D2.1 Analysis of innovative technical solutions

Synthesis Report

July 2017

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 649883.

P R O J E C T P A R T N E R S

- TINA VIENNA GMBH (COORDINATOR)
- AGENCE PARISIENNE DU CLIMAT ASSOCIATION
- GEMEENTE AMSTERDAM
- BERLINER ENERGIEAGENTUR GMBH
- ENERGETSKI INSTITUT HRVOJE POZAR
- VILLE DE PARIS
- STOCKHOLMS STAD
- MIASTO STOŁECZNE WARSZAWA
- MAGISTRAT DER STADT WIEN
- GEMEENTE ZAANSTAD
- GRAD ZAGREB

Main author: David Uong,
Institution: Berliner Energieagentur
Review: Achim Neuhäuser, Berliner Energieagentur

Contributing authors: The city chapters were supported with comments on the report by:

Amsterdam :	Geert den Boogert et al (City of Amsterdam)
Paris:	Sébastien Emery et al (City of Paris, Environment department)
Stockholm:	Lukas Ljungqvist et al (City of Stockholm, Planning administration)
Vienna:	Ute Gigler et al (TINA Vienna), Herbert Hemis (City of Vienna, MA20 – Department for energy planning)
Warsaw:	Andrzej Olszak and Marcin Wróblewski (Infrastructure Department of Warsaw City Hall)
Zaanstad:	Maria Santman et al (City of Zaanstad)
Zagreb:	Sanja Malnar Neralić (City of Zagreb – City Office of Energy, Environment and Sustainable Development) and Nives Mornar (City Bureau for Physical Planning); Marko Matosović and Margareta Zidar (EHIP – Energy Institute Hrvoje Požar)

This report is created as part of the H2020 action 649883: **Integrative energy planning of urban areas: Collective learning for improved governance** – **URBAN LEARNING** and reflects only the author's views. The *Executive Agency for Small and Medium-sized Enterprises (EASME)* is not responsible for any use that may be made of the information it contains.

Table of Contents

1. Introduction

As part of the project URBAN LEARNING – Integrative energy planning of urban areas: collective learning for improved governance – the focus is put on the administrative processes ("governance processes") related to the (re-)development of concrete urban development sites in the partners' cities. Within the project, most partner cities focus on new development areas and whereas Berlin and Zagreb rather on the refurbishment and redevelopment of existing areas. Nevertheless, transformation of the building stock is for each city important.

To link innovative technological solutions to urban planning processes, a comprehensive understanding and learning is required to support low carbon development of new and also existing city areas. Systematically planned development areas, based on anticipated planning implications of different technical solutions would prevent from ad-hoc solutions, which are often of unsatisfactory results concerning environmental, economic and social benefits.

This report summarizes the main results of the "Analysis of innovative technical solutions" in work package 2. The main objective of this analysis is to identify innovative technical solutions for low-carbon development and analyze the implications for the urban energy planning processes. The analysis will be carried in search for commonalities and differences relevant for future city developments.

In the context of URBAN LEARNING "innovative technologies" are not confined too tight, but rather be understood as a focus on technical solutions with high potential for low-carbon development in the respective cities, in particular focussing on new building development and heat supply. Therefore, the following technical characteristics were considered:

- Support low/efficient energy use and integration of renewable energy sources/systems
- Technical solutions should not stop at the building systems, but rather refer to solutions for whole **city quarters or districts as main level of analysis**, which are often combinations of different technologies (e.g. efficient solar settlement/quarter combining solar use, use of natural geothermal energy or utilization of waste heat by heat pumps and low-energy housing) as well as a (micro)grid connection.
- Solutions which might serve the respective city objectives/priorities best and fit best to local circumstances

As part of the analysis relevant framework conditions concerning the energy systems, innovative technical options and implications for the urban energy planning processes were assessed.

This report presents a summary of analysis of the different cities and provides core findings to support an energy transition in the cities by incorporating suitable technologies.

2. Summary

The UL-cities have committed themselves to ambitious climate change objectives and underlying endeavours to transform their respective energy infrastructures. The following table gives an overview of main features of the energy systems and structures in the UL-cities and shows the climate change objectives for each participating city.

City	Main features on city level	Climate change objectives
Amsterdam	In the current situation a gas network, an electricity network, two main district heating systems and 2 cooling networks fulfil Amsterdam's energy demand. There are also 37 windmills in the harbour area.	> -40% greenhouse gas (GHG)** (2025) – compared to 1990 > -75% GHG (2040) – compared to 1990 till 2020: > -20% energy consumption per cap > +40,000 dwellings district heating > +18 MW wind power > +151 MW solar power
Zaanstad	In the current situation a gas network and an electricity network fulfil Zaanstad´s energy demand.	Climate neutral
Berlin	Almost 71% of the total heated area is supplied centrally and almost exclusively by natural gas and oil. 29% of the heated area is generated and distributed centralized via district heating network. The district heating fuel mix of Vattenfall (90% Market share) in 2014 was: 50% hard coal, 31% natural gas, 14% lignite and 5% Biomass etc. Combined heat and power (CHP) will probably remain an important option in the future energy system for Berlin's densely populated area.	Climate neutral till 2050 > -40% GHG (2020) > -60% GHG (2030) > -85% GHG (2050)
Paris	Paris energy demand depends mostly on imported fossil fuels, and on electricity produced in other regions of France. Electricity is the first energy source used in Paris (40%), ahead of a natural gas whereas oil is only 10% of the global energy mix. District heating covers 16% of total energy consumption and 30% of heating. Regarding the production of each renewable source, waste heat recovery is the first source of supply. District cooling is the second provider of local renewable and recovery energy thanks to the using on the river.	Factor 4: > -75% GHG (2050) > -25% GHG & Energy (2020) > 25% energy from renewable (2020)
Stockholm	At present, 75-80% of the City's heating requirements in buildings are met by district heating, about 20% by geothermal energy or direct electricity. Only a few hundred buildings and about one thousand single-family homes across the entire city have oil-fired boilers.	Fossil free till 2040 (= 0.4 t GHG capita)
Vienna	Depending on the location of the building, either the gas network or the district heating network or both are available, as the predominant part of Vienna is connected to a grid-bound energy source. The energy provider "Wien Energie" also decided in 2016 to enlarge the Viennese district heating network wherever and whenever economically and technically feasible. At the same time, the city subsidizes efforts in the following areas: energy efficiency, renewable electricity (photovoltaics, electricity storage, hybrid collectors) and renewable heat (solar thermal, heat pumps, seasonal heat storage).	till 2050: > -80% GHG (that's < 1 t GHG/capita) > 3,000 → 2,000 watts/capita > 10% → 50% renewables

Warsaw	The crucial challenge is changing energy mix in the Warsaw CHPs and heat plants, which is still predominantly based on coal. However, owner of the plants – PGNiG Termika – recently opened a large block utilizing biomass. Another block, utilizing natural gas, is to be operational in 2017. Nonetheless, further steps need to be made, which constitutes a huge challenge for cooperation of the local energy companies with the City.	Objectives from the SEAP till 2020 > -80% GHG (compared to 2007) – binding > -80% energy consumption (compared to 2007) – auxiliary > 20% energy from renewables – auxiliary
Zagreb	Analysis of the structure of energy forms in total primary consumption shows that the largest share belongs to natural gas 43.2%, followed by petroleum products with a share of 33.9%, electricity ("import" outside of the city area) of approximately 17.5% and firewood by about 3.8%. Other renewable energy sources (except fuel wood) occupy about 1.6% share in the structure of total energy consumption.	SEAP till 2020: > -21% GHG (compared to 2008)

Table 1: Main features of energy systems/infrastructure; Source: Own research

The findings of the analysis highlight the technical, economic and political challenges to promote decarbonisation on all levels of urban development. On one hand existing large-scale supply systems such as district heating and gas networks are in place, which are operated by private and partly public (shareholder) energy companies, with interests to maintain or increase business opportunities. On the other hand the energy demand of existing and new buildings decrease (due to legal framework etc.) while production of renewable energy systems increase on all levels (regional, quarter, building etc.). These developments lead to potential interest conflicts and require suitable strategies and business models.

The complexity and interdependencies of supply and demand systems for heat and electricity as well as new forms of storage and flexibility are visible challenges for the cities and its urban development.

The analysis shows that in urban planning the consideration of suitable energy systems in the context of (new) development areas mainly corresponds with following questions:

- Which energy supply systems are technically feasible for the development area based on the spatial circumstances and existing infrastructure?
- Which amount of energy demand and energy density (heating, cooling, power, electro mobility) is expected based on the foreseen land use (residential only/mixed), building density and energy standards?
- How can an energy efficient and in particular renewable energy supply be realised?
- Who are potential implementers and operators of the energy supply systems?
- Which costs incur for which party (tenants, owners, city etc.) through the construction and operation of different energy supply system alternatives?
- Which ecological factors (primary energy factor, CO_2 emissions) are expected by the different technical solutions and how are these evaluated concerning environmental city objectives?
- How can the energy supply system adapt to changes (e.g. reduced or increased energy demand in the future)?

In order to answer these guiding questions, it is important to understand the implications for planning, which refer to

- Land use and building use,

- Building density, distances between buildings, surface-volume ratio, orientation,
- Energy standard of buildings,
- Existing infrastructure on and around development areas,
- Spatial circumstances and local potentials (ground water level, contamination etc.),
- Stakeholders involved (public/private), landownership and
- Political objectives (carbon-emission-reduction, rent incl. heating/m^2 etc.).

A sound understanding of implications and interdependencies between planning processes and technical characteristics will ensure the integration of suitable (win-win-) solutions, ideally in early planning stages (before any ad-hoc solutions is being decided). The quarter and district level has been proven to be an appropriate level of action for planning to create benefits across different building ensembles and link energy supply and demand systems as a whole. This is also highlighted and outlined in WP4 results referring to the planning and governance processes in the partner cities.

In the following main findings are briefly summarized:

Commonalities in Energy Systems and Infrastructure

Central district heating and gas networks are predominant energy supply systems for heating purposes, in some cities district heating taking up to almost 80% of the total heat supply. The energy sources for district heating vary a lot in the participating cities though. In cities such as Warsaw and Berlin the majority is fossil based whereas in Stockholm waste heat and recycled fuels are taking up the biggest shares, and thus significantly contributing to accomplish the climate change objectives.

Due to the dense and heritage protected urban areas in most of the partner cities, the consideration of large scale renewable energy systems (RES) such as wind power or open space-photovoltaic plants is quite limited compared to rural areas. Examples for exception are among others the Port of Amsterdam with potentials for large-scale power wind plants. Within the city boundaries, therefore RES supply systems are predominantly established on small to mid-scale, on building or quarter level, for both building stock as well as new buildings (for later commonly national building regulations prescribe shares of renewables). The city developments and city targets indicate an increase and higher relevance in the cities, but RES in particular for heat supply is still on low level in some cities (e.g. Zagreb, Berlin) and commonly demand further promotion.

Besides supply based energy systems, the main energy consumption sector is still related to existing buildings and the required refurbishment of old supply systems (e.g. inefficient decentralized boilers based on oil) and most importantly the building envelopes. City strategies and actions are also addressing these important sectors to accomplish the targeted objectives.

Reduction of Fossils in District Heating Generation

The transformation of existing district heating plays a central role in the participating cities to support the accomplishment of the targeted climate change objectives. In order to reduce emissions, responsible energy companies have started to optimize the heat production by applying modern CHP systems such as in Warsaw. In addition, energy companies in cities such as Stockholm, Paris, Amsterdam and Berlin have started to substitute or target to phase out (shares of) fossil based energy sources by less carbon-intensive energy sources such as biomass or switch from coal to gas. Political and legal agreements have partly been established between the city authorities and respective energy companies (e.g. carbon emission reduction agreement between City of Berlin and Vattenfall).

However, it is expected that overall the share of fossils for district heating will still be significant in most of the cities in the next years. Thus, decisions to maintain and extent district heating networks will be in place for many years influencing the accomplishment of climate change objectives of the cities in one or another direction.

Strategic Development of the Gas Networks

In most of the UL-cities a large-scale gas network is in place and gas usage, besides district heating. Currently, in cities such as Vienna, Amsterdam/Zaanstad and Paris intensive discussions are on-going concerning the strategic relevance of the gas network in the future. Some cities seek to reduce the use of gas, in particular in new housing development areas (e.g. Amsterdam/Zaanstad). Also strategies to increase the share of bio gas are being considered and targeted by cities such as Paris to decrease the fossil gas consumption. The role and significance of gas networks is expected to decrease, but many cities within the UL-consortium as well as outside have mostly not yet defined a roadmap to define concrete steps to this vision. Such questions will be subject to further research and investigations.

Technical Options for Low-carbon Development in Urban Areas

The city analysis show that the solutions and options being applied and promoted are very similar. Due to decreasing energy performances of new buildings, refurbishment of existing buildings, increasing RES, political objectives and dynamic technological and market driven developments, the need for an adjusted energy supply and demand approach is required. This is noticeably related to an increase of decentralized systems (in particular concerning the power section) and concepts such as power-to-heat or smart grids.

The discussion and technologies to be considered in the cities is therefore related to

- Power-to-heat
- Integration of waste heat
- Low exergy heat networks/Open district heating
- Concepts of smart solutions (e.g. smart homes, smart metering)
- Power storage systems (e.g. batteries, E-Mobiles).

The coupling of electricity, heat and gas networks and E-mobility systems (overall “electrification”) become more obvious and significant in the participating cities. Technologies such as open district heating grids, storage systems (also E-Mobility) and also power-to-heat solutions gain more importance. The transition from energy supply and energy demand is fluent and refer to the terms “consumers” and “prosumers”.

Innovative technical solutions such as low-ex grid projects or power-to-heat solutions are being considered and partly tested in pilot projects in the different UL-cities (e.g. Berlin “Adlershof”, Vienna “Seestadt Aspern”, Zagreb “Borongaj”). The overall role out is still lacking and requires more force (in particular from national level) and investigations to establish adequate models for replication. Most of such innovative projects are pilot projects, which received subsidies to be implemented. Besides technical and economic aspects, adjusted regulations play also crucial role. The implementation of low temperature heating networks (below 60 °C) is partly in conflict with hygienic regulations (as in Vienna/Austria).

An increased role out is not expected in the short-term but maybe in the mid- to long-term as dynamic (market driven) factors (energy prices, new regulations, subsidies, feed-in-tariffs, etc.) might change quickly, enhancing new technologies such as low-exergy grids.

Quarter and District Level as Main Level of Action

The complexity and interdependencies of supply and demand systems could be very well addressed not on building level but rather on quarter and district level in most cases. By choosing the respective quarter as the major planning scope synergies will be created both on the level of more efficient (decentralised) energy supply (including renewables) and energy distribution, as well as economies of scale in the implementation of measures (e.g. micro-grids). Several good-practice examples in the partner cities could be identified (see annex).

Planning Implications

The findings in the cities and results of related research and discussions allow to identify a set of criteria which can function as an initial checklist for the urban planners concerning the suitability of rather decentralized and/or centralized supply systems. By defining urban development objectives (e.g. compact and mixed cities) planning authorities can considerably promote one or another energy supply system directly. Indirectly, urban planning can contribute through the active engagement and management of the related multi-stakeholder processes among suppliers, developers, grid operators, building owners, tenants etc..

