DECARB CITY PIPES 2050

REPORT ON DATA AVAILABILITY, DATA SOVEREIGNTY, QUALITY AND EXCHANGE IN THE PARTICIPATING CITIES AND POLICY RECOMMENDATIONS

Deliverable 2.4

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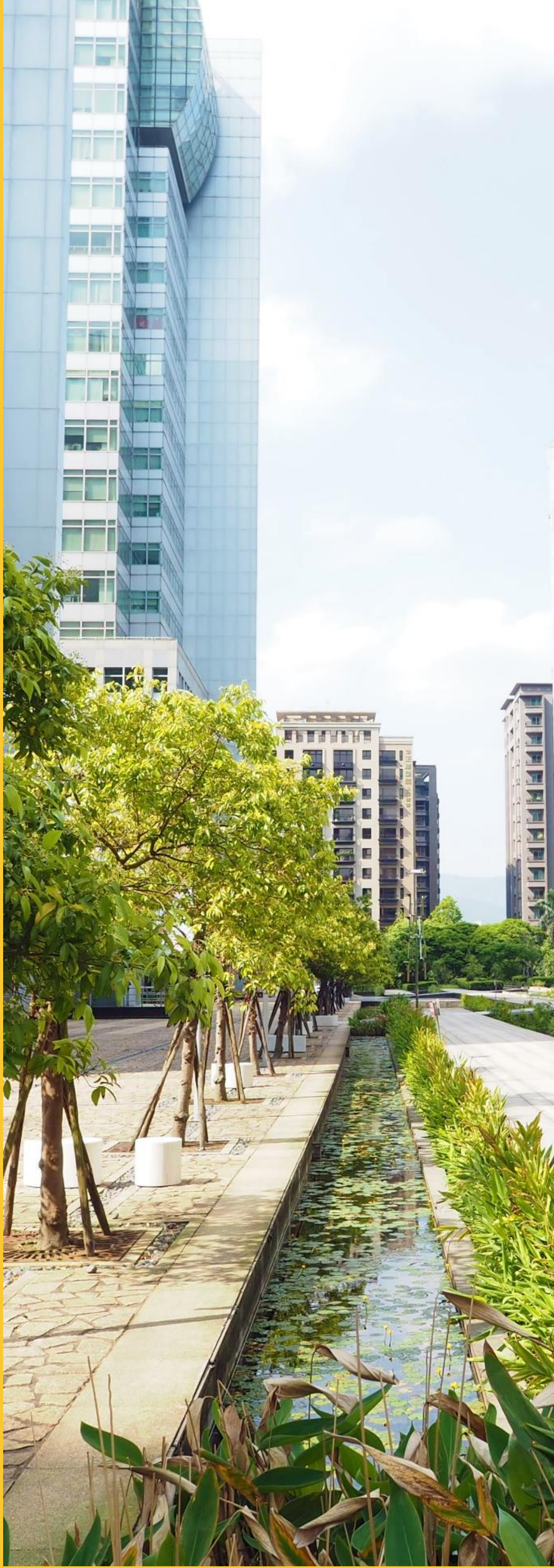

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Summary & Content

This report focuses on the issues of data governance & sovereignty and data availability & quality. The chapters have been divided accordingly. Results were prepared together with the cities involved in the project (alphabetically): Bilbao, Dublin, Munich, Rotterdam, Vienna and Winterthur. The results were generated through interviews with all participating cities, both in joint exchange rounds and in individual interview sessions.

The first central chapter on "Data governance and sovereignty", explores the question of how data is organised in cities, what basic data management looks like and how data is generally handled in terms of governance and sovereignty.
More specifically, it includes different approaches to topics such as, metadata, GIS infrastructure, data management, responsibilities and data protection/privacy.

From Bilbao to Winterthur, the second main chapter deals with the topic of data quality and availability in each city regarding energy demand, energy-related infrastructure and energy potentials. It was possible to derive common features and learnings from the cities, resulting in a city synthesis.

