WIEN ENERGIE

Climate Impact of Urban Energy Systems

A Comparative Study of Eleven EU Cities

Conducted by Compass Lexecon in cooperation with Wien Energie, 2023.

Imprint

Media owner and publisher:
Wien Energie GmbH | Thomas-Klestil-Platz 14 | 1030 Vienna | Austria
office@wienenergie.at | www.wienenergie.at
Phone: +43 (0)1 4004-0

Concept, editing: Wien Energie in cooperation with Compass Lexecon.

Contents: The benchmarking study was conducted by Compass Lexecon on behalf of Wien Energie. Compass Lexecon study contact: Gerald Aue (gaue@compasslexecon.com)

2023.

Graphic editing of the report by Noodles Agency GmbH.

Content

COMPASS LEXECON

Compass Lexecon is one of the world's leading economics advisory firms and part of FTI Consulting. Compass Lexecon provides corporations, governments and law firms with clear analysis of complex issues. Our experience and expertise apply to virtually any question of economics, in virtually any context of the law or business, and in any industry. Compass Lexecon employs more than 800 professionals worldwide and more than 350 professionals in Europe – while its parent company, FTI Consulting, has more than 7 500 employees. The 50+ members of our European energy team operate from offices in Berlin, Düsseldorf, Paris, London, Brussels, Madrid and Helsinki.

Our European energy team comprises highly experienced energy economists, engineers and financial analysts. Members of our team have worked in leading roles for European energy regulators and European utilities. Our expertise covers energy market and network modelling (electricity incl. ancillary services, gas, ETS, district heating, PtX, Biomethane (forthcoming)), regulatory economics, environmental economics, strategy, market analysis, state aid support, transaction support, energy competition economics (incl. REMIT investigations), asset valuation, and expert reports as part of e.g. arbitrations and damages assessments.

This study was developed by Gerald Aue and Yadira Funk Albancando from our Paris and Berlin offices.

Preface

The climate crisis is one of the greatest challenges of our time. Temperatures are rising and the consequences are becoming increasingly tangible with the intensity, frequency, and duration of extreme weather events all around the world. Climate-related events have costly impacts on a city's infrastructure, housing, livelihoods, and safety. At the same time, cities are major contributors to climate change, as activities in urban areas are pivotal sources of CO_2 emissions. Globally, around 56% of the world's population, which is equivalent to 4.4 billion inhabitants, lives in urban areas. The World Bank estimates that cities are accountable for over 70% of global CO_2 emissions, with energy use in buildings and transport being among the largest contributors.

In order to reach the EU's ambitious goal of climate neutrality by 2050, an intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels was included in the European Climate Law. Cities are indispensable actors in climate change mitigation and are forced to adapt to the challenges related to climate change. Reaching the climate goals means considerable effort to promote decarbonization efforts of cities, which will require investments in low-carbon energy and transport systems, programs to reduce suburban sprawl, innovative solutions for urban cooling, as well as disaster management.

The City of Vienna committed itself to the objective of becoming climate neutral by 2040 and the path towards reaching net zero is laid out in the Vienna Climate Guide drawn up by the Vienna City Government. It defines specific instruments and measures for counteracting the effects of climate change and preparing for changing conditions. The Vienna Climate Guide comprises more than one hundred measures to ensure that Vienna remains the most livable city in the world, for all its inhabitants in the decades to come.

Wien Energie holds a pivotal role in the implementation of the city's decarbonization strategies and the implementation of a CO_2-free energy system. As the largest regional energy provider in Austria and a subsidiary of the municipal utility company Wiener Stadtwerke, it has the power to actively drive forward climate protection in Vienna. However, only with a coordinated approach and action at a global, regional, national, and local level, we can be successful.

This study seeks to provide context, with city portraits that not only explain the challenges, strengths, and weaknesses of each city, but also highlight emerging best practice projects for potential future application in other cities. Moreover, it is the aim to render both the City of Vienna and Wien Energie visible in an international comparison, to establish a basis for cooperation between cities and for further exchange of knowledge on the energy transition in urban areas. In conclusion, the intention of the study is to encourage European cities to move towards being a bigger part of the solution to mitigate climate change and other environmental challenges. It outlines that by sharing best practice projects, technical solutions and effective policy measures, any community can decrease its reliance on carbon-intensive technologies.

Study Introduction

Study Aim and Structure

Goal of the bench-marking

Goals
- Identify cities with climate impact performance to be learned from
- Provide a basis for further exchange

Non Goals
- Overall city ranking
- Determine a "winner"

11 ×

Analysis of Vienna and ten other cities

1 Comparison of quantitative indicators

Analysis of 16 indicators characterising the cities and their respective urban energy system

Review and benchmark

of the climate impact of urban energy systems

2 Analysis of Best Practice Examples

Selection and analysis of a best practice project to foster urban decarbonisation for each of the eleven cities

Overview of the applied Methodology

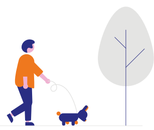
Property underlying the bench-marking

1 Select cities

Selection of **cities** for which
- a comparison with Vienna makes sense and
- the indicators can be evaluated

2 Select, define and evaluate indicators

- **Indicators** should make the property underlying the benchmarking as measurable as possible
- The informative value of an indicator can only be assessed against the property to be benchmarked
- The selection of indicators is also determined by the availability of data for the selected cities



3 Select and analyse best practice projects

Selection of **best practice examples** that
- are of high relevance for reducing the climate impact of energy systems of the respective city and
- that bear learnings for other cities

Selection of Cities

The benchmarking focuses on European cities comparable to Vienna. This allows for a discussion of solutions to common challenges across cities.

The selection of cities to be analyzed followed a two-step process:

I. creation of a long list of cities comparable to Vienna
II. selection from this long list based on data availability

The long list of cities was based on four criteria:

1. EU membership
2. population size
3. number of heating degree days (as an indicator of pronounced winter heating demand)
4. economic importance of the city within the respective country.

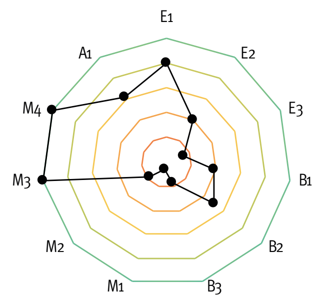
The final selection of cities included in the study was based on data availability – particularly with respect to sectoral energy consumption and greenhouse gas emissions data. A similar structure of energy utilities as in Vienna – like (partly) municipal ownership - was also taken into account.

Sources and Data

In addition to publicly available reports and statistics, interviews were conducted with the administration of the participating cities and the respective utilities. Since the most recent data was preferred for the calculation of the indicators, the year covered varies by city and indicator. The publicly available sources used can be found under "Sources" on page 46.

The geographic scope of the cities covered was chosen to correspond to the respective municipality. In all but three cases (Amsterdam, Stockholm and Copenhagen), the municipality corresponds to a "NUTS3" area. The Nomenclature of Territorial Units for Statistics (NUTS) is a hierarchical system for subdividing the economic territory of the EU, used for example for socio-economic analysis. This allowed the use of EU data at NUTS3 level for population, GDP and area for 8 of the 11 cities.

Interpretation of Figures



As seen in city profiles (p. 24 – 45)

Spider charts

Each figure provides an overview of the performance of a city relative to the performance of the other cities. The figure shows all indicators that could be calculated for the respective city based on available data. The number of indicators included therefore varies across cities. "General indicators" as well as "Policy indicators" are not included in the figure. All indicator values were normalized to obtain a scale from zero to one. The least desirable performance across all cities (innermost line) is represented by a score of zero, the most desirable performance (outermost line) by a score of one.

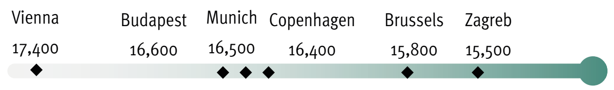
The spider chart can be found in the respective **city profile**.

The sample chart shows a strong performance for indicators M3 and M4 but a weaker one for E3 and M1 compared to the other analyzed cities. More information about each indicator can be found in the indicator profile (page 24 – 45).

Scales

The scales can be found in the respective **indicator profile**. To emphasize the idea of learning from best practices, the benchmarking scales show **the five cities** (plus Vienna if not included in top five) with the most desirable results for each indicator. Indicator results are progressively better from left to right. The values are rounded.

The available indicator values for each city can be found in the **city profile**.

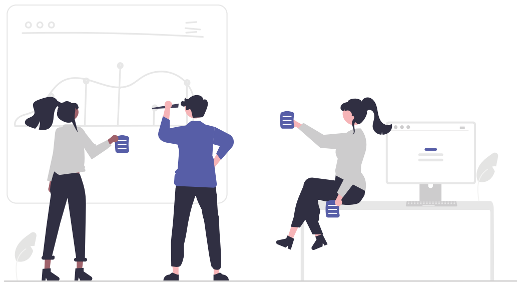


As seen in city profiles (p. 12 – 19)

Comparison of Climate Impact Indicators across Cities

Indicators analyzed

The 11 cities analyzed are characterised using 4 general indicators and 12 indicators for the climate performance of their urban energy systems.



G GENERAL INDICATORS

G1	Population
G2	City area
G3	Population density
G4	GDP per capita

B BUILDING INDICATORS

B1	Residential energy consumption per residential floor space
B2	District heating energy supplied as share of residential energy consumption
B3	Renewable share in district heating generation

E ENERGY SYSTEM INDICATORS

E1	Final energy consumption per capita
E2	Total GHG emissions from final energy consumption per capita
E3	PV-generation as share of total electricity consumption

A AIR POLLUTION INDICATOR

A1	Annual average PM2.5 concentration

M MOBILITY INDICATORS

M1	Public Electric Vehicle (EV) charging points per 1 000 citizens
M2	EV as a share of all passenger cars
M3	Annual public transport passes per 1 000 citizens
M4	Modal split (distance travelled): cars

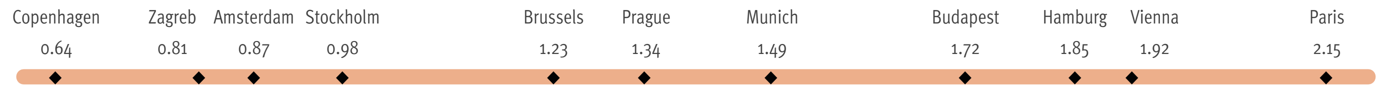
P POLICY INDICATOR

P1	End of natural gas in new buildings

G1 Population

in million habitants

2021, NUTS3 region except Copenhagen, Stockholm, Amsterdam on municipality level



G2 City area

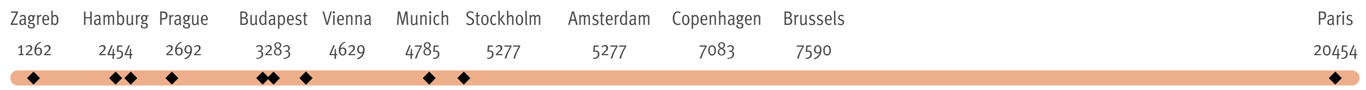
in km²

2021, NUTS3 region except Copenhagen (2021), Stockholm (2016) and Amsterdam (2020) on municipality level

G3 Population density

per km²

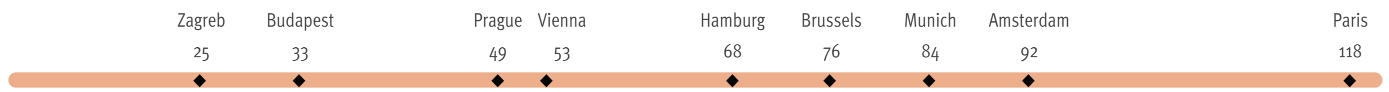
2021, NUTS3 region except Copenhagen, Stockholm and Amsterdam on municipality level



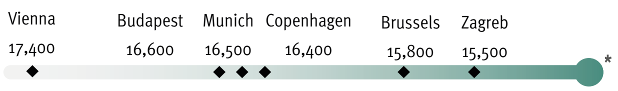
G4 GDP per capita

in thousand EUR

2021, NUTS3 region except Amsterdam on municipality level, no muncipality level data for Copenhagen and Stockholm



E1 Energy consumption per capita



Indicator	Final energy consumption per capita
Unit	kWh
Indicator definition	Sum of final energy consumed across all sectors (except air and international maritime traffic) divided by the total population
Indicator background	The indicator accounts for the final consumption of fossil and renewable fuels as well as electricity and district heating consumption. To avoid double counting it disregards fuel consumption in the electricity generation sector (often outside the influence of cities) and district heating generation (covered by a separate indicator).
Year(s) covered	2018
Data restrictions	No data available for Stockholm, Amsterdam, Prague, Paris
Key insights	Zagreb performs particularly well and exhibits the lowest energy consumption per capita among the analyzed cities. Across the top five-performing cities, Zagreb has the second lowest energy consumption per capita in the sector "industry and services" and in the "residential" sector. On average, these sectors make up for 70% of final energy consumption per capita.

