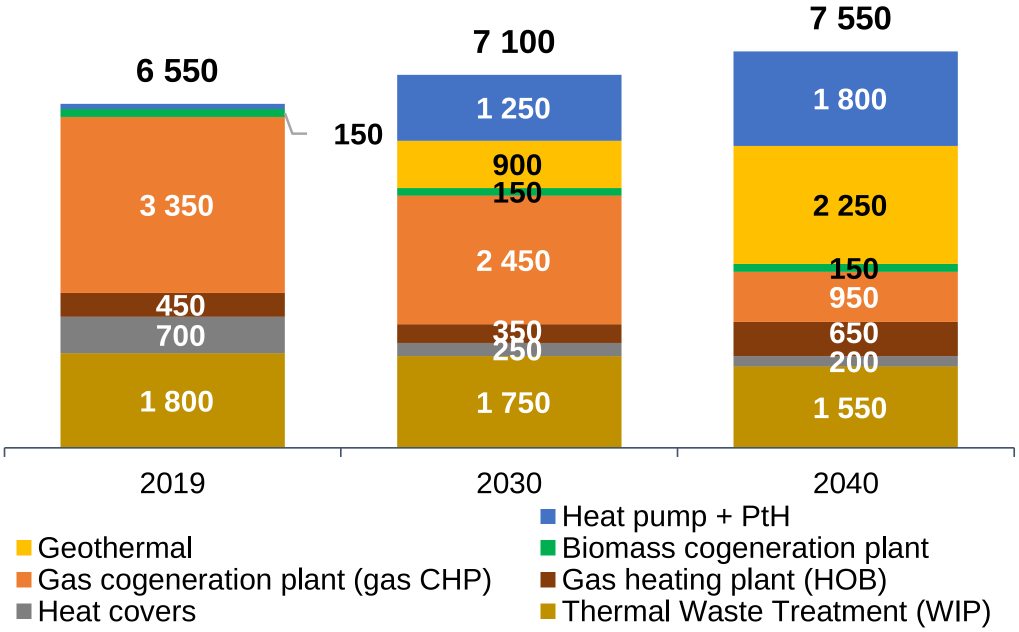


Notes: Schematic diagram – the heat pump arrangement does not correspond to the description in Box 4 (Concept study for a selected site, storage tank serves as pilot plant)
Source: Wien Energie

Based on the evolvement of the asset park, there is a clear shift in the **focus of heat production** in the "Climate Neutral 2040" scenario from CHP heat to district heating **from geothermal energy and large heat pumps** (Figure 16). Although also in the scenario "Climate Neutral 2040" Wien Energie still has considerable gas-fired CHP capacities in 2040 (2040: 880 MW_{th}), they are used significantly less often than in the years before. On the one hand, CHP heat will be displaced by production in then greatly expanded geothermal and heat pump capacities. On the other hand, the changes in the electricity market – with a sharp increase in the number of hours with very low electricity prices and a few hours with very high electricity prices – lead to reduced CHP generation times.

In 2040, the main base-load technologies are (still) the thermal waste utilisation plants and – now new – geothermal plants. Apart from maintenance intervals in summer, waste incineration plants and geothermal plants produce heat practically all year round. Heat pumps have an equally high number of operating hours (6,000 to 7,000 full load hours) (Figure 17). While the annual production of CHP plants is declining significantly, CHP heat continues to play a significant role in winter. **CHPs still produce almost 1 TWh of district heat in 2040**. Furthermore, CHPs allow for heat production in times of very high electricity prices, which can reduce or completely avoid the (then very expensive) electricity consumption of heat pumps (Figure 17).

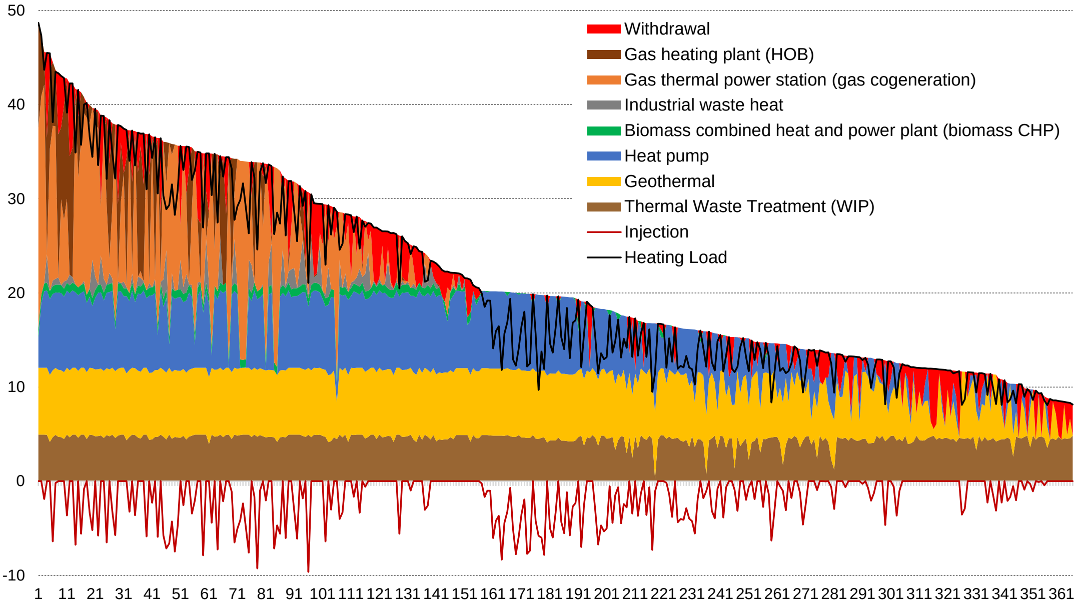
Figure 16: Development of district heating production [GWh/a] – "Climate Neutral 2040"



Notes: Values are rounded to the nearest 50 GWh; total production above the columns. Totals of rounded values do not always correspond to the rounded totals.

Source: Compass Lexecon analysis based on (Statistics Austria, 2020a) (for 2019) and based on the study assumptions (2030 and 2040).

Figure 17: Duration curve of district heating production in 2040 [GWh/d] – "Climate Neutral 2040"



Notes: Shown is the duration curve of the daily quantities.

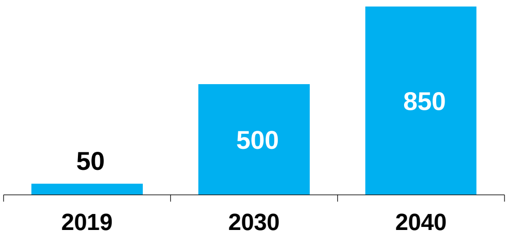
Source: Compass Lexecon analysis based on the study assumptions.

In addition to investments in new plants (geothermal energy, heat pumps, storages, and CO_2 sequestration for thermal waste utilisation), the exclusive use of green gases from 2040 onwards is the keystone to completely CO_2 -neutral district heating production in the "Climate Neutral 2040" scenario. At the same time, the associated central electricity production in Wien

Energie's CHP plants will also be decarbonised (see section 8). In total, Vienna's **CHPs and heat only plants** will require **c. 3.9 TWh of green gas in 2040**. However, as soon as more plants reach the end of their service life in the 2040s, the amount of green gas required will be reduced.

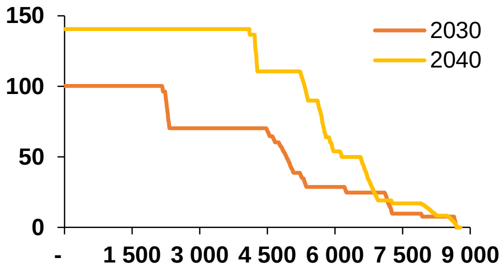
Due to the strong expansion of the usage of large heat pumps and geothermal energy, the **electricity demand in district heating production** increases significantly. In the scenario "Climate Neutral 2040", this means that in **2040**, **c. 850 GWh per year**, **or** about 10% of Vienna's total current electricity demand[25] will be used for district heating production (Figure 18). However, due to the high capacity factors of heat pumps and geothermal plants, the electricity demand in district heating production – despite high annual quantities – remains moderate in comparison reaching a maximum of c. 140 MW in 2040 (Figure 19).

Figure 18: Annual electricity demand for district heating [GWh] – "Climate Neutral 2040"



Note: Values rounded to whole 50 GWh
Source: Compass Lexecon analysis based on the study assumptions

Figure 19: Duration curve of electricity demand for district heating [MWh/h] – "Climate Neutral 2040"



Source: Compass Lexecon analysis based on the study assumptions

In discussions with Wien Energie, several **success factors** for the decarbonisation of the heating sector and the extensive use of decarbonised district heating in line with the modelled scenarios were identified:

- Incentives for **connecting existing buildings to district heating**: Currently, new buildings account for the majority of new district heating connections. In order to achieve the ambitious new connection targets and the necessary expansion of district heating also for existing buildings, additional incentives (e.g., within the framework of the Heat and Cooling Pipeline Expansion Act – WKLG) will be necessary in the foreseeable future;
- Coordinate the expansion of district heating within the framework of "**spatial energy planning**", to ensure that the largest possible number of buildings are actually supplied with district heating once an investment in expanding the district heating network is made;
- Incentives for the rapid ramp-up of **green gas production and use** to ensure that green gas becomes available and usable in the required quantities and at attractive prices by

---

[25] In addition to the final electricity demand, this also includes the grid losses and the demands in the energy sector.