There are many similarities between the cities, especially in terms of challenges and aspirations. For instance, every city has its own energy demand model which is based on multiply data sources. The data sources are often the same, but with different terms, that are used. Calibration of energy demand models using real consumption data poses a main challenge to all cities.

Other common challenges refer to regular data updates or how to deal with green gas, as well as future ideas towards a digital twin. However, the availability of data is quite different in the cities. But, data quality is consistently rated better for residential buildings than for industrial buildings. The report concludes with general recommendations for cities.

Introduction

Data are the basis for energy-related calculations, plans or maps or, simply put, for decision-making processes. Therefore, it is not only important to generate and collect data, but also to process and prepare them in order to make them useful for the respective user. Furthermore, data also create information and facts, and help in building up trust. Thus, they are also an essential element for achieving climate goals.
In this regard, the City of Vienna emphasises the benefits of data in its city-wide Data Excellence Programme:

“Data [...] form the foundation for information and knowledge and are an essential production factor for a "smart, intelligent and digital" city. [...] the digital IQ of the city is increased by data” (Stadt Wien, 2019).

Data also help us to better understand the energy situation of buildings, cities or entire countries. One of the major challenges today is the decarbonisation of the heating sector. At the same time, cooling demands across Europe will also continue to increase due to rising temperatures especially in summer. Currently, however, only 23 % of gross final energy consumption for heating and cooling in the EU is covered by renewables (see Figure 1).

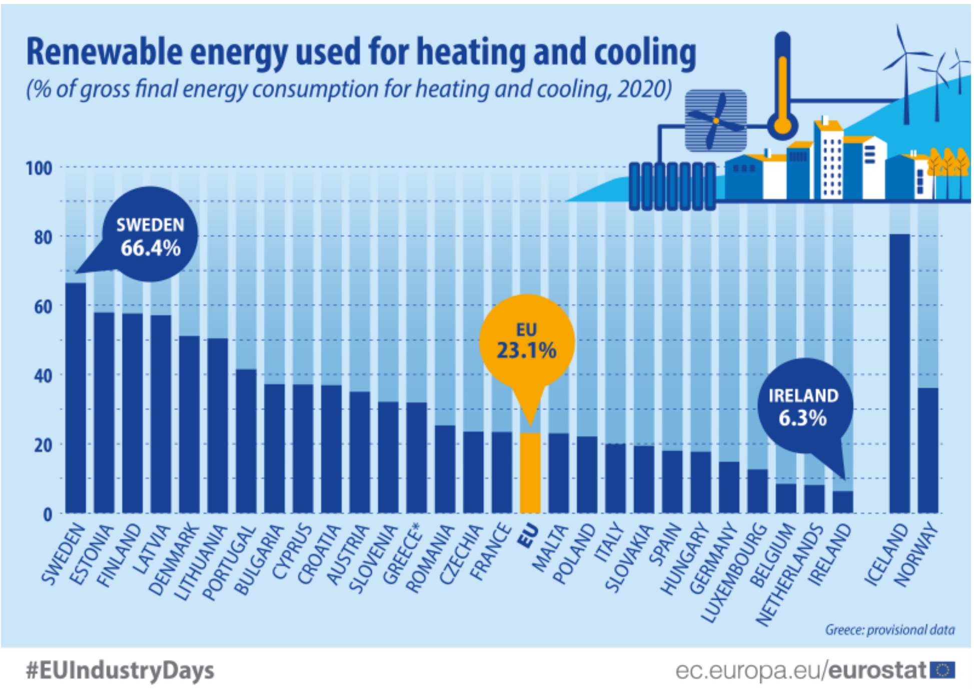

FIGURE 1 : SHARE OF RENEWABLE ENERGY USED FOR HEATING AND COOLING IN THE EU (EUROSTAT, 2022)

In addition to reducing energy consumption and increasing energy efficiency, the use of renewable energy sources for heating purposes also needs to further increase.

