H/C plan

City of Munich

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Introduction

Sustainability means that we use only as many resources as we need to meet our current needs and the needs of future generations (Brundtland Commission, 1987).

The construction sector is one of the largest consumers of energy and resources. Around 30% of global CO_2 emissions and 40% of resource consumption are caused by the construction industry. In Germany, the construction sector is also responsible for 54% of waste generation. The provision of heating, hot water and electricity alone accounts for 40% of final energy consumption. This illustrates the huge influence of the construction sector on the consumption of resources and energy. The average lifespan of buildings between 50 and 100 years shows the social responsibility for future generations when it comes to the design of the built environment and the sustainable use of available resources.

The aim of the Energy Plan for the City of Munich is to identify potential for energy savings and for the efficient, climate-friendly provision of energy for the heating and cooling of Munich's building stock.

On the basis of a thorough spatial analysis, paths of action have been developed, which lead to detailed measures for politicians, the administration and the public. The measures contribute significantly to the achievement of Munich's climate protection goals.

Climate protection goals of the City of Munich

In line with the German federal government's climate protection plan 2050 and the Paris climate protection agreement of 2015, the City of Munich declared to become a "climate neutral" city by 2035. The city administration

and the city owned companies have to reach the goal of climate neutrality in 2030, already.

With the city council resolution of 18 December 2019, Munich has declared a climate emergency. The city administration was commissioned to develop an action plan that defines a path to achieve climate neutrality for the entire city by 2035 and for the city administration by 2030.

To achieve this goal, the potential for reducing greenhouse gas emissions through energy saving in municipal properties should be exhausted. The passive house or the German so-called efficiency house 40 standard (EH 40) in combination with energy-efficient heat generation, the use of renewable energy systems such as solar energy in municipal properties and the introduction of a climate protection check in the decisions of the city administration should make a decisive contribution here.

Goals of Stadtwerke München (SWM)

Stadtwerke München (SWM) makes a significant contribution to Munich's energy transition with its own goals and by actively supporting the goals of the city of Munich.

SWM developed an ambitious District Heating Vision in the year 2012 to achieve the energy transition in the heating market.

The aim is to cover Munich's entire district heating demand on a CO_2-neutral basis. Geothermal sources will account for the major share of district heating in the future.

Furthermore, from 2025, SWM intends to produce as much green electricity in its own plants as the entire municipality of Munich requires.

The expansion of district cooling to replace individual air conditioning systems is a further component of SWM’s climate commitment. Energy consumption for cooling is reduced by using groundwater and city streams.

Facts & figures: the context

The City of Munich of Munich is the third largest city in Germany. Munich is the capital of Bavaria and has about 1.56 million inhabitants. The city is characterised by its ongoing growth and economic prosperity. Therefore, Munich's property market has always been under high pressure, although about thousand new buildings are built every year. In 2020, 8.300 new flats were built.

Energy standards of new buildings are quite high in Germany. However, the existing building stock is the main challenge of the heat transition. Munich has more than 300.000 buildings in total. About 172.000 heated buildings were identified based on the analysis of the Energy Plan. More than half of the buildings were built before 1978, when the first ordinance on thermal insulation came into force in Germany. The following map shows the main residential building types in Munich.