2040 (incentives can be provided, for example, through investment or operating subsidies for green gas production or use, reductions in taxes and levies, access to preferential financing measures or measures to stimulate demand);

- Support **geothermal development** through administrative procedures that are commensurate with the importance of this technology for the decarbonisation of urban energy systems in terms of complexity and duration;[26]
- Reduction of the **tax burden** (taxes and levies) **for electricity used** in large heat pumps or geothermal plants for district heating production, thus contributing to the decarbonisation of the heating sector;
- Technology-specific **incentives to develop sources needed to decarbonise district heating production** (large-scale heat pumps, geothermal plants and carbon capture) – or their extension and expansion.

The transformation of district heating also offers a wide range of opportunities, the most important of which are:

- district heating opens up a **decarbonisation option** in densely built-up urban areas;
- the **heat yields** achievable with geothermal energy and large-scale heat pumps from the electricity used is significantly higher than that of heat pumps used in individual heating; overall, therefore, district heating use **limits the burden on the electricity sector**;
- embedding heat pumps in an **asset portfolio** that also includes storage enables further **relief for electricity generation**. Since the portfolio also includes plants that do not require electricity for heat production, electricity consumption can be limited in times of reduced renewable generation – an option that is typically not available or only available to a limited extent for heat pumps in individual heating;
- regional **Viennese value creation** for the expansion of the district heating network and district heating production.

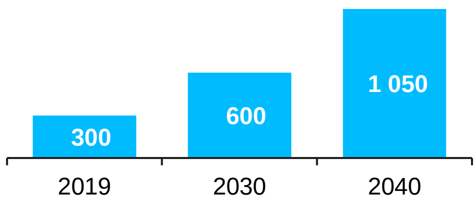
---

[26] These administrative procedures are within federal competence.

5.7 Cooling & air-conditioning: Electricity demand for cooling & air-conditioning is expected to increase significantly by 2040

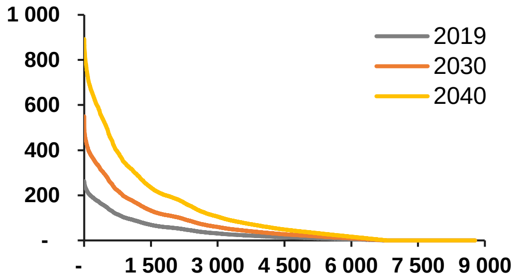
The starting point for the analyses is the current energy demand for cooling and air conditioning according to the energy usage analysis for Vienna (Statistics Austria, 2020a) and for households also an update of the estimate (Treberspurg et al., 2017). The modelling of air conditioning in both scenarios follows the assumptions of the calculations for the Smart City Framework Strategy. Therefore, both (i) **rising demand for cooling and air conditioning** as a result of increasing cooling degree[27] (0.5 percentage points increase per year) and (ii) **broader usage of cooling and air conditioning** in the service, industry and household sectors (5% increase per year) are assumed.

Figure 20: Annual electricity demand for air conditioning [GWh] – "Climate Neutral 2040"



Note: Values rounded to the nearest 50 GWh
Source: Compass Lexecon analysis based on the study assumptions.

Figure 21: Duration curve of electricity demand for air conditioning [MWh/h] – "Climate Neutral 2040"



Source: Compass Lexecon analysis based on the study assumptions.

As a result, the **energy demand for cooling** and air conditioning **increases** significantly in both scenarios, **by about 240%** from about 300 GWh today (2019) **to more than 1 TWh in 2040**. Due to the weather dependency of the air conditioning demand and the resulting strong concentration of the energy demand on the summer months, a considerable electricity demand for air conditioning can be assumed. Using measured load profiles, this was estimated at almost 900 MW in 2040.[28]

The foreseeable strong correlation between air conditioning demand and electricity production in photovoltaic systems has an advantageous effect. However, the comparison of the electricity demand for air conditioning with the electricity production from PV systems also shows the importance of this segment as well as any incentives and measures to reduce demand (see

---

[27] A statistical quantity for estimating the air conditioning requirement, in which the difference between the standard indoor temperature (18.3°C) and the daily mean temperature of a day is added up for all days on which the daily mean temperature is above the cooling limit temperature (18.3°C).

[28] For this estimation, a Wien Energie load profile for a district cooling network (with a diversified consumer structure) was used – however, it is neither modelled nor expected that the entire air conditioning demand will be covered by district cooling.

section 8.2. In 2040, c. 1.3 TWh of PV electricity will be produced in Vienna if the expected potentials are exploited).

In addition to the use of individual cooling and air-conditioning units, part of the air-conditioning demand in Vienna is already covered by district cooling (Box 6). District cooling is generally more efficient than individual air conditioning systems and can therefore contribute to reducing electricity demand. In addition, cooling networks avoid the release of waste heat from air conditioning in urban areas and can thus contribute to improving the urban climate.

Box 6: District cooling

Vienna already has **district cooling networks**. District cooling networks transport 7°C cold water that has been cooled with absorption or compression chillers or heat pumps. In the buildings connected to a district cooling network, it is used to operate ventilation systems, chilled ceilings or fan coils to cool rooms and appliances. Currently, district cooling is primarily used in the service sector and to a lesser extent in residential buildings. In particular, areas with a high share of commercial activity – such as Vienna's city centre – are typically well suited for the expansion of district cooling due to the high demand density for air conditioning.

Chapter 6

Mobility

6.1 Changed framework: The changed targets accelerate the complete decarbonisation of the mobility sector by ten years

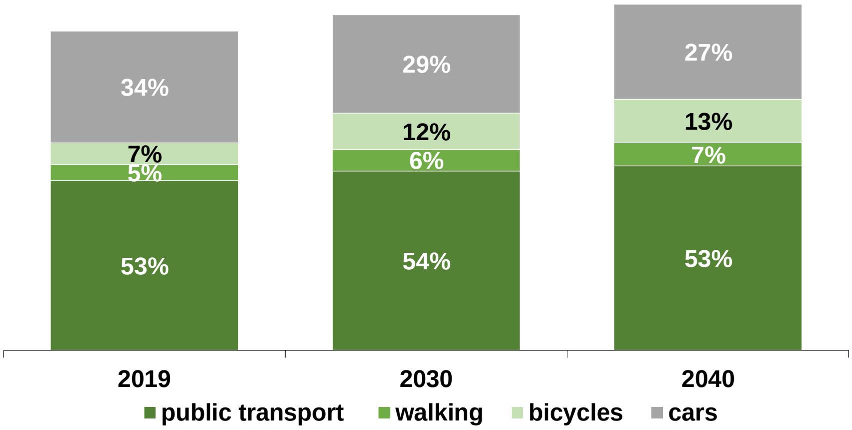
Both scenarios assume basically the same mobility demand and the same changes in the modal split over time – towards more walking, cycling and use of public transport. However, the main difference between the two scenarios is the time for complete decarbonisation. While up to now the mobility sector was not supposed to cause any more CO_2 emissions post 2050 (this is reflected in the “Previous Targets” scenario), this target is supposed to be reached already in 2040 according to the new targets (“climate neutral 2040” scenario). As a result, the new political targets accelerate the development in the mobility sector by ten years.

6.2 Mobility needs: As traffic volumes increase the shift away from motorised private transport is progressing

In the study, public transport on the one hand and individual transport on the other hand were modelled. In individual transport, a further differentiation was made between passenger transport (passenger cars), light commercial vehicles and heavy goods vehicles (HGVs).

In both scenarios, the development of the mobility volume in Vienna is characterised by population growth with a corresponding growth in mobility demand and a change in the modal split towards public transport as well as cycling and walking (Figure 22). The assumptions underlying the Smart City Framework Strategy 2019 (Urban Innovation Vienna, 2019) were used as a basis for the modelling of both scenarios.

Figure 22: Development of journeys made and the modal split (as a proportion of journeys made) in passenger transport



Notes: The development of the modal split represents an input to the modelling carried out – not an outcome. The column height corresponds to the development of the distances travelled The values for 2040 represent interpolations of the targets for 2030 and 2050.
Source: Compass Lexecon analysis based on (Urban Innovation Vienna, 2019)

6.3 Individual transport: Electromobility picks up speed

In private transport – especially for passenger cars – the trend of development is seemingly unstoppable in the direction of electromobility. In recent years, a considerable growth of electromobility in passenger transport has been observed – internationally and in Austria. At the end of 2020, electric vehicles accounted for 0.9% of the vehicle fleet in Austria – an increase of 50% compared to 2019 (Statistics Austria, 2021). However, electric vehicles now account for 9.7% of new registrations (first half of 2021) and are thus already ahead of plug-in hybrid drives with approx. 6% of new registrations (Statistics Austria, 2021). This is the case not least due the fact that **electric cars** are **now competitively priced** (e.g., (Rauecker, 2021)) – mainly due to corresponding subsidies and tax breaks. Finally, the EU Commission recently presented a legislative proposal that would allow only zero-emission vehicles to be registered from 2035 onwards (European Commission, 2021b).