The technical most feasible option for a certain development area as part of initial and preparatory planning stages might not be the alternative, which is realized in the implementation phase, e.g. due to short-term economic objectives (investments of builder/owner vs life-cycle-costs in particular for tenants).

In most cases of the partner cities, this highly depends on the individual decisions of the developers etc., if the cities are not the owners of the land. The implementation of one or another technical solution is therefore subject to consultation and negotiations. This applies in particular to the existing building stock for which regulations allow lesser extent of influence by urban planning.

The overall implication therefore refers to a sound initial evaluation of the planning situation and framework, which should be based on a profound knowledge base derived from existing plans, energy concepts and tools and instruments (e.g. Heat Map) as well as bundling of internal and external know how.

3. Synopsis of Analysis Results in UL-Cities

3.1. Key Aspects for Assessment of Technical Solutions in Urban Planning

In order to analyse and assess different technologies in urban development, it is crucial to outline (common) implications for the planning processes. In particular, the dependency of energy demand and energy supply systems as well as influencing parameters have to be incorporated to identify optimal technical solutions, not only on building level but rather at quarter/urban development level.

In the following, key aspects (which can be widened and be added of course) concerning energy demand, local energy potentials, technical solutions and basic relevant parameters are described. All aspects interrelate and should be considered parallel:

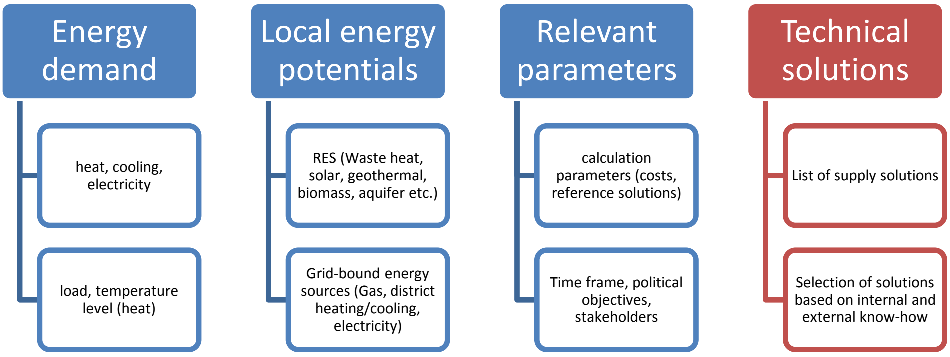


Figure 1: Key aspects for assessment of technical solutions in urban planning; Source: Own research; data source:

Assessment of Energy Demand and Energy Density

The assessment of estimated energy demand and more precisely energy density of an urban area is in most cases the starting point of investigations.

The energy demand depends on the land use (e.g. residential, office, retail or other commercial uses), type and shape of buildings and building energy standard. Energy demand for heating, warm water, cooling etc. can be calculated as well as energy loads and energy density, based on defined standards and energy performance of the buildings (thermal envelope). As a result basic energy demand modelling for heat, cooling and electricity can be derived.

Assessment of Local Energy Potentials

Crucial for the selection of one or another energy supply solution is the assessment of local energy potentials in the respective urban development areas or in surrounding areas (e.g. adjacent property). On one hand this includes consideration of grid-bound energy sources and available capacities such as gas, district heating, district cooling or electricity and on the other hand local energy sources such as waste heat utilisation, ground water, geothermal, solar energy or biomass.

Relevant Parameters

As part of the assessment of technical solutions it is crucial to set the framework. This should include the definition of calculation parameters for the overall evaluation of technical solutions (e.g. investment costs, maintenance costs) and reference solutions (e.g. conventional solutions with district heating). Based on the comparison of reference scenarios based on the same calculation parameters an overall evaluation can be elaborated. In addition, stakeholder analysis is also important to identify overlapping interests and more importantly potential conflicts.

Assessment of Potential Solutions for Energy Supply

Based on the energy demand (as well as energy density and loads) and the local energy potentials a list of different technical solutions can be derived and investigated in more detail. As part of the urban development planning the participation of relevant stakeholders (e.g. energy service provider, municipal utilities, sanitation facility and developers) should be incorporated to bundle the available know-how and validate the plausibility of (pre-) selected technical solutions. In addition, early and continuous participation and consultation can enhance acceptance in the different planning stages as well as mitigate potential interest conflicts between the city, energy providers and developers.

3.2. Technical Solutions in Urban Development in the Partner Cities

The range of technical solutions on the supply and demand side is wide. Even though, the city findings highlight similar technologies being applied and considered in different combination in urban development projects. A list of technologies as follows:

Supply related systems	Demand related systems
• Photovoltaic • Solar thermal • Geothermal • Storage systems • Waste heat • Biomass • Power-to heat • (Open) District heating • District cooling • CHP • Low-exergy grids • Solar road	• Low-/ Zero-/ Plus- energy buildings • Smart meter/data • Smart grids • (Open) district heating

Table 2: List of considered technologies in UL-cities; Source: Own research

A summary of selected project examples displaying the integration of technology combinations outlined above in the different partner cities is enclosed in the annex of this report.

Based on the local energy potentials the use of one or another solution might be favourable in the different cities.

Example: Geothermal use represents an important opportunity for the City of Paris. 58 plants in the city produce 94 GWh of renewable heating per year with two major plants in Paris North-East and Clichy Batignolles districts. On the contrary, the use and potential of geothermal in Berlin is only limited as drinking water production is based on ground water. Relevant water regulations in Berlin constrain geothermal potential in practice to a low level only.

3.3. Relevant Planning Implications

Implications of technologies for planning processes vary very much depending on the respective technologies being considered and applied in urban development projects. Based on the schematic methodology described before and the list of considered technologies, a list of key criteria and general implications for urban planning can be concluded. This list could function as an initial checklist to consider certain technologies in urban development projects and help urban planners to anticipate impacts ideally before or during preparatory planning stages.

The implications are divided into the sections ENERGY DEMAND, LOCAL ENERGY POTENTIALS and RELEVANT PARAMETERS and have to be considered as an interdepend system in order to determine optimised solutions for urban development areas (existing and new building stock).

ENERGY DEMAND

The land use and building structures are central concerning the energy demand of development areas and the calculation for heating, cooling, power, and electro mobility. Building and land use arrangements such as roof conditions or designation of areas for utilities are also relevant for potential supply systems on building and quarter level.

	Criteria	Implications
Land use and building structures	Distribution of land use	The land use ratios of residential, commercial or mixed zones in an urban development area imply different energy demand and different loads for heat/cooling but also electricity. The overall land use distribution and ratios could therefore promote or hinder the selection of one or another supply system. Example: Decentralised cogeneration plants (CHP) operated on a thermal basis achieve a high total rate of efficiency if full hours of use is high. This could e.g. be given in residential areas assigned mainly for retirement homes and/or public/commercial uses such as swimming baths with high and constant heat demand (base load). Besides, open space or space foreseen/available for energy supply systems (incorporated in the land use planning) is relevant to consider technical facilities such as storage systems.
	Building density	The building density is relevant for the overall heat density – which is the amount of thermal energy used within a defined area and is an indicator for the economic viability of different energy supply systems and (district) heating schemes. The viability of district heating schemes is increased when the building density is high (due to higher demand, shorter pipelines and reduced heat losses). On the other hand, high building density might adversely affect the passive solar gain of neighbouring buildings (shadowing etc.). Suitable alignment of buildings will have to be incorporated to ensure overall energetic benefits.
	Surface-Volume-Ratio (SVR)	Compact building structures with low SVR require less energy demand and should therefore be promoted in development of new buildings. The interdependencies with building density and orientation should be included in the urban planning and concept development. Exemplary values of SVR: Single family house 0.7-1.0; double family house 0.6-0.9; multifamily house 0.3-0.5 etc.
	Orientation	South orientation of buildings main façade and optimisation of windows (e.g. small windows to the north, big windows to the south) promote passive solar gain. The optimised solutions for passive solar gain as part of urban planning can be supported with simulation software Example: GOSOL is a software tool developed by the Institute for Solar Urban Development (Germany), which can be used in urban development concepts to analyse optimal benefits concerning passive solar gain.
	Roof conditions	The setting of roof conditions (slope, roof orientation) in combination with the building orientation is central for the consideration and application of solar energy systems, either photovoltaic or solar thermal. Flat roofs principally show good suitability.

		Alternatively, the greening of plain roofs can support the energetic balance of the building as well. Combinations of greening and photovoltaics (PV; with elevation arrangements) are technically also feasible.
	Energy performance standard	The minimum performance standard for new buildings and major renovations of building stock is usually set by the national building legislations referring to European Building Regulations and Directives, soon expected to be a nearly-zero energy buildings standard. Energy performance of buildings is significant for the expected energy demand of a new area or changes of an existing area (in case of major renovations). In addition, the applied energy performance also facilitates or hinders the feasibility of certain technologies. Example: Low energy housing require not only less energy demand (compared to a building with higher energy performance standard) but also low level temperatures for heating. The application of high temperature district heating might therefore not be suitable or rather the demand for high temperatures is not given.

Table 3: Implications of energy demand; Source: Own research

LOCAL ENERGY POTENTIALS

The local conditions concerning space and infrastructure in urban development areas and surrounding areas give implications for the potential of energy on-site and help to define which energy supply systems are feasible for the development area.

	Criteria	Implications
Existing infrastructure	Gas network	Proximity to existing gas networks – usually consisting of low-pressure or mid- to high-pressure gas network – of an urban development area is a central characteristic to consider gas based supply solutions in the initial planning. Besides proximity, it is important to estimate/define the expected energy demand of the urban development area. Based on the energy demand, the network provider might be able to provide relevant information on the (economic) probable connection to the existing network and available gas capacities to be provided. Based on the estimated energy demand, a connection to the low-pressure or mid- to high-pressure gas network might be required. Besides direct consultation with network providers, available network plans might be available giving first indications for gas supply potential for development areas. Example: In Paris the city owns the network and give concession to companies for operation. Relevant discussions and information for extension of networks might be part of the "Energy grid control commission" meetings (see WP3).
	District heating network	Proximity to existing district heating of urban development areas is a central technical characteristic to consider district heating solutions in the initial planning. Similar to gas networks, it is important to estimate/define the expected energy demand of the urban development area. Based on the energy demand, the district heating provider might be able to provide relevant information on the (economic) probable connection to the existing network and available capacities to be provided. A central technical characteristic is the high dependency of district heating on the overall energy demand and underlying building structures. Example (as outlined before): Low energy housing require not only less energy demand (compared to a building with higher energy performance standard) but also low level temperatures for heating. The application of high temperature district heating might therefore not be suitable or rather the demand for high temperatures is not given and value different local energy sources and waste heat.

		It is essential to decide early on, if an area or parts of an area should be connected to district heating or not.
	District cooling network	Urban development areas with predominant residential use usually do not require significant cooling load (depending on the climate zone and expected increases of temperature due to climate change). Therefore, cooling solutions might be considerable in mixed land use areas or areas with significant commercial businesses or social/public building (e.g. hospitals) with high cooling demand. Potential technical linkages between district heating and cooling systems (such as in Amsterdam or Paris) could therefore be considered and investigated in more detail in energy concepts etc.. So a strong link to the land use is given on supply and demand side.
	Waste heat	Waste heat of industrial/commercial businesses could be considered for heat supply of existing and new development areas, if existent and in proximity to the relevant urban development areas. Information of waste heat potentials could be investigated through involvement of local stakeholders (e.g. in Berlin waste water utility) or if available by waste heat maps, which is for instance currently being developed in Vienna (see WP3). A mixed land use of new development areas could therefore be promotive for the utilisation of waste heat, which could be incorporated in the district heating network (e.g. in Stockholm). Example: Recovery of heat from data centres is an important piece of the puzzle in Fortum Värme's efforts to make the production of district heating in Stockholm 100% fossil-free. Heat recovery from a major green data centre in Stockholm would annually be able to heat up to 20,000 apartments.
Spatial circumstances	Ground water and soil conditions	Potentials of (close to the surface) geothermal (in combination with heat pumps) are related to underground and ground water conditions. Contamination of grounds and water related framework are usually tight and impose requirements for geothermal use. Respective maps of authorities in charge might give relevant information on the potential of urban areas. In Vienna a geothermal map has been elaborate, which can be used as part of the planning process (see WP3).
	Solar potential	Solar potential in European countries differ a lot. But principal suitability is given in most of the partner cities and countries. Solar radiation information and also buildings with high potential are usually available and displayed e.g. in solar maps (Example: Paris, see WP3). In order to maximise the solar energy use, either for photovoltaic or solar thermal, an optimum orientation and arrangement of roofs or facades needs to be incorporated in the urban planning process (see section ENERGY DEMAND above). Solar energy is a volatile intermittent energy source due to daily and seasonal availability, which in combination with power as well as heat storage systems could be economically be more viable (depending on the development of costs for storage systems). Therefore, solar is currently limited suitable to provide base loads for heat and power.
	Wind potential	Large-scale wind power plants are usually not permitted in urban development areas with residential zones due to required buffers and distances. The consideration of small scale wind power facilities in the range up to 50 kW_{el} could be taken into account, if wind and market conditions are suitable. Promoting factors could be heights of buildings, which is subject to the urban development process (see WP4). Wind energy is a volatile intermittent energy source due to daily and seasonal availability, which in combination with power storage systems could be economically be more viable (depending on the development of costs for storage systems).

Table 4: Implications of local energy potentials; Source: Own research

RELEVANT PARAMETERS

The parameters of the planning processes, which will differ for urban development areas is an important:

	Criteria	Implications
Political and individual scale	**Political objectives**	The application of selected technical solutions such as RES directly refers to the political city targets as well as legal framework (e.g. Building codes, land use regulations). Due to the need to provide affordable and sufficient housing in the UL-cities considering climate change objectives at the same time, the development of urban areas usually refers to political strategies and objectives as well as legal framework These relate to energy performance of buildings, rent incl. heating/m², share of RES, favoured technical solutions etc., which set the framework for planning.
	Stakeholder	Conventional options related to grid-bound energy supply systems such as district heating, gas and electricity networks are being promoted by the respective energy companies (and partly on political level) and are in most cases easy to achieve solutions, in particular for densification or new housing development. Decentralised systems usually do not have one strong stakeholder in place to promote the use of renewables (besides legal framework, which is also partly lacking, see WP3 and WP4). Renewables and other forms of decentralised systems in combination with high thermal building standards require a strong influence and need of action from urban planning as well as small energy cooperatives, energy service providers etc.. Decentralised systems are mostly efficient if the quarter level is being considered to create economic and environmental scales of benefits ("critical mass"). Therefore the main implication for planning is to steer and if possible lead and manage initial stakeholder talks in order to find suitable solutions for urban development areas, focussing on cross-building and stakeholder solutions. If the city is landowner of an urban development area the prescription of technical solution could be considered and e.g. incorporated in urban development contracts (see WP3 and WP4).
Time scale	**Plot development**	The development of urban areas and its plots might be at times or at the same time. This is an important implication as the overall timescale for delivery is linked to the energy demand, layout, and phasing of the proposed development.
	Total planning time	The need in the UL-Cities to provide affordable and sufficient (new) housing puts pressure on planning processes, especially from a time perspective. Energy related objectives are practically often not taken into account (see WP4 results as well). Technical options other than conventional alternatives, which require detailed investigations (e.g. energy concepts, variant analysis, Life-Cycle-Cost-Analysis) thus might take more time for planning, which is potentially in conflict with the quick response to provide new housings. In this way, in is important to address time conflicts at early stage to gain acceptance on political and individual level to find solutions with best outcome, shifting away from ad-hoc/conventional solutions only.
Environmental scale	**Reduction of resource use**	Energy and resource use savings of technical solutions are important factors to display the environmental benefits of a project. Therefore, the calculations of energy savings etc. need to be considered in the planning where applicable. The method to calculate could refer to primary energy, final energy etc.. Usually the methods used in the respective city strategies (e.g. Smart City Framework Vienna, Berlin Energy and Climate Protection) should be taken into account to ensure coherent calculations, if possible. Many cities would like to be able to monitor the energy performance efficiency of a building or quarter over its lifetime but it seems difficult for some of them to have access to the energy efficiency data. Therefore further investigations and/or external know-how might be required to develop and apply suitable calculation methods (see WP3).