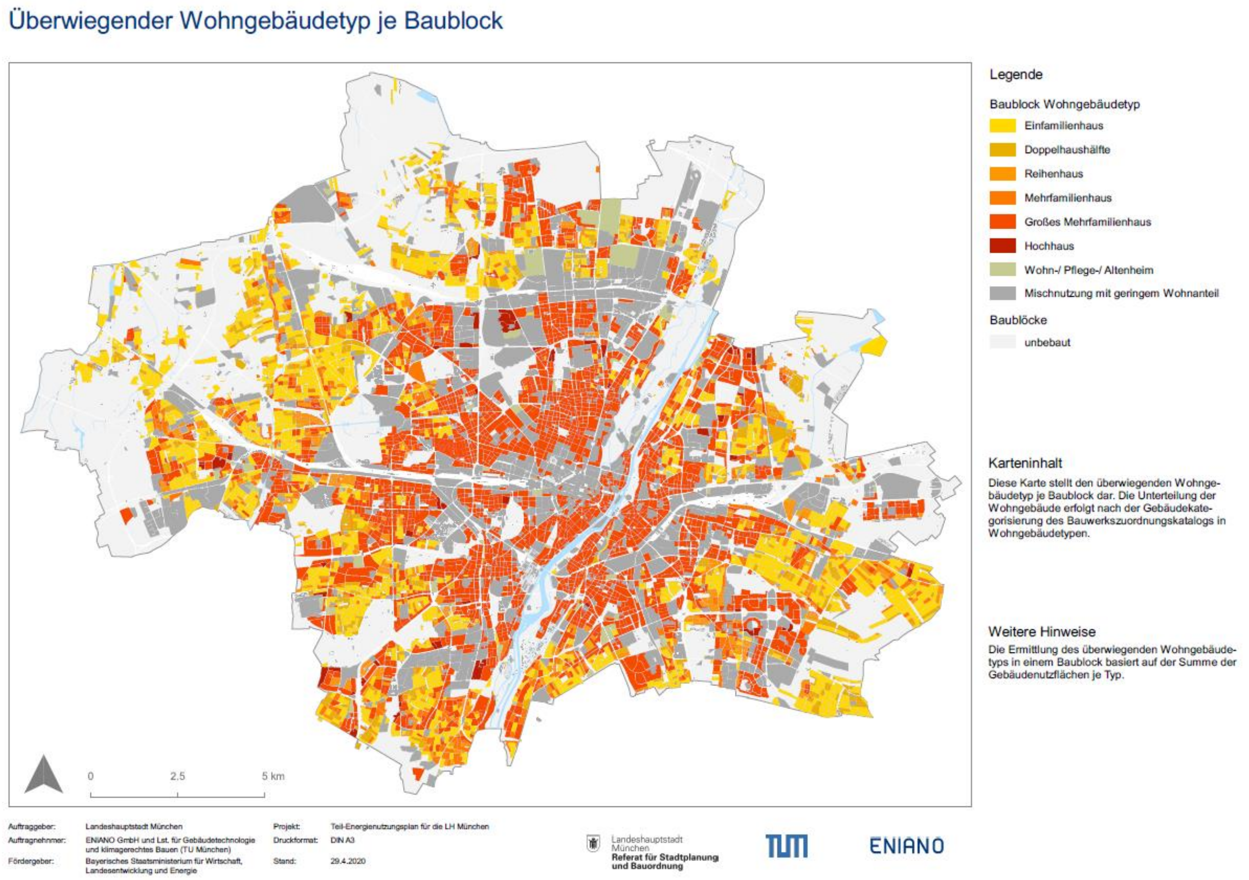

FIGURE 1: MAIN RESIDENTIAL BUILDING TYPES PER BLOCK (YELLOW: SINGLE-FAMILY HOUSES; ORANGE: SEMI-DETACHED HOUSES AND TERRACED HOUSES; RED: APARTMENT BUILDINGS, LARGE APARTMENT BUILDINGS AND HIGH-RISE BUILDINGS)

The Energy Plan (ENP) makes a significant contribution to achieving the climate protection goals of Munich and shows perspectives and recommendations for action for a sustainable and climate-neutral heat supply for the City of Munich. The development of a building-specific database forms the basis of a decarbonization strategy for the building stock. Minimizing heat-related greenhouse gas emissions through energy saving and the use of climate-friendly energy technologies is a top priority.

A key goal of the ENP is to accelerate and optimize planning processes with regard to energy management issues. The time-consuming data acquisition and editing of various data sources is no longer necessary with the ENP database.

Energy efficiency deficits within the districts are identified. Furthermore, the measures within the framework of the Energy Plan include areas of energetic refurbishment of buildings, the potential of solar thermal energy and near-surface geothermal energy as well as expansion potential for local and district heating systems. The measures define the technical scope for reducing heat demand and heat-related greenhouse gas emissions for the building stock.

Additionally, the ENP is an important source of information for the public and politicians. It also aims to make the population more aware of the issues of climate protection, sustainability, and energy efficiency.

Baseline information

The following figures were presented in in the framework of the heating and cooling outlook in Work Package 2.

Heat density

The following map shows the result of the heat density analysis. The heat density in the city centre and the in the quarters north of the centre is the highest. These parts of the city are very densely populated. The city centre includes the old town of Munich with many listed buildings and the main shopping streets. The quarters north of the city centre (Maxvorstadt, Schwabing) are characterised by multi-family houses from the end of the 19th and the beginning of the 20th century.