E2 Total GHG emissions per capita

Indicator	Total GHG emissions from final energy consumption per capita
Unit	t CO_2e
Indicator definition	Sum of direct emissions (excluding emissions of energy generation and electricity consumed) for all sectors (except air and international maritime traffic) divided by the number of citizens in the municipality
Indicator background	The indicator captures the effect of decarbonisation efforts but disregards electricity generation emissions as these are often outside the city's influence.
Year(s) covered	2018
Data restrictions	–
Key insights	Copenhagen (in terms of CO_2) and Stockholm (in terms of CO_2e) perform particularly well. In both cities, the low emissions presumably result from the use of predominantly renewable energy generation In addition, Copenhagen exhibits a relatively advanced decarbonisation of the transportation sector and overall advanced efforts given Copenhagen's highly ambitious plan of becoming carbon neutral by 2025 (now likely to be postponed).

E3 PV generated electricity

Indicator	PV-generated electricity as a share of total electricity consumption
Unit	%
Indicator definition	Total amount of PV-generated electricity divided by total final electricity consumption in the city
Indicator background	The indicator accounts for PV-based electricity generation of the city.
Year(s) covered	2019 (Wien, Copenhagen, Munich, Budapest) or 2020 (Brussels, Hamburg, Prague, Zagreb)
Data restrictions	No data available for Amsterdam, Paris
Key insights	Brussels performs particularly good. Potential reasons are a comparatively lower total electricity consumption[1] and simultaneously higher generation from PV in absolute terms. Brussels has more than doubled its PV capacity from 24 MWp in 2018 to 66 MWp in 2020. Given a reduced number of green certificates handed out in 2021, PV-owners had an incentive to finalize and register their installations in 2020.

[1] In Brussels, natural gas is the primary energy source in final energy consumption: in 2018, the share of electricity in final energy consumption was 22%; that of natural gas was 44%. In comparison: in Vienna, the share of final electricity consumption was 31% and that of natural gas 28%.

B1 Buildings energy consumption

* City comparison (for the top five cities and Vienna)

Indicator	Residential energy consumption per residential floor space
Unit	kWh/m²
Indicator definition	Total residential end-energy consumption (heating and other energy use) divided by the total residential floor space in the city
Indicator background	Lower energy consumption in the living space points towards higher energy efficiency in buildings.
Year(s) covered	2019 (Vienna, Hamburg, Copenhagen, Munich) or 2020 (Zagreb)
Data restrictions	No data available for Stockholm, Amsterdam, Paris, Brussels, Budapest, Prague
Key insights	Munich performs particularly good. A potential reason is Munich's long standing programme for energy savings in the buildings sector (Förderprogramm zur Energieeinsparung, FES). The programme offers subsidies for refurbishments, switching to renewables, energy efficient new constructions and advisory services that are compatible with supports on the national level. Vienna's performance may result from the comparatively old building stock.

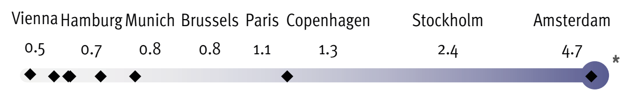
B2 District heating energy supplied

Indicator	District heat (DH) energy supplied as share of residential energy consumption
Unit	%
Indicator definition	End-energy supplied as district heat (excluding grid losses) divided by the total residential final energy consumption
Indicator background	The indicator is a proxy for the relevance of district heating in a city. The denominator does not account for non-residential buildings and includes non-heating energy consumption, as more precise data (e.g. heating energy consumption in budlings) was not widely available.
Year(s) covered	2019 (Hamburg, Vienna, Munich, Copenhagen) or 2020 (Zagreb)
Data restrictions	No data available for Stockholm, Amsterdam, Prague
Key insights	With national and municipal regulations (e.g.the Heat Supply Act, 1979 and the Heat Plan Copenhagen, 1984) allowing city councils to make district heating connections mandatory for buildings in defined areas, Copenhagen steadily increased the use of district heating. The introduced laws facilitated the expansions of the network and lead to decreasing costs for consumers.

B3 Renewable share in district heating generation

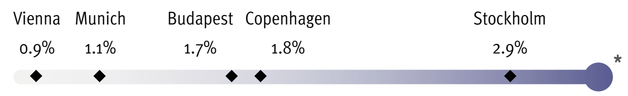
Indicator	Renewable share in district heating generation
Unit	%
Indicator definition	Share of renewable energy sources in total district heat generation
Indicator background	Renewable sources include biofuels, ambient heat, electricity and biogenic waste.
Year(s) covered	Between 2019 (Vienna, Munich), 2020 (Hamburg, Paris, Budapest), 2021 (Copenhagen, Stockholm), 2023 (Zagreb)
Data restrictions	No data available for Amsterdam, Brussels, Prague If no split of waste into biogenic/non biogenic waste was provided (for Paris, Stockholm), waste was excluded from renewable sources. The share of waste in DH generation is 47.4% for Paris and 29% for Stockholm. Because of the lack of detailed official data the renewables shares for Munich, Budapest, Hamburg are those reported by the utilities (without disclosing the calculation).
Key insights	Copenhagen is particularly good with average CO_2 emissions of 35 g/kWh district heat in 2021. The city's DH generation is mostly based on biofuels (70.4% in 2021).

M1 Public electric vehicle charging points



Indicator	Public electric vehicle (EV) charging points per 1 000 citizens
Unit	Number of EVs
Indicator definition	Number of public electric vehicle charging points divided by the number of citizens
Indicator background	A relation to the population instead of a relation to EVs was chosen to get a better understanding of the E-Mobility-readiness of the infrastructure of the city. It also avoids the issue of interdependence between the number of EVs and the construction of charging stations.
Year(s) covered	2020 (Copenhagen, Amsterdam), 2021 (Stockholm, Vienna, Hamburg, Munich, Budapest), 2022 (Paris, Brussels, Prague)
Data restrictions	No data available for Zagreb
Key insights	Amsterdam performs particularly good. A potential reason is Amsterdam's demand-driven approach to expand the charging infrastructure in the city. Citizens can apply for additional charging points in their neighborhood. Currently, TotalEnergies holds the concession to expand the charging infrastructure in the city.

M2 Number of electric vehicles



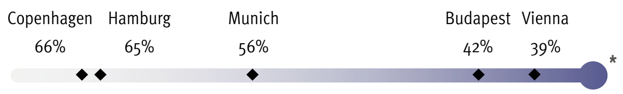
* City comparison (for the top five cities and Vienna)

Indicator	Number of electric vehicles (EVs) as a share of all passenger cars
Unit	%
Indicator definition	Number of electric passenger vehicles (defined as vehicles with electric motor and energy stored in batteries) registered in the city divided by the total number of registered passenger cars in the city
Indicator background	The decarbonisation of the transportation sector depends on the use of EVs and a phase-out of combustion engines.
Year(s) covered	2019 (Stockholm), 2020 (Vienna, Hamburg, Munich, Copenhagen, Paris, Prague, Budapest, Zagreb)
Data restrictions	No data available for Amsterdam, Brussels
Key insights	Stockholm is particularly good. Potential reasons are financial incentives on the national level, such as bonuses for low emission vehicles (until 2020: 25% of the purchase price –up to 6 000 EUR) and tax reductions for company cars (up to 40% for EVs). Additionally, EVs are granted free access to high occupancy vehicle-and bus-lanes in some areas, Stockholm is well equipped with charging points (see indicator M1) and the city provides free charging for EVs with a subscription to a parking space (only parking fee).

M3 Annual passes for public transport

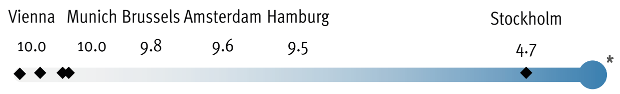
Indicator	Annual passes for public transport per 1 000 citizens
Unit	Number of passes
Indicator definition	Total number of annual passes for the municipal public transport system divided by number of citizens
Indicator background	The number of sold annual passes indicates the intensity of the use of public transportation.
Year(s) covered	2020 (Vienna), 2021 (Hamburg, Munich, Prague, Zagreb)
Data restrictions	No data available for Copenhagen, Stockholm, Amsterdam, Paris, Brussels, Budapest
Key insights	Vienna is particularly good. Potential reason is the moderate price of the annual pass (EUR 365 p.a.). In Vienna the number of annual passes per 1 000 citizens was higher than the number of passenger cars per 1 000 citizens in 2020.

M4 Modal split



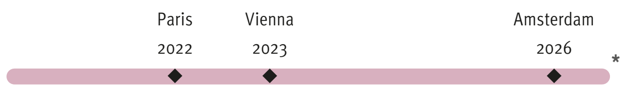
Indicator	Modal split share of private cars in distance travelled
Unit	%
Indicator definition	Distances travelled by car as a share of all distances travelled in the municipality
Indicator background	The modal split share for cars (in terms of travelled distances) shows the prominent role private cars still have in the city' s mobility sector.
Year(s) covered	2014 (Budapest), 2015 to 2019 average (Vienna), 2017 (Hamburg, Munich), 2020 (Copenhagen)
Data restrictions	No data available for Stockholm, Amsterdam, Paris, Brussels, Prague, Zagreb. As the available data is from different years it allows only for limited comparability. The reported modal split of Copenhagen only considers the categories walking, cycling and driving by car. Public transportation is not considered.
Key insights	Vienna is particularly good. In Vienna the number of cars relative to the population is comparatively lower and citizens travel mostly using public transportation (52%), which may be due to the affordable annual pass (1€ a day).

A1 PM 2.5 concentration



Indicator	Annual average concentration of particular matter sized 2.5 µm and below (PM2.5)
Unit	µg/m³
Indicator definition	Annual average across all measuring stations in the city
Indicator background	PM2.5 emissions result predominantly from combustion and production processes as well as from agriculture. Metering values also recognize emissions from far away that are displaced via atmospheric flows.
Year(s) covered	2020 for all cities except Zagreb (2019)
Data restrictions	–
Key insights	Stockholm's air quality is particularly good. The city of Stockholm states that the downward trend since 2006 is mainly the result of reduced particles from other European countries transported to Stockholm through the air.

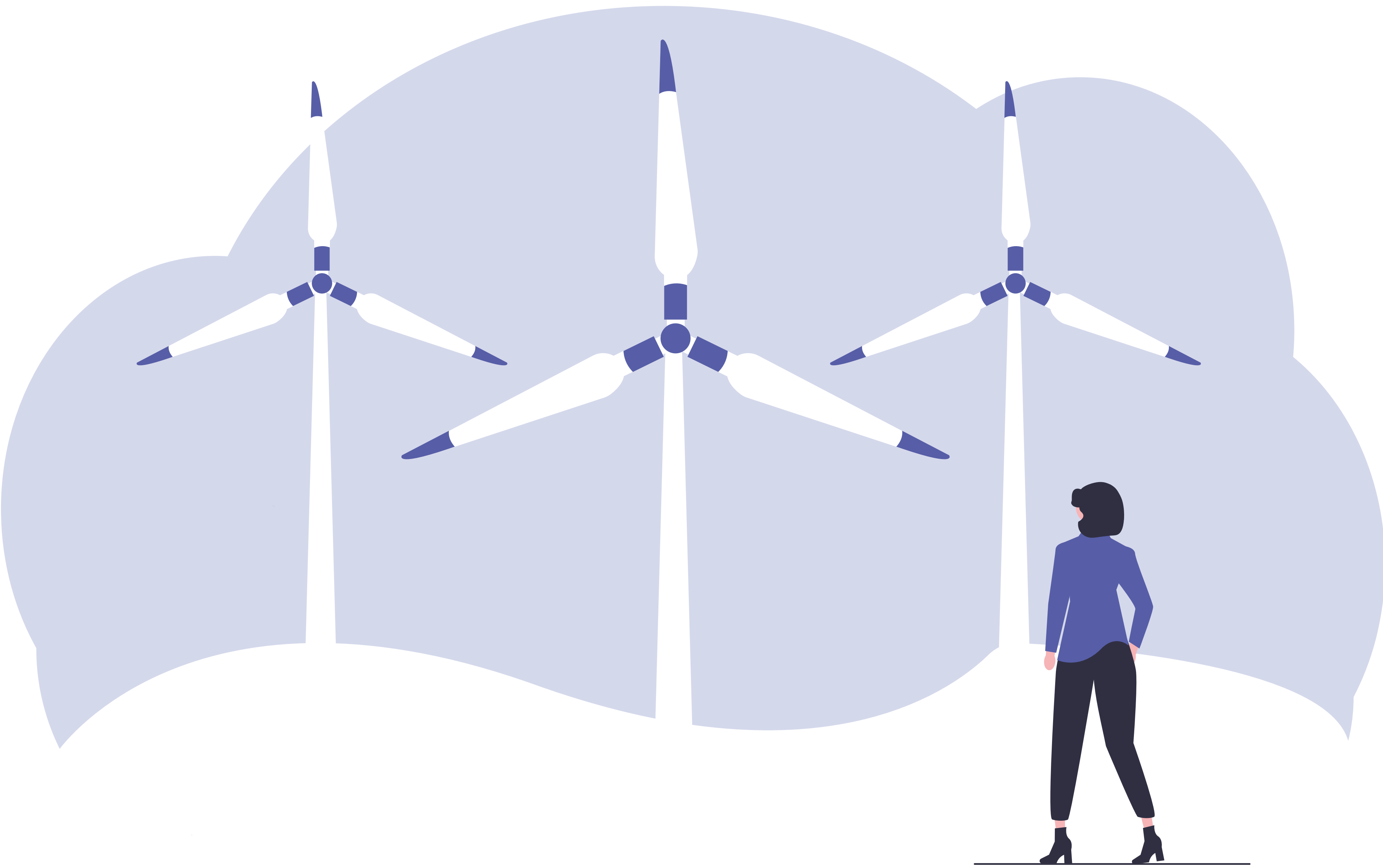
P1 End of natural gas permissibility new buildings