Against the backdrop of these dynamic developments, **decarbonisation of passenger car transport and light commercial vehicles** was modelled **entirely via electric vehicles** in both scenarios. Hybrid drives are only used as an intermediate step towards full electrification. In order to achieve the complete decarbonisation of mobility in Vienna in 2040 or 2050, an ambitious ramp-up of electric mobility in passenger transport is required. The ramp-up curves of electric mobility in Vienna on which the two scenarios are based are oriented towards the scenarios developed by AustriaTech (an agency of the Ministry of the Environment) in its studies ((Eberhard & Steger-Vonmetz, 2019) and (Eberhard T. , 2020)). Accordingly, battery-electric vehicles reach a technology share of 27% in 2030 in the “Previous Targets” scenario and 100% only after 2040; in the “Climate Neutral 2040” scenario, however, they already reach 58% in 2030 and 100% in 2040.

For trucks, however, it is currently still unclear whether electric drives will make the complete breakthrough. Especially for heavy goods transport over long distances, the technology race between battery-electric vehicles, hydrogen fuel cell drive and vehicles with combustion engines using decarbonised liquid fuels does not seem to be decided yet. Therefore, only partial electrification – c. 50% of the traffic volume in each case in the final state – was modelled for the heavy traffic attributable to Vienna in both scenarios. For the decarbonisation of the remaining heavy goods traffic, the use of hydrogen was assumed in each case.

6.4 Public transport: Complete decarbonisation of public transport can be achieved via moderate increases in direct electricity demand and significant amounts of electricity for the production of hydrogen

Due to the extensive use of metros and trams, Vienna's public transport is already largely electrified today, and the corresponding final energy use is therefore decarbonised.[29] Only the bus fleet currently causes CO_2 emissions due to the use of diesel fuel and liquid petroleum gas (Wiener Linien, 2020).

The modelling assumed an extensive conversion of the Vienna bus fleet to hydrogen propulsion (c. 70% of the wagon kilometres). For the buses not powered by hydrogen, a battery-electric drive was modelled.

The total **electricity demand required for public transport in Vienna** thus consists of three components:

- Electricity used directly for the operation of **metros and trams**
- Electricity used in **battery-electric buses**
- Electricity required to **produce hydrogen** for the fleet

As part of the modelling, the public transport routes were updated according to the traffic volume and the modal split and the final energy demand – taking into account the change in energy source and the associated changes in efficiency – was scaled. As a result, the modelled **electricity demand for public transport** increases in both scenarios from c. 420 GWh in 2019 to c. **460 GWh** in 2040 – **plus c. 270 GWh for the production of hydrogen** used in buses (c. 230 GWh hydrogen).

6.5 Electricity demand: Electromobility drives electricity demand significantly – peak electricity demand can be limited through smart charging.

As a result, the electricity demand for mobility increases significantly in both scenarios. However, due to the early complete decarbonisation in the scenario "Climate Neutral 2040", a

---

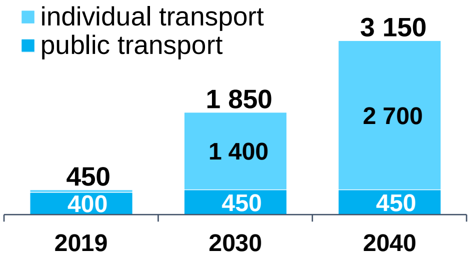
[29] The share of the energy demand required for rail transport attributed to Vienna is not taken into account in the modelling.

significantly increased **electricity demand for mobility of almost 3.2 TWh** is reached already in 2040 – compared to only close to 2.2 TWh in the "Previous Targets" scenario. While electricity demand in the mobility sector currently (2019) comprises mainly the demand of the Vienna public transport system (underground trains and trams), the picture changes radically in 2040. In line with the expansion of public transport, its electricity demand will grow moderately to just over 450 GWh. In contrast, the electricity demand for electromobility grows from an almost negligible size today to **more than 2.7 TWh** in 2040 (corresponding to about one third of today's total final electricity consumption in Vienna) in the "Climate Neutral 2040" scenario. Due to the delayed ramp-up of electromobility in the "Previous Targets" scenario, the electricity demand for electromobility in 2040 remains limited to 1.7 TWh. Overall, however, the transition to electromobility reduces the final energy demand in mobility, as electric cars are significantly more efficient than comparable vehicles with combustion engines.

The hourly load profiles for the electricity use of public transport in Vienna were determined by applying historical load profiles to the development of annual quantities. For electric mobility, the annual quantities were converted into load profiles via the e-mobility standard profile of ENTSO-E. The latter does not take into account smart charging. Using these profiles, the electricity demand in the mobility sector is estimated to reach c. 870 MWh/h in 2040 in the "Climate Neutral 2040" scenario. In the "Previous Targets" scenario, the peak electricity demand in 2040 is only around 570 MWh/h due to the less rapid ramp-up of electromobility.

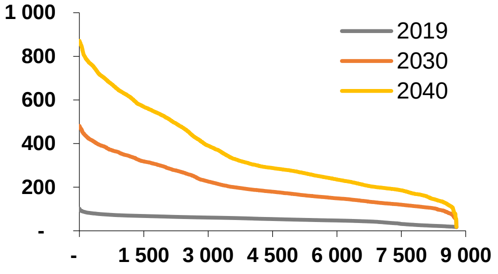
The demand profiles determined open-up, however, **potential for peak demand reduction via intelligent charging**.

Figure 23: Annual electricity demand for mobility [GWh] – "Climate Neutral 2040"



Note: Values rounded to the nearest 50 GWh incl. electricity demand for public transport
Source: Compass Lexecon analysis based on the study assumptions.

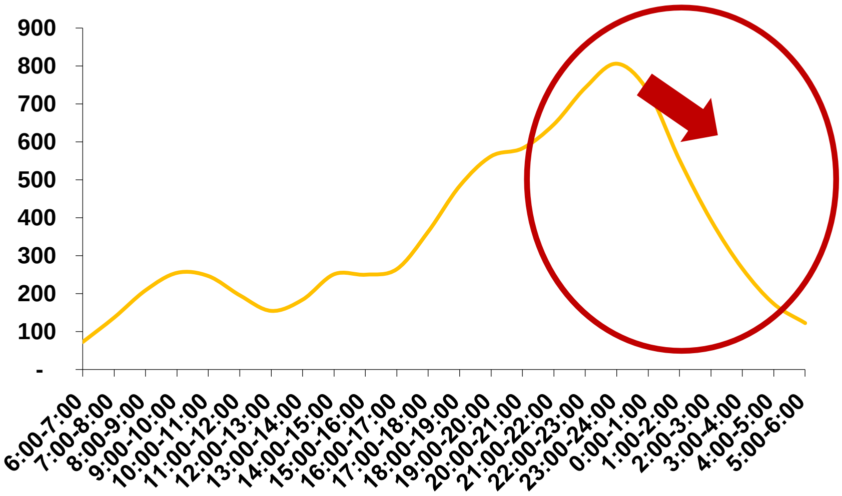
Figure 24: Duration curve of electricity demand for mobility [MWh/h] – "Climate Neutral 2040



Source: Compass Lexecon analysis based on the study assumptions.

A look at the e-mobility standard profile used from ENTSO-E clearly shows this potential for peak demand reduction lying applying in smart charging (Figure 25). The characteristic peak demand in the evening or early night and the massive drop in charging demand after midnight are also confirmed by empirical studies specific to Vienna e.g., (Hüttler et al., 2019).

Figure 25: Electricity demand for electromobility over one day in January 2040 not considering smart charging [MWh/h] – "Climate Neutral 2040"



Source: Compass Lexecon analysis based on (ENTSO-E , 2020)

Electric cars connected for charging in the evening complete the charging process during the night. In the early morning, the electricity demand is at the daily minimum. Time-delayed charging during the night therefore opens-up the possibility of considerably reducing the electricity peak demand for electric mobility in buildings with several charging points, but also for Vienna as a whole. Similarly, a diversification of the charging infrastructure with increased charging options also at the workplace – and thus an expansion of charging during the day – can contribute to the reduction of peak demand.

Overall, the reduction of electricity peak demand for e-mobility can contribute to making the decarbonisation of mobility easier, faster and cheaper to implement in the areas of electricity production and distribution grids.

6.6 Charging and refuelling infrastructure: A ramp-up of electromobility requires the expansion of the charging infrastructure – in many cases also in existing buildings.

In line with the ramp-up of electromobility, a significant expansion of the charging infrastructure in Vienna is also required. The extent of the required charging infrastructure is still the subject of analyses and discussions. While empirical analyses from Norway report 0.2 to 0.6 charging points per electric car (Pfaffenbichler et al., 2017), scenario calculations for Austria assume 1.0 charging points per electric car (Eberhard T. , 2020). In order to estimate the investment needs for charging infrastructure in Vienna, a total of 0.8 charging points per electric car (mostly in the private sector, i.e., in/near residential and office buildings) was assumed.[30]

---

[30] The wide range of literature values illustrates the great uncertainties underlying estimates of the development of the charging infrastructure in urban areas. This is not least due to still unclear changes in user behaviour (especially with regards to the question of how often or how long charging will typically take place in the future).