Economic scale	**Costs/investments**	Economic aspects play a crucial role and consists of different dimensions such as • Private/public investments • Specific building costs per m² • Specific rental costs per m² • Heat production costs • Funding/subsidies available (e.g. for social housing) • Life-Cycle-Costs Depending on the stakeholders involved, share of social housing, political objectives etc. the economic parameters will differ accordingly. On-going discussions lead to the recommendation to urban planning to define costs based on a life cycle assessment, rather than investment costs only. Such analysis can help to clarify very early in planning, if a grid solution is recommended (especially district heating) or not (single supply of buildings while using RES). Lifecycle costs are also crucial for a fair comparison of different energy supply solutions. Depending on the results, the best potential supply options are selected and can later be implemented by using certain instruments such as urban contracts. That could increase planning security for energy provider(s) and building developer(s). Moreover, it will be easier for the net operator and city institutions responsible for the infrastructure like streets or sewage, to coordinate needed measures and their construction.

Table 5: Implications of relevant parameters; Source: Own research

The descriptions above aim to help authorities to take into account different criteria and implications for potential technical options on demand and supply side. To define the relevant parameters and formulate open questions concerning selected technical options, will help to steer and manage the planning and decision-making processes in early stages towards a sustainable development.

It is not expected that the potential planning implications can all be assessed by the planning authority itself. But at least to identify potential implications and define the data and information needed, would be supportive and could be subject for further investigations and outsourced to external consultants (e.g. energy concepts) as part of the planning process.

In the following, different potential options are being described in more detail to deepen the previous findings and results.

3.4. Selected Technical Options for Urban Development Areas

This chapter of the analysis seeks to cluster the technical options, based on discussions in project meetings, and the analysis carried out by the cities and their respective Local Working Groups. The descriptions do not aim to be complete but rather an initial overview regarding technical options, which can be taken into account by respective planning authorities and related stakeholders in the development of new urban development areas.

The overall results show a range of established (conventional) technologies such as solar thermal, district heating as well as options for less established solutions (e.g. Low-exergy grids, Power-to-heat) to promote the energy transition in the future. The main options being discussed are described in more detail concerning their technical characteristics and implications for planning. The options represent core discussions and have to be considered as interrelated systems, some with increasing and some with decreasing importance in or another city.

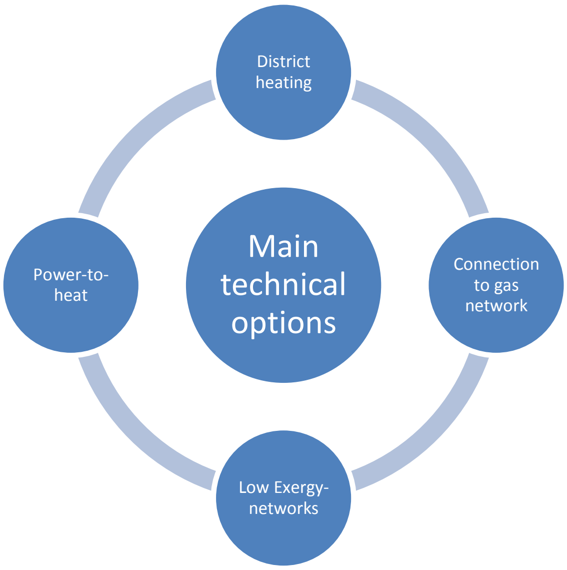


Figure 2: Main technical options

3.4.1. **Technical Option: District Heating**

As outlined before, district heating is a central pillar of the heat supply in most of the UL-Cities and findings highlight that this supply system will also remain a central option (with new challenges) in the development of existing and new urban areas in the future, due to different reasons such as political objectives (e.g.: Amsterdam aims to connect 40,000 more dwellings to the city heating grid before 2020).

The main challenge for the district heating networks and providers in the UL-Cities is commonly the decreasing energy demand of buildings, different energy standards of buildings (next to each other) and increasing decentralised energy production, which requires adaptation of the heating networks concerning different temperature levels, integrability of RES, pressure and also dimensioning.

Following scheme shows a schematic and simple approach for the consideration of district heating and related needs for actions:

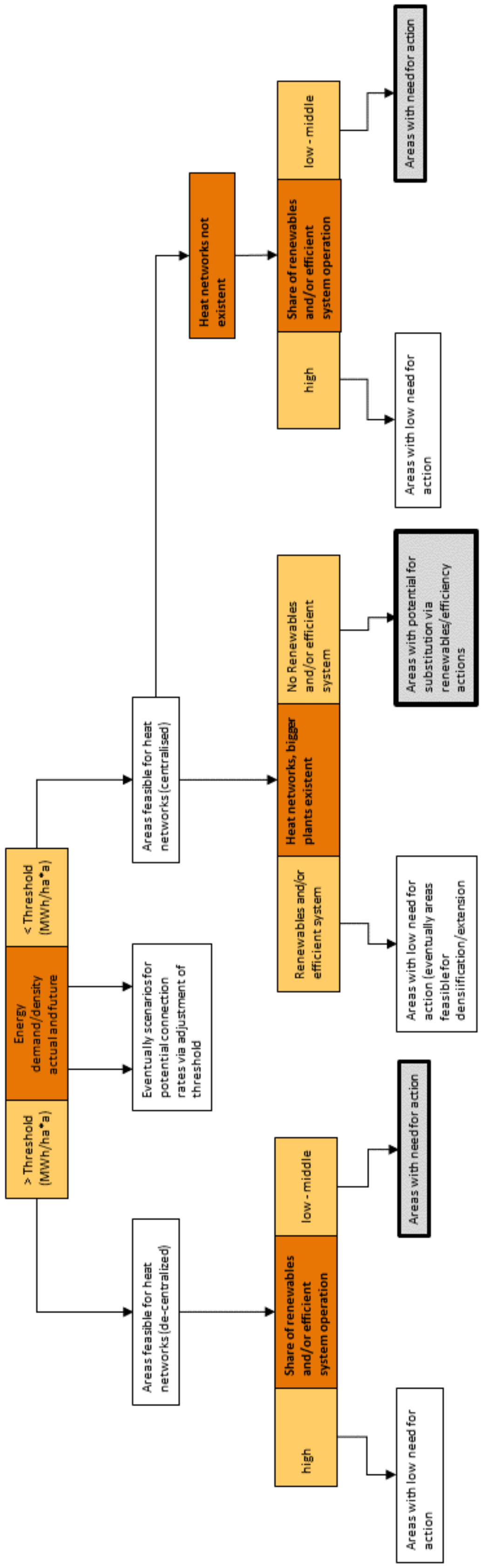


Figure 3: Schematic decision tree for district heating; Source: Own research; data source:

In the following sections central technical characteristics and planning implications are summarized in order to support the understanding in urban development, when and where to consider or simply not to consider the integration of district heating.

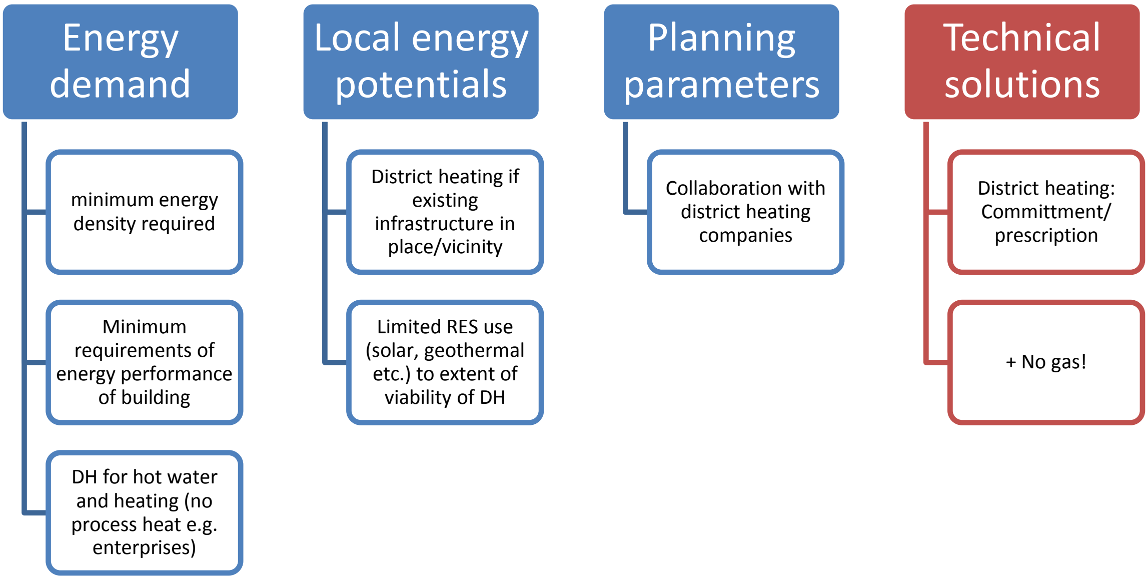


Figure 4: Key aspects of district heating development in urban planning; Source: Own research; data source:

ENERGY DEMAND

Land Use and Building Structures

A strong **link between district heating and assigned land use exists**. As district heating is mainly suitable to ensure a base load for heating and hot water purposes, thus in particular office and/or residential areas are preferable potential areas among other aspects (see below). Industrial or commercial areas requiring process heat are principally less eligible for district heating or demand additional energy supply facilities.

The feasibility of district heating is closely related to the **energy building standard**. Low or passive house standards are currently limited suitable due to low temperature demand, unless secondary networks or technical arrangements to convert high temperature to low-temperature district heating are in place. The conversions of high temperature to low temperature heating networks is a central challenge in the cities, which need to be addressed in the cities through multi-stakeholder processes. This also refers to low-exergy grids, which is also considered as a technical option in the following.

With regard to the urban structures of the partner cities, mostly areas with high and medium **building density** in outskirt areas are being found. The building density and underlying heat density is one major factor to consider district heating schemes or not. The viability of district heating schemes is increased when buildings are closer together (due to shorter pipelines and reduced heat losses). In addition, the **connection rate of building units/apartments** is crucial for the overall feasibility of district heating.

The required **energy demand density** is not fixed and in particular subject to energy suppliers market led objectives. Research results such as “Leitfaden Energienutzungsplan Bayern” indicate energy densities in the range of 150 MWh/(ha*a) whereas results of the EU-project „SPECIAL“ indicate a heat density above 70 MWh/(ha*a) (in South Dublin County areas), which have been identified as those of best potential for initial development. Indicators such as the energy demand in relation to the pipe length (in kWh/m*a) are also used by providers as indication for feasible district heating supply in certain urban areas.

A common threshold has not been identified and will depend on national and local circumstances (energy prices, legal framework etc.). But to identify such threshold from (a neutral point of view) could help planning authorities to review priority zones for district heating from an urban development point of view.

Once such areas of potential have been identified using the heat density methodology, development plan policy and development management standards facilitating the development of district heating projects could ensure that all new developments above a certain threshold, within or directly adjoining such areas of potential, should undertake an energy analysis.

LOCAL ENERGY POTENTIALS

Existing Infrastructure

Proximity between heating networks and heating demand is an important factor for general suitability and implication for planning. In case of consideration, alignment of roads, sewage systems etc. as part of planning process should be linked to district heating network planning.

The heat supplier will be able to provide information on the available capacities for heating and hot water purposes. If capacities are not sufficient, other option need to be investigated or certain plots of development areas might be supplied by alternative/ backup systems (e.g. biomass, solar thermal).

The use of district heating requires a minimum energy demand and energy density (see above), so that in practise the **combination potential with other local energy sources** such as solar thermal or geothermal is practically limited (status quo), from a technical and especially from an economic point of view of the suppliers.

Due to decreasing heat demands of existing and new buildings the technical need for heat suppliers is to find ways to integrate alternative energy systems and adjust networks to required tube pressure and (low-) temperatures. Concepts for integration of decentralised renewable energy sources are related to the idea of “open district heating” or “democratic district heating” allowing so called “prosumers” to feed in (excess) heat into the network. Thus the network functions as a storage system as well. Different projects on national level currently investigate technical feasibility and roll out (e.g. “Adlershof” Berlin). These technical options need to be incorporated and promoted in the UL-Cities in order to reduce the fossils in district heating.

RELEVANT PARAMETERS

Political and Individual Scale

Results in WP4 have shown that energy solutions for newly developed areas are decided between energy providers and developers. There is no general steering of centralised energy systems such as district heating by the city (for instance by defining zones) or defining general energy criteria for districts and quarters to ensure long-term sustainability and the transition towards a low-carbon energy system.

Therefore it is important for urban planning to actively steer the decision-making process of stakeholders involved (mainly developers, housing companies, energy suppliers, ESCOs) towards an open discussion and investigation, which should not only be led by investment costs but rather include life-cycle-costs, which would favour also to consider solutions with high investments but lower maintenance and operations costs.

Environmental Scale

From an environmental point of view the connection of development areas to a district heating network is in particular considerable if the district heat is generated in an efficient way and/or based on a (high share of) renewable energy sources such as waste heat or biomass. In the case of Stockholm and also Amsterdam this is the case, so that from an initial point of view this cities do not need to take any special steps when planning new buildings in order to achieve its fossil-free/climate change objectives.

In cases where district heating is mainly based on fossil fuels (e.g. Warsaw, Berlin) different systematic parameters have to be defined, leading to a stronger consideration of other decentralised systems.

3.4.2. **Technical Option: Connection to Gas Network**

In most of the UL-cities a large-scale gas network is in place and gas usage, besides district heating, is a (conventional) option in the cities. In most of the UL-cities the dismantling of the gas network is discussed and partly already addresses through concrete actions such as in Amsterdam and Zaanstad. Cities, which aim to become climate neutral are asked to reduce the overall amount of gas consumption and also substitute it partly through bio gas. The roadmap to dismantle the gas network is not being developed in most of the cities yet, but actions are emerging step by step.

The main findings concerning driving factors planning implications with regard to gas usage are summarized as follows:

ENERGY DEMAND

Land Use and Building Structures

In comparison to district heating the use of gas allows application of decentralized energy systems such as boilers or decentralized cogeneration facilities, with different performance ranges to ensure supply on building level or neighborhood level.

Using gas allows providing heat for base load as well as for peak loads, thus allowing mixed land use in urban development areas. In case of high-energy standards of buildings, the use of gas might be limited suitable or considered only for peak loads by installing backup heat boilers.

LOCAL ENERGY POTENTIALS

Existing Infrastructure

Close distances between gas networks and heating demand are a central implication for planning to consider gas usage or not. Depending on the overall energy demand, the respective gas supplier will be able to provide information on the capacities to provide gas. If capacities are not sufficient, certain plots of development areas might be supplied by alternative systems (e.g. biomass, solar thermal) and/or energy standards of buildings are adjusted to low energy housing standards.