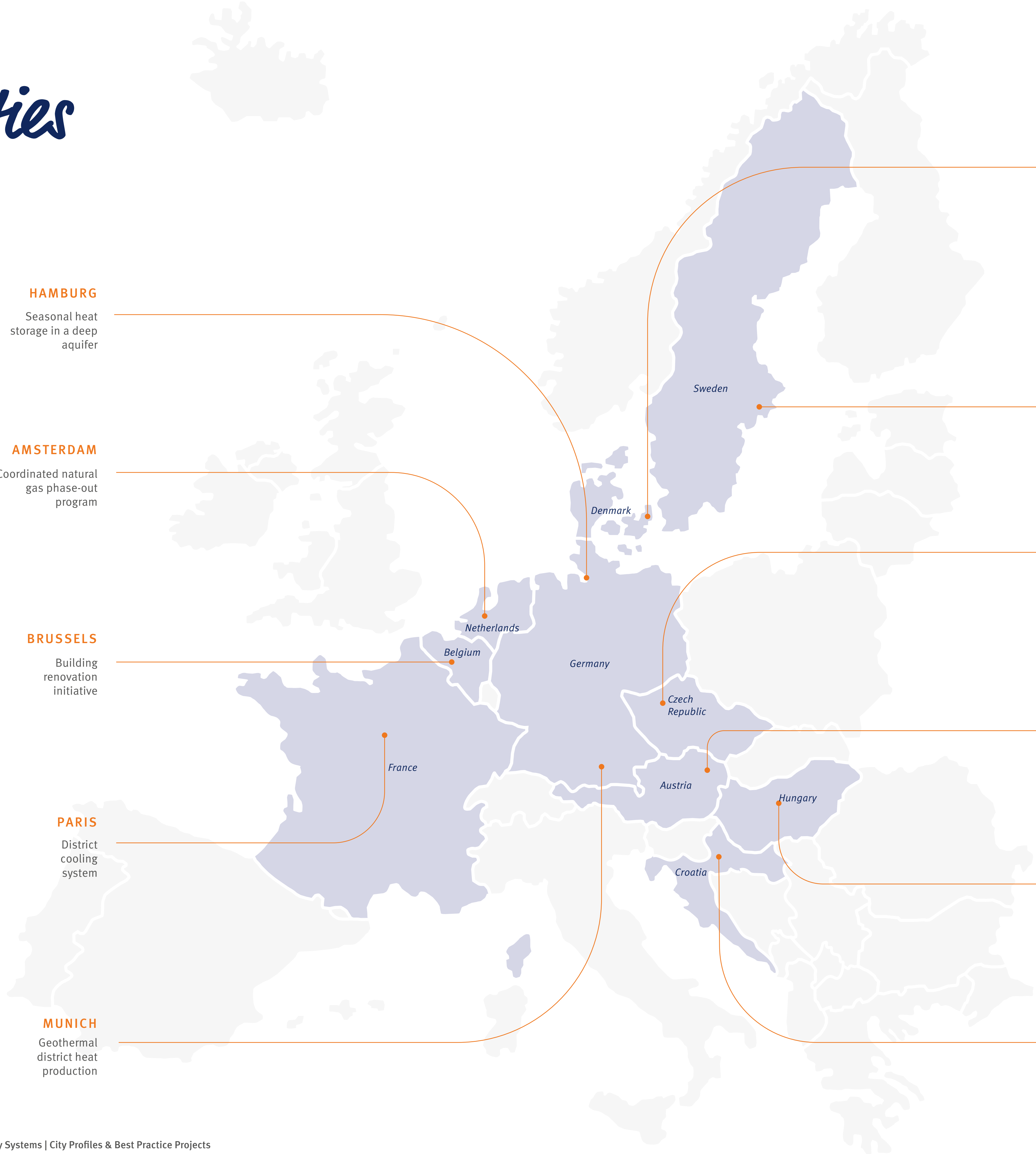
* City comparison (for the top five cities and Vienna)

Indicator	End of natural gas permissibility as a fuel for heating in new buildings
Unit	[Y/N]
Indicator definition	Existence of a regulation explicitly stating an end for the use of gas heating for newly built buildings
Indicator background	A ban of gas heating in new buildings on the national or provincial level by law is a crucial step in the decarbonisation of the buildings sector.
Year(s) covered	Not relevant. State as of August 2022
Data restrictions	–
Key insights	Among the cities with an explicit ban of gas heating, Paris is the one with the earliest required implementation. The law has been set on the national level with the RE 2020 regulation and is effective since January 2022.

City Profiles & Best Practice Projects



The Cities



HAMBURG

Seasonal heat storage in a deep aquifer

AMSTERDAM

Coordinated natural gas phase-out program

BRUSSELS

Building renovation initiative

PARIS

District cooling system

MUNICH

Geothermal district heat production

COPENHAGEN

District heating temperature reduction project

STOCKHOLM

Biomass based carbon capture and storage (BECCS) project

PRAGUE

Renewable energy community project

VIENNA

“VILLAGE IM DRITTEN” urban development project

BUDAPEST

Geothermal district heat production

ZAGREB

Revitalization of the hot water network

General City Data (2021)[1]

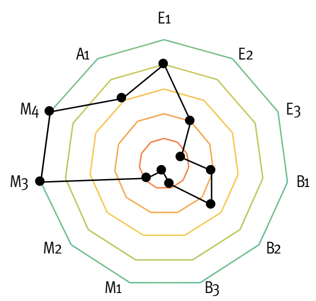
G1	Population	1.92 m
G2	City area	415 km^2
G3	Population density	4 629 /km^2
G4	GDP per capita	53 205 EUR

Urban Energy System Data[1]

E1	Final energy consumption per capita[2,3]	17 406 kWh (2018)
E2	Total GHG emissions from final energy consumption per capita[2]	2.76 t CO_2e (2018)
E3	PV-generation as share of total electricity consumption	0.47%(2019)
B1	Residential energy consumption per residential floor space[3]	181 kWh (2019)
B2	DH energy supplied as share of residential energy consumption[3]	50 % (2019)
B3	Renewable share in DH generation	15 % (2019)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	0.52 (2021)
M2	EV as a share of all passenger cars	0.87 % (2020)
M3	Annual public transport passes per 1 000 citizens	428 (2020)
M4	Modal split (distance travelled): cars	39 % (2015-2019)
A1	Annual average PM2.5 concentration	10 µg/m^3 (2020)
P1	End of natural gas in new buildings	Yes (from 2023)

Vienna

City Profile



Spider chart of the city's performance.
Detailed explanation see page 9.

Vienna is the capital and the commercial centre of Austria. It is also one of nine Austrian provinces. Among the analyzed cities, Vienna has the second largest population within its municipal boundaries. The main energy utilities active in Vienna are municipal-owned (**Wien Energie** operates the district heating and cooling system and is the main power plant operator in Vienna, **Wiener Netze** operates the electricity and gas grid).

Vienna has set the **target to achieve climate neutrality by 2040.** Natural gas-based heating will be banned in new buildings in Vienna as of **2023**.

One of Vienna's unique features is the **run-of-river plant Wien-Freudenau** operated by Verbund. The plant is located within the Vienna city limits and generates around **1 TWh of electricity per year**.

Vienna is **particularly well placed** regarding the following indicators:

- **E1 Final energy consumption per capita:**
  Vienna exhibits a lower energy consumption in the transportation and service sectors as well as less industrial activities in comparison to the other cities. Vienna exhibits the lowest energy consumption per capita in Austria.
- **M3 Annual public transport passes per 1 000 citizens:**
  The number of sold annual passes per 1 000 citizens was higher than the number of passenger cars per 1 000 citizens in 2020.
- **M4 Modal split – share of private cars of distance travelled:**
  The number of cars relative to the population is lower than in the other cities and 52 % of citizens travel using public transportation.

Urban Development Project "VILLAGE IM DRITTEN"

The "VILLAGE IM DRITTEN" is a development project for a **new urban district in Vienna** with 2 000 apartments, office space, commercial space, a school and pre-schools as well as a 2 ha-sized park.

Low temperature **geothermal heat** is collected from deep probes. The probes also make the ground usable as a **storage for waste heat.**

The integrated heating and cooling system comprises **two thermal grids**:

- An **energy grid** (10-30°C) connecting the boreholes with heat-pumps in the buildings (providing heat to the mid temperature grid) and collecting waste heat (industrial and from tempering buildings in summer).
- **A district heating grid** (63°C/40°C) – providing room heat not produced on-site and hot water.

All heating and cooling installations operated by Wien Energie and Austrian Real Estate will **use renewable energy,** from which parts will be produced from the on-site solar PV installation. The PV electricity will also be available to residents via energy communities.

The project is aiming for producing as much of the needed energy as possible on site and consuming as much of the energy produced on-site locally (including 100 % of solar electricity produced).

Public perception: The project is perceived positively by the public. It is considered a showcase project in Vienna and other urban development areas also want to implement the concept.

Key success factors and learnings for other cities:

- Involve property developers from an early stage to accurately estimate requirements and related investments.
- In order to be successful, all building sites should opt for the concept

[1] for NUTS 3 region AT130

[2] Energy consumption and corresponding emissions in the transportation sector have been corrected to only reflect consumption/emissions occurring within Vienna, and not all those accounted for in Vienna due to fuel exports at tank fills.

[3] Final energy consumption is corrected to exclude the consumption of ambient heat.

General Project Data

Project status	• 2021 start of construction works • Q4/2022 first boreholes • Q4/2023 first heat supplied • 2027 finalisation of construction
Project stakeholders	• ARE Austrian Real Estate (100% owned by the Republic of Austria) • Wien Energie
Funding & Financing	n.a.
Key Financials	n.a.
Climate impact	n.a.
Other impact	Avoidance of "exhaust heat" in summer

Project Specific Data

Total area size	11.5 ha
Building plots	22
Heated space	• 190 000 m^2 (residential) • 60 000 m^2 (non-residential)
Boreholes	500 at a depth of up to 150 m
Installed capacity (heat)	• Heat: ~ 9 MW • Cooling: ~ 1 MW • moderate cooling: ~ 1 7 MW
PV installation	1 000 kWp

General City Data (2021)[2]

G1	Population	873 338
G2	City area	166 km²
G3	Population density	5 277 /km²
G4	GDP per capita	91 727 EUR (2020)

Urban Energy System Data[2 3]

E2	Total GHG emissions from final energy consumption per capita	3.52 t CO_2e (2018)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	4.7 (2020)
A1	Annual average PM2.5 concentration	9.56 µg/m³ (2020)
P1	End of natural gas in new buildings	Yes (as of 2026)

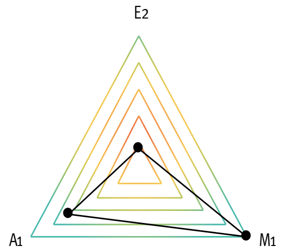
[1] 76% of its parent Alliander is jointly owned by several Dutch municipalities – including Amsterdam.

[2] The city of Amsterdam is not a separate NUTS3 region; the analysis therefore has to rely on just municipal data for Amsterdam municipality.

[3] Due to highly limited data availability, only three out of the 11 quantitative indicators could be computed.

Amsterdam

City Profile



Spider chart of the city's performance.
Detailed explanation see page 9.

Amsterdam is the capital and the commercial center of the Netherlands. Amsterdam has set the target to **reduce CO_2 emissions by 5 % in 2025,** by **55 % in 2030** and **95 % in 2050**, compared to emissions in 1990. Amsterdam municipality is part-owner of some of the main utilities active in the city. The electricity and gas grids are operated by **Liander**[1]. The district heating operator **Westpoort Warmte** is 50 %-owned by Amsterdam and **50 % by Swedish Vattenfal**l.

A **ban on gas heating** in new buildings will be in place as of 2026.

Amsterdam is **particularly well placed** regarding the following indicator:

- **M1 Public electric vehicle charging points per 1 000 citizens:** Amsterdam ranked first in this indicator, which could be due to the fact that the city started building e-charging stations as early as 2012. Amsterdam follows a demand-driven approach to expand its charging infrastructure. Citizens can apply for additional charging stations at the municipal administration and will be notified within ten days whether their application is being processed. The installation of the charging point will then take four to eight months.