Maps are very well suited to provide decision-makers with a wide range of different information for energy planning. Areas can be identified with local potentials for renewable energy, in which refurbishment measures should be focussed, or in which densification and expansion of district heating is recommended.
The basis for such H/C maps1 is geodata - the focus of this report. The aim of this report is to identify relevant data that can be used to transform the energy system. More specifically, this report addresses the following questions:

- What data relevant for H/C mapping is available to the participating cities and its organisations?
- What data is necessary and available to develop a solid energy demand model?
- What is the quality of the data?
- Who is the holder of the data and who has access to the data?

In addition, this report also deals with issues related to governance, data management, metadata, GIS infrastructure, data responsibilities, data protection/privacy.
The report concludes with a comparison across all cities and an overview of common challenges and solutions.

This deliverable forms part of Work Package 2 on "Heating and Cooling Outlook 2050" of the Decarb City Pipes 2050 project and addresses one of the corner stones of developing the H/C maps of each city: Without data, H/C mapping is simply not possible.
The following chapter thus provides an overview of applicable data for H/C mapping. The chapter on "Data governance and sovereignty" explores how data is organised in cities, what basic data management looks like and how data is generally handled in terms of governance and sovereignty. This report also includes detailed information of cities with regard to data availability and quality. Lastly, recommendations for other cities that point the way towards better and easier data generation, access and usage.

[1] In the course of the Decarb City Pipes 2050 project, six cities – Vienna, Winterthur, Bilbao, Rotterdam, Munich and Dublin – created their own Heating and Cooling Plan. These plans as well as a cross-city synthesis have been submitted/published under D3.3.

Data for H/C Mapping

Energy-related geodata are the indispensable basis when developing Heating and Cooling plans. Hence, this chapter will give a brief overview on data that can be used for H/C mapping. City-specific details on data availability and quality as well as data governance and sovereignty are part of the following chapters of this deliverable.
The term “data” in this report – if not otherwise stated – refers to geographic data (geodata). Geographic data refers to “data with implicit or explicit reference to a location relative to the Earth” (International Organization for Standardization [ISO], 2021)
A common approach for structuring energy-related geodata, as used in the specific concept for Integrative Energy Planning (Energy zoning) of the City of Vienna (Magistratsabteilung 20 – Energieplanung, 2019), is as follows:

- Energy demand
- Energy-related infrastructure
- Energy potentials

Energy demand data, for instance, incorporates the heating, cooling or electricity demand of buildings. Data on district heating (DH), gas networks and electricity networks are among the energy-related infrastructures. Infrastructure also includes energy storage systems such as geothermal heat storages. Within this project, the energy potentials comprise data on on-site renewable energy potentials (within and in the vicinity of the respective city), such as solar energy, geothermal energy, wind energy or waste heat.
In general, energy-related geodata is available on different spatial scales. For H/C mapping, the building or address point represents the largest scale, continuing with data on the building block, neighbourhood, district or province level. Regional statistical grids represent another option to calculate and visualise energy related geodata. In Austria, for instance, data for regional statistical grids are available from 100m x 100m up to 100,000 m x 100,000 m.
Figure 2 shows data as GIS vector data, including point-, polyline-, and polygon-features. The point features (black dots) represent address points within a certain area. Address-point layers commonly include data about street name, street number, units of use, building period etc. The grey polygon-features represent buildings from which the building footprint can be calculated or the corresponding gross-floor area can be derived. Polygon-features are also useful for visualisation purposes. The red and blue lines in Figure 2 show district heating networks in two qualities.

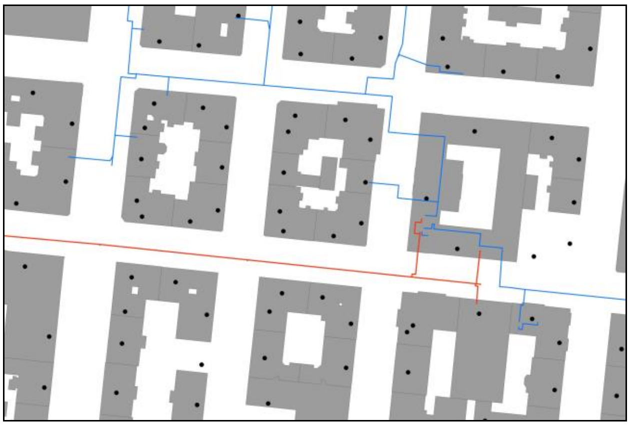

FIGURE 2 : VISUALISATION OF GEODATA (STADT WIEN, BUNDESAMT FÜR EICH– UND VERMESSUNGSWESEN (BEV), STATISTIK AUSTRIA)