Following the overarching target of reducing electricity peak demand, the majority of these charging points were assumed to be 11 kW charging points at most. In line with the need to provide access to charging points for vehicles that are not parked on public roads and to expand charging options at the workplace, the installation of charging points in existing buildings will also be required to a large extent.

Based on these assumptions, the estimated **investments** in **Vienna's** public and private **charging infrastructure for e-mobility and hydrogen filling stations** for the "Climate Neutral 2040" scenario amount to **c. 1.3 billion EUR$_{2021}$ by 2040.**[31] Necessary adjustments in the electricity distribution grid were not analysed in this study. However, the investment estimate took into account grid access fees that (at least partially) compensate for the necessary expansions. Also expected cost degressions for charging infrastructure were taken into account (Capros et al., 2019).

6.7 Success factors: The decarbonisation of Vienna's mobility is primarily dependent on the rapid expansion of the charging infrastructure in the non-public sector

As public transport is already largely electrified and heavy goods traffic plays a subordinate role in terms of its emissions in Vienna, the decarbonisation of Vienna's mobility is primarily dependent on passenger and light commercial traffic. In view of the momentum in the market for electric cars itself, the development of charging infrastructure becomes the key element. Several **success factors** have been identified for its rapid development:

- Expansion of the **charging infrastructure in existing buildings:**
  - The current legal framework at federal level makes it difficult to install charging points, especially in multi-party buildings – initial adjustments to federal regulations (including the Residential Property Act – WEG) have now been initiated (Parliament, 2021).
  - Creating or strengthening incentives for **coordinated installation of charging infrastructure in existing buildings** for all (prospective) users can also reduce overall costs (e.g., by using economies of scale and enabling coordinated/intelligent charging).
- Ensure sufficient **charging infrastructure in new buildings**: Review the requirements (building regulations) for **pre-installation in new buildings** for appropriateness in light of the complete electrification of individual transport by 2040.
- Maintaining or, if necessary, strengthening incentives for the **use of smart charging infrastructure** (especially in large residential buildings) to limit the electricity demand peaks for charging Vienna's electric vehicles.

---

[31] This value is not reduced by current and any future subsidies for the installation of charging infrastructure.

- **Skilled workers** for the installation of charging points – also in the mobility sector, there is a need to retrofit a large number of existing buildings with charging infrastructures. This goes hand in hand with the corresponding need for skilled workers to carry them out and possibly positive effects on regional value creation in Vienna.[32]

- Finally, the expansion of the **electricity distribution grid infrastructure** may be necessary for the success of electromobility in Vienna.[33]

---

[32] Corresponding macroeconomic analyses were not the subject of the present study.

[33] Adaptation requirements for the electricity distribution grid infrastructure in Vienna were not considered within the scope of this study.

Chapter 7

Other Energy Demand

7.1 Changed framework: Early and complete decarbonisation of other energy needs is already required in 2040

Previously, the targets of the Smart City Framework Strategy envisaged a reduction of emissions from other energy consumption to about half by 2050 compared to the 2005 value. This target is therefore used for the modelling of the “Previous Targets” scenario. However, the new political target of climate neutrality for Vienna in 2040 also means a significant increase in ambition for this sector. In the “Climate Neutral 2040” scenario, the reduction of CO_2 emissions of other energy consumption to zero is therefore already modelled in 2040.

7.2 Current situation: Vienna’s “other” energy demand is already heavily electrified today.

Vienna’s other energy demand includes the following applications:

- Energy for **cooking**
- Electricity for **electrical appliances** in households, industry and services[34]
- Energy for **process heat** in the industry and services sectors[35]
- Energy for “**stationary motors**”[36]

Already today (2019), the majority of the "other energy demand" is covered by electricity (80% of the final energy demand in this segment) (Figure 26). This leaves three applications (Statistics Austria, 2020a) in which fossil fuels are still used: cooking gas, stationary engines in industry and commerce, and process heat.

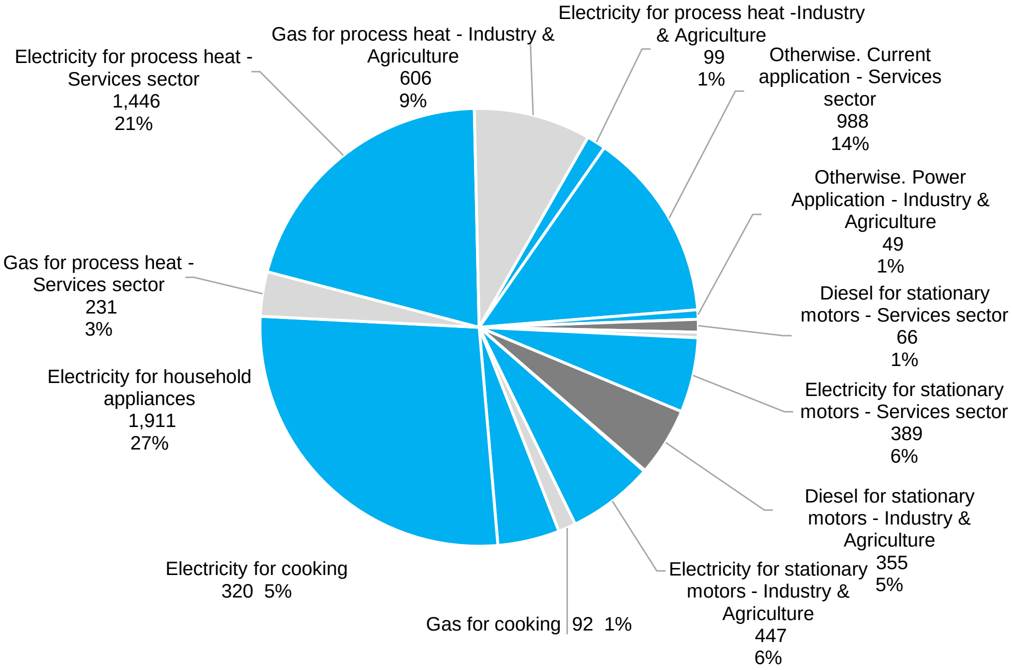
---

[34] Excluding air conditioning which is treated in the building sector.

[35] Excluding water heating in the service sector which is treated in the building sector.

[36] Unlike engines in vehicles, these motors have a fundamentally fixed location.

Figure 26: “Other” energy demand – breakdown of final energy demand 2019



Source: Compass Lexecon analysis based on Statistics Austria (Statistics Austria, 2020a)

7.3 Development: Decarbonisation requirements centre around process heat, stationary engines, and cooking gas

The other energy demands (with the exception of cooking energy) are more complex in terms of decarbonisation due to the more diverse fields of application compared to mobility and space heating. General statements on technology options for decarbonisation are therefore more difficult or subject to greater uncertainty. This applies even more as data on specific applications is limited. For this study the evolvement of the other energy demands was estimated against this background.

The modelling of useful energy demand considers two opposing developments. On the one hand, demand increases due to population growth (for household appliances and cooking energy) or economic growth (in the other areas). On the other hand, demand is reduced by energy efficiency improvements (which were modelled in line with the approaches used for preparing the Smart City Framework Strategy 2019 (Urban Innovation Vienna, 2019)).

In the “Previous Targets” scenario, a largely unchanged energy carrier mix is assumed. The decarbonisation target is achieved solely by the energy efficiency effect.

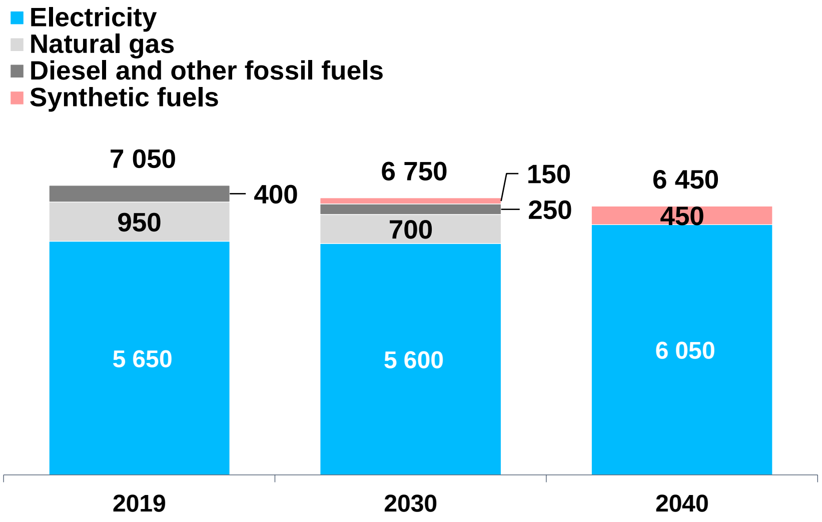
For the scenario “Climate Neutral 2040” scenario, on the other hand, change is required in the remaining areas of fossil fuel use. The three areas comprise:

- **840 GWh natural gas** and other fossil fuels for **process heat** in the industrial and service sectors
  - The focus of the process heat demand is on heat below 200°C (c. 70% of the final energy demand).
  - Of the remaining c. 260 GWh final energy demand for process heat above 200°C, almost 100 GWh result from the “food & beverages and tobacco” sector, followed by the service sector with c. 40 GWh.
  - For process heat, decarbonised alternatives to the use of fossil energy are available in the form of heat pumps and direct electric heat (Madeddu et al., 2020). The classic industries that are difficult to electrify, such as the iron and steel, cement, or glass, are not present in Vienna anyway.
  - The “Climate Neutral 2040” scenario therefore assumes the complete electrification of process heat by 2040. As a conservative approach, an efficiency of 1 – i.e., direct electric heat – is assumed. In many cases, however, it will also be possible to use heat pumps with a correspondingly higher efficiency and thus lower electricity demand.
  - As an alternative to complete electrification, however, the use of green gases would also be conceivable for process heat – especially for high-temperature applications.
- **450 GWh diesel** and other fossil fuels for **stationary motors** in the industrial and service sectors
  - These are mainly diesel-powered emergency generators and construction machinery.
  - Electrification is either fundamentally impossible (emergency electricity generators) or foreseeably difficult (construction machinery).
  - In the “Climate Neutral 2040” scenario, a replacement of fossil fuels with decarbonised liquid fuels (of biological or synthetic origin) is therefore modelled. As a result, c. **450 GWh of decarbonised liquid fuels** will be required in this sub-segment in 2040.
- **90 GWh of cooking gas –** an equivalent decarbonised technology is available here in the form of electric stoves; the “Climate Neutral 2040” scenario therefore assumes complete electrification by 2040.

7.4 Electricity demand: While increasing energy efficiency reduces “other” final energy demand, electricity demand increases by 2040.

By shifting the final energy demand previously covered by fossil fuels to electricity, **the electricity demand** in the “Climate Neutral 2040” scenario **increases** by **c. 10% to c. 6.2 TWh**. Progressive energy efficiency prevents a stronger increase.

Figure 27: Development of “other” energy demand [GWh] – “Climate Neutral 2040”



Notes: *Results rounded to the nearest 50 GWh*
On top of the columns: Sum of "other" final energy demand across all energy sources
Totals of rounded values do not always correspond to rounded totals.
Source: *Compass Lexecon based on study assumptions.*

In the “Previous Targets” scenario, on the other hand, electricity demand falls by c. 5% to c. 5.4 TWh by 2040.

7.5 Success factors: Avoidance of “lock-in” in fossil technologies through early information and incentives for decarbonisation

The key **success factors** for decarbonising Vienna’s “other” energy demand include:

- **Incentives** to switch to decarbonised technologies – these are particularly necessary, if and to the extent that electrification is not yet competitive in the respective application, but long reinvestment cycles would lead to a longer-term retention (i.e., after 2040) of fossil technologies (“lock-in” effect).

- Early **information** on the need to decarbonise all remaining fossil applications in order to initiate corresponding internal company planning and thereby also prevent lock-in effects.

In the area of other energy demands – with sometimes high electricity peak loads in commercial or industrial applications – electrification can also encounter **hurdles in the distribution grid** that require corresponding forward planning (this was, however, not a focus of the present study).

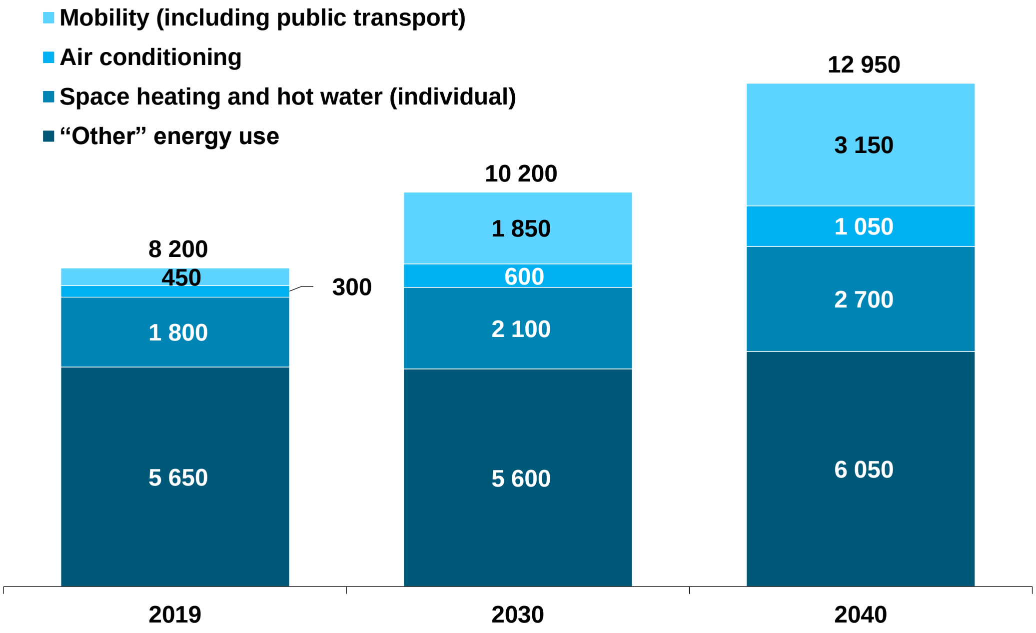
Chapter 8

Vienna's Electricity Demand and its Coverage

8.1 Electricity demand: Decarbonisation significantly increases Vienna's electricity demand by 2040

Due to the decarbonisation of the Viennese energy system in the "Climate Neutral 2040" scenario – which is largely driven by electrification – the final electricity demand in Vienna increases considerably by 2040. Starting from c. 8.2 TWh in 2019, **final electricity demand in Vienna grows by c. 5 TWh or almost 60% to 13 TWh in 2040** in the scenario "Climate Neutral 2040" (Figure 28). The main demand drivers are the mobility sector (+2.8 TWh – mainly electromobility), followed by electricity use in individual heating (more than +0.9 TWh) and the increasing demand for air conditioning (+0.75 TWh).

Figure 28: Annual electricity demand per application [GWh] – "Climate Neutral 2040"



Notes: Values rounded to the nearest 50 GWh
On top of the columns: total final electricity consumption
Totals of rounded values do not always correspond to the rounded totals.
Source: Compass Lexecon analysis based on the study assumptions.

In the “Previous Targets” scenario, final electricity consumption grows by only about 2 TWh or 24% to 10.2 TWh by 2040 due to slower growth in electromobility and lower use of heat pumps.

In addition to electricity for final consumption, there are other electricity needs to be covered in Vienna’s energy sector. This includes electricity used for district heating and hydrogen production, other electricity consumption in the energy sector and electricity grid losses. Overall, the **electricity demand to be covered** in the “Climate Neutral 2040” scenario thus grows **by c. 65%** from c. 9.5 TWh today (2019) **to c. 15.5 TWh in 2040** (Figure 29); in the “Previous Targets” scenario by 30% to 12.3 TWh.

8.2 Electricity production: Vienna’s electricity production will decrease significantly by 2040 – it can be completely decarbonised by using green gas

In the area of electricity production in Vienna, the adjusted political decarbonisation target also entails significant changes. Previously, a complete decarbonisation of electricity production in Vienna was only planned for 2050 (“Previous Targets” scenario). The new target of climate neutrality for Vienna as early as 2040 means avoiding fossil CO_2 emissions as far as possible, also in Vienna’s power plant fleet, this is therefore modelled in the scenario “Climate Neutral 2040”.

Due to the end of the technical service life of thermal power plants, both scenarios assume a **reduction of thermal electricity generation capacities in Vienna from** today's **1,720 MW_{el}**[37] **to 2040 only 1,240 MW_{el}**. This includes a new CHP plant built in the 2030s with a capacity of 400 MW_{el}. When taking the decision not to replace other CHP capacities, no considerations were made regarding the establishment of black start capability or grid reserve provision for transmission system operators. However, if required by the transmission system operator, corresponding reserves would have to be ensured. However, when the Simmering 1 CHP unit (840 MW_{el}) reaches the end of its service life during the 2040s, Vienna’s electricity generation capacities will continue to decline significantly.

Against this background, in the “Climate Neutral 2040” scenario, **thermal generation in Vienna is reduced by c. 78%** from c. 5.7 TWh in 2019 **to less than 1.3 TWh in 2040**. In the “Previous Targets” scenario, on the other hand, it only falls by c. 50% to c. 2.9 TWh. Apart from lower generation capacities, this development is due to reduced operating times as a result of changing dynamics of wholesale electricity prices (with an increasing number of hours with very low prices). Finally, the tightened emissions target in the “Climate Neutral 2040” scenario leads to a significant difference in electricity generation between the two scenarios. The use of exclusively green gases in the CHPs modelled to achieve the complete decarbonisation of Vienna’s electricity production also reduces their electricity production.[38] Green

---

[37] Excl. biomass CHP Simmering.