Besides **technical feasibility** and **road safety** the **number of charging points** within a radius of 200 meters and **their occupancy rate** matter for the decision. Amsterdam aims at extensively increasing the number of electric vehicles as part of the Clean Air Action Plan 2030. The overall goal is to achieve an emission-free transportation sector by 2030. For that purpose, the city will gradually establish **zones** where busses, taxis, vans and trucks have to be **emission-free to enter**. In the final step, motorbikes and cars will also have to be emission-free.

Natural Gas Phase-out Program

City of Amsterdam | Westport Warmte | VATTENFALL

The city and its partners follow a neighborhood-by-neighborhood approach to achieve a full gas-phase out by 2040.

Today, around 90 % of all homes in Amsterdam use natural gas for heating. The Climate Neutral 2050 Roadmap and the **Transitievisie Warmte** (Heat Transition Vision) outline the city's approach to achieving a natural gas-free Amsterdam.
The approach is based on three pillars:

- expand availability of district heating
- decarbonize heating sources
- develop city-wide heating infrastructure

A complete natural gas phase-out in buildings is foreseen for 2040. This means that around **650 000 units** in overall 480 neighborhoods must be natural gas-free. The target is to be reached in several steps, with an interim target of **260 000 natural gas-free units in 2030.**

The scenarios expect that 50 % to 60 % of houses will be connected to **district heating**[4] (DH), 35 % to 40 % will be heated with **all-electric**, and 15 % will be heated with **hybrid solutions**. 110 000 units are already connected to DH.

The municipality of Amsterdam, social housing associations and district heating suppliers Vattenfall and Westpoort Warmte agreed on the share of houses to be connected to district heating (compared to other energy sources). **Together** the parties follow a **neighborhood-by-neighborhood approach**, developing business cases for all neighborhoods that **specify how to connect units to DH in a cost-efficient way**. The construction of new networks is expected as of 2023.

However, there is a risk that only a limited number of privately owned homes will be connected to district heating, therefore, a commitment to phase out natural gas is being discussed.

Public perception:

- Because the plan is not widely discussed, **public perception** is neutral to slightly positive.

Key success factors:

- The **joint approach** of the city, social housing companies and district heating suppliers and their willingness to share information on costs and revenues.

[4] Low in carbon emissions due to district heating generation from biomass, waste heat, green gas, newly developed geothermal plants and aqua-thermal solutions in the future.

General Project Data

Project status	October 2022: Connection of first four neighborhoods to the DH system based on neighborhood-approach
Project stakeholders	• City of Amsterdam • Westpoort Warmte • Vattenfall • Social housing companies
Funding & Financing	National and municipal subsidies. As it stands, private funding is assumed unless a business model without subsidies is not possible.
Key Financials	On average 20 K EUR per connection: From source to heat unit in the house. Incl. small construction activities and exchange of gas-fired stoves.
Climate impact	Annually avoiding 1 to 1.5 t CO_2 per connection to the system
Other impact	n.a.

Project Specific Data

Planned DH neighborhoods	At least 45 neighborhoods from 2020 to 2030 and 26 from 2022 to 2032.
Planned unit connections to DH	15 000 per year
Potential target situation for annual final heat consumption	• 134 GWh from green gas • 187 to 424 GWh district heat • 156 to 727 GWh electric • 200 GWh local networks

General City Data (2021)[1]

G1	Population	1.23 M
G2	City area	162 km²
G3	Population density	7 590 /km²
G4	GDP per capita	75 626 EUR

Urban Energy System Data[1]

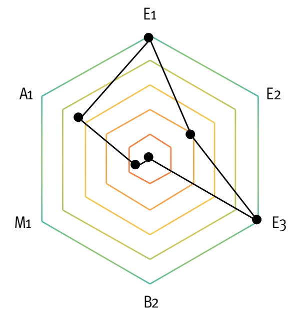
E1	Final energy consumption per capita	15 793 kWh (2018)
E2	Total GHG emissions from final energy consumption per capita	2.84 t CO_2 (2018)
E3	PV-generation as share of total electricity consumption	2.66 % (2020)
B2	DH energy supplied as share of residential energy consumption	0 % (2022)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	0.8 (2022)
A1	Annual average PM2.5 concentration	9.8 µg/m³ (2020)
P1	End of natural gas in new buildings	No[2]

[1] for NUTS 3 region BE100

[2] The regional government of Brussels aims at implementing an obligation of zero-carbon heating in construction and major renovation projects as of 2025.

Brussels

City Profile



Spider chart of the city's performance.
Detailed explanation see page 9.

The capital region of Brussels is the most densely populated region in Belgium and the European center for international politics and international organizations. Brussels has set the target to reduce its **direct greenhouse gas emissions in 2030 by more than 40 % compared to 1990**, to approach **carbon neutrality by 2050**. The electricity and gas grids are operated by **Sibelga** which is 100 % municipality owned. The largest electricity and gas supplier is **Engie Electrable**. Brussels does not yet have a widely operating district heating system.

Brussels is **particularly well placed** regarding the following indicator:

- **E3 PV-generation as a share of total electricity consumption**: Brussels has the highest values in this indicator of all the cities surveyed. Potential reasons are a comparatively **lower total electricity** consumption and **higher generation from PV** in absolute terms. Brussels has more than doubled its PV capacity from 24 MWp in 2018 to 66 MWp in 2020. In 2020, Brussels exceeded its target of 86 GWh and generated 126 GWh PV-based electricity. PV-owners had an **incentive** to install their plants in 2020 because the energy regulator, Brugel, reduced the volume of green certificates as of 2021.

Building Renovation Program RENOLUTION

Brussels' program structures and supplies financial aid to renovate the city's entire building stock.

The building stock in Brussels is among the most **energy-intensive** ones in Europe and accounts for more than half of Brussels' greenhouse gas emissions. With the Air, Climate & Energy Plan (ACEP, adopted in May 2022) Brussels' government aims to achieve a reduction of **47 % of GHG emissions by 2030** compared to 2005 levels:

- implementing a mandatory installation of zero-carbon heating in construction and deep renovation projects by 2025
- implementing a **ban on oil-fired boilers** (public sector: as of 2030, all sectors: as of 2035).
- **imposing renovation** of low efficient buildings (Energy Performance of Buildings (**EPB**) certificate scale: F, G) by 2033
- **triple the renovation** rate in the residential sector.

One part of the ACEP is the **RENOLUTION** program. The program aims at **speeding up building renovations** and **increasing energy efficiency** of the building stock across all sectors in Brussels.

The program goals (already mandated by law) include:

- achieving an average **energy performance** of 100 kWh/m² per year (EPB certificate: C+) for social housing by 2040 and for the entire Brussels housing stock by 2050.
- Reducing **energy consumption** to a third of current consumption.
- Achieving **carbon neutrality** for heating, domestic hot water production, cooling, lighting, and electricity for public buildings in 2040 and for the entire tertiary building stock in 2050.

Various **financial measures** are available under the program, such as bonuses or interest-free bonds, to support renovation financing for all income groups. The reformed grants cover 50 % of required housing investments to achieve the set targets. Public consultation on the ACEP will start in December 2022. Citizens will have the opportunity to respond to the plan and obligations within the RENOLUTION program.

Key success factors and learnings include:

- The implementation, administrative procedures and the consistency of program measures are facilitated through the **Renolution Alliance**, including the regional administration, construction sector, financial players and architects.
- The implementation of the program is facilitated with the **one-stop-shop for residents** assisting them in practical, technical, administrative, financial and other questions as well as encouraging concrete choices that promote sustainability.

General Project Data

Project status	Installed and open for financial support application and EPB certificates.
Project stakeholders	• Brussels Environment (Environment and Energy Administration) • Constructiv Brussels (Construction service provider) • Urban.brussels (Urban Development Administration)
Funding & Financing	n.a.
Key Financials	• 350 M EUR provided for the program until 2024. • 30 B EUR required for renovating the entire Brussels' residential building stock.
Climate impact	n.a.
Other impact	Reduced vulnerability to fluctuating prices of fossil fuels. Direct and indirect creation of 8 000 jobs.

Project Specific Data

Total building stock	• 194 260 building • 562 996 dwellings
Energy performance of residential buildings	In the period 2011-2017: A-C: 15 % D: 19 % E: 20 % F: 15 % G: 31 %
Targeted energy performance by 2050	100 kWh/m² or C+

General City Data (2021)[1]

G1	Population	1.72 M
G2	City area	525 km²
G3	Population density	3 283 /km²
G4	GDP per capita	33 008 EUR

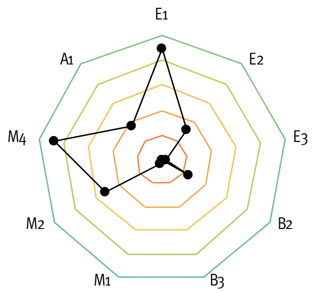
Urban Energy System Data[1]

E1	Final energy consumption per capita	16 552 kWh (2018)
E2	Total GHG emissions from final energy consumption per capita	3.01 t CO_2 (2018)
E3	PV-generation as share of total electricity consumption	0.21 % (2019)
B2	DH energy supplied as share of residential energy consumption	24 % (2019)
B3	Renewable share in DH generation	0.06 % (2020)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	0.4 (2021)
M2	EV as a share of all passenger cars	1.7 % (2020)
M4	Modal split (distance travelled): cars	42 % (2014)
A1	Annual average PM2.5 concentration	13.85 µg/m³(2020)
P1	End of natural gas in new buildings	No

[1] for NUTS 3 region HU110

Budapest

City Profile



Spider chart of the city's performance.
Detailed explanation see page 9.

Budapest is the capital and the commercial center of Hungary. Budapest has set the target to **reduce CO_2 emissions by at least 40 % by 2030** compared to 2015 levels.

Of the energy utilities active in Budapest only **FŐTÁV** – the operator of the district heating system – is municipally owned, as are the municipal waste management companies.

Budapest is **particularly well placed** regarding the following indicator:

M4 Modal split in terms of travelled distances:

- Budapest's citizens travelled mostly using public transport (45 %) and passenger vehicles (42 %) in 2014.
- Previous programs such as the **Heart of Budapest program** and the **new Main Street** in the city center have helped calm traffic in the city by renovating squares, adding bus lanes, and creating more space for pedestrians and bicycle traffic.

M2 EVs as a share of all passenger cars:

- The city of Budapest has drawn up the **Balázs Mór Plan**, the city's transportation development strategy for the period 2014-2030. To boost electric mobility, the plan relies on **tax and fee reductions,** access to restricted areas in the city, and an **expansion of charging infrastructure.**
- Hungary provides discounts and benefits for car owners with green license plates for full electric and hybrid cars. Among these benefits is **free parking in urban areas** including the city of Budapest.

Geothermal Energy in District Heating

Geothermal energy potential will enable Főtáv to decarbonize its district heating system.

Főtáv operates Budapest's **eight district heating systems** with a total grid length of 580 km, 3.3 TWh annual heat supplied and 2 150 MW installed heat generation capacity mostly fueled by natural gas and waste (data from 2021).

District heating currently is responsible for 531 kt annual CO_2 emissions (8 % of Budapest's total). In line with Hungary's National Energy Strategy the **share of natural gas usage shall be reduced from 70 % to 50 % by 2030.** While 8.8 % of total district heating production in Hungary was based on geothermal heat production in 2020, Budapest does not yet use this energy source.

The South Pest region has been selected to develop the **first geothermal project in Budapest.** The project shall cover **10-15 %** of the 0.5 TWh annual heat demand in this sub-system. The implementation is planned over a 2 to 2.5 years period. The main steps of the project development are:

- Preparation and research: about 1 year.
- Authorisation: about 0.5 to 1 year.
- Purchases: about 0.5 to 1 year.
- Well drilling: about 0.5 years.
- Execution: about 0.5 to 1 year.

The public and the government of Hungary support the drilling of geothermal wells.

Key success factors and learnings for other cities:

- The key success factors are beyond Főtáv's control (water temperature, pressure and downhole mass flow).
- Consequently, the reduction of and the ability to absorb the economic exploration risk (in terms of cost, duration and yield) is of great importance to make the project viable.

General Project Data

Project status	• 2021: project initiation • 2022: aerial geological survey to provide a detailed picture of the location of the seeders and target the reservoir
Project stakeholders	• Főtáv • Arctic Green Energy (responsible for the drilling)
Funding & Financing	Need for external investors. Determination of geothermal heat price.
Key Financials	n.a.
Climate impact	Reduction of greenhouse gas emissions: 15 to 30 kt CO_2 /year.
Other impact	Independence of Russian fossil fuels.