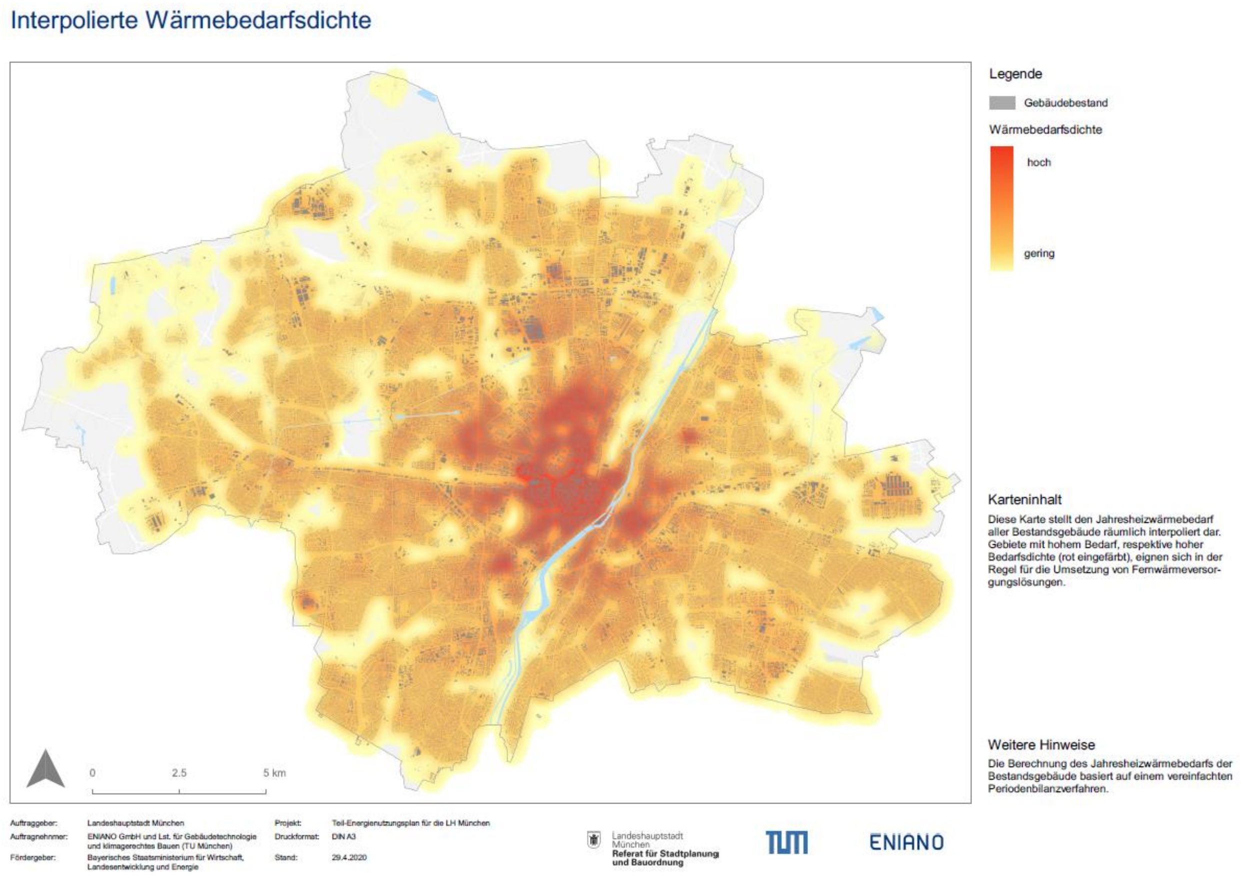

FIGURE 2: HEAT DENSITY MAP

Heat consumption

The heat consumption of residential buildings in Munich adds up to 6,3 TWh/a. Residential buildings have a share of 70 % of the total heat consumption.

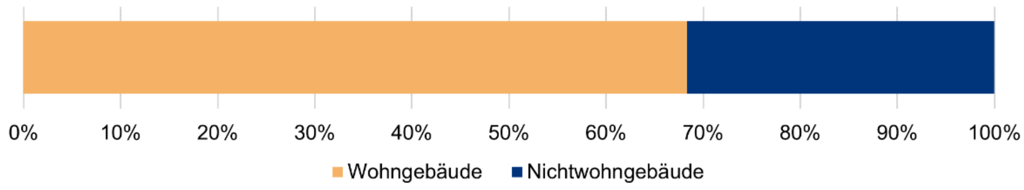

FIGURE 3: SHARE OF RESIDENTIAL (ORANGE) AND NON-RESIDENTIAL BUILDINGS (BLUE) OF THE TOTAL BUILDING STOCK

The analysis of the age and building structure shows that large apartment buildings from all age groups have the highest heat consumption. Buildings from the age group 1958 – 1968 have the highest consumption of all.

The yellow columns show the heat consumption of single-family houses. It is distinctly lower than the multi-family houses. But due to the high number of single-family houses, they have a significant heat consumption.