[38] As a result, local emissions from plants in Vienna that are subject to the European Emissions Trading Scheme (ETS) are reduced faster than they are stimulated by the ETS.

gases are assumed to be more expensive than fossil natural gas (plus CO_2 costs) also in 2040. Therefore, the number of hours in which electricity can be produced with a positive margin by the Viennese CHPs is lower than in the “Previous Targets” scenario, in which natural gas can still be used after 2040.[39, 40]

In contrast, the significant expansion of Vienna’s photovoltaic **capacities** by 2030 (800 MW_p – (SPÖ & NEOS, 2020)) as well as their further expansion up to the technical potential of 1,300 MW_p estimated by Wien Energie (Wien Energie, 2020) will lead to a **significant increase in electricity production** in Vienna. The PV targets for 2030 would require almost 12 km² and those for 2040 almost 19 km² of roof space in Vienna assuming current PV technology. Vienna has a total of about 53 km² of roof space – only part of which is, however, well suited for use by PV systems (Fechner, 2020). Alternatively, open space could be used to partially realise the PV targets (1,300 MWp would require about 20 km² of open space or 0.5% of Vienna’s urban area with current technology).

In both scenarios, the required **investments in Vienna’s electricity production** (PV plants as well as half of the CHP ret-investment) are estimated to amount to **c. 1.3 billion EUR_{2021}** up until 2040. The focus on expanding PV capacities only is justified by the lack of area for the expansion of wind capacities in the urban area.

Overall, however, the significant reduction in thermal electricity generation in Vienna’s CHP plants cannot be compensated by renewable electricity production in Vienna due to the very limited space available. **In the “Climate Neutral 2040” scenario, electricity production in Vienna therefore falls by more than 40%** from just under 7.3 TWh in 2019 to just under 4.2 TWh in 2040. In the “Previous Targets” scenario, natural gas is still fired in the CHP plants in 2040 due to the less strict emission limit. As a result, significantly higher operating hours can be achieved in the CHPs and overall electricity production in this scenario only falls by just under 22% to a total of 5.8 TWh. In both scenarios, the new CHP plant has a considerable share in the remaining electricity production in Vienna in 2040: 0.5 TWh (“Climate Neutral 2040”) and almost 0.8 TWh (“Previous Targets”).

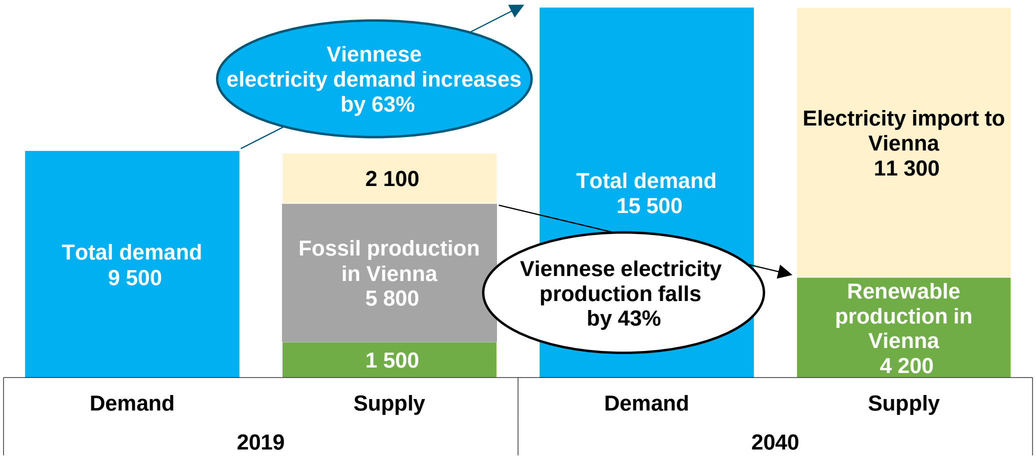
The interaction of the strongly increasing electricity demand on the one hand and the significantly decreasing electricity production in Vienna on the other hand results in the need for considerable electricity imports to Vienna in 2040. In 2019, almost 78% of Vienna’s annual electricity demand was covered by generation in Vienna. Thus, just under 22% of consumption had to be imported to Vienna. In the “Climate Neutral 2040” scenario, **the required electricity imports to Vienna increase to more than 73% or 11.3 TWh in 2040** (Figure 29). In the “Previous Targets” scenario, demand grows slower, and generation declines less, so that imports remain significantly lower both in relative (at 53%) and absolute (6.5 TWh) terms.

---

[39] The same energy and CO_2 price scenario is used in both scenarios.

[40] Any operations to provide system services (and the associated electricity production) for electricity transmission system operators (in Austria or neighbouring countries) were not taken into account.

Figure 29: Vienna's electricity demand and its coverage [GWh/a] – "Climate Neutral 2040"



Notes: Results rounded to the nearest 100 GWh
Source: Compass Lexecon analysis based on the study assumptions

The significantly increasing share of imports illustrates the general problem of **limited potential for renewable electricity generation in urban areas** (IEA, 2021)). However, in addition to electricity production directly in the city area, other current and future planned generation capacities are in the sphere of influence of the City of Vienna.

While electricity imports to Vienna increase, the decarbonisation in the "Climate Neutral 2040" scenario reduces the need for "imports" of other energy carriers. In particular, the demand for natural gas and crude oil products – which are produced outside of Vienna and the majority of which are also produced outside of Austria – will be eliminated by 2040. In 2019 a total of almost 20 TWh of natural gas and more than 9 TWh of fossil fuels were used in Vienna.

Key **success factors** for meeting Vienna's demand with decarbonised electricity are:

- the success of the **PV expansion initiative** and here primarily
  - **access to usable open spaces and roof tops** (especially in existing buildings additional incentives are often required)
  - the **availability of skilled workers** to install the required PV systems on a large number of Viennese roofs.
- the increasing **availability as well as commercial attractiveness of green gas** for electricity and district heating production (or corresponding support measures) by 2040 (see also on district heating production in section 5.6)
- the **availability of** the **required electricity production outside Vienna** – in this respect, Vienna remains dependent on the success of Austria-wide efforts to expand renewable generation and its system integration.

Annex A

Assumptions, Data and Data sources

The two scenarios developed in the study (“Previous Targets” and “Climate Neutral 2040”) were based on the assumptions presented in this section.

Table 2: Summary of assumptions, data and data sources used

Sector	Topic	Assumptions	Source
Heat	Thermal refurbishment – Refurbishment rate	• “Previous Targets”: linear increase from 0.9% in 2022 to 2.3% of the building stock p.a. from 2031 onwards • “Climate Neutral 2040”: linear increase from 0.9% in 2022 to 2.4% of the building stock p.a. from 2031 onwards	• “Previous Targets”: (Urban Innovation Vienna, 2019) • “Climate Neutral 2040”: Urban Innovation/Smart City Framework Strategy 2021 ((not yet) published)
	Thermal refurbishment – depth of refurbishment	Assumptions in both scenarios similar to the Smart City Strategy 2019: Reduction of the heating demand by 55% (with unchanged hot water demand)	(Urban Innovation Vienna, 2019)
	Thermal refurbishment – Refurbishment costs	Both scenarios based on EU pathways (191 EUR_{2020} /m²)	(Capros et al., 2019), Alignment with: (Energy Design Cody Consulting, 2017) and (Mitterndorfer et al., 2012)
	Climate-related change in heat demand	Both scenarios: Reduction of heating degree days by 0.5 percentage points per year until 2050	Urban Innovation/Smart City Strategy 2021 (not published)

Sector	Topic	Assumptions	Source
Heat – cont.	Gas in individual heating	• "Previous Targets": Natural gas can be used until after 2040 • "Climate Neutral 2040": no use of decarbonised gases in individual heating; from 2040 no use of natural gas in individual heating also in the existing buildings. • In both scenarios: no use of natural gas in new buildings	• "Previous Targets": (Urban Innovation Vienna, 2019) • "Climate Neutral 2040": Viennese government programme (SPÖ & NEOS, 2020), federal government programme (Federal Chancellery Austria, 2020) and expected contents of the Renewable Heat Act
	Conversion of existing building to central heating	In both scenarios: • Costs according to the study "Making existing buildings gas-free" by MA 20 • Losses according to approaches of the Smart City Framework Strategy (20% in-house losses)	(Wimmer & Holzer, 2020), Urban Innovation (2021) ((not yet) published)
	Heat demand new building	Both scenarios: • Heating requirement: 35 kWh/m² • Area per additional person in Vienna: 37 m²	Urban Innovation/Smart City Strategy 2021 (not published)
	District heating expansion	• "Previous Targets": 45% district heating share in the low-temperature market in 2040 • "Climate Neutral 2040": 55% district heating share in the low-temperature market in 2040	Wien Energie
	Possible applications for heat pumps	Both scenarios: • In smaller buildings (<1,000 m²) predominant use (90%) of air-source heat pumps • In larger buildings (>1,000 m² predominant use (90% in new buildings, 70% in existing buildings) of ground-source heat pumps	Wien Energie/MA20