An example for raster-based heating and cooling maps is the Pan-European Thermal Atlas: https://heatroadmap.eu/peta4/. In this case (Figure 3), energy related data was processed and finally visualised as a heat density map in a resolution of 100m grids.

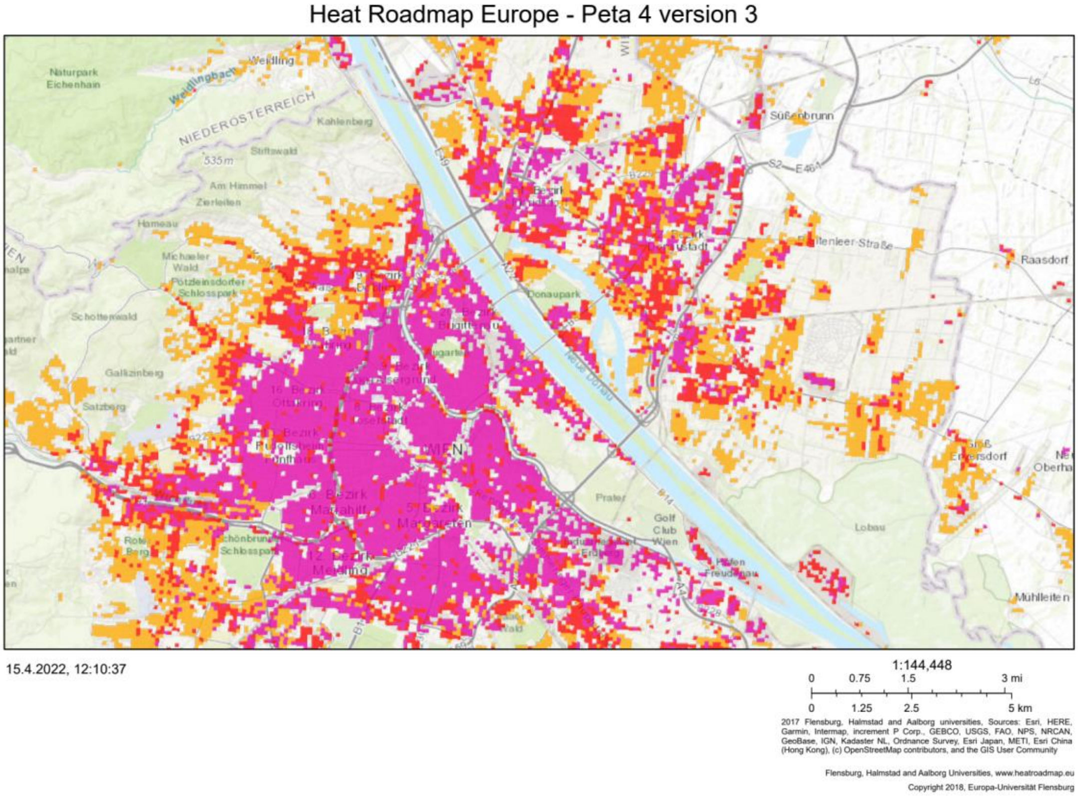

FIGURE 3 : PAN-EUROPEAN THERMAL ATLAS (WWW.HEATROADMAP.EU)

Concerning the modelling of geodata, it is also possible to distinguish between top-down und bottom-up modelling. Top-down modelling describes the process of calculating the energy demand from statistical units. Regional statistical grids are, for instance, such units. This way, inferences can be drawn about the energy demand of individual buildings. However, splitting the data into smaller units often compromises the quality of the results. If the right assumptions and calculation steps are chosen, then bottom-up modelling is the preferable method for generating energy data in high spatial resolution. As presented in this report, the participating cities of the project Decarb City Pipes 2050 all concentrated on bottom-up modelling and used specific data in high spatial resolution for their H/C maps.