Project Specific Data

Drillings	Planned depth 1 500 m
Type of use	Hydrothermal
Average operating temperatures	Heating period: • 80-84°C forward • 51- 53°C return. Summer: • 60-68°C forward • 54-56°C return
Geothermal heat production	55-83 GWh/a (expected) from the geothermal system
Yield of a well	150 to 300 t/h

General City Data (2021)[2]

G1	Population	0.64 M
G2	City area	90.1 km²
G3	Population density	7 083 /km²

Urban Energy System Data[2]

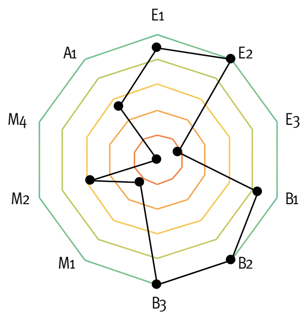
E1	Final energy consumption per capita	16 436 kWh (2018)
E2	Total GHG emissions from final energy consumption per capita	0.88 t CO_2 (2018)
E3	PV-generation as share of total electricity consumption	0.56 % (2019)
B1	Residential energy consumption per residential floor space	138 kWh (2019)
B2	DH energy supplied as share of residential energy consumption	100 % (2019)
B3	Renewable share in DH generation	85 % (2019)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	1.3 (2020)
M2	EV as a share of all passenger cars	2 % (2020)
M4	Modal split (distance travelled): cars	66 % (2020)
A1	Annual average PM2.5 concentration	11.6 µg/m³ (2020)
P1	End of natural gas in new buildings	No[3]

[1] As of April 2023, no information on an updated target for carbon-neutrality.

[2] The city of Copenhagen is not a separate NUTS3 region; the analysis therefore has to rely on just municipal data for Copenhagen municipality (i.e. excl. the municipality Frederiksberg).

Copenhagen

City Profile



Spider chart of the city's performance. Detailed explanation see page 9.

Copenhagen is the capital and the commercial center of Denmark. Among the analyzed cities Copenhagen has both the smallest population and city area. Copenhagen **had the target to become CO_2 -neutral by 2025**. However, the city will reportedly not be able to reach this target as the Amager Resource Centre (ARC) failed to meet the criteria to benefit from the government's Carbon Capture and Storage (CCS) fund, which would have been needed to set up a large-scale CCS plan at the ARC incinerator[1].

The municipality of Copenhagen, via its utility **HOFOR,** is owner of Copenhagen's district heating and district cooling systems. Copenhagen also owns its gas grid as well as the major gas retailer in Copenhagen and a large, combined heat and power plant.

Copenhagen is **particularly well placed** regarding the following indicators:

- **E2 Total GHG emissions from final energy consumption per capita**: Copenhagen exhibits a relatively advanced decarbonization of the transportation sector and overall advanced efforts given Copenhagen's highly ambitious plan of becoming carbon-neutral by 2025.
- **B2 DH energy supplied as share of residential energy consumption**: With national and municipal regulations (e.g. the Heat Supply Act, 1979 and the Heat Plan Copenhagen, 1984) allowing city councils to make DH connections mandatory for buildings in defined areas, Copenhagen steadily increased the use of DH.
- **B3 Renewable share in DH generation:** Copenhagen mainly uses wood pallets and wood waste in the generation of district heating. In addition, the city utilizes CHP-plants that are equipped with emission reduction technologies.

[3] In June 2022, the Danish government achieved a majority vote to ban gas heating as of 2035 in Denmark. The legal implementation is expected but still depends on discussions with the European Commission and financial specifications.

Temperature Reduction in the District Heating System

HOFOR

HOFOR plans to r**educe the operating temperature of its district heating** (DH) system to increase its use of heat pumps, integrate geothermal heat in the system and reduce losses.

HOFOR operates Copenhagen's DH system with c. 1 500 km distribution grid length supplying 4.4 TWh heat annually, covering more than **98 % of required heat** in Copenhagen. Heat generation is largely **based on biofuels** (70.4 % of generation). Copenhagen's DH system is part of a larger system with annual heat demand of c. 11 TWh.[4]

Copenhagen has the ambition to become carbon-neutral by 2025 (however, likely to be postponed) – **the same target is envisaged for the DH system**. 85 % of Copenhagen's DH system is already carbon-neutral with average CO_2 emissions of 35 g/kWh heat. HOFOR plans to achieve carbon-neutrality by intensifying the use of heat pumps running on sea water, industrial waste heat, ambient air or geothermal water.

Integrating heat pumps into the DH system will **require lowering the temperature of the distribution system** (currently between 65 and 95°C) – which will also lower heat losses. Newly connected areas are already using lowered grid temperatures of 65 to 75°C.

In areas already connected to the system a **transformation** is required as both the building sub-stations and the radiators in the apartments often require higher temperatures:

- The **cost of replacing** equipment compatible with lower temperatures, both for building substations (typically owned by the building owners) and for in-building heating systems, must be borne by the building owners.
- HOFOR is entitled to change the delivery temperatures for existing contracts if the customers are informed in time (10 years).
- In cases where it is not possible to lower the temperature (old buildings), the installation of electric boilers to increase the temperature level of the supplied heat is considered

HOFOR has contracted "energy consultants" to identify and advise customers who need to upgrade their equipment to be suitable for lower temperature DH. Developers are aware of the plans and welcome them. HOFOR will be providing information in the near future, particularly to those parties most affected.

National building codes for new buildings require compatibility with 60°C district heating. The demand for heat pumps and geothermal energy in the district heating network is high, which promotes temperature reduction.

[4] Data on grid length, supplied heat and heat demand from 2021, percentage of required heat from 2019

General Project Data

Project status	Achieved temperature reduction: 9°C. Next: plan for heat pump ramp-up and cooperation with private companies for drillings and geothermal energy.
Project stakeholders	• HOFOR • Potentially: Danish District Heating Association and real estate owners.
Funding & Financing	Costs borne by HOFOR and building owners. So far, no financial support identified.
Key Financials	Expected building investment costs: c. 150 M EUR. HOFOR expects savings of c. 300 M EUR by 2025 which will be passed on to customers via lower heating bills.
Climate impact	Reduced emissions from oil and gas in peak load boilers with an increased use of heat pumps.
Other impact	Increased resilience of the DH system with the introduction of heat pumps and geothermal energy combined with biomass.

Project Specific Data

Lowered DH temperature	Targeted: 65°C (throughout the year) in low temperature DH areas.

General City Data (2021)[1]

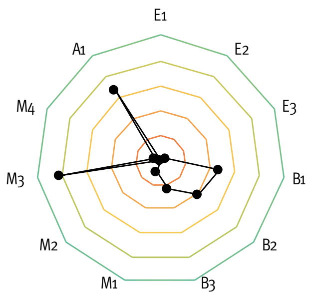
G1	Population	1.85 M
G2	City area	755 km²
G3	Population density	2 454 /km²
G4	GDP per capita	68 401 EUR

Urban Energy System Data[1]

E1	Final energy consumption per capita	24 845 kWh (2018)
E2	Total GHG emissions from final energy consumption per capita	4.04 t CO_2 (2018)
E3	PV-generation as share of total electricity consumption	0.26 % (2020)
B1	Residential energy consumption per residential floor space	172 kWh (2019)
B2	DH energy supplied as share of residential energy consumption	41 % (2019)
B3	Renewable share in DH generation	20 % (2020)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	0.7 (2021)
M2	EV as a share of all passenger cars	0.42 % (2020)
M3	Annual public transport passes per 1 000 citizens	358 (2021)
M4	Modal split (distance travelled): cars	65 % (2017)
A1	Annual average PM2.5 concentration	9.50 µg/m³ (2020)
P1	End of natural gas in new buildings	No

Hamburg

City Profile



Spider chart of the city's performance.
Detailed explanation see page 9.

Hamburg is the second largest city in Germany and has one of the biggest ports in Europe. It is also one of the 16 German federal states. Among the analyzed cities it has the largest city area and the lowest population density.

Hamburg has set the target to **reduce CO_2 emissions by 55 percent by 2030,** and to reach climate neutrality by 2050.

Over the last years the municipality of Hamburg has regained full ownership of Hamburg's district heating system (Hamburg Wärme as part of Hamburger Energiewerke) and its gas and electricity distribution grid. The municipal owned utility **Hamburger Energiewerke** also operates retail gas and electricity businesses and the power plants in Hamburg.

Hamburg is **particularly well placed** regarding the following indicators:

- **M3 Annual public transport passes per 1 000 citizens:** In 2021, 358 annual public transport passes per capita were sold in Hamburg. The city provides different tariffs for specific customer groups, such as students or employees. Employers receive a discount when buying annual passes for more than 20 employees.
- **A1 Annual average of PM 2.5 concentration**: With an annual average of 9.5 µg/m³ Hamburg shows the **second lowest concentration** of particulate matter. Hamburg has not surpassed the limit for annual average PM 2.5 as set by EU legislation (25 µg/m³ now, 20 µg/m³ in 2020) since 2012. The city has installed **a Clean Air Plan** (Luftreinhaltungsplan) outlining measures to comply with EU air quality standards, e.g. vehicle passage restrictions in especially polluted areas, general expansion of public transportation or support for cycle paths.

Deep Aquifer as a seasonal District Heat Storage

Storing "summer heat" using a seasonal aquifer storage at the Tiefstack energy site.

Hamburger Energiewerke (HEnW) operates Hamburg's district heating system. Heat generation in the main grid (851 km length and 4.1 TWh annual heat supplied in 2021) is currently fueled by hard coal, waste heat and natural gas. HEnW is fully municipally owned and has set the target to **phase out of its two coal-fired plants by 2030** and to be **carbon neutral by 2045**.

As part of these efforts, HEnW is developing a seasonal heat storage in an aquifer 1 300 m below the surface. The **aquifer** is accessed via boreholes drilled from an existing power plant site (gas- and coal- fired combined heat and power, CHP, Tiefstack). The project is integrated in the federal state's research initiative "Norddeutsches Reallabor". HEnW aims at storing excess summer heat from its waste to energy plant (WtE) to meet winter demand.

There are significant baseload industrial waste heat sources leading to summer oversupply in HEnW's grid. Withdrawn heat needs temperature uplift before reinjection in the district heating grid operating at about 130°C in winter. Project realization risk will be limited once drilling works are completed.

Successful access to the aquifer would open the road for follow up projects.

Technological novelty:

- The depth of the aquifer and the associated issues of high salinity
- Integrating geothermal seasonal heat storage into a large district heating system
- Located at the Tiefstack energy site to easily integrate it into the existing district heating system.

Public perception:

- The project receives public acclaim due to its contribution towards decarbonizing Hamburg's energy supply.

Key success factors and learnings for other cities:

- Availability of the geological formations is a key prerequisite.
- Support for the project not depending on the exploration results reduces (but does not remove) risk for HEnW.

[1] For NUTS 3 region DE600

General Project Data

Project status	• Q1 2021: Approval of funding by Norddeutsches Reallabor. • 2022/2023: Planning and construction. • 2024: Commissioning
Project stakeholders	• Hamburger Energiewerke • Kiel University • Hamburg University of Technology
Funding & Financing	Funded by HEnW. Federal Ministry for Economic Affairs and Climate Action
Key Financials	n.a.
Climate impact	Avoiding up to 1 400 t CO_2 emissions annually compared to heat production via gas-fired CHP (Finnish method)
Other impact	n.a.

Project Specific Data

Storage capacity	5 GWh per year
Storage performance	c. 2.6 MW
Storage temperature	c. 85°C
Aquifer depth	1 300 m

Munich

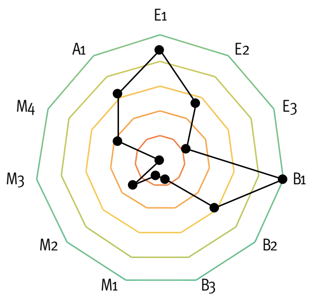
City Profile

General City Data (2021)[1]

G1	Population	1.49 M
G2	City area	311 km²
G3	Population density	4 785 /km²
G4	GDP per capita	84 343 EUR

Urban Energy System Data[1]

E1	Final energy consumption per capita[2]	16 525 kWh (2018)
E2	Total GHG emissions from final energy consumption per capita	2.33 t CO_2e (2018)
E3	PV-generation as share of total electricity consumption	0.68 % (2019)
B1	Residential energy consumption per residential floor space[2]	124 kWh (2019)
B2	DH energy supplied as share of residential energy consumption[2]	58 % (2019)
B3	Renewable share in DH generation	13 % (2019)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	0.8 (2021)
M2	EV as a share of all passenger cars	1 % (2020)
M3	Annual public transport passes per 1 000 citizens	55 (2021)
M4	Modal split (distance travelled): cars	56 % (2017)
A1	Annual average PM2.5 concentration	10 µg/m³ (2020)
P1	End of natural gas in new buildings	No



Spider chart of the city's performance.
Detailed explanation see page 9.

Munich, the capital of the federal state Bavaria, is the third largest city in Germany and its most densely populated municipality. Among the analyzed cities it has the second highest GDP per capita. Munich has set the target to become **climate-neutral by 2035** while the city administration aims to decarbonize its operations by 2030.

Munich's energy and public transport utility **Stadtwerke München** (SWM) is 100 % owned by the municipality.