Sector	Topic	Assumptions	Source
Heat – cont.	Techno-economic data Individual heating technologies	In both scenarios, the most conservative EU Pathways assumptions on efficiencies, acquisition/production costs and operating costs were used (note: any subsidies were not taken into account).	(Capros et al., 2019)
	Techno-economic technology data District heating	Both scenarios: Assumptions on efficiencies, acquisition/manufacturing costs and operating costs as well as earliest dates of deployment (Note: Possible subsidies were not taken into account).	Wien Energie
Cooling & Air Conditioning	Climate-related change in cooling demand	Both scenarios: Increase in cooling degree days by 0.5 percentage points per year until 2050	Urban Innovation/Smart City Framework Strategy 2021 (not published)
Mobility	Change in Vienna's mobility needs and modal split	Both scenarios: Development according to the Smart City Framework Strategy 2019	(Urban Innovation Vienna, 2019)
	Change in the rate of motorisation	Both scenarios: Development according to the Smart City Framework Strategy 2019	(Urban Innovation Vienna, 2019), (Magistrate of the City of Vienna, 2019)
	Charging infrastructure – costs	Both scenarios according to EU pathways	(Capros et al., 2019), Comparison with empirical data from Wien Energie

Sector	Topic	Assumptions	Source
Waste management	Waste volume evolvement in Vienna	Both scenarios until 2050: • Constant annual waste volumes despite population growth • Unchanged calorific values, biogenic fractions, and CO_2 intensities of waste	Wien Energie
	Carbon capture in thermal waste utilisation – capture rate	Both scenarios: CO_2-capture rate 85%	Wien Energie
	Carbon capture in thermal waste utilisation – ramp-up	Both scenarios: gradual installation from 2031 onwards	Wien Energie
Power production in Vienna	Expansion of photovoltaic capacity in Vienna	Both scenarios: Expansion of photovoltaics in Vienna • to 250 MWp by 2025 • to 800 MWp by 2030 • to 1,300 MWp by 2040	• 2025 & 2030: Vienna Government Programme (SPÖ & NEOS, 2020) • 2040: Wien Energie
General	Price scenario	The same price scenario for electricity, fossil fuels, biomethane, hydrogen and CO_2 was used for both scenarios.	Wien Energie

Source: Compass Lexecon in coordination with Wien Energie

Annex B Methodological Supplements

B.1 Delimitation of the final energy requirements considered in the study

The study covers the energy consumption attributed to the province of Vienna in the Austrian energy balances (Statistics Austria, 2020b). However, the following limitations apply – which largely correspond to those of the calculations underlying the Smart City Framework Strategy (Urban Innovation Vienna, 2019):

- In the transport sector, only the emissions according to the “second estimate” of the Austrian Federal Environment Agency (Federal Environment Agency, 2020) and the energy requirements derived from them are used as the basis for modelling individual transport evolvement. Accordingly, energy consumption that is only allocated to Vienna on the basis of an organisation’s headquarters, without actually occurring in Vienna, is not taken into account;
- The final energy demand of the railway sector allocated to Vienna (pro rata) is not considered.

B.2 Delimitation of the emissions considered in the study

In addition to emissions from final energy consumption (see above), the study also considers the following emissions:

- Emissions from electricity and district heating production in Vienna (incl. from thermal waste utilisation)
- Emissions for heat imported to Vienna

Emissions for electricity imported to Vienna are not taken into account in the reported years 2030 and 2040, as Austrian electricity is assumed to be “*covered to 100% from renewable energy sources nationally and on an annual net basis from 2030 onwards*“ (Renewable Energy Expansion Act).

B.3 Sector models

Five sector models were developed, parameterised, and applied to model the scenarios:

- Low-temperature heat
- District heating application
- Air conditioning

- Mobility
- Other energy demand

The modelling of the scenarios was accompanied by a large number of discussions with experts on various aspects of the Viennese Energy system (including representatives of MA 20, Statistik Austria, Urban Innovation, Wien Energie, Wiener Linien and Wiener Netze).

B.3.1 Low-temperature heat

Based on the most recent data on Vienna's actual building stock, a building stock with seven typical buildings, each with three refurbishment status was modelled and calibrated to the energy demand in 2019. The evolvement of the building stock and its useful energy demand were modelled on the basis of population growth, progressive thermal refurbishment and the assumed effects of climate change up to 2040. Based on this, pathways for the heating system change of the individual building types were developed, which overall fulfil the requirements for the respective scenario. These paths were then evaluated regarding their techno-economic properties (energy requirements, emissions, investments, etc.).

B.3.2 District heating application

To determine the evolvement of district heating production, the current Viennese district heating generation portfolio (incl. centralised electricity production) as well as possible development options were modelled in the dispatch optimisation software Plexos®. Based on the hourly district heating demand (derived from the results of the low-temperature heat model), the total cost-optimal expansion path for generation capacities was determined. The optimisation considers capital cost as well as operating cost, energy carrier and CO_2 costs (the latter tow based on exogenously specified price scenario). The generation park determined in this way was then subjected to an hourly dispatch optimisation based on marginal generation costs. Thereby, among other things, heat generation per technology in both scenarios as well as the associated use of energy carriers and the resulting emissions were determined.

B.3.3 Air conditioning

The current electricity demand for air conditioning in the household, industry and services sectors was subjected to the effects of increasing use by end consumers and increasing air conditioning demand (resulting from the assumed increasing cooling degree days per year) and modelled up until 2040.

B.3.4 Mobility

The most recent data on vehicle stock and traffic volumes were extrapolated to 2050 based on the framework conditions of the two scenarios (including changes in traffic volume and modal split). Based on this, paths for changes in drive technologies were identified that meet the respective scenario requirements. These paths were evaluated regarding their techno-economic properties (energy requirements, emissions, required charging infrastructure, etc.).

B.3.5 Other energy demand

Based on the composition of today’s final energy demand and the efficiency levels estimated in the respective application, useful energy demands were first determined for each application. These were then modelled up to 2040 with a sector-specific demand driver on the one hand and assumptions on progressive energy efficiency on the other hand. The useful energy demands were then converted to final energy demands with energy carrier shares per application (incl. corresponding efficiencies) that varied over time and were adapted so as to meet the requirements of the two scenarios.

Annex C

References

Amann, W. et al. (2020): *Definition and measurement of the thermal-energy renovation rate in Austria.* [online] available at: iibw.at/documents/2020%20IIBW_UBA%20 Sanierungsrate.pdf (last access: 09.08.2021)

Benke, G. (2017): *Gas floor heating in the light of the decarbonisation of the energy system – short study.* [online] available at: www.wien.gv.at/stadtentwicklung/energie/pdf/ gasetagenheizungen-studie.pdf (last access: 09.08.2021)

Capros, P. et al. (2019). *Energy system modelling of the EU strategy towards climate-neutrality*. Energy Policy, 134, 1-15.

Eberhard, T & Steger-Vonmetz, C. (2019): *Charging electric cars at home – Need for and measures for home charging stations in residential complexes.* [online] available at: https://www.austriatech.at/assets/Uploads/Publikationen/PDF-Dateien/7a80fa2cb2/WEB-Mobility-Explored-April-2019.pdf (last access: 24.08.2021)

Eberhard, T (2020): *Public charging infrastructure – regulatory framework and what else is needed?* [online] available at: https://www.wko.at/site/wirtschaft-in-bewegung/praesentation_austriatecheberhard-1.pdf (last access: 13.08.2021)

Energy Design Cody Consulting (2017): *Investigation into the heat supply of a representative Viennese Gründerzeit block, as a supplement to the KLIEN-funded exploratory project Smart Block II – commissioned by the City of Vienna MA 20.* [online] available at: www.wien.gv.at/stadtentwicklung/energie/pdf/smart-block-2.pdf (last access: 09.08.2021)

ENTSO-E (2020): *Mid-term Adequacy Forecast 2020 – Datasets*. not published.

European Commission (2021a): *'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality.* [online] available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN (last access: 26.08.2021)

European Commission (2021b): *Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2019/631 as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition.* [online] available at: https://ec.europa.eu/info/sites/default/files/amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en.pdf (last access: 29.08.2021)

Fechner, H. (2020): *Ermittlung des Flächenpotentials für den Photovoltaik-Ausbau in Österreich: Welche Flächenkategorien sind für die Erschließung von besonderer Bedeutung, um das Ökostromziel zu realisieren zu können – Study commissioned by Österreichs Energie.* [online] available at: https://oesterreichsenergie.at/fileadmin/user_upload/Oesterreichs_Energie/ Publikationsdatenbank/Studien/2020/PV-Studie_2020.pdf (last access: 28.08.2021)

Federal Chancellery Austria (2020): *Aus Verantwortung für Österreich – Regierungsprogramm 2020-2024*. [online] available at: www.bundeskanzleramt.gv.at/ dam/jcr:7b9e6755-2115-440c-b2ec-cbf64a931aa8/RegProgramm-lang.pdf (last access: 09.08.2021).