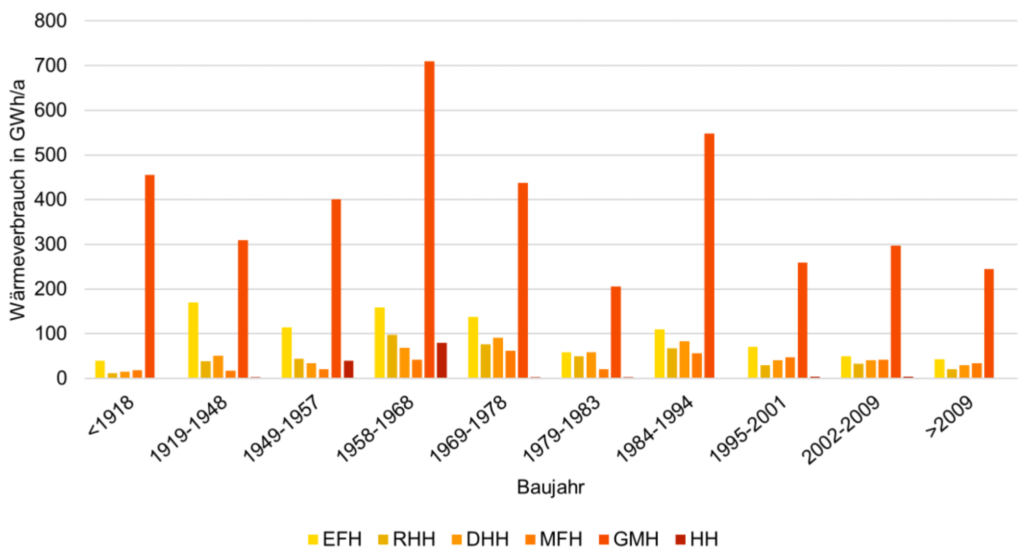

FIGURE 4 : HEAT CONSUMPTION OF THE BUILDING STOCK BY BUILDING TYPE AND AGE CLASS

Final energy consumption

The final energy consumption of all heated buildings in Munich adds up to 12,2 TWh/a. The highest share of the final energy consumption has gas, followed by district heating and oil:

Gas: ~7.000 GWh/a (57 %)
District Heating: ~4.200 GWh/a (34 %)
Oil: ~1.050 GWh/a (9 %)

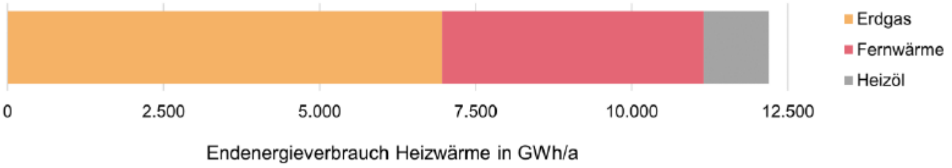

FIGURE 5: FINAL ENERGY CONSUMPTION IN GWH/A (ORANGE: GAS; RED: DISTRICT HEATING; GREY: OIL)

Heated buildings

About 172.000 heated buildings were identified and analysed in the Energy Plan. About 129.000 buildings (75 %) are heated with gas, about 31.000 buildings (18 %) are connected to district heating, and 13.000 buildings (7 %) still have oil heating.

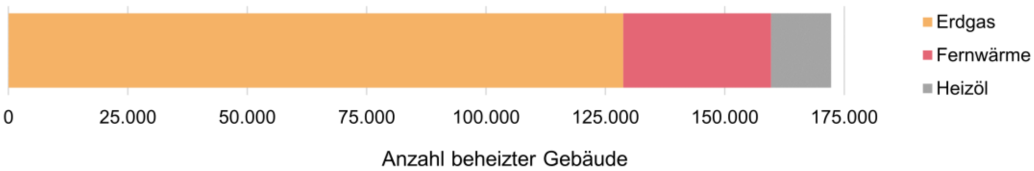

FIGURE 6: NUMBER OF HEATED BUILDINGS AND ENERGY SOURCES (ORANGE: GAS; RED: DISTRICT HEATING; GREY: OIL)

The following map shows the main energy carriers per building block. It shows the spatial distribution of the prevailing heating technologies very well. Gas is still the dominant source of heating. The map shows clearly that there are many blocks inside the district heating area that are heated with gas.