Munich is particularly well placed regarding the following indicator:

- **B1: Residential energy consumption per residential floor space**: Munich has a relatively low residential energy consumption. A potential reason is Munich's municipal **support program for energy efficiency in the buildings sector** (Förderprogramm zur Energieeinsparung, FES) established more than 30 years ago. The program is renewed frequently and adapted to new legislation. Within the program, Munich offers subsidies for energy-efficient refurbishment of existing buildings, switching to renewables and energy-efficient new constructions as well as for advisory services. The funds can be combined with other supports on the national level.

[1] for NUTS 3 region DE212

[2] Final energy consumption is corrected to exclude the consumption of ambient heat.

Geothermal Installation in Munich-Sendling

SWM built Germanys largest deep geothermal installation.

SWM operates Munich's district heating system – historically fueled by natural gas, waste and hard coal – with 900 km grid length and 4.0 TWh annual heat supplied (data 2020). Munich has set itself the aim to **decarbonize district heating by 2035.** In support of this target, SWM has already developed six geothermal projects in and around Munich (c. 190 MWth[3]). The most recent project in **Munich's Sendling** district is located next to an old, combined heat and power (CHP) plant ("Energiestandort Süd"). It will **supply heat directly to the main grid** of Munich's district heating system. At this location **six boreholes** were realized – deviating from the former standard of just two per location.

SWM estimates geothermal projects to bring a total capacity to **400 MW by 2033**.

Technical challenges, innovations or insights:

- Establishing of Reservoir Management
- First ever permanent installation of a glass fiber optic cable for live reservoir monitoring
- Noise control concept to allow for drilling in an urban area
- District cooling integration

Public perception:

- The **public perception** of the project and overall geothermal operations in Munich is positive. Munich initiated a public information and communication campaign already in 2015.

Key success factors and learnings for other cities:

- Comprehensive public information to counter anxieties.
- Simplification, standardization and shortening of permitting process would support geothermal development.

[3] Not all are connected to the main district heating grid. Project status 08/22.

General Project Data

Project status	• 2007: first plans • 2018: drilling start • Since 2021: test operations • Late 2022: regular operations (planned)
Project stakeholders	SWM (100 % municipal owned utility)
Funding & Financing	Financed by SWM. This project is also co-financed by the European Union from the European Regional Development Fund (ERDF) and the Free State of Bavaria.
Key Financials	n.a.
Climate impact	n.a.
Other impact	n.a.

General City Data (2021)[1]

G1	Population	2.15 M
G2	City area	105 km²
G3	Population density	20 454 /km²
G4	GDP per capita	118 243 EUR

Urban Energy System Data[1]

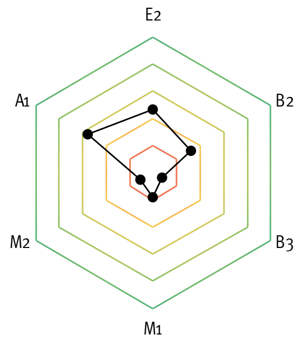
E2	Total GHG emissions from final energy consumption per capita	2.57 t CO_2e (2018)
B2	DH energy supplied as share of residential energy consumption	32 % (2019)
B3	Renewable share in DH generation[2]	6 % (2020)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	1.1 (2022)
M2	EV as a share of all passenger cars	0.69 % (2020)
A1	Annual average PM2.5 concentration	11 μg/m³ (2019-2021)
P1	End of natural gas in new buildings	Yes (as of 2022)

[1] for NUTS 3 region FR101

[2] As there is no data available on the biogenic/ non-biogenic share of waste, the indicator is computed excluding waste

Paris

City Profile



Spider chart of the city's performance. Detailed explanation see page 9.

Paris is the capital and the commercial center of France. It is one of the 96 departments of metropolitan France. Among the analyzed cities Paris is the largest with the highest population, population density and GDP per capita. Paris has set the target to reduce greenhouse gas emissions by **50 % by 2030** compared to 2004 and to achieve **net zero emission by 2050.**

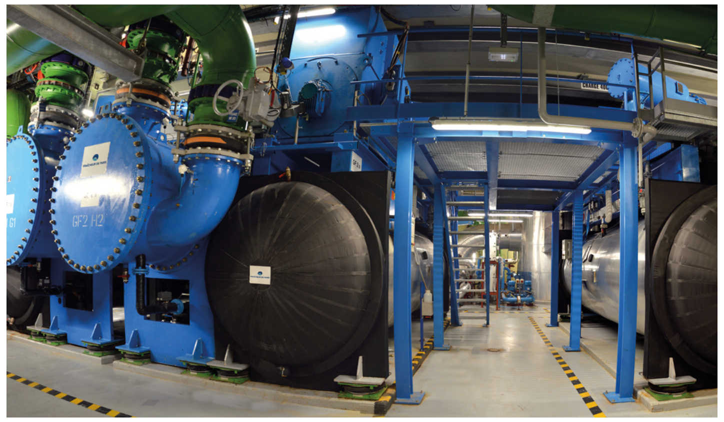
Except for the district heating operator, all other energy utilities active in Paris are independent of the municipality. The district heating system operator CPCU is a joint venture between Engie (66 %) and the City of Paris (33 %) and has been operating the system since 1927 as the concessionaires. **Climespace** (100 % owned by Engie) has been operating the district cooling system from 1991 to early 2022, and **Fraîcheur de Paris** (85 % Engie, 15 % RATP) will be operating the system for the next 20 years.

Paris is **well placed regarding** the following indicator:

- **M1 Public electric vehicles charging points per 1 000 inhabitants**: With 1.05 charging points per 1 000 inhabitants Paris exhibits one of the more developed charging infrastructures among the analyzed cities. In 2020, Total Energies won the concession for the modernization and extension of Paris' public charging points network and increased the number of charging points to 2 300 by 2022.
- **P1 End of natural gas in new buildings:** With the Environmental Regulations RE 2020, France has imposed a ban on gas boilers in new buildings as of 2022.

District Cooling System

FRAÎCHEUR DE PARIS



Fraîcheur de Paris operates Europe's biggest district cooling system.

The district cooling system in Paris is the largest in Europe and supplies 464 GWh of cooling per year (data 2022). It is operated by Fraîcheur de Paris (FdP) based on a 20-year concession granted by the municipal administration.

Expanding district cooling is part of Paris' ambition to **achieve carbon neutrality by 2050**. District cooling in Paris comprises a large integrated system covering the city center as well as two smaller grids. The grid runs largely in the sewage system delivering chilled water (2-4°C) and returning heated water (12-14°C). It incorporates various cooling plants (including the use of Seine water) and cooling storages (water and ice).

To further improve its environmental impact, the system has been running on **100 % renewable electricity since 2013**.

Extensive plans to **expand and improve the system** over the next years were agreed as part of the concession:

- **Network expansion** by 158 km to connect all arrondissements and 2 300 additional buildings.
- **20 new production plants** (incl. use of Seine water for "free cooling") and 10 new **storage facilities**.
- 65 % of the required renewable electricity will come from four new **dedicated solar farms**. (currently already at 50 %)

Public perception:

- FdP runs a comprehensive information campaign for the general public. The perception among end users is very good and among the general public neutral to positive.

Key success factors and learnings for other cities:

- Using the existing sewage system and technical galleries, as well as cross-utility coordination wherever possible, reduces disturbance and investment. District cooling is a **long-term project** paying-off financially and ecologically once the grid has achieved a certain size.

General Project Data

Project status	• 1991: start of grid development • 2022: 20-year concession granted to Fraîcheur de Paris
Project stakeholders	• Fraîcheur de Paris (licensee) • 85 % Engie (French multi-utility) • 15 % RATP Solutions Ville (urban service provider) • Municipality of Paris (licensor)
Funding & Financing	• Private sector financing • participative financing • access to ADEME subsidies
Key Financials	Total investment over 20 years: 1 B EUR Revenue: 90 M EUR (2021)
Climate impact	Compared to an equivalent fleet of stand-alone cooling installations: • -35 % energy consumption • -90 % refrigerant emission • -50 % GHG emissions
Other impact	Supporting 2 200 jobs in Île-de-France (direct, indirect and induced jobs). Reducing urban heat islands.

Project Specific Data

Grid length	90 km
Distributed energy	464 GWh/a
Production	11 sites with total capacity 284 MW
End-users	740 with 6 M m² cooled space
Cooling Storage	4 storage facilities with 166 MWh storage capacity

General City Data (2021)[1]

G1	Population	1.34 M
G2	City area	496 km²
G3	Population density	2 692 /km²
G4	GDP per capita	48 544 EUR

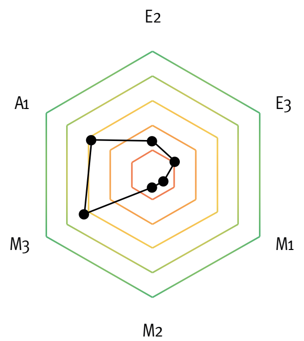
Urban Energy System Data[1]

E2	Total GHG emissions from final energy consumption per capita	3.49 t CO_2e (2018)
E3	PV-generation as share of total electricity consumption	0.38 % (2020)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	0.3 (2022)
M2	EV as a share of all passenger cars	0.43 % (2020)
M3	Annual public transport passes per 1 000 citizens	257 (2021)
A1	Annual average PM2.5 concentration	12.3 µg/m³ (2020)
P1	End of natural gas in new buildings	No

[1] for NUTS 3 region CZ010

Prague

City Profile



Spider chart of the city's performance.
Detailed explanation see page 9.

Prague is the capital and the commercial center of the Czech Republic as well as one of its 14 administrative regions. Prague has set itself the target to achieve a **45 % reduction of CO_2 emission by 2030**.

Many of the energy utilities active in Prague are at least partially owned by the municipality. The electricity grid operator and supplier **PREdistribuce** belongs to **Pražská energetika** which is 30 % owned by the municipality. The district heating operator **Pražská teplárenská** is 24 % owned by the municipality. All other utilities are independent of the city.

Prague is **particularly well placed** regarding the following indicator:

- **M3 Annual public transport passes per 1 000 citizens**: Prague ranked third in this indicator. Prague's public transportation network is well developed and among the most reliable ones in Europe. Prague **lowered the price** of annual passes from 4 750 CZK (195 EUR) to 3 650 CZK (150 EUR) in 2015. The operation of the public transport operator DPP was highly **subsidized** by the city in 2019. Subsidies for the public transport sector were also provided on a national level to address declining passenger numbers.

Prague Renewable Energy Community

The program supports the increase of PV-generated electricity in Prague.

In 2019, Prague committed itself to reducing **CO_2 emissions by 45 %** within a decade. The **expansion of solar energy** is one of the key measures in the **Prague Climate Plan 2030**. Prague aims to gradually install photovoltaic systems on the roofs of **23 000 suitable buildings** by the end of the decade, including public and administrative buildings as well as family or apartment buildings.

One of the means to achieve this objective is the municipal organisation **Pražské společenství obnovitelné energie** – PSOE (Prague Renewable Energy Community), established in 2022. PSOE aims to set-up thousands of small photovoltaic (PV) installations distributed across Prague.

While the PV installations are owned by the building owners, PSOE acts as:

- a one-stop shop for permitting, subsidy application, installation planning and prime contractor for installation works.
- The owner of PV installations (for public sector buildings only).
- The operator of the PV installations: sub-contracting operations and maintenance tasks to service companies based on long-term bulk contracts.
- The buyer and marketer of excess PV generation not consumed in the building itself.

Electricity generated by community PV systems can be used by community members for their own needs, for the needs of other co-owners or tenants of the property. PSOE will sell any excess generation.

First projects in 2022 focused on **municipal apartment buildings** (50 kWp) and buildings of the city administration (76 kWp). Projects on private residential buildings are currently being developed, and discussions are underway in the city government about how (and whether) PV panels can also be installed in the historic city center. As of fall 2022, a community energy legislation is under discussion to establish rules for remunerating electricity sales within the community. The **public perception** is positive, and Prague's citizens largely support PSOE and the PV expansion initiative.

General Project Data

Project status	Early 2022: installation of the first PV plants
Project stakeholders	City of Prague
Funding & Financing	• Community members (private investor) • The city of Prague • Modernisation fund • Potentially EIB fund (application in preparation)
Key Financials	Total investment of 55 K CZK (2.24 K EUR) for sustainable energy per year until 2030
Climate impact	Avoiding up to 160 Kt CO_2e by 2030
Other impact	• Reduced energy costs for residents in Prague • Increased energy independence

Project Specific Data

Planned number of buildings with PV	23 000 by 2030
Prague rooftop PV capacity	• Currently: 126 kWp (October 2022) • Planned: 500 MWp by 2030

General City Data (2021)[1]

G1	Population	978 770
G2	City area	187.16 km^2
G3	Population density	5 277 $/km^2$

Urban Energy System Data[1]

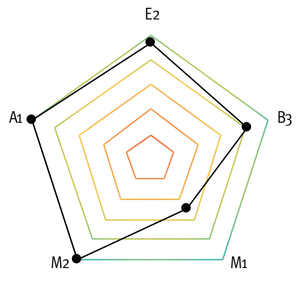
E2	Total GHG emissions from final energy consumption per capita	1.07 t CO_2e (2018)
B3	Renewable share in DH generation[2]	69 % (2021)
M1	Public Electric Vehicle (EV) charging points per 1 000 citizens	2.4 (2021)
M2	EV as a share of all passenger cars	2.92 % (2019)
A1	Annual average PM2.5 concentration	4.7 $\mu g/m^3$ (2020)
P1	End of natural gas in new buildings	No

[1] The city of Stockholm is not a separate NUTS3 region; the analysis therefore has to rely on just municipal data for Stockholm municipality.