Depending on the matching of available gas capacities and energy demand, the use of gas could be considered either for providing a base load and/or peak load supply.

An overview of gas networks might be available in some cities as part of the elaboration of energy concepts or energy maps (see WP3) and could help to define areas generally suitable for gas supply, if not precluded in general as in Amsterdam for instance.

Depending on the energy demand and expected loads gas based supply systems can basically be considered for multiple purpose, making it flexible and adaptive to local conditions and future developments. Besides heat production only, cogeneration is a technical solution, which could increase economic and environmental benefits through efficiency by generating heat and power at the same time.

CHP is an established technology, which has been used in bigger building complexes in commercial and industrial areas as well as residential areas with a certain threshold of heat demand. In recent years the use of CHP for smaller complexes of buildings have been introduced on the market to enlarge the field of application. Thus potentials for smaller CHP-systems, e.g. in the range of 5-50 kW_{el} could be considered in urban development projects as well, if considering gas usage.

As a fossil based energy source, gas is still a carbon emission source, which should be minimized and/or substituted by renewable energy. The production use of biogas in waste treatment plants or biogas plants (in dense urban districts less feasible) is therefore a general option to minimise the environmental impacts of gas usage. In addition, CHP can use biogas from the gas grid (biomethan).

Besides, concepts such as power-to-gas might be considered as well. An increasingly large percentage of power is being generated from renewable energy sources with intermittent and fluctuating outputs. Therefore there is a growing need for energy storage. With power-to-gas, excess electricity can be converted into hydrogen by water electrolysis as well as synthetic methane. Due to large investment costs for such processing plants and relatively low gas prices at the moment (and probably in the next few years) the economic incentive for implementation of this technology is currently low.

RELEVANT PARAMETERS

Political and Individual Scale

In order to achieve the climate change objectives in the partner cities of becoming climate neutral or approximately climate neutral (e.g. Berlin -85% carbon-reduction), the predominant use of fossil based energy sources such as coal, oil and also gas needs to be phased out or limited to an increased extent. Amsterdam for instance precludes gas usage in new development areas, in favour of district heating or aquifer thermal energy solutions, in order to support the decarbonisation and energy transition. The City of Vienna also investigate gas free urban developments and strategies to minimise gas usage.

Nevertheless, gas will be part of future developments in most of the UL-Cities, even if limited. In particular in new building developments the use of fossils should only be allowed and promoted under special circumstances such as CHP-applications. In Paris the political vision is not to stop gas usage but rather to “green” it, by increasing bio gas up to 75% to 100% before 2050.

Economic Scale

The use of gas via CHP or condensing boilers implies also the need to the erection, maintenance and improvements of these supply systems causing heating costs, which incur for building owners and respective end consumers such as tenants/residents.

The responsibility for the operation of the supply facilities (e.g. CHP) depends on the stakeholders involved and could for instance be operated by technical departments of housing companies/owners (e.g. municipal housing company). For smaller housing companies such as cooperatives the consideration of energy service companies could be considered to outsource investment costs as well as maintenance and management costs. Such business models should be incorporated in urban planning processes.

3.4.3. **Technical Option: Low-Exergy Networks**

The findings show that energy neutral or low energy housing development is in place and targeted within the next years (anticipatory of respective regulations), but also still a challenge in most of the cities (in particular when the city is not the landowner) and depends on many different factors.

A central technical option being discussed is related to district heating and the concept to design and construct adjusted forms of heat grids. A flexible local energy grid so called low-exergy-grid is a central technical solution to cope with the challenge of low energy demand of housing and decentralised production of energy at the same time in the near future.

Low-ex networks are generally applicable for retrofitting of existing building areas and for new building areas as well. The grid is flexible to integrate and supply heat at different low temperature levels (e.g. 15 °C, 30 °C). This allows for the integration and maximization of heat from renewable energy sources (such as solar heat, geothermal and groundwater energy) and waste heat. The grid thus functions as a big thermal store, analogous to a stratified storage tank with variable feed-in and consumption.

Main features of such grid are as follows:

- District energy network for heating and opt. cooling purpose
- Pipe network with low and variable temperature levels
- Flow and return flow are bidirectional/not determined
- Open for all producers connected to the grid (i.e. renewable energy and excess heat)
- Administration of the network via intelligent controlling equipment

The main characteristics and planning implications of this quite "new" technological concept, which could be identified, are summarized as follows:

ENERGY DEMAND

Land Use and Building Structures

The technical requirements of low-exergy grids are similar to conventional district heating. Existing and new areas with **high building density and low energy demand** (due to high building standards/major renovations), which are not suitable for conventional district heating are promoting factors for consideration of low-ex solutions. Threshold concerning energy demand and density based on urban structures could not be identified yet and would thus be subject for further investigations, which is also part of existing research projects (e.g. “LowExTra”/Germany).

Concerning urban structures **mixed land use** including commercial or industrial zones with waste heat (depending on the temperature etc.), could be used for integration into the network.

Due to the complex management of low-exergy grids to balance energy supply and demand a good data base is required referring to following:

- Data of consumer temperature requirements and energy demand
- Building energy standard
- Type and number of buildings (residential, commercial, industry)
- Data of heat production especially potential for renewable energy, excess heat and waste heat
- Centralised and accessible platform for plans and concepts for construction sites of streets to lower the costs of implementation

LOCAL ENERGY POTENTIAL

Existing Infrastructure and Local

Realization of LowEx networks could preferably considered in areas without existing gas infrastructure (combinations are also not precluded as e.g. heat from gas-fired CHP or heat pumps could be feed into a LowEx network). Definition of priority areas for LowEx networks with low PE-factor could be considered in the planning processes.

Due to the tubes with big nominal widths sufficient subsurface space is required, which could potentially overlap and conflict with existing pipes and systems, in particular concerning existing building areas in the dense inner cities.

RELEVANT PARAMETERS

Political and Individual Interests

Besides political framework, the central planning parameter for the technical implementation refers to the stakeholders involved.

- Building owners: Due to a minimum energy demand it is necessary that a building owners with minimum number of buildings are willing to participate in the implementation of this innovative technology. In case of involvement by municipal housing companies the commitment is expected to be higher and more feasible.
- Producer: According to the expected energy demand, it is necessary to provide sufficient heat, which is generated by decentralized systems such as waste heat (industrial enterprises), or solar thermal, biomass (housing companies). External ESCOs (Energy Service Providers) could also be considered here, if general profitability is given under the local circumstances (heat price, legal framework etc.)
- Net operator: The network operator of low-exergy grids is the central interface between end users and producers and ensures a secure energy supply for the respective development area by monitoring and adjusting the parameters of the grid (pressure, temperature flow, anticipated loads etc.). Potential net operators are private or municipal companies,

cooperatives or public-private partnerships. Such concept would also promote the required unbundling of network operator and supplier.

- Consumer: Consumers are public and private building owners/companies, respectively tenants. In addition, non-housing buildings such as office, schools, public swimming pools and hospitals are suitable, optional in combination with other heat supply facilities, based on renewables or fossils.

Main driving factors for implementation are economic and in practice to a lesser extent environmental scale effects. Concerning **economic scale** effects, current investigations analyse suitable business models to erect, maintain and improve low-exergy grids. Potential options refer to main heat supplier (status quo), transmission models or open heat platforms.

For consideration and piloting of more projects in the cities, a profound data base is required (e.g. feasibility assessment) and multi stakeholder process, which needs to be steered by urban planners or related departments to support implementation in the long term. Besides local level endeavors national policies are also driving factors to promote the energy transition in the heat market on city/local level.

3.4.4. **Technical Option: Power-to-heat (“No Fossils”)**

Strategies such as electricity based and preclusion of fossils approaches are among others being discussed and considered in the partner cities such as Amsterdam. In Amsterdam in March 2017 a new instrument was launched: the Green Deal “Experiments Natural Gas free districts”. With this deal participating municipalities (28 of in total 390), grid companies (5) and umbrella organizations (3) help the National Government to make good laws by performing experiments. Perhaps the most important experiment is to abrogate the connection obligation to natural gas (due to the Gas and Electricity Act). Amsterdam and Zaanstad participate in this deal.

With regard to fossil free developments, discussions refer to ways to use excess power from large-scale wind or solar plants, leading to technical solutions such as power-to-heat, which are gaining importance and receive more recognition in the partner cities.

In particular, in times when excess power is available power to heat solutions are cheap solutions to provide negative balance energy for heating purposes.

Power-to-heat could be realized in various applications: indirect via heat pumps (heat but also refrigeration per air conditioners) or direct via resistance heating (heat, hot water, steam etc.). The usage of balance energy could also be part of an overall e-mobility concept providing additional storage at times with exceeding power. An overall integrated concept is necessary, which is already part of current city discussions. Further research is required.

The main planning implications and driving factors for the consideration of this technical solution, which could be identified, are as follows:

ENERGY DEMAND

Land Use and Building Structures

Power-to-heat can be applied for any type of foreseen land use or building structures and is highly complementary to regular energy supply systems. Promoting factors for the application in buildings and quarters are low energy demand and storage systems in place locally leading to a high coverage of the overall energy demand.

In particular well insulated buildings with a heating load max. 25 W/m^2, including thermal activation of the concrete core and increase of the concrete mass, are feasible application cases. The thermal activation of the concrete core has to be decided during the planning phase of the building. Practical experiences have proven, that the realisation does not need more time than a conventional building.

Different studies showed that the combination of a high thermal quality of the building with the thermal mass storage enables to bridge a winter period of approx. one week without activating the heat supply (for space heating). 95% of the needed heat pump power for space heating is covered by "direct" wind power. Additional benefit can be generated when the system is also used for space tempering. If scaled up, the system supports the increase of the share of RES in the energy system as it shows a high potential for demand side integration.

Power-to heat solutions in large scale would lead to increasing electricity demand and potentially increase installed loads, with potential effects on the electricity network. The actual impacts are still being investigated in projects such as WINDNODE in North-Eastern Germany including Berlin (Link: www.windnode.de). So further research is required, in particular concerning data management to link renewable energy production (low energy prices) to times of heat and cooling demand.

LOCAL ENERGY POTENTIALS

Spatial Circumstances

Current developments show that high amount of (volatile) excess wind or solar power from regions outside metropolitan cities (e.g. Federal State Burgenland around Vienna, Federal State Brandenburg around Berlin) can be used for heat purposes on quarter and building level.

This option is actually rather considered as a combinatory (secondary) energy supply system, which is substituting other primary supply systems for a certain time period (e.g. a smaller amount of performance hours per year). The relevance and application is expected to increase in the upcoming years. The consideration of this option could be preferably focus on areas without existing gas and district heating infrastructure (e.g. outskirt areas), but also existing building areas with overhauled heating technologies. Depending on the energy demand and loads, options for a storage (besides thermal activation) is required, due to the dependency on low energy prices.

The spatial requirements are minimal due to small equipment size.

RELEVANT PARAMETERS

Political and Individual Scale

Considering this option in urban planning as a large-scale option requires a close collaboration of the planning authority with the electricity grid operator (local and regional) to identify potential conflicts concerning load peaks. The overall application should be based on energy modelling approaches, which are not original tasks for urban planning but rather net operators, providing new business opportunities as well.

Environmental Scale

In particular in the long-term electricity and related technology concepts such as power-to-heat could be a cost-effective and environmental friendly solution, if large wind and solar plants increase in number (on regional and national level).

Economic Scale

In the context of urban development, the investment costs based on existing findings are relatively cheap as no cost intensive (heat) grid system such as district heating or gas has to be build. At the moment, this option is still a secondary supply system. So the economic benefits have to be considered in the overall context of other relevant supply systems etc.

4. Main Findings per City

The following sections give a more detailed picture of the analysis per city and focus on background information on the energy systems and infrastructure in place, technical options considered and a summary and outlook for future developments for decarbonisation in the cities.

4.1. City of Amsterdam/Zaanstad

4.1.1. Background Information

Amsterdam

In the current situation Amsterdam's energy demand is fulfilled by a gas network, an electricity network, two main district heating systems and 2 cooling networks. The historic city is mainly powered by gas and electricity. In the expansion areas after World War II a city district heating network is available. There is one heating network in the west side of the city that recently expanded to the north side. This system is powered by a CHP burning waste and biomass, called the AEB Amsterdam (Waste and Energy Company Amsterdam).

The second heating network is on the East and South side of the city, powered by a CHP burning gas. In the south side of the city there are two deep lakes that provide cooling to the office areas on the South axis and within the Southeast. Extra electricity is produced in the harbor area on the west side of the city. There is an electricity power plant fueled by gas and coal (not CHP), close to the AEB Amsterdam. There are also 37 windmills in the harbor area.

Figure 6: Amsterdam historic growth: 17th century, 19th century, after WW2 (Source: Energie in beeld)

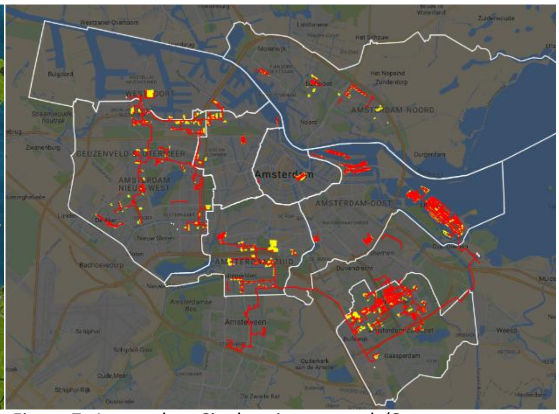


Figure 7: Amsterdam City heating network (Source: Energie in beeld)

The underlying image gives an insight in the CO_2 emissions due to total energy consumption (gas and kWh) for Amsterdam divided in areas. The biggest emissions is seen at the outskirts of the city were also is the biggest amount of industry in the North West of Amsterdam and a big emission on the location Zuidas where there is a big concentration of big offices. Also there is a bigger energy concentration/CO_2 emission in the centre of Amsterdam, where lots of shopping malls, restaurants, hotels et cetera can be found.

So the intensive emission in these areas can be explained. And of course there is a relation with the number of households in the areas. The dense populated areas give a bigger CO_2 emission because there is more total gas and electricity usage.

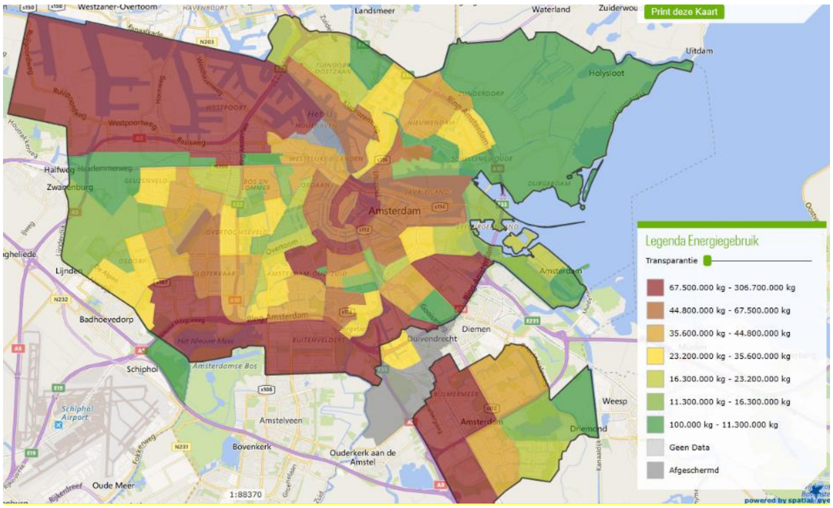


Figure 8: Amsterdam emissions (Source: Energie in beeld)

The underlying picture gives an insight in the energy labelling for dwellings in Amsterdam. Here one can see relation with density and age of dwellings which can be related to the CO_2 emission overview on the previous page.