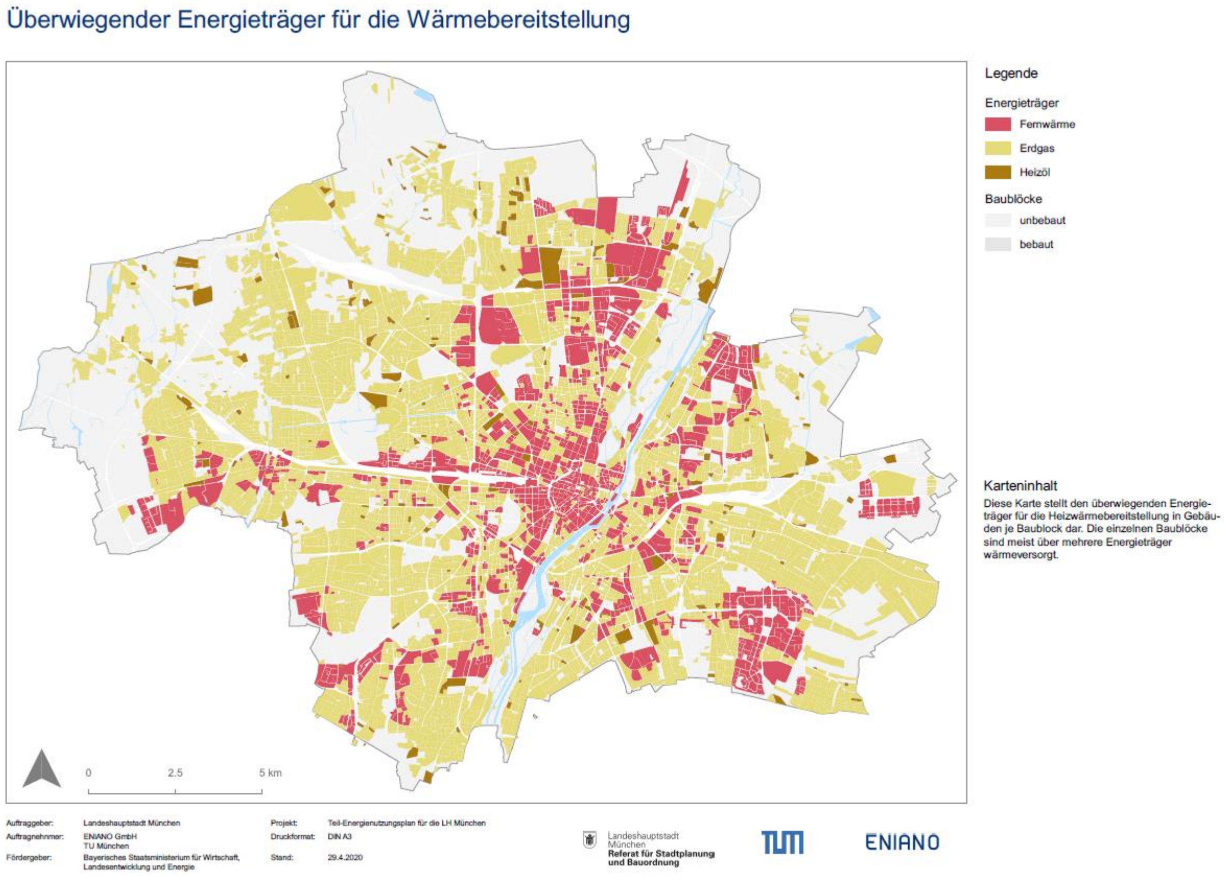

FIGURE 7: THE CURRENT PREVAILING HEAT SUPPLY ON BLOCK LEVEL (RED: DISTRICT HEATING; YELLOW: GAS; BROWN: OIL)

Process

In 2018, the project to set up an Energy Plan was commissioned to an external energy planner team (ENIANO and TU Munich). A working group with members from different departments of the City of Munich, Stadtwerke München (SWM) and other relevant stakeholders was founded to accompany the process ("Arbeitskreis Energienutzungsplan"). The Energy Plan (ENP) was set up in four phases, starting with an extensive phase of data collection and processing to create a building database. Essential steps in the first phase were, for example, the creation of a 3D building model of level of detail 2 from remote sensing data, the georeferencing of data sources or semantic transformations to harmonise data sets. The central result of this phase is a database (ENP database) that combines all relevant basic data for processing the Energy Plan from distributed data sources in a processed and documented format.

In the second phase, as part of the status-quo analysis, a digital image of Munich's building stock was created, which contains all available and energy-related information. In addition, the existing energy infrastructure of the heating sector was included in this model, which contains energy networks, heating (power) plants and renewable energy producers. These components form the basis of an energy system model that combines comprehensive results of the analysis of energy demand and energy supply as well as energy balances and greenhouse gas emissions. The result is a digital image of the heating and cooling sector and the building stock, which allows the virtual analysis and evaluation of future developments.

The third phase, the analysis of potentials, is based on the digital energy system model of Munich's current heating and cooling sector. It aims to determine the existing and future potential for energy savings and climate-friendly energy generation, and thus shows technical solutions for the implementation of the heat transition within the City of Munich. Paths of action were identified by comparing various technical options and scenarios. The paths of action form the basis of strategic consideration processes that include the given framework conditions such as climate neutrality, the available investment funds, the chronological sequence and interdependence of measures, etc.

Finally, the options for action and the coordination processes with relevant actors resulted in a comprehensive catalogue of measures with detailed instructions for implementation. The Energy Plan thus describes the medium and long-term path for the implementation of the heat transition in Munich, underpinned by projects and instructions.

In 2019, the external planners transferred the energy database to the data centre of the City of Munich. The final project report was completed in May 2021.

Framework and principles

An Energy Plan (in German: Energienutzungsplan, ENP) is an informal, strategic planning instrument that encompasses the entire area of a municipality. It formulates spatial energy efficiency objectives for energy generation, distribution, and consumption.

In Bavaria, the Ministry of Economic Affairs, Regional Development and Energy offers a funding programme to all Bavarian municipalities, which covers 70% of the cost for Energy Plans. Therefore, Munich's Energy Plan was set up according to the funding requirements. Based on the existing building stock, the Munich Energy Use Plan systematically estimated the current and future energy demands of the city. The comprehensive ENP database comprises data of about 172.000 heated buildings (e.g. age, main use, energy supply etc.) linked to a new 3D model, which was made from high-resolution aerial photographs of the entire city.

The 3D model enables planners to know the exact volume of each building, which is an important figure to estimate energy demands. Furthermore, more than 100 different data sources have been added to the model. The model will be updated regularly for example with real consumption data, information about demolition and reconstruction of buildings, and renewable energy production plants.

By spatially locating heat demands and renewable energy supply options, energy saving potentials have been identified within the city. The results of the Energy Plan are stored in the energy database, illustrated on detailed maps, and summarised in a catalogue of measures, which comprises targeted energy efficiency measures for the whole city.