[2] As there is no data available on the biogenic/ non-biogenic share of waste, the indicator is computed excluding waste

Stockholm

City Profile



Spider chart of the city's performance. Detailed explanation see page 9.

Stockholm is the capital and the commercial center of Sweden. Stockholm has set itself the target to be **fossil-free by 2040**. Apart from **Stockholm Exergi** (50 % owned by the municipality and the rest by institutional investors) the energy utilities active in Stockholm are **independent** from the municipal administration. Stockholm Exergi operates Stockholm's district heating and cooling systems and is one of the city's power plant operators.

Stockholm is **particularly well placed** regarding the following indicators:

- **M2 Number of electric vehicles as a share of all passenger cars**: Sweden has installed financial incentives for the ownership of low emission vehicles, such as **bonuses of 6 000 EUR** for up to 25 % of the purchase price (until 2020) and **tax reductions** of up to 40 % for company's electric vehicles. Electric vehicles are also granted free access to high occupancy vehicle- and bus-lanes in some areas. Stockholm is well equipped with charging points. The city provides free charging for electric vehicles with a subscription to a parking space so that only the parking fee needs to be paid.
- **A1 Annual average concentration of particular matter sized 2.5 µm and below (PM2.5)**: Stockholm's air quality is particularly good. This might, however, not be due to activity in Stockholm alone. The city states that the downward trend since 2006 is mainly the result of reduced particles from other European countries transported to Stockholm over the air. According to the WHO lower levels of PM2.5 can avoid air pollution-induced cardiovascular and respiratory diseases.

Bio-Energy Carbon Capture & Storage

Stockholm Exergi operates Stockholm's district heating (DH) system with 400 km grid length and 9.6 TWh annual heat supplied (data 2021). Heat generation is largely based on biofuels, waste and heat-pumps (combined 98 % of production). Stockholm Exergi plans to build a **Carbon Capture and Storage** (CCS) **facility** at its biomass-fired combined heat and power (CHP) plant **Värtaverket in Stockholm** ("BECCS Stockholm"). CCS at biomass-fired plants turns them from carbon neutral to carbon negative.

BECCS Stockholm is expected to be more energy-efficient compared to conventional CCS plants as it will combine carbon capture with **heat recovery** for DH. About 0.8 Mt of CO_2e will be avoided by using heat and electricity from renewable energy sources in addition to **7 Mt CO_2** removal in the first ten years of operation.

Stockholm Exergi plans to have installed an operational facility in the second half of 2026 with the capacity to remove about 800 000 t CO_2 per year from the plant's flue gas stream. The captured CO_2 will be **liquified and temporarily stored** in the Stockholm port. Subsequently it will be shipped from the Baltic Sea to an **underground storage** site in the **North Sea** (storage itself is not within the scope of the project).

BECCS projects are generally eligible for Swedish national and EU level subsidies. Even the maximum funding under either scheme, however, is not sufficient to enable BECCS Stockholm to operate profitably. Stockholm Exergi therefore aims to establish a **third revenue stream** from the **sale of Carbon Removal Certificates**. These would be offered in a voluntary market to companies wanting to compensate their residual emissions.

The project is structured in three phases:

- Pre-engineering (27 months): to obtain permits (environmental, building and construction) and to reach financial closure
- construction (34 months): to start construction and installations and
- operation (10 years): to operate facility with full capacity to meet the annually set target of 800 000 t CO_2.

Public perception:

- The project does not face public resistance. Surveys show public concerns centering around **visibility and noise** as the plant is in the center of Stockholm. Stockholm Exergi lobbies for the establishment of a **regulatory framework** for carbon removal via BECCS (not recognized under the ETS). **Regulatory uncertainties** are currently seen as more critical to project success than any technical challenges.

stockholm exergi

General Project Data

Project status	• 2019: establishing research facility • 2022: in the process to obtain construction permit of large-scale facility
Project stakeholders	Stockholm Exergi
Funding & Financing	• EU-Innovation fund (Grant Agreement signed in August 2022) • Swedish Energy Agency: reverse auctioning for state aid (initial auction potentially in 2023) • Sale of Carbon Removal Certificates in a voluntary market
Key Financials	Total project costs 2.7 B EUR
Climate impact	Removing 7 Mt CO_2 over the first ten years of operation, avoiding another 0.8 Mt CO_2e through use of renewable energies.
Other impact	Developing a market for net carbon removals. Industry target: 28 000 jobs (direct and indirect employment) and adding 24 B SEK to Swedish GDP with successfully establishing a BECCS industry.

Project Specific Data

Removal capacity	800 000 t CO_2 per year (planned)
Temporary storage tanks	1 000 –2 000 m^3 tanks for max. 20 000 m^3 stored in the port of Stockholm
Technologies	Hot Potassium Carbonate for CCS applied to a CHP plant

General City Data (2021)[1]

G1	Population	808 785
G2	City area	641 km²
G3	Population density	1 262 /km²
G4	GDP per capita	24 548 EUR

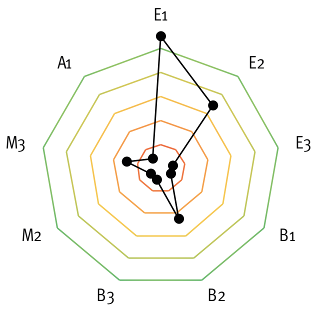
Urban energy system Data[1]

E1	Final energy consumption per capita	15 495 kWh (2018)
E2	Total GHG emissions from final energy consumption per capita	2.2 t CO_2e (2018)
E3	PV-generation as share of total electricity consumption	0.11 % (2020)
B1	Residential energy consumption per residential floor space	217 kWh (2020)
B2	DH energy supplied as share of residential energy consumption	35 % (2020)
B3	Renewable share in DH generation	0 % (2023)
M2	EV as a share of all passenger cars	0.16 % (2020)
M3	Annual public transport passes per 1 000 citizens	127 (2021)
A1	Annual average PM2.5 concentration	19 (2019)
P1	End of natural gas in new buildings	No

[1] for NUTS 3 region HR050

Zagreb

City Profile



Spider chart of the city's performance.
Detailed explanation see page 9.

Zagreb is the capital and largest city of Croatia and has a special status as it is an own city-county. Among the analyzed cities, Zagreb has the lowest population density.

Zagreb has set itself the **target to reduce GHG emissions by 40 % until 2030,** compared to emissions in 2008.

Of the main energy utilities active in Zagreb, only the gas supplier and distributor are municipally owned under the Zagreb Holding (City Gasworks Zagreb and City Gasworks Supply Zagreb). Electricity production and distribution as well as district heating are provided through subsidiaries of the national power company **HEP Group**.

Zagreb is **particularly well placed** regarding the following indicators:

- **E1 Final energy consumption per capita:** Across the top five-performing cities for this indicator, Zagreb has the second lowest energy consumption per capita in the industry and services sector as well as in the residential sector. On average, these sectors make up for 70 % of final energy consumption per capita in the top five cities.
- **E2 Total GHG emissions from final energy consumption per capita:** While Zagreb is placed **first** among the top five-performing cities for the indicator on energy consumption per capita, the city follows as **third** in terms of emissions per capita. This is explained by a **more extensive** use of fossil energy sources in Zagreb compared to its peers.

Revitalisation of the Hot Water Network[2]

HEPTOPLINARSTVO

State owned HEP Toplinarstvo is the largest district heating company in the Republic of Croatia and operates Zagreb's system. District heating generation in Zagreb is fueled by natural gas and oil. The grid has a total length of circa 227 km and supplies circa 1,2 TWh of heat annually (data from 2017).

HEP Toplinarstvo is modernizing a third of the DH grid in Zagreb, supplying about 100 000 customers.

More than half of the existing hot water network in Zagreb was built between 1962 and 1995 using the standard technology of the time of laying steel pipes in concrete channels.

In its current state, the grid is prone to external influences such as high groundwater levels or rainwater penetration into concrete channels, that may cause deterioration of pipes, pipe ruptures, supply interruptions, and more generally, heat losses.

The project executed by HEP Toplinarstvo aims to replace 68.5 km of the network and is the largest project in the history of the district heating system of the city of Zagreb.

In the period January 2021 to October 2023, the old pipes will be **replaced** by ductless laying of pre-insulated pipes.

The overall project aims to increase system **reliability and energy efficiency.** Energy savings are estimated at 56 GWh, which corresponds to 20% of Croatia's total target savings within the EU Operational Program Competitiveness and Cohesion 2014 - 2020. As reduced heat losses will require less heat generation, **emissions** are expected to be reduced by 11 K t CO_2 in 2025 compared to emissions without the revitalization.

Additional improvements expected by 2023 compared to 2018 include:

- Reduction in losses of replenishment of operating water by approximately 47%
- Reduction in the number of emergency interventions by 90%

[2] All details of the project are based on publicly available information, as no interview could be conducted.

General Project Data

Project status	Ongoing, 2021-2023
Project stakeholders	HEP Toplinarstvo
Funding & Financing	• EU grants via the European Fund for Regional Development • Project financing by HEP
Key Financials	• Total project value: 700 M HRK (93 M EUR) • EU grants: 421 M HRK (56 M EUR) • HEP: 135 M HRK (18 M EUR)
Climate impact	• GHG emission reduction by 11 K t CO_2 compared to business-as-usual case • Energy savings of 56 GWh
Other impact	Reduction of replenishment of operating water. Reduction of emergency interventions.

Project Specific Data

Grid length to be revitalized	68.5 km
Total gird length	227 km
Connected customers	c. 100 000
Construction of initial grid	More than half of the grid between 1962 and 1995
New technology	Ductless laying of pre-insulated pipes
Old technology	Laying of steel pipes in concrete channel

Sources

Public reports

Bayerisches Landesamt für Umwelt (2021):
Lufthygienischer Jahreskurzbericht 2020.

Behörde für Umwelt und Energie (2017):
Luftreinhalteplan für Hamburg (2. Fortschreibung).

Behörde für Umwelt, Klima, Energie und Agrarwirtschaft (2020):
3. Fortschreibung des Luftreinhalteplans für Hamburg.

Belügyminisztérium Nyilvántartások Vezetéséért Felelős Helyettes Államtitkárság (2020):
ZÖLD RENDSZÁMMAL ELLÁTOTT JÁRMŰVEK SZÁMA 2020.

Bruxelles Environnement (2021):
BILAN ÉNERGÉTIQUE 2019 DE LA RÉGION DE BRUXELLES-CAPITALE.

Bruxelles Environnement (2021):
LA QUALITÉ DE L'AIR EN RÉGION DE BRUXELLES-CAPITALE.

Budapest Főváros Önkormányzata (2022):
Budapest Környezeti Állapotértékelése.

Budapest Főváros Önkormányzatának hivatalos oldala (2012):
BUDAPEST KÖRNYEZETI ÁLLAPOTÉRTÉKELÉSE 2012.

Budapest Főváros Önkormányzatának hivatalos oldala (2013):
BUDAPEST KÖRNYEZETI ÁLLAPOTÉRTÉKELÉSE 2013.

Budapest Főváros Önkormányzatának hivatalos oldala (2014):
BUDAPEST KÖRNYEZETI ÁLLAPOTÉRTÉKELÉSE 2014.

Budapesti Közlekedési Központ (2020):
BUDAPEST MOBILITY PLAN 2030.

Bundesministerium für Verkehr und digitale Infrastruktur (2019):
Mobilität in Deutschland – Kurzreport Stadt München, Münchner Umland und MVV-Verbundraum

Bundesministerium für Verkehr und digitale Infrastruktur (2019):
Mobilität in Deutschland – Kurzreport Stadt München, Münchner Umland und MVV-Verbundraum.

European Parliament and Council of the European Union (2010):
DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast).

Gemeente Amsterdam (2019):
Amsterdam Climate Neutral 2050 Roadmap.

Gemeente Amsterdam (2020):
Transitievisie warmte Amsterdam.

Geneeskundige Gezondheidsdienst Amsterdam (2020):
Meetresultaten luchtkwaliteit.

Haveaux, C.; Frippiat, J. (2021):
Photovoltaïque: record d'installations à Bruxelles en 2020.

Københavns Kommune (2020):
CO_2-REGNSKAB FOR 2019.

Københavns Kommune (2021):
Analyse af behovet for ladestandere i Københavns Kommune frem mod 2050.

Københavns Kommune (2021):
Mobilitetsredegørelse 2021.

Københavns Kommune (2022):
CO_2-regnskab for Københavns Kommune 2021.