In contrast to the visualised results of the Pan-European Thermal Atlas however, ready-to-use geodata is unfortunately not always available. Hence, relevant geodata has to be generated or modelled from different databases in order to obtain, for example, the final energy demand of a building. How participating cities of this project dealt with this issue and with the availability and quality of the data is explained in more detail in the chapter Data availability and quality.

Once valuable geodata is generated, another essential question arises: Who is the holder of the data and how is it handled within the organisation? Thus, the following chapter will deal with the topic of data governance and sovereignty.

Data Governance & Sovereignty

This chapter addresses data governance and data sovereignty, including city-specific examples. Starting with examples from Vienna and further examples from other cities, in particular Munich and Winterthur, an attempt is made to prepare the topic across cities. Principles and recommendations on the topic of data governance and sovereignty are summarized at the end of this report.
The amount of data in cities is increasing and so is the effort to deal with the data, to process it, to manage it and to make it available. For instance, Vienna's vision on data is to handle data

"as accessible as possible and as protected as necessary" (City of Vienna[2]).

The data excellence strategy of the City of Vienna3, details how the city wants to become a city of "Data Excellence". The city's strategy is based on three pillars:

- Data Governance (DG),
- Data Quality Management (DQM) and
- Enterprise Data Management (EDM)

According to the data excellence strategy, DG serves as the foundation for a company-wide coordinated data management, which is based on rules, organisation and processes. DQM includes quality-oriented organisational, methodical, conceptual and technical measures to control and manage data. The aim of EDM is to use data resources innovatively.

Figure 4 further illustrates the organisation of data excellence in the City of Vienna, with the Data Governance Advisory Board (Data Governance Fachbeirat) at the heart of the organisation and the data excellence group (MA 01 Wien Digital) and the Centre for Data Analytics (MA 23 Stelle für Data Analytics) as the central units. Towards the right side of the illustration, Data Stewards and Data Experts are the link to data users (Data UserIn) and data consumers (Daten-KonsumentIn) within the city. From there, stakeholders outside the city, the public population, the economy as well as science are addressed.

[2] *https://www.intern.magwien.gv.at/md-os/ikt/data-excellence.html*
[3] https://digitales.wien.gv.at/wp-content/uploads/sites/47/2019/03/Data-Excellence.pdf