Munich's deep geothermal district heating is an important component of the future energy supply system. Munich has an existing district heating network with a length of more than 800 kilometres. Currently, it is still mainly supplied by coal, gas, and waste incineration. The network supplies most of the city centre and central, densely populated districts with high energy demands in the north (e.g. Schwabing, Maxvorstadt, Milbertshofen), the south-eastern district of Neuperlach as well as the west of Munich including the new district of Freiham. The following figure shows the decision tree, which was developed to choose suitable measures for all buildings.

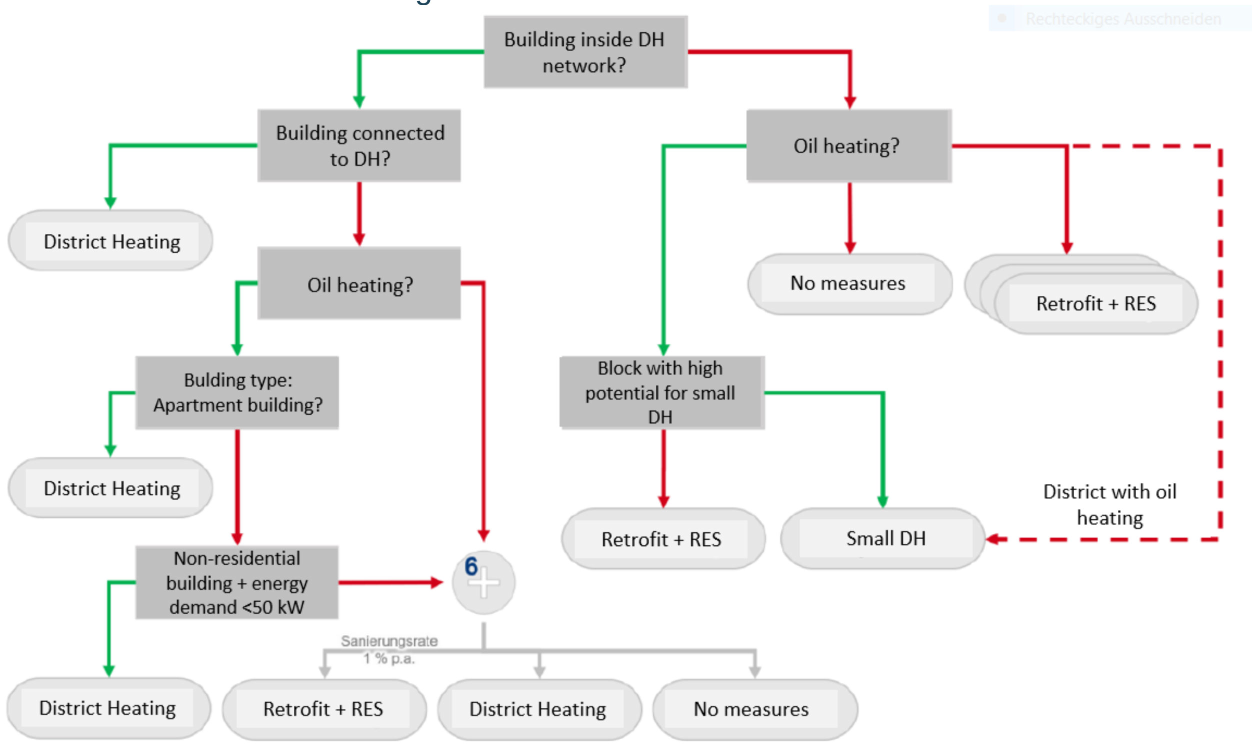

FIGURE 8: DECISION TREE FOR THE DEVELOPMENT OF MEASURES

The geological characteristics of Munich’s underground allow the use of deep geothermal energy from a depth of 2.000 metres up to more than 3.000 metres. This source of energy will account for the biggest share of district heating in the future. Therefore, a prerequisite for the scenarios of the Energy Plan was to favour district heating connections inside the district heating network and to concentrate the analysis on areas outside the district heating network.

Another framework condition was that large-scale solar parks and wind farms are not yet an option for renewable energy generation in Munich as the city area is quite small. However, Munich is situated in of the sunniest areas of Germany. There is a high potential for rooftop solar power systems, which has not been fully exploited, yet.

Small district heating networks and heat pumps were chosen to be the most suitable supply options outside the main district heating network. Analyses of hydrogeologists showed that the depth of ground water allows the use of decentralised ground water heat pumps in most areas outside the district heating network.

The Energy Plan was intended to develop a spatial heating and cooling strategy, which uses suitable renewable energy sources to phase out gas and oil heating in all parts of the city, based on the current building stock. The reduction of heat demand is as important as the transition to renewable energy sources. Thus, the most common German retrofitting standards were analysed for each building.