Landeshauptstadt München – Referat für Klima- und Umweltschutz (2021):
Münchner Förderprogramm Energieeinsparung.

Landeshauptstadt München (2022):
THG-Monitoring der Landeshauptstadt München 1990 bis 2019.

Landeshauptstadt München:
Detailbetrachtung der Ergebnisse der THG-Bilanzierung 1990 bis 2017 inklusive Hinweisen zu Datengrundlagen und Methodik.

Ministère de la Transition écologique et de la Cohésion des territoires (2023):
Réglementation environnementale RE2020.

Ministry of Foreign Affairs of Hungary (2021):
Smart and sustainable mobility market in Hungary.

Referat für Klima- und Umweltschutz der Landeshauptstadt München (2022):
Münchner Förderprogramm Energieeinsparung.

Stadt Wien – Abteilung für Energieplanung (2021):
Energiebericht der Stadt Wien.

Stadt Wien – Abteilung für Wirtschaft, Arbeit und Statistik (2022):
Statistisches Jahrbuch der Stadt Wien 2022.

Stadt Wien – Abteilung für Wirtschaft, Arbeit und Statistik:
Gebäude und Wohnungen.

Stadt Wien – Abteilung für Umweltschutz (2021):
Luftgütemessungen der Umweltschutzabteilung der Stadt Wien.

Stadt Wien (2022):
Energiebericht.

Stadt Wien (2022):
Vienna Climate Guide.

Statista (2023):
Anzahl der Inhaber von Jahreskarten für die Wiener Linien von 2009 bis 2021.

Statistisches Amt für Hamburg und Schleswig-Holstein (2021):
Hochbautätigkeit und Wohnungsbestand in Hamburg 2019.

Statistisches Amt München (2022):
Personenkraftwagenbestand 2020 – 2022 nach Kraftstoffart/Energiequelle.

Stockholms stad (2020):
Evaluation of public charging for electric vehicles in Stockholm.

Umweltbundesamt (2021):
Bundesländer LuftschadstoffInventur 1990–2019.

Ville de Paris (2020):
Bilan des émissions de gaz à effet de serre de Paris.

Public articles and websites

Bayerisches Landesamt für Statistik:
Bautätigkeit und Wohnungsbestand.
https://statistik.bayern.de/statistik/bauen_wohnen/bautaetigkeit/index.html#link_6

Bruxelles Environnement (2022):
Le bilan énergétique de la Région.
https://environnement.brussels/citoyen/nos-actions/projets-et-resultats/le-bilan-energetique-de-la-region

Bruxelles Environnement (2023):
Bornes de recharge pour véhicules électriques à Bruxelles.
https://environnement.brussels/pro/gestion-environnementale/devenir-plus-durable/bornes-de-recharge-pour-vehicules-electriques-bruxelles

Bruxelles Environnement (2023):
RENOLUTION – une stratégie pour rénover le bâti bruxellois.
https://environnement.brussels/citoyen/outils-et-donnees/sites-web-et-outils/renolution-une-strategie-pour-renover-le-bati-bruxellois

Budapesti Közlekedési Központ:
Heart of Budapest Programme.
https://budapestszive.bkk.hu/koszonto/

Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie:
Erneuerbaren-Wärme-Gesetz (EWG) –
ab 2023 keine Gasheizungen in Neubauten.
https://infothek.bmk.gv.at/erneuerbaren-waerme-gesetz-ewg-ab-2023-keine-gasheizungen-in-neubauten/

Danmarks Statistik (2023):
BIL710 – Bestanden af personbiler pr.1.
januar efter område, ejerforhold og drivmiddel.
https://www.statistikbanken.dk/BIL710

European Commission:
EU air quality standards.
https://environment.ec.europa.eu/topics/air/air-quality/eu-air-quality-standards_en

European Commission:
Urban Data Platform Plus.
https://urban.jrc.ec.europa.eu/downloads?lng=en&ctx=ardeco

Eurostat (2021):
NUTS – Nomenclature of territorial units for statistics.
https://ec.europa.eu/eurostat/web/nuts/background

Gemeente Amsterdam:
Policy: Clean air – Cleaner, healthier air thanks to zero-emission mobility solutions.
https://www.amsterdam.nl/en/policy/sustainability/clean-air/

Prague City Tourism:
Getting Around Prague by Public Transport.
https://www.prague.eu/en/practical/getting-around-prague-by-public-transport-17064

Rijksoverheid (2022):
Hybride warmtepomp de nieuwe standaard vanaf 2026.
https://www.rijksoverheid.nl/actueel/nieuws/2022/05/17/hybride-warmtepomp-de-nieuwe-standaard-vanaf-2026

Statistikamt Nord Hamburg:
Energie- und CO_2-Bilanzen für Hamburg.
https://www.statistik-nord.de/zahlen-fakten/umwelt-energie/energie/dokumentenansicht/product/3381/energie-und-co2-bilanzen-fuer-hamburg-361?cHash=4201529a752424c94a05eb3c4ae751ea

Stockholms stad (2023):
Bränslemix i fjärrvärmen.
https://miljobarometern.stockholm.se/energi/energianvandning-och-energiproduktion/branslemix-i-fjarrvarmen/

Stockholms stad:
Fossil energi I elmixen.
https://miljobarometern.stockholm.se/energi/energianvandning-och-energiproduktion/fossil-energi-i-elmixen/

Stockholms stad:
PM 2,5 – årsmedelvärden.
https://miljobarometern.stockholm.se/luft/partiklar/pm2-5-arsmedelvarden/

Stockholms stad:
Produktion av solenergi.
https://miljobarometern.stockholm.se/energi/energianvandning-och-energiproduktion/produktion-av-solenergi/solel

Stockholms stad:
Trafikbarometern.
https://miljobarometern.stockholm.se/trafik/

Stockholms stad:
Utsläpp av växthusgaser totalt.
https://miljobarometern.stockholm.se/klimat/utslapp-av-vaxthusgaser/utslapp-av-vaxthusgaser-totalt/

UN Environment Programme:
Cities and climate change.
https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities/cities-and-climate-change

World Bank (2023):
Urban Development.
https://www.worldbank.org/en/topic/urbandevelopment/overview

World Bank Blogs (2022):
Cutting global carbon emissions: where do cities stand?
https://blogs.worldbank.org/sustainablecities/cutting-global-carbon-emissions-where-do-cities-stand

World Health Organisation (2022):
Ambient (outdoor) air pollution.
https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

Enterprise documents

Belib' Paris:
THE NEW BELIB' SERVICE – A FULLY RENEWED,
UNIFIED AND EXPANDED CHARGING OFFER.
https://belib.paris/assets/pdf/brochure_belib_en.pdf

CPCU (2021):
LA CPCU EN 2020, ACTEUR DE VOTRE QUOTIDIEN.
https://www.cpcu.fr/wp-content/uploads/2021/06/Brochure-CPCU-2020-page-a-page.pdf

Danish Energy Agency (2017):
Regulation and planning of district heating in Denmark.
https://ens.dk/sites/ens.dk/files/Globalcooperation/regulation_and_planning_of_district_heating_in_denmark.pdf

HOFOR (2021):
Årsrapport 2021.
https://hoformedia.dk/pdf/hofor_aarsrapport2021_wcag-kompatibel.pdf

HOFOR:
DISTRICT HEATING IN COPENHAGEN –
ENERGY-EFFICIENT, LOW-CARBON, AND COST-EFFECTIVE.
https://www.hofor.dk/wp-content/uploads/2016/09/district_heating_in_cph.pdf

Implement Consulting Group (2022):
The economic impact of BECCS in Sweden.
https://www.stockholmexergi.se/content/uploads/2022/02/BECCS-Economics-Sweden-final.pdf

Enterprise websites

BECCS Stockholm:
Homepage.
https://beccs.se/about-beccs-stockholm-2/

Dopravní podnik hl. m. Prahy (DPP):
Homepage.
https://www.dpp.cz/en

Erneuerbare Energien Hamburg:
Homepage.
https://www.erneuerbare-energien-hamburg.de/de/service/suche.html

FŐTÁV:
Homepage.
https://fotav.budapestikozmuvek.hu/

FRAÎCHEUR DE PARIS:
Homepage.
https://www.fraicheurdeparis.fr/

Hamburger VerkehrsVerbund (HHV):
Homepage.
https://www.hvv.de/en

HEP Group:
Start of hot water network revitalization in Zagreb worth HRK 700 million.
https://www.hep.hr/start-of-hot-water-network-revitalization-in-zagreb-worth-hrk-700-million/3617

Münchner VerkehrsVerbund (MVV):
Homepage.
https://www.mvv-muenchen.de/en/index.html

Norddeutsches Reallabor (NRL):
Teilvorhaben.
https://norddeutsches-reallabor.de/teilvorhaben/

Pražské společenství obnovitelné energie, příspěvková organizace:
Homepage.
https://prazskespolecenstvi.cz/

Revitalizacija Vrelovoda Zagreb:
Homepage.
https://vrelovod-zagreb.hr/o-projektu/

SparEnergi Energistyrelsen:
København Kommune.
https://sparenergi.dk/energi-og-co2-regnskabet/koebenhavn?year=2019

Stadtwerke München (2022):
Der neue Energiestandort Süd.
https://www.swm.de/magazin/energie/energiestandort-sued

TotalEnergies (2021):
Electric Vehicles – TotalEnergies expands the charging network of
the municipality of Amsterdam with 2 200 new EV charging points.
https://totalenergies.com/media/news/TotalEnergies-expands-the-charging-network-of-Amsterdam-with-2200-new-EV-charging-points

Transport Styrelsen (2022):
Bonus for low emission vehicles.
https://www.transportstyrelsen.se/en/road/Vehicles/bonus-malus/bonus/

Verbund:
Laufkraftwerk Wien-Freudenau.
https://www.verbund.com/de-at/ueber-verbund/kraftwerke/unsere-kraftwerke/wien-freudenau

Wärme Hamburg:
Primärenergiefaktor und CO_2-Emissionen – Bestwerte für die Fernwärme.
https://waerme.hamburg/fernwaermesystem/primaerenergiefaktor#:~:text=Mit%20einem%20Anteil%20Erneuerbarer%20Energien,anerkannte%20Ersatzma%C3%9Fnahme%20gem%C3%A4%C3%9F%20Hamburger%20Klimaschutzgesetz.

ZAGREBAČKI ELEKTRIČNI TRAMVAJ d.o.o. (2022):
POSLOVNO ZVJEŠĆE 2021.
https://www.zet.hr/UserDocsImages/Dokumenti%20i%20obrasci%20za%20preuzimanje/Poslovna%20izvje%C5%A1%C4%87a%20ZET/Poslovno%20izvje%C5%A1%C4%87e%202021.pdf?vel=3085042

Photographs

P.1 & p.26: Wien Energie/Ian Ehm
P..27 Wien Energie/ Superblock
P. 28: Unsplash/Samuele Giglio Ams
S .29: Vattenfall
P. 30: Unsplash/Stephanie LeBlanc
P. 31: Unsplash/Milivoj Kuhar
P. 32: Unsplash/Ervin Lukacs
P. 33: FŐTÁV
P. 34: Unsplash/Peter Lloyd
P. 35: Hofor
P. 36: Unsplah/ Julia Schwendner
P. 37: Hamburger Energiewerke GmbH
P. 38: Unsplash/Tuguldur Baatar
P. 39: Stadtwerke München
P. 40: Unsplash/Alexander Kagan
P. 41: Fraîcheur de Paris/Bruno Placier
P. 42: Unsplash/Azamat Esmurziyev
P. 43: Unsplash/Bill Mead
P. 44: Unsplash/Jon Flobrant
P. 45: Stockholm Exergi
P. 46: Unsplash/Kristijan Arsov
P. 47: HEP

Articles

Johnston, R. (2020):
Prague transit pass increase will likely be
more affordable than previously reported.
https://www.expats.cz/czech-news/article/praha-sobe-pushes-for-365-crown-annual-transit-pass-increase-not-50-percent

Radio Prague International (2019):
State subsidies drive up bus passenger numbers.
https://english.radio.cz/state-subsidies-drive-bus-passenger-numbers-8117973

Szumsky, C. (2022):
Copenhagen's dream of being carbon neutral by 2025 goes up in smoke.
https://www.euractiv.com/section/energy-environment/news/copenhagens-dream-of-being-carbon-neutral-by-2025-go-up-in-smoke/

WallBox:
The Essential Guide To EV And EV Charger Incentives In Sweden.
https://blog.wallbox.com/sweden-ev-incentives/

Interviews

Additionally, interviews with city- and energy utility representatives were conducted.

Wien Energie
Thomas-Klestil-Platz 14
1030 Wien

www.wienenergie.at

Wien Energie, ein Unternehmen der Wiener Stadtwerke-Gruppe.

NB-002 | 072023 | 1000 | DMB. | Wien Energie GmbH, Thomas-Klestil-Platz 14, 1030 Wien | FN 215854h | Druck: GröbnerDruck, Steinamangerer Straße 161, 7400 Oberwart | Vorbehaltlich Änderungen, Satz- und Druckfehler.