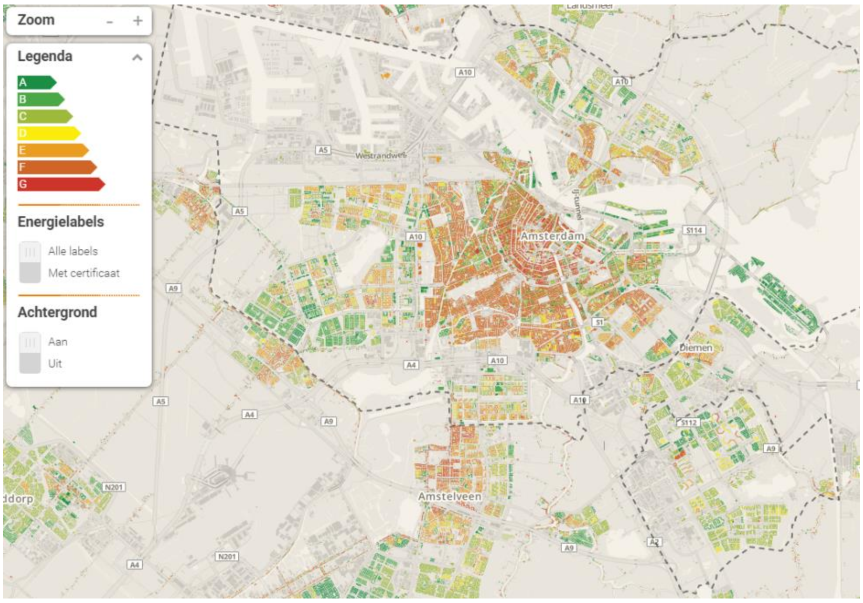


Figure 9: Amsterdam Energy Labelling (Source: Energie in beeld)

Noticeable fact is the production of Sustainable Energy (kWh per annual) grows each year in Amsterdam.

Amsterdam	**2013**	**2014**	**2015**
Sustainable energy (solar) (kWh)	3,367,900	5,488,496	8,249,486
Sustainable energy remaining (kWh)	269,739	130,597	488,704
Total	3,637,639	5,619,093	8,738,190
Difference/growth		1,981,454	3,119,097

Table 6: Development of renewable energy production Amsterdam 2013-2015; Source: Own research

Zaanstad

In the current situation Zaanstad´s energy demand is fulfilled by a gas network and an electricity network. The underlying image gives an insight in the total energy (gas and kWh) CO_2 emission for Zaanstad divided in areas. Here one can also see a relation with industrial areas in the energy usage expressed in CO_2.

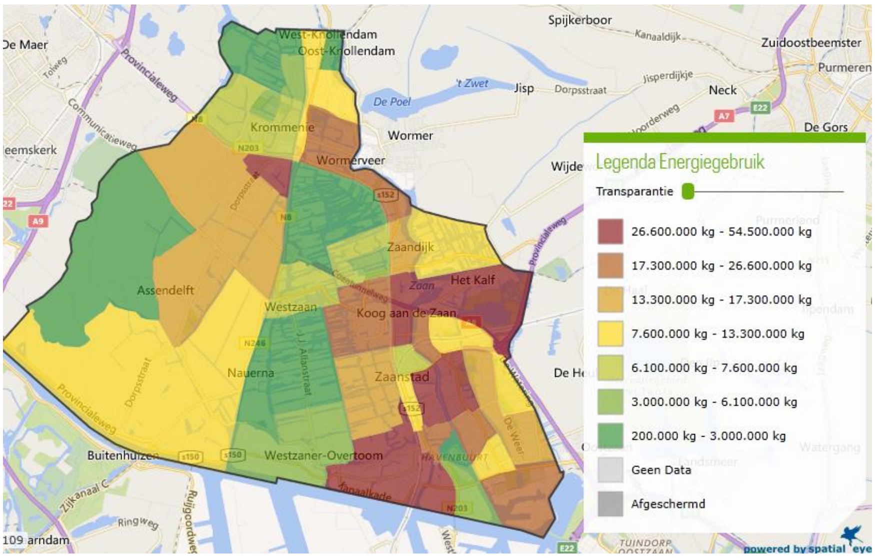


Figure 10: Zaanstad emissions (Source: Energie in beeld)

The underlying picture gives an insight in the energy labelling for dwellings in Zaanstad. Here one can also see relation with density and age of dwellings which can be related to the CO_2 emission overview on the upper image.

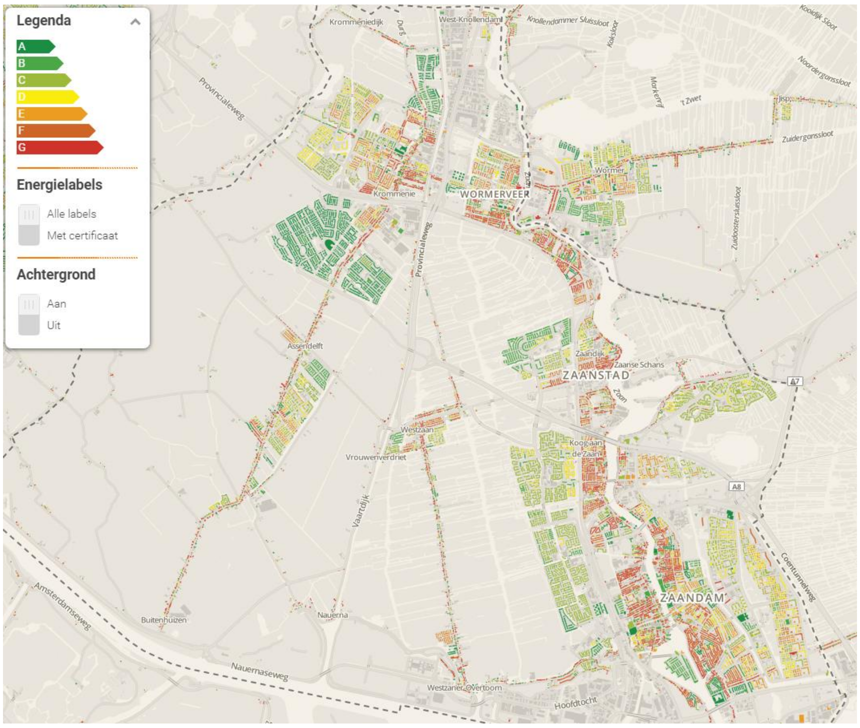


Figure 11: Zaanstad Energy Labelling (Source: Energie in beeld)

4.1.2. **Technical Solutions**

Amsterdam

For the urban (re)development areas the starting point is NO GAS. There are several energy solutions, but typically the choice is between (1) district heating or (2) aquifer thermal energy storage; a seasonal storage for heat and cold underground (50-100 meters). Depending on the location it is possible to combine a district heating network with a cooling network. The cooling network could be direct from the deep lakes or indirect from surface water in combination with seasonal storage for cold. Another distinction in the system for district heating is whether it is part of the long distance city network or that a local CHP is installed for a decentralized heating network. The third (3) solutions is the all-electric solution with storage facilities for electricity and heat.

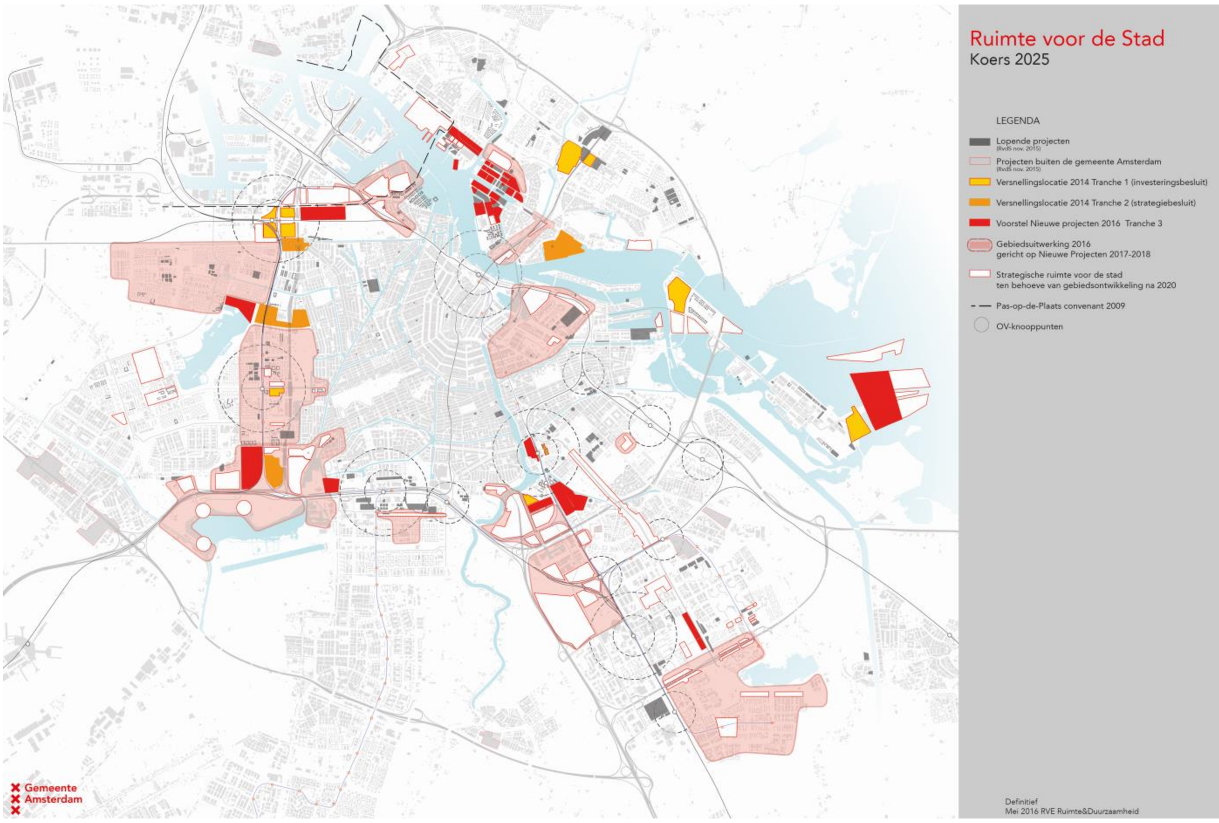


Figure 12: Amsterdam area development mostly in the “ringzone” (Source: City of Amsterdam)

Project developers are not obliged to join a collective energy solution if they provide an alternative that is more sustainable than the collective solution. These are mostly solutions that apply to a plot. Mostly a closed system is used for heat and cold storage in the underground close to the ground. This in combination with Smart architecture, PV-panels and a backup system with biomass or biogas.

On March 8 2017 a new instrument was launched: the Green Deal “Experiments Natural Gas free districts”. With this deal participating municipalities (28 of in total 390), grid companies (5) and umbrella organizations (3) help the National Government to make good laws by performing experiments.

Zaanstad

For Zaanstad the starting point is Energy neutral and No Gas. There are several energy solutions, but typically the choice is between (1) optimizing reduction and maximum generating renewable energy and (2) aquifer thermal energy storage; a seasonal storage for heat and cold underground (50-100 meter). A district heating network is foreseen in the eastern part of Zaandad, but at this moment connections are not possible yet.

4.1.3. **Outlook**

Landownership is the most powerful instrument of the city of Amsterdam to enforce its energy goals. In Amsterdam this is very common, and Amsterdam also remains to be the owner (permanent ground lease). Zaanstad owns less ground and if they sell it to the property developer. Another situation is that a property developer owns the land, but there are adaptations of the Land use plan needed to build at that location. In all these cases cities use private law (permanent ground lease agreements, purchase agreements, anterior agreements). In all these type of agreements an EPC ≤0.15 is put on. Also monitoring to show that the building (after construction or renovation) will reach the EPC is tried to get into the private agreements.

For demarcated areas municipalities require – when they have made a heating plan – that each new building project is connected to district heating. But when the initiator shows that his solution is equal on sustainability and doesn’t threaten the feasibility of the heat distribution grid. Sometimes a heating plan allow at max 10% non-connections to the district heating grid (for instance Buiksloterham).

Interesting technologies for Amsterdam and Zaanstad to look at in the future are:

Area Systems:

- Aquifer thermal storage system (WKO) for an area as a whole in combination with a low temperature heating and a low temperature cooling network (different sources possible for balancing the system: energy from surface water, energy from grey water (shower etc.), waste heat from offices, etc.)

Specific Technologies/Energy Sources:

- Energy from seawater: heat and cold storage as well as electricity production
- Storage of electricity (neighbourhood battery, larger scale)
- balancing of electricity (SMART grids)
- Power to gas (H_2 or CH_4)
- Possibilities for Direct Current (DC) solutions instead of or in addition to Alternating current (AC)
- Energy from asphalt roads
- System with vacuum tapwater
- Heat recovery in buildings from hot air ventilation system

Other Way of Ownership/Organisation:

- Local low temperature heating network in ownership by the users (private collective ownership)

Regional Energy Solutions:

- Could regional energy solutions be better than local? Are there any sustainable technologies that profit from large scale solutions?

4.2. Berlin

4.2.1. **Background Information**

Central instrument of Berlin's energy and climate protection policy is the Berlin energy and climate protection programme (BEK). It is the "roadmap" towards climate neutrality, in which strategies and measures are defined. Energy supply in particular presents considerable challenges in Berlin: renewables still only account for a small percentage. Fossil fuels are currently still dominant: natural gas for generating heat; mineral oil for transport or as heating oil; in the electricity sector beside natural gas above all hard coal and lignite in major power stations for generating electricity and district heating.

Almost 71% of the total heated area is supplied centrally and almost exclusively by natural gas and oil. 29% of the heated area is generated and distributed centralized via district heating network. The district heating fuel mix of Vattenfall (90% Market share) in 2014 was: 50% hard coal, 31% natural gas, 14% lignite and 5% Biomass etc. Vattenfall signed a carbon emission reduction agreement to reduce greenhouse gas emissions by implementing power plants with combined cycle process and with an increased usage of biomass (fuel switch) in existing power plants.

The following diagram shows the primary heating technology of constructed residential buildings in 2014 in Eastern Germany. It can be stated that natural gas and heat pump are the prevalent decentralized systems. The share of district heating might me much higher in urban areas, especially in Berlin.

4.2.2. **Technical Solutions**

Combined heat and power (CHP) will probably remain an important option in the future energy system for Berlin's densely populated area. But solar power and heat pumps have enormous potential which the measures in the BEK aim to exploit in a targeted way. In particular, the most important current field of action – buildings – can make a great contribution to climate protection in the areas energy generation and energy saving.