Federal Environment Agency (2020): *Bundesländer Luftschadstoff-Inventur 1990-2018*. [online] available at: https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0746.pdf (last access: 02.09.2021)

Federal Ministry for Transport, Innovation and Technology – BMVIT (2019a): *How do I charge my electric car? Band 01: Information for charging at home, house and co.* [online] available at: https://www.bmk.gv.at/dam/jcr:39090675-bb8b-4cf1-b87e-da2686501402/aufladen_band1_ua.pdf (last access: 24.08.2021)

Federal Ministry for Transport, Innovation and Technology – BMVIT (2019b): *Wie lade ich mein Elektroauto? Volume 02: Tips for charging in an apartment building/residential complex*. [online] available at: https://www.bmk.gv.at/dam/jcr:aeba2823-7b48-49b2-96f8-b34b934f4dd0/aufladen_band2_ua.pdf (last access: 24.08.2021)

Haas, R. et al. (2021): *Perspectives for Green Gases in Vienna – commissioned by Wien Energie*. not published

Hüttler, W. et al (2019): *Pilot project electric mobility 2030 – Implementation of electric mobility scenario 2030 in an existing residential complex*. [online] available at: https://www.e-sieben.at/publikationen/18056_e-MobPilotprojekt/18056_Pilotprojekt-Elektromobilitaet-2030_Endbericht_final.pdf?m=1570190380& (last access: 23.08.2021)

IEA (2021): *Empowering Cities for a Net Zero Future – Unlocking resilient, smart, sustainable urban energy systems.* [online] available at: https://iea.blob.core.windows.net/assets/4d5c939d-9c37-490b-bb53-2c0d23f2cf3d/G20EmpoweringCitiesforaNetZeroFuture.pdf (last access: 12.08.2021)

Madeddu, S. et al. (2020): *The CO2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat)*. Environmental Research Letters, Volume 15, Number 12 [online] available at: https://iopscience.iop.org/article/10.1088/1748-9326/abbd02 (last access: 12.08.2021)

Magistrate of the City of Vienna (2019): *Smart City Wien Framework Strategy 2019-2050 – The Vienna Strategy for Sustainable Development.* [online] available at: https://www.wien.gv.at/ stadtentwicklung/studien/pdf/b008551.pdf (last access: 06.08.2021)

Mitterndorfer, M. et al. (2012): *Calculation of cost-optimal minimum energy performance requirements for buildings (according to EPBD Art. 5).* [online] available at:

www.energyagency.at/fileadmin/dam/pdf/publikationen/berichteBroschueren/Endbericht_EPBD.pdf (last access: 09.08.2021)

Municipal Department 20 (2020): Energiebericht 2020 der Stadt Wien. [online] available at: https://www.wien.gv.at/spezial/energiebericht2020/files/Energiebericht2020.pdf (last access: 26.08.2021)

Parliament (2021): WEG-Novelle 2022. [online] available at: https://www.parlament.gv.at/PAKT/VHG/XXVII/ME/ME_00134/index.shtml (last access: 15.08.2021)

Pfaffenbichler, P. et al. (2017): *Hochlaufzahlen E-Autos in der Metropolenregion Wien – Studie der TU Wien im Auftrag der Wien Energie und der MA 33*. unpublished.

Prinzing, M., et al. (2019): *Outlook on possible developments of heat pump systems until 2050*. [online] available at: www.ost.ch/fileadmin/dateiliste/3_forschung_dienstleistung/ institute/ies/wpz/other_important_documents/2019_outlook_on_possible_developments_of_wp_systems_until_2050.pdf (last access: 19.08.2021)

Rauecker, G. (2021): *Petrol, diesel, e-car – the costs in comparison.* [online] available at: https://www.oeamtc.at/autotouring/auto/benzin-diesel-e-auto-die-kosten-im-vergleich-42887730 (last access: 29.08.2021)

Schimmel, M et al. (2018): *Electricity. Heat. Mobility. Scenarios for decarbonisation in the Vienna metropolitan area until 2050*. [online] available at: https://positionen.wienenergie.at/wp-content/uploads/2019/07/szenarien-zur-dekarbonisierung.pdf (last access: 01.09.2021)

SPÖ & NEOS (2020): *The Progressive Coalition for Vienna.* [online] available at: www.wien.gv.at/regierungsabkommen2020/files/Koalitionsabkommen_Master_FINAL.pdf (last access: 09.08.2021)

Statistics Austria (2013): *Housing stock and usable floor space by municipal district 1981, 1991, 2001 and 2011*. [online] available at: www.wien.gv.at/statistik/verkehr-wohnen/tabellen/wohnungsbest-flaeche-bez-zr.html (last access: 09.08.2021)

Statistics Austria (2020a): *Beneficial energy categories Vienna 1993 to 2019 (detailed information).* [online] available at: www.statistik.at/wcm/idc/idcplg?IdcService=GET_NATIVE_FILE&RevisionSelectionMethod=LatestReleased&dDocName=066287 (last access: 16.08.2021)

Statistics Austria (2020b): *Energiebilanz Wien 1988 bis 2019.* [online] available at: https://www.statistik.at/wcm/idc/idcplg?IdcService=GET_NATIVE_FILE&RevisionSelectionMethod=LatestReleased&dDocName=065509 (last access: 16.08.2021)

Statistics Austria (2020c): *Bevölkerungsprognose 2020 – Wien: Ausführliche Tabellen der Hauptvariante (Schnellbericht).* [online] available at: https://www.statistik.at/wcm/idc/idcplg?IdcService=GET_NATIVE_FILE&RevisionSelectionMethod=LatestReleased&dDocName=027327 (last access: 16.08.2021)

Statistics Austria (2021): *Fahrzeug-Bestand am 31.12.2020 nach Fahrzeugart.* [online] available at: https://www.statistik.at/wcm/idc/idcplg?IdcService=GET_PDF_FILE&RevisionSelectionMethod=LatestReleased&dDocName=125434 (last access: 23.08.2021)

Treberspurg, M. et al. (2017): *Heat! avoidance – Avoiding summer overheating in housing*. [online] available at: https://www.wien.gv.at/stadtentwicklung/energie/pdf/ueberwaermung.pdf (last access: 19.08.2021)

UIV Urban Innovation Vienna (2019): *Vienna's Climate & Energy Targets for 2030 & 2050 – Documentation of Calculations within the Update of the Smart City Wien Framework Strategy 2018/2019.* [online] available at: smartcity.wien.gv.at/wp-content/ uploads/sites/3/2019/06/Documentation-of-calculations-for-updating-the-smart-city-vienna-framework-strategy.pdf (last access: 06.08.2021).

Vienna Provincial Government (2021): *Ordinance of the Viennese Provincial Government on the Granting of Subsidies under Part II of the Viennese Housing Subsidies and Housing Redevelopment Act – WWFSG 1989 (Redevelopment Ordinance 2008) – Amendment 2021.* [online] available at: www.ris.bka.gv.at/ GeltendeFassung.wxe?Abfrage=LrW&Gesetzesnummer=20000091 (last access: 09.08.2021).

Warmuth, H. & Veigl, A. (2016): *Use of solid biomass in selected European cities and economic calculations for solid biomass in the Viennese electricity and heating market – A study commissioned by MA 20 – Energy Planning of the City of Vienna.* [online] available at: https://www.wien.gv.at/stadtentwicklung/energie/pdf/nutzung-biomasse.pdf (last access: 19.08.2021)

Wertgas (2016): *Feasibility Study – Waste-to-Biogas Plant Wien Energie – commissioned by Wien Energie*. not published

Wien Energie (2020): *Photovoltaics in Vienna: Theory vs. practice.* [online] available at: https://positionen.wienenergie.at/blog/wien-pv-potenzial (last access: 29.08.2021)

Wien Energie (2021): *Energy is our responsibility – Consolidated Environmental Statement 2021 of the electricity and heat generation plants of Wien Energie GmbH in accordance with the EMAS Regulation.* [online] available at: https://dokumente.wienenergie.at/wp-content/uploads/umwelterklaerung-2021.pdf (last access: 19.08.2021)

Wiener Linien (2020): *Facts & Figures Operating data 2019*. [online] available at: https://www.wienerlinien.at/media/files/2020/wl_betriebsangaben_2019_deutsch_358274.pdf (last access: 12.08.2021)

Wimmer, F. and Holzer P. (2020): *Gebäudebestand gasfrei machen – Untersuchung der technischen Möglichkeiten, Bestandsgebäude gasfrei zu machen im Auftrag der Stadt Wien Magistratsabteilung 20 – Energieplanung*. [online] available at: www.digital.wienbibliothek.at/wbrup/download/pdf/3289554?originalFilename=true (last access: 09.08.2021)

COMPASS
LEXECON

Contact:
Gerald AUE | Vice President
+33 7 61 93 93 46
gaue@compasslexecon.com

COMPASS LEXECON
EMEA Energy Practice

www.compasslexecon.com/practice-areas/energy

Paris
22 pl. de la Madeleine
75008 Paris

Berlin
Kurfürstendamm 217
10719 Berlin

Düsseldorf
Kö-Bogen
Königsallee 2b
40212 Düsseldorf

London
5 Aldermanbury Square
London, EC2V 7HR

Madrid
Pas. de la Castellana 7
28046 Madrid

Helsinki
Unioninkatu 30
Helsinki, 00100

Brussels
23 Square de Meeus
1000 Brussels