While the Energy Plan was developed, the city council of Munich decided to shift the climate protection goal of climate-neutrality from 2050 to 2035. This had no effect on the spatial assertions of the plan, but it means that all buildings in Munich must be retrofitted by 2035 already. At current prices, this means an investment for retrofitting (only insulation and windows) of about 13 billion to 22 billion Euros.
Munich’s Energy Plan is the basis for further planning steps, for example for integrated urban development concepts, preparatory studies, and integrated quarter concepts as well as for retrofitting managements.

Analysed data and aggregation

The Munich Energy Plan was created in four phases that correspond to the specifications of the Bavarian Ministry of Economic Affairs, Regional Development and Energy. At the beginning there was an extensive phase of data acquisition and processing to form an energy database. This included, among other things, the creation of a 3D building model from the remote sensing data of the “GeodatenService” Munich. The main result of this phase is the ENP database, which includes all relevant basic data for the building stock.

In the next phase, the status quo analysis, all available energy-related information about the building stock was determined and compiled into a digital image of the city of Munich in its current state. This included, for example, calculating the heat demand of all buildings using the 3D building model. The existing energy infrastructure of the heating sector was then integrated in the model. Comprehensive analyses of energy demand and energy supply as well as energy and emission balances were carried out using the model.

The analysis of potentials was carried out based on the current situation. It served to determine the existing and future potential for energy saving and climate-friendly energy generation, and thus shows technical solutions for the implementation of the heat transition in Munich. The range of potentials was limited to the most relevant components of the heating and cooling sector for Munich. The following potentials were examined:

- Retrofitting (for different German efficiency standards)
- Solar heat and photovoltaic
- Shallow geothermal energy
- District heating (from deep geothermal energy)
- Small / local district heating

The analysis of options and consultation with stakeholders from administration and science resulted in a comprehensive catalogue of measures with detailed instructions for implementation.

To map Munich's heating and cooling sector and its development for each building, all relevant available data was collected, documented, validated, and transferred to a uniform system. On the one hand, the data came from different departments of the City of Munich, which are usually stored there locally. On the other hand, other relevant basic and specialist data from external bodies were gathered and included in the ENP database.

The data collection included the basic geodata of the “GeodatenService” Munich, which form an essential basis of the Energy Plan and serve as a reference data set for the digital image of the building stock.

The data from the Department of Urban Planning and Building Regulations originate primarily from urban development planning, urban planning and urban redevelopment. This includes mainly information on land use, building uses, years of construction of buildings, listed (historical) buildings, conservation statutes and redevelopment areas.

The data of the (former) Department of Health and Environment contains essential information on the structure of the energy system model, on existing energy sources (fossil and renewable) and on oil tanks as well as on completed retrofitting measures. This data comes from the city’s energy efficiency funding programme.

Furthermore, energy consumption data of all municipal properties from the Building Department and the Department of Communal Services (real estate management) were included in the analysis.

To investigate the potential of near-surface geothermal energy in the city, data on drinking water protection areas and a groundwater model from the Technical University of Munich were provided by the Chair of Hydrogeology with high-resolution information on the hydrogeological conditions in the City of Munich.

Since all data had different statuses, the year 2017 was defined as the reference year for the Energy Plan. For data that is not collected regularly and older data, it was a particular challenge to indicate the status of 2017 as closely as possible. If more recent data were available, these were also used.

The analysis of potentials was divided in two parts: analysis of the building stock and analysis of heat infrastructure. The building stock analysis included different retrofitting scenarios for each building. About 70 combinations of German retrofitting standards with different heat supplies for each building in Munich were simulated and integrated in the database to form a comprehensive building model. Furthermore, a solar potential analysis was carried out that not only estimated the solar potential of the roofs itself, but also how many solar cells could be installed on the roofs. The results of this analysis are visualised on an aerial view of the city. The analysis of the potential of shallow geothermal energy from groundwater resulted in site-specific and building-specific information on the use of heat pumps. The results are also shown on maps available in the Geoportal (geoportal.muenchen.de/portal/energie).

The analysis of the heat infrastructure included basic information on the number and power of Munich's heat and power plants. Furthermore, an analysis of potential extensions to the existing district heating network was carried out. For areas with sufficient heat density, an analysis of potential small district heating networks was also included in the analysis.