The recommendations of the BEK predominantly aim at promoting voluntary climate protection activities. Overarching climate protection instruments, such as CO_2 taxes or regulatory targets for renewables or energy efficiency are currently unenforceable and would be primarily a matter for national or international legislation. It is more a question of dismantling barriers, developing markets as well as introducing good examples and strategically or structurally significant activities for urban climate protection.

Innovative systems for Berlin are Low Exergy System and Power-to-Heat solutions for instance, which could be considered in the building stock as well in new development areas. The planning indications are that such technologies still not "established" and require further examination (see "Adlershof" in Berlin). The consideration of such technologies in planning processes needs to be ensured through continuous exchange between research facilities such as "Adlershof" and planning departments.

4.2.3. Outlook

The elaborations above give an **overview on the Berlin** energy transformation plan to become climate-neutral until 2050. Buildings are responsible for more than half of the final energy consumption and play therefore a key role in the energy turnaround. There are strict energy performance requirements for building construction and renovation, nevertheless the Berlin heating technology and the electricity production is still based on fossil fuels.

The district heating network is one of the largest in Europe and constructed or renovated buildings near the existing infrastructure are connected to it. The focus innovative technologies are Low Exergy Systems and power-to-heat.

- **LowEx systems** allow the implementation and utilization of RE and excess heat
- Could be viable in areas of low energy density (renovated buildings)
- Necessary to lay subsurface tubes
- Recommendable for areas with re-/construction of public streets
- Legislative or regulatory framework for viable operation

- **Power-to-heat-applications** could contribute to mitigate the problems of fluctuation renewable energy electricity generation
- Are already in the market (approx. 1/3 of new constructed residential houses)
- Recommendable for areas without existing gas/district heating infrastructure
- Regulatory framework or incentives for preferable use of excess/renewable electricity

4.3. Paris

4.3.1. Background Information

Paris´ energy demand depends mostly on imported fossil fuels, and on electricity produced in other regions of France. Electricity is the first energy source used in Paris (40%), ahead of a natural gas whereas oil is only 10% of the global energy mix. District heating covers 16% of total energy consumption and 30% of heating. Paris produces just over 6% of its energy implications, thanks to the Paris Urban Heating Company (CPCU), a government-approved body responsible for the heating network.

Paris’ Climespace district cooling network uses electric chillers to produce the cooling, which has led to 35% less electricity used, a 50% improvement in primary energy efficiency (saving 25 GWh/a), 65% less water used, and 50% less CO_2 emitted compared to an equivalent stand-alone cooling capacity. District heating and cooling allows energy savings, promotes the use of local resources, helps guarantee flexibility and security, and improves efficiency. The combination of city ownership and the use of a concession model has allowed Paris to maintain a high degree of control over district heating development, while also benefiting from the efficiency improvements and capital investment contributed by the private sector. The Paris authorities own the electricity, gas, heating and cooling networks and organise energy distribution.

Renewables represent as well an issue for improving local energy production. 464 plants and systems produce 2,100 GWh per year and contribute to a decrease of 370,000 tCO_2. Regarding the production of each renewable source, waste heat recovery is the first source of supply even if the plants are not located in Paris, only the share of Parisian waste are considered in the assessment. District cooling is the second provider of local renewable and recovery energy thanks to the using on the river. Geothermal resource represent an important opportunity for Paris. 58 plants in the city produce 94 GWh of renewable heating per year with two major plants in Paris North-East and Clichy Batignolles districts.

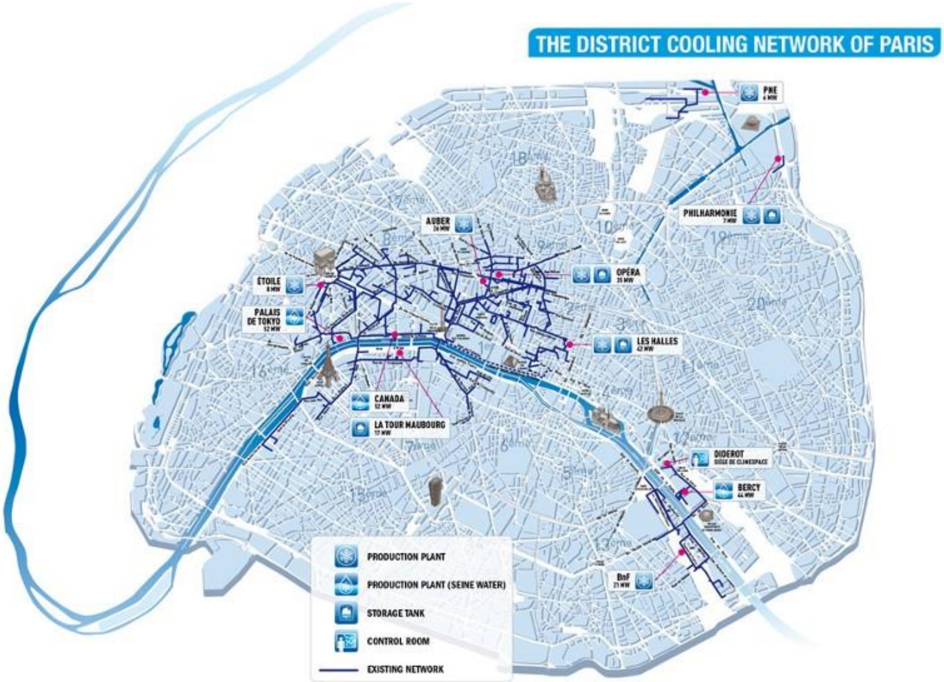


Figure 13: District cooling network Paris (Source: Climaspace)

Figure 14: District heating network Paris (Source: CPCU)

4.3.2. **Technical Solutions**

In Paris, Climate Action Plan improves the implications and fixes the objective for new buildings of 50 kWh/m² per year for maximum energy consumption. This represents an average consumption level 20% lower than the thermal regulation. For renovation, Climate Action Plan objective is to move towards 80 kWh/m² per year. These implications apply to sectors in undergoing urban development, to social housing buildings and renovations to municipal buildings and to any builder who want to reach Climate Action Plan goals.

The combination of city ownership and the use of a concession model has allowed Paris to maintain a high degree of control over district heating development, while also benefiting from the efficiency improvements and capital investment contributed by the private sector. The Paris authorities own the electricity, gas, heating and cooling networks and organise energy distribution.

In addition Paris Land Use Plan allows:

- to exceed the maximum height of building to implement solar panels
- a building to overtake on the street in order to fix some insulation structure (20cm)
- to exceed the FAR (floor area ratio) by up to 20% by the construction of buildings with high energy efficiency standards or facilities for renewable energy production

The following diagram shows the share of heating technology in Paris. District heating represents 24% of the total heated area. The district heating fuel mix of CPCU (Paris Urban Heating Company), local government-approved network company, in 2014 was: 41% heat waste recovery, 30% natural gas, 16% coal, 10% biomass, 2% biofuel and 1% geothermal. The CPCU was committed to meet 50% of renewable and recovered energy in its energy mix in 2015 according to Paris Climate Action Plan. The objective is 60% renewable or recovered energies by 2020 in the heat production mix. The net reduction in greenhouse gas emissions could then be around 350,000 tCO2eq in 2020. With a length of 480 km and 500,000 dwellings eq. connected, the Paris district heating network is the largest in France and the densest within Europe.

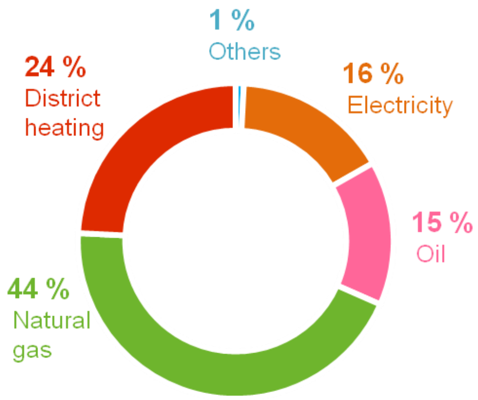


Figure 15: Energy sources Paris (Source: City of Paris)

The focus of innovative technologies are Low Exergy Systems and experimental/recent decentralized production solutions: data center micro grid/ solar road/ piezoelectric pavement.

- **LowEx systems** allow the implementation and utilization of RE and excess heat
- Could be viable in areas of low energy demand
- Necessary to lay subsurface tubes
- Recommendable for areas with re-/construction of public streets
- regulatory framework for energy share with district heating company
- **Decentralized data center and housing heating** could contribute to reduce electricity demand during winter and reduce energy dependency
- Contribute to develop local data storage and calculation in the city with no spatial impact compared to data center
- Different technologies are in the market : Two examples in Paris to heat a public swimming pool and a social housing building
- Specific implications concern internet with optic fiber and a monitoring operator to manage the production

4.3.3. **Outlook**

The climate-neutral and 100% renewable city framework for Paris is ongoing and to be adopted in last 2017. Paris also work on development strategies for heating and cooling energy grid, they will be established before 2019 and will provide a guideline for energy production and supply within the city. There are efficient energy performance implications for building construction and renovation, nevertheless these implications have to be reinforced as it was established in 2008 and updated in 2015. It will be done in 2017.

4.4. Stockholm

4.4.1. Background Information

The city's initiatives to be fossil fuel free by 2040 from the draft edition of the climate roadmap. Making Stockholm fossil fuel-free by 2040 means changing the city's approach, and it is critical for the City of Stockholm to continually investigate the potential to increase the speed and scope of its climate efforts.

In brief, the following initiatives must be implemented in order to achieve independence from fossil fuels. Responsibility within the city's organisation must be allocated and specified in the strategy. The strategy is a minimum level for achieving the long-term objective. Making Stockholm fossil fuel-free by 2040 means changing the city's approach, and it is critical for the City of Stockholm to continually investigate the potential to increase the speed and scope of its climate efforts.

Sustainable energy use

- The city ensures that Fortum Värme implements its decision to phase out the use of coal. The city's ambition is to phase out the use of coal completely by 2020. A phase-out plan should be provided by 2017 at the latest.
- The city partners with concerned entities to ensure that the use of fossil fuels for peak loads by energy companies, hospitals, etc. is replaced by renewable fuels, and reports on progress in 2018.
- The city assists Fortum Värme in its efforts to increase connections to open district heating, and investigates opportunities for additional connections. The report containing proposed actions
- Must be submitted for decision no later than 2017.
- The city investigates opportunities to increase the amount of renewable energy produced in the city. The report containing proposed actions must be submitted for decision no later than 2017.
- The city works to ensure that control tools, legislation and regulations support fossil fuel-free energy use.

The City of Stockholm's systematic approach in the building sector, comprising investments in district heating, conversions from oil heating to geothermal systems, energy-efficiency improvements by property owners and stricter energy-performance requirements for new buildings, has reduced the sector's energy needs from 10 TWh/a in 2000, to 8 TWh/a in 2015. By switching to more renewable energy sources, greenhouse gas emissions declined from 1,976,000 tons of CO_2e/a in 1990, to 855,000 tons in 2015. In tons per capita, emissions declined from 3 tons CO_2e/capita in 1990, to 1.3 tons CO_2e/capita in 2015. Despite a growing population, both energy needs and greenhouse gas emissions have been significantly reduced.

At present, 75-80% of the city's heating requirements in buildings are met by district heating, about 20% by geothermal energy or direct electricity. Only a few hundred buildings and about one thousand single-family homes across the entire city have oil-fired boilers.

Swedish society has changed over the past decade, and residents are increasingly able to choose their own service providers. This has also meant that district heating is now exposed to competition from geothermal energy, in particular. To date, relatively few property owners have switched from district heating to geothermal energy, but the city has noted a growing interest from property owners with district heating to replace their heating systems. This is complex from a planning perspective, since district heating requires major investment in the city's power plants and pipeline systems. It should also be noted that increasingly lower energy requirements in new construction lead to higher investment costs for district heating per kWh of energy sold per building.

The city ensures that Fortum Värme implements its decision to phase out the use of coal. The city's ambition is to phase out the use of coal completely by 2020. A phase-out plan should be provided by 2017 at the latest.

The city assists Fortum Värme in its efforts to increase connections to open district heating, and investigates opportunities for additional connections. The report containing proposed actions must be submitted for decision no later than 2017.

The city must take steps to ensure climate-smart district heating that reduces total emissions (by at least 240,000 tons CO_2e by 2020). City must enact implications that the maximum energy usage of newly constructed buildings on land assigned by the city must be 55 kWh/m^2 Atemp, with a target of 45 kWh/m^2 Atemp.

The City of Stockholm's systematic approach in the building sector, comprising investments in district heating, conversions from oil heating to geothermal systems, energy-efficiency improvements by property owners and stricter energy-performance implications for new buildings, has reduced the sector's energy needs (from 10 TWh/a in 2000 to 8 TWh/a in 2015).

At present, **75-80% of the city's heating implications in buildings are met by district** heating, about 20% by geothermal energy or direct electricity. Only a few hundred buildings and about one thousand single-family homes across the entire city have oil-fired boilers.

The **storage of energy** of various types will presumably become an ever more important question for both large and more small-scale solutions, which means that it must be incorporated as a requirement during the various stages of the planning process.

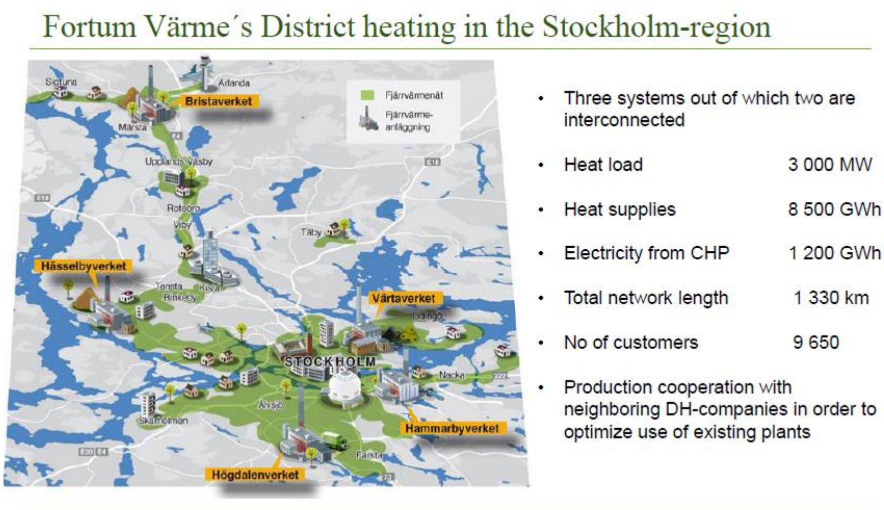


Figure 16: District heating in Stockholm (Source: City of Stockholm)

4.4.2. **Technical Solutions**

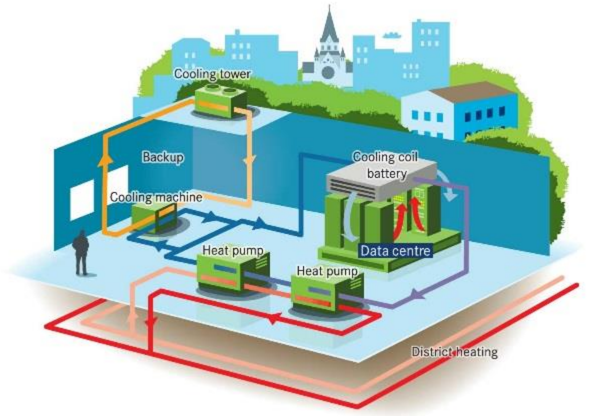


Figure 17: Scheme for open district heating (Source: City of Stockholm)

The main objective of the city and its largest heating supplier, Fortum Värme, is to improve and expand the existing district heating network. Since district heating is expected to be nearly completely fossil fuel-free in the near future, this is an efficient way for Stockholm as a city to reach its established climate targets.

District heating is now a well-functioning large-scale solution, with a relatively low proportion of fossil fuels (25-30%), but property owners are as stated above tending to move towards a more decentralised market. This presents opportunities for the development of innovative business models based on smart circular system solutions for energy storage and delivery.

The liberalisation of energy markets has reduced the city's opportunities and obligations to impact the planning of energy systems for production and supply. Nor does the city have the jurisdiction to regulate the energy systems chosen by property developers in new construction projects. Furthermore national legislation – such as the energy distribution law – limits opportunities to generate renewable energy for the city and other major property owners.

The commercial aspect of the company's governance reduces the ability to investigate new solutions that would support the city's environmental goals, since this entails conflict between the profit motive and environmental goals.

Waste heat/open district heating (In 2015, open district heating contributed to the heating of about 6,000 apartments in Stockholm, as well as a 2,500 tonne reduction in carbon dioxide emissions.)

Storage Systems

The remaining options for municipal influence on energy-related issues in planning are to render the systems used by the city's own organisation more efficient, to enable effective solutions linked to voluntary agreements in the planning project's project management, and to increase energy-performance implications when land owned by the city is being developed. This is also implemented at present by the 55 kWh/m^2 requirement, which is one such example of how more stringent implications than those applicable at national level are applied in land-allocation and development agreements. This requirement alone will not mean that energy-related issues are integrated with planning. To achieve results, the project must also be managed throughout the entire process and the completed buildings must be monitored. The Development Administration has begun monitoring the projects governed by energy-performance implications. Due to the long timeframe for development projects – about 6.5 years from site allocation until completion – it will take a long time before the city sees the results of this monitoring process.

Low-temperature district heating is desirable for buildings with low energy demand (about 40 kWh/m^2 or less for heat and hot water). This is not currently in use in Stockholm:

- For instance, open district heating is currently only profitable if there are large amounts of relatively high-temperature surplus energy, and only during the heating season at that.
- Solar heat is not currently utilised to the extent possible during the summer months, since waste “must” be incinerated year-round, as otherwise extensive storage and efficient waste sorting would be necessary to deal with the waste during the summer months. The boilers for waste incineration are also extremely expensive investments due to flue-gas scrubbing implications, leading to a need for long operating times for them to be cost-effective.

The investment in a massive biomass-fired power and heating **plant blocks the options for other technologies.** The risk is that the current situation, where the city’s mandate to regulate commercial firms that act in a market that resembles a monopoly is not strong enough, will result in decisions largely being made in view of short-term commercial goals rather than goals that are more beneficial to the public economy in the long term.

Since future energy supply is not only about fossil or renewable fuels, but about resource efficiency as well, the city plans to conduct studies on how energy can be moved between buildings, stored between daytime and night time (24-hour energy storage), and stored between summer and winter (seasonal energy storage). If Stockholm reaches the decision through these studies that energy storage is resource-efficient for a reasonable cost and that it should be implemented in the city, the space for energy storage must be incorporated early on in the planning process. Voluminous energy storage facilities are out of the question in an urban environment. Possible alternatives are geothermal energy storage systems underneath buildings (which however make it impossible to bore tunnels underneath a building), hydrogen gas storage (which probably requires special safety arrangements) and battery storage for electricity

Know-how is a factor that affects the desire to try this technology, even though the technology itself is not new. A great increase in knowledge is needed for the technology to be more widely used.

4.4.3. **Outlook**

Since the city’s supply of energy for heating is largely expected to become CO_2-neutral through greater investment in biomass-fired heating and power plants alone, and since the electricity supplied in the national network is already 98% CO_2-neutral today, the large-scale solutions for conversion to a future CO_2-neutral Stockholm are already in place. One future attractive scenario might be to develop the current network according to the principles for open district heating and smart electricity grids, and to use it to store and move energy loads so that heat pumps, solar and wind energy facilities at the building and neighbourhood level can be connected to it, building resilience into the system. Greater variation and flexibility are needed if the energy supply is to be less vulnerable during unanticipated extreme events.

However economic incentives for players to do so today are limited. This would need to be addressed at both the national and municipal levels. A change to market conditions could also affect the situation. For example, an expected greater demand for biofuels could lead to higher prices, causing other energy sources to appear advantageous from a cost perspective. In such a situation it becomes even more important to direct the market away from coal and natural gas in order to achieve climate objectives.

Together, the four technologies selected provide flexibility and are necessary components of an efficient energy system for the city.

Open district heating and smart energy grid

The district heating- and energy grid can become the backbone of a future resilient energy system, transferring locally produced energy- and heat loads from producer to user.

Low-energy buildings

Reducing the energy demand of our cities is crucial to combat climate change as long as heating continues to produce CO_2 into the atmosphere. Reducing the energy demand of the built environment is one important step that in the long run will helping turning the cities from energy consumers to producers of energy.

At the moment the incentives to make the built stock, especially existing stock, more energy efficient is to slow, mostly caused by low energy prizes and lack of financing.

4.5. Vienna

4.5.1. **Background Information**

The **Smart City Vienna Framework Strategy** was adopted by the Vienna City Council in 2014 and contains 53 objectives in three major areas (resources, innovation and quality of life). The following objectives are the most relevant in the context of energy and Urban Learning:

- Per-capita greenhouse gas emissions in Vienna drop by at least 35% by 2030 and by 80% by 2050 (compared to 1990)
- Increase of energy efficiency and decrease of final energy consumption per capita in Vienna by 40% by 2050 (compared to 2005).
- At the same time, the per capita primary energy input should drop from 3,000 watt to 2,000 watt.
- In 2030, over 20%, and in 2050, 50% of Vienna's gross energy consumption will originate from renewable sources.

The above mentioned document provides a very important framework for the City, but it is not binding. Other highly relevant instruments include the Vienna Building Code (Urban and Spatial Planning Act for Vienna) and the STEP 2015 (Stadtentwicklungskonzept). The STEP is divided in eight major subchapters that include topics such as mobility, greenspace management and providing space for the growing population. Several thematic concepts (e.g. greenspace and mobility) supplement the STEP and provide objectives and measures as to how to achieve those measures in the respective field.

However, there are currently a number of processes underway that will enable Vienna to achieve its energy and climate objectives and to integrate energy issues and new technologies/combinations of technologies much better into urban planning matters to ultimately achieve integrated urban energy planning. Most importantly, a strategic working group is currently developing an **energy strategy** (Energierahmenstrategie) for the City of Vienna which is supposed to be finalized and adopted by the city council by the end of 2016. The strategy builds on the Smart City Vienna Framework strategy and will serve as a framework document for all other energy-related documents in Vienna. Vienna has been working with an energy efficiency program (SEP) since 1993 and is updating its efficiency measures in 10-year increments. A new 10-year program is currently being developed. Vienna also has developed a document that includes hundreds of measures to protect the climate in Vienna (KliP, climate protection program; the Vienna SEAP is based on measures in the KliP). The first Klip was launched in 2000 and is valid for 10 years; KliP II contains measures until 2020. This new strategic process is intended to draw the most important objectives, measures and elements from a number of already existing documents (SEP and Klip) and harmonise all efforts at the strategic level.

Another very important process was initiated on December 1st – the development of the **thematic concept "integrated energy planning"** (Fachkonzept Energieraumplanung). The energy planning department of the City of Vienna is in charge of the process and was responsible to put together a working group (core group) which includes planning and energy experts from different departments as well as representatives from the energy and grid providers. A steering group (consisting of high level administrators) as well as a legal specialist oversee the process and feed critical issues to their respective departments for discussion. The working group intends to conclude the process (energy planning concept) by the end of 2017. The document will serve as a very important framework document that merges energy and urban planning issues and guides urban development in the City of Vienna.

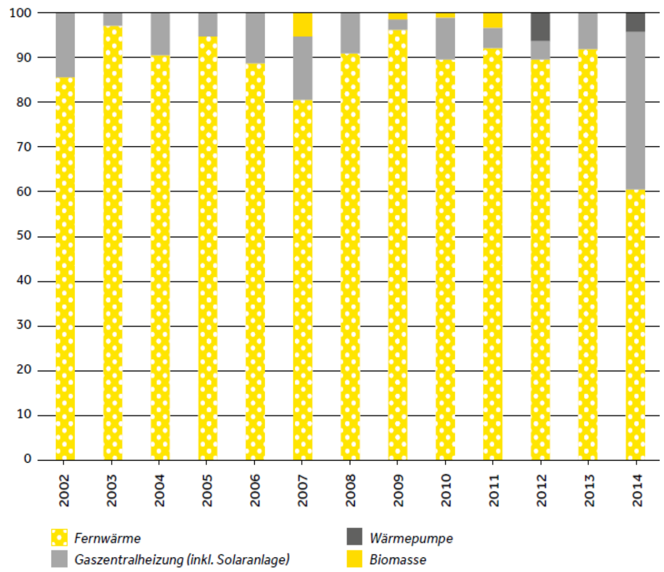
In parallel, another important working group (**working group: Stadtteilenergieversorgung**) will work on how to supply new urban developments with energy – it was also recently launched and it is going to meet approximately four times/a. Simultaneously, another "**political working group**" was created whose task it is to coordinate efforts on how to better integrate energy in urban planning matters between the two administrative groups in the City of Vienna most relevant for urban energy planning (Environment and Vienna public utilities and urban development, traffic and transport, climate protection, participation). There will be a continuous exchange between the two groups to ensure expedient and effective decision-making.

The energy provider "Wien Energie" also decided in 2016 to enlarge the Viennese district heating network wherever and whenever economically and technically feasible. The grid operator also expressed a strong interest in reducing development costs for new infrastructure and in avoiding any type of redundant provision of services. At the same time, the city subsidizes efforts in the following areas: energy efficiency, renewable electricity (photovoltaics, electricity storage, hybrid collectors) and renewable heat (solar thermal, heat pumps, seasonal heat storage).

These intertwined efforts are supposed to move Vienna toward a transformed energy system which promotes decarbonization, the use of renewables, energy efficiency and reduces overall energy consumption.

4.5.2. **Technical Solutions**

The following chart shows the share of heat supply technologies in new subsidized residential buildings. It might be reasonably assumed that the picture looks rather the same also for privately funded residential buildings. Depending on the location of the building, either the gas network or the district heating network or both are available, as the predominant part of Vienna is connected to a grid-bound energy source.

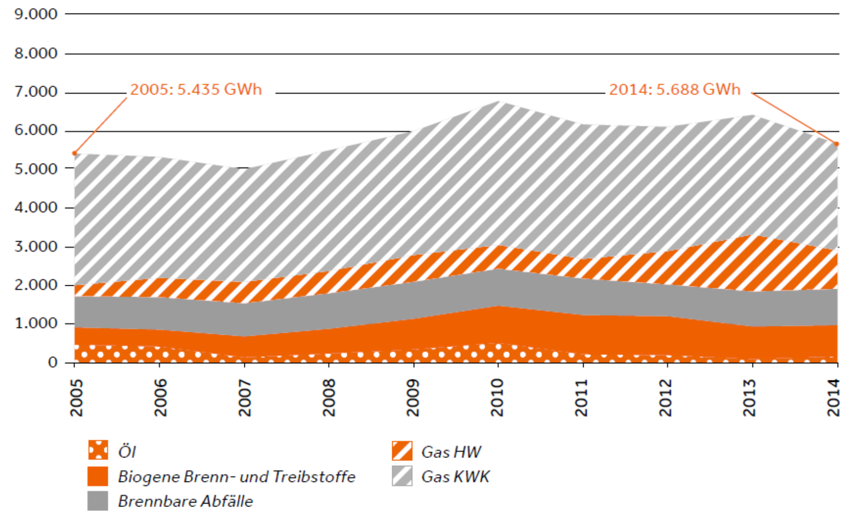


Fernwärme = district heating
Wärmepumpe = heat pump
Gaszentralheizung (inkl. Solaranlage) = central gas boiler with solar thermal collector
Biomasse = biomass

Figure 19: Heating supply in new subsidized residential buildings in Vienna (Source: Energy Report Vienna, 2016)

If the building is connected to the gas network, a central gas fired condensing boiler is installed. The distribution of heat inside the flats is mainly realised by a medium temperature radiator. Since 2012 the builders are obliged to install also a defined amount of solar collectors on the building, if gas is used.

If the building is connected to the district-heating network the heat distribution system is mainly realised by a medium temperature radiator. Since 2016 the district heating operator (Wien Energie) requires (by contract) a maximum supply temperature of approx. 65 °C. The hot water supply is realised by a fresh water station. The graph below shows the district heating production mix in Vienna.



Öl = oil
Gas HW = gas fired hat plant
Biogene Brenn- und Treibstoffe = biogenic combustibles and fuels
Gas KWK = gas fired CHP
Brennbare Abfälle = combustible refuse

Figure 5: District heating production mix in Vienna (Source: Energy Report Vienna, 2016)

4.5.3. **Outlook**

Vienna has just initiated a number of processes in order to be able to achieve its energy and climate objectives including the development of an energy strategy, an energy framework concept as well as 2 additional working groups that deal with energy supply of new urban developments.

In a typical development area the buildings have a high quality thermal envelop (low or nearly zero energy buildings) and are connected to a grid-bound energy source (gas or district heating).

Innovative development areas aim at using on-site energy sources (ground source heat pumps, solar thermal, PV and surplus heat) and, if necessary, use the grid-bound energy sources as backup.

The concept wind/power-to-heat shows a high potential for wide multiplication, as the realization is rather easy and cheap. It offers a good possibility for the storage of surplus electricity of volatile producers, increasing the share of renewables in the energy system and is financially attractive for the energy supplier as well as the customer.

4.6. Warsaw

4.6.1. **Background Information**

Almost a decade ago the City of Warsaw, aspiring to become the “green metropolis”, set itself a prospective goal of ensuring a high standard of living for its inhabitants in conditions of sustainable development. Once the city heard about a new initiative under the patronage of the Commission – Covenant of Mayors – they analyzed the matter thoroughly. Ambitious reduction goal of the Covenant was especially challenging for the City of Warsaw, taken into consideration that in Warsaw energy consumption and related emissions were growing.

Nonetheless, the city decided to join in 2009, while in 2011 the city adopted the resulting Sustainable Energy Action Plan. It calls for reducing both CO_2 emissions and energy consumption by 20%, while increasing share of renewable energy to 20%. In turn in 2015 the City of Warsaw adopted the Low-

Carbon Economy Plan, envisaging expenditure of four billion Euros for investments improving both air quality and energy efficiency. The Warsaw's strategic documents and projects include all elements which implementation the city considers crucial for making cities truly energy-efficient and sustainable:

- Production of clean energy (also from waste), in particular in cogeneration;
- Energy-efficient buildings and districts;
- Sustainable transportation, including e-mobility;
- Preserving green spaces and conservation of wildlife;
- Smart city, friendly to use and live in for its citizens.

The City of Warsaw supports development of dispersed installations renewable energy sources employed by small producers both using renewable energy for their own purposes and selling it to the grid-prosumers. The above is connected with supporting modern electric mobility, in which vehicles and their charging infrastructure are adapted to transferring electricity back to the grid.