H/C planning

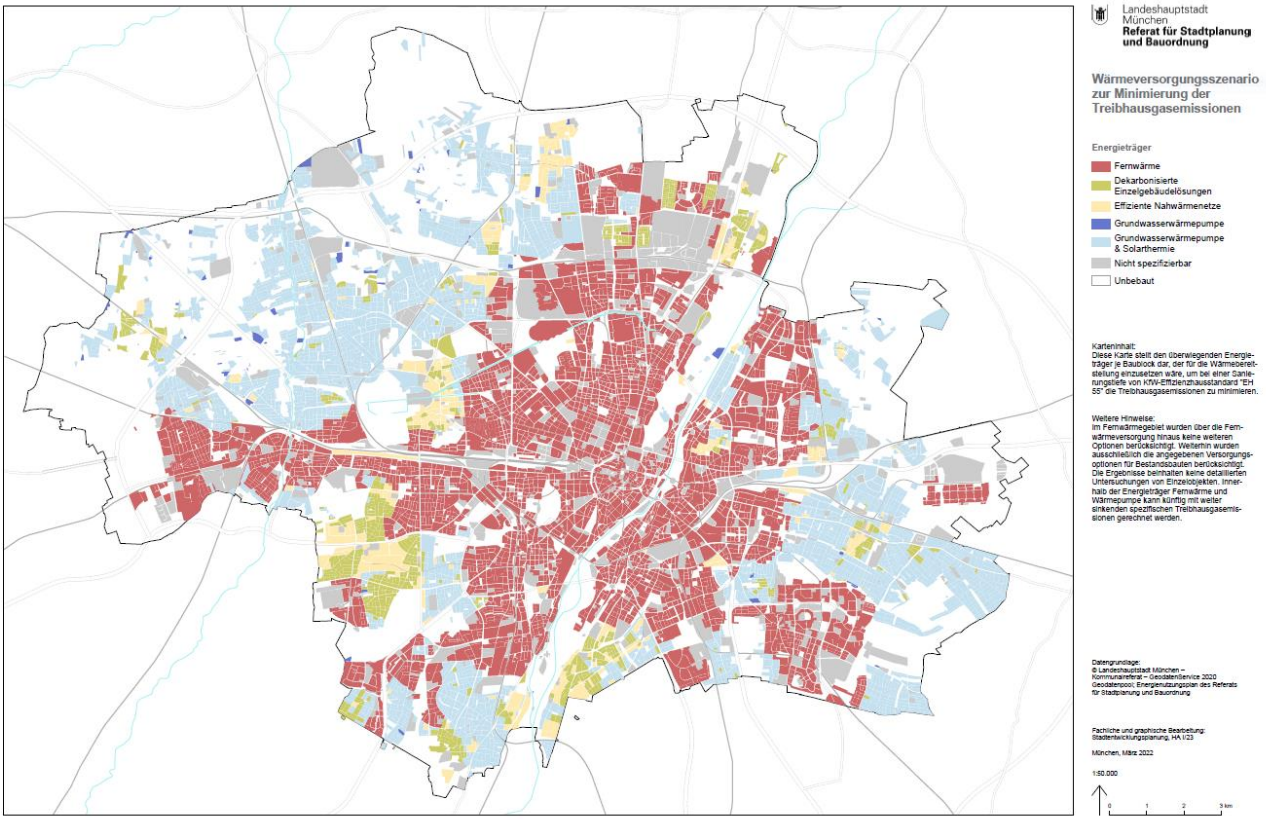

FIGURE 9: HEAT PLAN OF THE CITY OF MUNICH

The main result of the Energy Plan is the heat supply scenario above, which is Munich's current heat plan. It shows the future heat supply of Munich that is needed to reach climate-neutrality in the building sector. The map basically says that most of the 89.200 residential buildings inside the district heating network should be connected to district heating until 2035. The district heating areas are indicated red.

For the 83.200 residential buildings outside the district heating network, there are more options. The main strategy is to make all suitable buildings ready for heat pumps. The main source of energy for the heat pumps is groundwater (dark blue areas on the map) or groundwater heat pumps in combination with solar heat (light blue areas on the maps).

Yellow areas on the map show potential areas for the development of efficient small district heating networks. The green areas indicate areas with various buildings that need decarbonised building-specific solutions in a more detailed analysis on building level.
In a second approach, it was calculated which measures would be necessary in the short-term to reach at least 33 per cent of greenhouse gas emission reduction. Although this calculation is not in line with the goal of climate-neutrality in 2035, it still shows the huge effort which is needed in the building sector.

According to the calculations, inside the district heating network, it would be necessary to connect about 15.000 additional buildings to district heating. Furthermore, more than 5.400 buildings should be retrofitted and equipped with renewable heating systems.
Outside the district heating network, about 31.600 buildings would need retrofitting and renewable heating systems. 7.700 buildings would be suitable for small district heating solutions.
Even in this least ambitious scenario, about 60.000 buildings would need thorough measures to lower the heat demand and to replace fossil heating.

Next steps

As a next step, integrated quarter concepts will be developed based on the calculations of the energy plan. The quarter concept approach means that all relevant information from the energy plan database will be analysed in more detail on a smaller scale with the aim to develop integrated quarter concepts ("Quartierskonzepte"). The preparation of the quarter concepts will be done in close cooperation with local house owners to ensure the implementation of the concepts.

Furthermore, retrofit managers in each quarter will implement measures of the integrated quarter concept in cooperation with local actors. The preparation of the quarter concepts and the retrofit managers are funded by the German government. Intergrated quarter concepts must include energy efficiency measures (retrofit, renewable heating), climate adaptation measures and mobility solutions. Furthermore, a concept of an Energy Agency is being developed.

At the same time, an analysis of existing legal instruments to implement the heat transition will be performed. The analysis will focus on the German Building Code (BauGB) and the Bavarian Building Code.

DECARB CITY PIPES 2050

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