Electric mobility and other forms of sustainable mobility (e.g. city bike system, car-sharing) are also to assist in reducing GHG emissions, which have been increasing in transportation sector in recent years due to growing number of private vehicles in Warsaw.

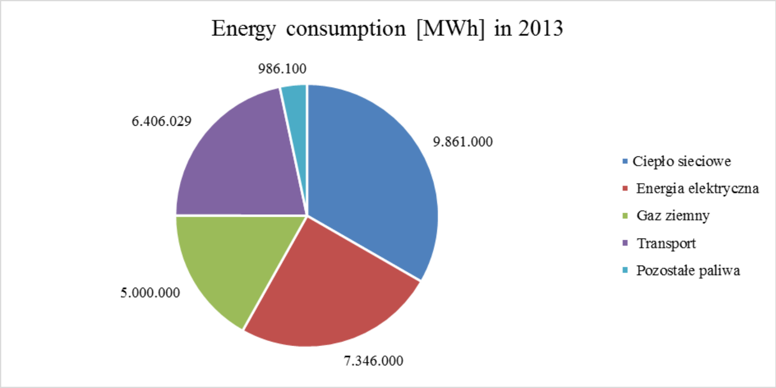
The basis for the energy system in Warsaw are two large combined heat and power plants of CHP Siekierki and CHP Żerań, two large heating plants and a number of smaller sources. The CHPs operate in cogeneration mode In contrast to typical power plant the waste heat is not squandered into the air or in river water but used for heating buildings and producing domestic hot water. As a rule the volume of electricity production depends on how much of the waste heat can be picked up by the district heating system. So the more buildings are heated by CHPs, the more electric energy can be produced. This means also the bigger energy security for Warsaw as Warsaw is not energy self-sufficient and missing part of the demand for electricity is taken from the National Power System.

4.6.2. **Technical Solutions**

The crucial challenge is changing energy mix in the Warsaw CHPs and heat plants, which is still predominantly based on coal. However, owner of the plants – PGNiG Termika – recently opened a large block utilizing biomass. Another block, utilizing natural gas, is to be operational in 2017. Nonetheless, further steps need to be made, which constitutes a huge challenge for cooperation of the local energy companies with the city. The issue is also heavily influenced by existing and planned regulations concerning emissions from energy sector and assistance for renewables, which are formulated by the Polish central authorities.

All crucial actions implemented and planned for next years in our city – mainly differentiating fuel mix, utilizing e-vehicles as backup reservoirs of electricity and reducing energy consumption by various methods (e.g. by changing consumers' behaviour or introducing smart metering) – are aimed to improve energy security of the City of Warsaw and its adjacent municipalities, while simultaneously reducing emission of GHG and pollutants.

The total length of the double heating pipes is 1,763 km, including 647 km of pre-insulated technology. District heating supplies 18,600 buildings with 15,000 substations. This represents 78% of the demand of the city heat.



Ciepło sieciowe – District heating

Energia elektryczna – Electricity

Gaz ziemny – Natural gas

Transport – Transportation

Pozostałe paliwa – Others

Figure 20 : Energy consumption Warsaw 2013; Source: Own research

The Warsaw district heating (DH) system operated by Veolia Energia Warszawa S.A. is one of two largest DH systems in the European Union. It comprises over 1,700 km network and supplies heat to 19,000 buildings in Warsaw, covering 65% of the needs of the capital and servicing almost 80% of the population of 1.7 million. Currently about 90% of the district heat is produced in cogeneration. The efficiency of Warsaw CHPs is about 90% in the year. Cogeneration in Warsaw saves 1.5 million tons of CO_2/a compared to separate production of the same volumes of heat and electricity. However, the system needs both further expansion and technical improvements. As to DH, it will include e.g. modernization of substations and group substations and implementation of project of Intelligent Heating Network.

Modern infrastructure allows monitoring and integrated management of each of its elements at a distance. The technologies will remotely control the work of three pumping stations, 79 heat chambers and 2.5 thousand substations. Until now, every change settings took place at the site to locate the individual elements. As a result of the reconstruction of the entire management will be carried out from one center of decision-making. The system will also provide dispatchers instant access to the necessary data, and "tell" the optimal solution based on a mathematical analysis of current and historical data. It will be applied in a central heating network in Warsaw.

The main tool for energy planning at the local level are **the assumptions for plan of supply with heat, electricity and gas fuels** which is an inventory of all energy systems with current demand and forecast on energy demand. At present the draft assumptions are at the consultation stage. Description of the energetics of the city, along with the forecast demand as a resolution of the City Council will be publicly available in the form of tables of numerical data in Excel format. In the future, the data bank, which are the assumptions, will be transformed into an active database with formulas allowing for decision-making calculations.

Energy policy of Warsaw establishes preferences of the power supply to heat buildings:

- Heating network
- RES
- Gas
- Electricity network

These priorities are set in view of the specific situation in Warsaw. Warsaw heat and power plants have no cooling towers. Water cooling from the Vistula is only possible in emergency situations. Consequently, the volume of electricity produced in CHP depends on the amount of heat taken by the district heating network. The more heat is taken up by the district heating network, the bigger the electricity production and the bigger city's energy security. Renewable energy installations should be located in areas outside the district heating network in order not to decrease the possibility of production of electricity in combined heat and power plants.

4.6.3. **Outlook**

There are strict energy performance implications for building construction and renovation, nevertheless the Warsaw heating technology and the electricity production is still based on fossil fuels.

Implementation of intelligent heating network in Warsaw can close the capital to the model of Smart City. Smart grids is one of the essential elements of the modern concept of the Smart City, or town managed in an environmentally sound, cost-effective, functional and efficient, using the latest available information and communication technologies.

Low-carbon development projects are seems as a good solution for energy demand decreasing. On the other hand in the area of Industrial Targówek there is an excess supply in both the heat source as well in the diameter of the pipelines which are nearby. From the standpoint of energy security of the city, the more buildings are connected to the district heating system the greater energy security. It is because two Warsaw's combined heat and power plants can produce more electric energy in cogeneration.

Power and heat generation in the Wastewater Treatment Plant "Czajka" uses various technologies of energy saving and recovery in one place. It is a good example of the integrated energy planning on local level – and it will be even better one once plans on adding PV panels are approved (possibly in 2017).

4.7. Zagreb

4.7.1. **Background Information**

Total energy consumption in 2015 in Zagreb amounted to 52.2 PJ. In the structure of total energy consumption, the largest share refers to the final energy consumption (86.6%), followed by energy transformation losses (4.4%), distribution losses (4.4%), direct non-energy consumption (2.9%) and energy for power plants (1.6%).

Analysis of the structure of energy forms in total primary consumption shows that the largest share belongs to natural gas – 43.2%, followed by petroleum products with a share of 33.9%, electricity ("import" outside of the city area) of approximately 17.5% and firewood by about 3.8%. Other renewable energy sources (except fuel wood) occupy about 1.6% share in the structure of total energy consumption.

Of the total energy consumption in the City of Zagreb, only 1.2% of energy is produced in the city. Export of energy outside city area is about 3% in relation to consumption which means that all the energy consumed in the City of Zagreb is "imported" from outside the boundaries of the City of Zagreb.

Final energy consumption in 2015 amounted to 45.2 PJ. The largest share, according to the form of energy, belongs to petroleum products (32.1%), followed by natural gas with a share of 24.9%, electricity 24.1% and thermal energy with 13.6%. Fuel wood occupies about 4.4% of the final energy consumption while other renewable energy sources account for only 1%

Looking at final energy consumption by sector, the largest share of final energy consumption is in the households' sector which in 2015 amounted to 38.1%. The transport sector is the second largest with respect to consumption, whose share in the total final energy consumption was 28.2%, followed by the services sector with a share of 22% and the industrial sector with 11.4%. Agriculture consumes only 0.3% of the total final energy consumption.

Goals and Features

Main long- and medium-term energy plans on the city level are Sustainable Energy Action Plan (SEAP) and Energy Efficiency Action Plan (EEAP).

With adoption of Sustainable Energy Action plan the City of Zagreb has pledged to reduce CO_2 emissions by at least 21% by 2020 (in comparison to 2008) although the analysis showed that even more ambitious goal of 25% would be attainable. Activities envisaged in the SEAP shall reduce energy consumption in buildings sector (both private and public), transport and public lighting. Proposed measures are further divided into those steaming from national legislation, those in the jurisdiction of the city, and measures that are funded and carried out on private initiative.

The activities with biggest potential for CO_2 reduction are subsidies for thermal insulation of the outer shell in the residential sector, implementation of individual consumption metering for apartments being heated by district heating, and development of integrated urban and suburban transport.

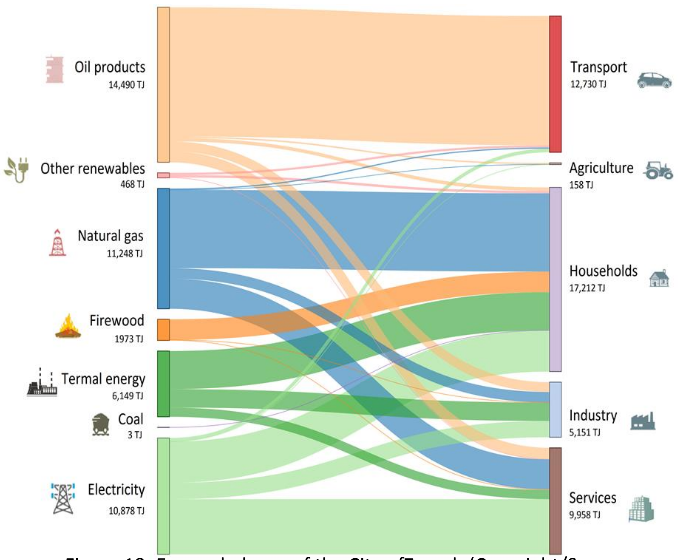


Figure 18: Energy balance of the City ofZagreb (Copyright/Source: City of Zagreb)

While buildings refurbishment and implementation of individual meters sometimes impose legal and practical challenges on the level of buildings and building code, the integrated transport asks for wider changes in space use and planning. Other measures with high impact on spatial planning are implementation of renewable energy sources in new and existing buildings, stimulation of new low- and nearly zero-energy buildings, and incentivising purchasing and development of infrastructure for alternative fuelled vehicles.

Time wise and scope wise, EEAP is smaller than SEAP and hence is the procedure of its development. EEAP is also obligation imposed by Energy Efficiency Act on counties and big cities, and covers activities related to improvement of energy efficiency in buildings and vehicles that are owned or maintained by the city.

4.7.2. **Technical Solutions**

Reaching energy performance indicators includes obligatory use of RES or alternative systems for new buildings and major refurbishments:

- at least 20% of RES share in total delivered energy or
- share in heating, cooling and SHW
  - At least 25% solar energy
  - At least 30% gaseous biomass
  - At least 50% solid biomass
  - At least 70% geothermal energy
  - At least 50% surrounding heat energy
  - At least 50% cogeneration based on RES
  - At last 50% district heating based on RES
- Or no obligatory RES share if heat energy demand is 30% lower than prescribed value

Decentralized RES facilities can be easily included in development projects while district heating systems require more complex and long lasting preparation due to infrastructure planning and construction. There are no completed projects with integral energy concept and energy performance indicators as required by Technical regulation but many energy refurbishment projects are oriented on use of RES or heat retention to achieve energy savings.

While buildings refurbishment and implementation of individual meters sometimes impose legal and practical challenges on the level of buildings and building code, the integrated transport asks for wider changes in space use and planning. Other measures with high impact on spatial planning are implementation of renewable energy sources in new and existing buildings, stimulation of new low- and nearly zero-energy buildings, and incentivising purchasing and development of infrastructure for alternative fuelled vehicles.

Decentralized RES facilities can be easily included in development projects while district heating systems require more complex and long lasting preparation due to infrastructure planning and construction. There are no completed projects with integral energy concept and energy performance indicators as required by Technical regulation but many energy refurbishment projects are oriented on use of RES or heat retention to achieve energy savings.

In order to encourage the implementation of energy efficiency measures and the use of renewable energy sources, the City of Zagreb needs to lead by example and show the benefits of the measures both for the individual and the society. The project ZagEE – Zagreb Energy Efficient City supports the realization of energy savings by using economically viable, energy-efficient technologies and measures to 87 public buildings including the building of the city administration, primary and secondary schools, kindergartens, homes for the elderly, health centers and local self-government buildings that are owned by the City of Zagreb as well as the modernization of the 3,000 LED street lightings with steering control.

The project is implemented within the framework of the IEE program for technical assistance 2012 – mobilization of local energy investments and includes the funding of technical assistance and making of the necessary documentation for the energy refurbishment of objects by awarding grants. This allows users to create projects, feasibility studies and to obtain the necessary administrative documentation needed to finance the energy refurbishment of objects from sources other than the city budget as well as foreign banks and EU funds.

Implementation of the project ZagEE began on 1 April 2013 and ended 31 March 2017. Investment should be completed during the next three years after the end of the project. The value of the project is 1,813,428 Euros, and the total planned investment value of the works on the implementation of the measures that will create technical documentation amounts to 29,379,114 Euros. The project partners are the City of Zagreb, as the leading partner, and the North-west Croatia Regional Energy Agency. The project is coordinated by the City Office for Energy, Environment and Sustainable development. The coordinating project body is responsible for the cooperation of all city offices and other relevant stakeholders in meeting their specific activities defined by the project within certain costs and time constraints.

The energy refurbishment of public buildings includes the application of standard energy efficiency measures (refurbishment of facades, roofs, exterior carpentry, interior lightning, replacement of energy etc.) as well as the application of systems of renewable energy sources (solar collectors and photovoltaic systems) on these buildings. By implementing the mentioned activities, it is expected that the average energy savings will be 49% on buildings and that the achieved energy savings will amount 32,056 MWh/a. At the same time, by implementing energy efficiency measures, the greenhouse gas emissions are expected to decrease by 8,043 tons of CO_2/a. By raising the building's energy class to B, according to the Ordinance on energy audits of buildings and energy certification of buildings aims to ensure a healthier and more comfortable environment for the public building users with significantly lower costs for energy and the maintenance of the building.

By modernizing parts of the public lighting system energy-inefficient public lighting will be replaced by LED lights with a special regulation of lighting at night. By increasing functionality and energy efficiency, it is planned to achieve average annual energy savings in the modernized system of public lighting in the amount of 1.47 GWh/a, reducing greenhouse gas emissions by around 347 tons of CO_2/a, a significant reduction in maintenance costs as well as reducing light pollution.

By launching investments for energy refurbishment, the local economy will get a significant boost through creating new business opportunities, new jobs, a contribution to positive economic developments and the promotion of economic development in general.

The public sector has a legal obligation to rationally and systematically manage the use of energy in all its facilities at the national, regional and local level. So he needs to be the initiator and promoter of activities for implementing measures for increasing energy efficiency and the reduction of the emission of harmful substances. The ZagEE project is the first project of this size and complexity in Croatia and region and the experiences gained through the implementation can serve as an example and guide for other public, local and regional self-governments who would like to implement the energy refurbishment of buildings in their area.

4.7.3. **Outlook**

The integrated measures based on analysis of each building were done and technical documentation was prepared and appropriate works as well. The City of Zagreb has been collected the data of energy consumption (gas, electricity and water) for all buildings in own ownership using smart metering and through the energy information system prepares the analysis needed.