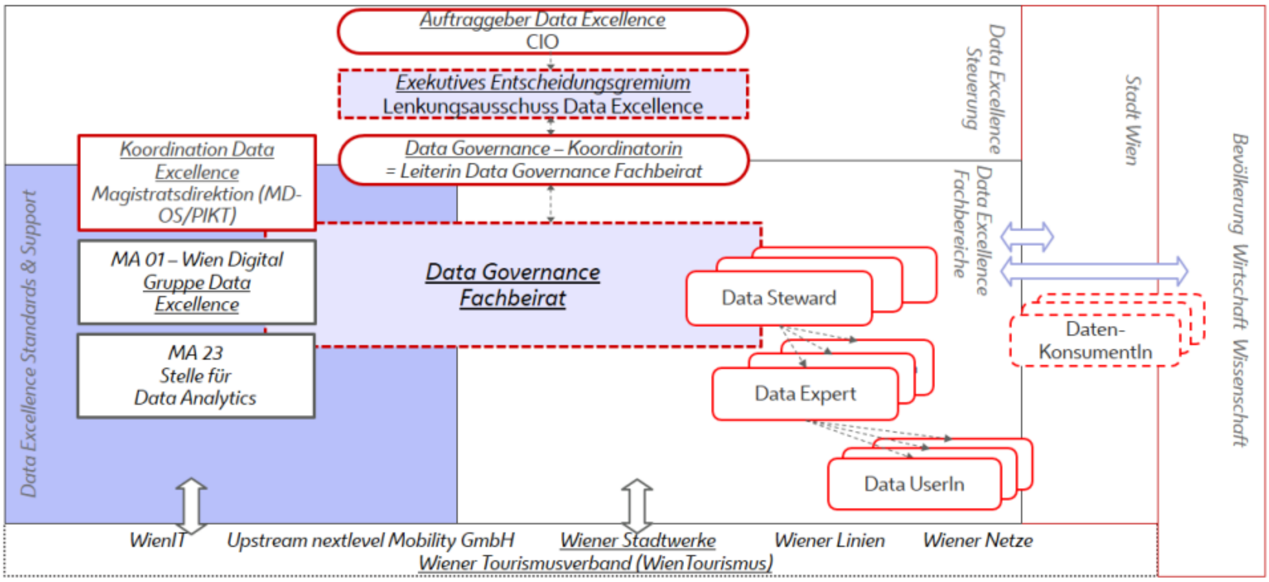

FIGURE 4 : ORGANISATION OF DATA EXCELLENCE IN THE CITY OF VIENNA[4]

Such efforts as in the case of Vienna can also be found in other cities across Europe. However, this is not discussed in detail in this report.
A practice-oriented deep-dive into the topic of data governance and sovereignty is presented below. Based on interviews with representatives from Munich, Vienna and Winterthur (in exchange sessions), conclusions were drawn on the following central topics:

- **Data management** – structure and responsibility;
- **Metadata** – data warehouse;
- **Geodata & GIS infrastructure** – software, GIS-server, internal and external analyses;
- **Data outputs** – responsibility, relevance to research project DCP
- **Data protection/privacy** – data protection officer etc.

Data management

Data management is addressed differently among cities. However, there is a central data management available in most cities. In Munich and Vienna, for instance, a central IT service provider and a central coordination department is part of the municipal organisation. However, despite the fact that there is a central point of access and management of data, responsibilities are often again divided between departments. In Munich, there is one central contact person/coordinator for data issues within the planning department. This person serves as a link between the department and the central IT unit of the city, for all data and IT related topics such as data management, processes, software or hardware. Within the IT unit, there is again a person responsible for all the geodata and databases of the department. Munich also has a central geodata base and a so-called geodata pool from which all other departments can obtain relevant geodata. The coordinator is in contact with all staff who provide or use data and is also in exchange with the central IT unit.
As also already detailed above, Vienna has a central data management called Data Excellence of the City of Vienna. Most departments have a separate data and geodata unit. Within the Energy Planning department, general data issues like statistic or monitoring data are operated by the renewable energy and energy efficiency unit. Geodata issues are handled by the energy zoning unit. The integration of data on the geodata server or on the website is done by another department upon order. Nevertheless, some analysis are done by external experts e.g. enhanced solar energy potentials or specific analysis based on energy zones.

[4] https://www.intern.magwien.gv.at/md-os/ikt/dx-organisation.pdf

In Winterthur, geodata as well as, more specifically, the geodata pool is managed with a centralised data management. Conveniently, the building model is also managed there and an automatic update with the building and dwelling register and with the building permits system is carried out on a daily basis. The respective project managers of the specialist departments can directly ask for geodata from the Geoinformation Department of the Land Surveying Office, which is responsible for the building data.

Metadata

Metadata is defined as “information that is given to describe or help you use other information” (Cambridge Dictionary 2022[5]). In Munich, direct access to a centralised metadata base is available for all departments of the city administration. Data can also be accessed via a metadata catalogue. In some cases there are access limitations depending on the type of data (e.g. personal data or data on social housing). Winterthur does not yet have a central metadata base. Similarly, Vienna has a central metadata base management system that carries out the systematic cataloguing and technical description of data. The professional data model describes the state of the data, the data holder, data protection issues and the responsibilities, among others. As an example, Figure 5 shows the description and metainformation about the data element “building”. It also contains the relation to other data elements as well as all attributes. Finally, most of the data will be available in a centralised data warehouse.

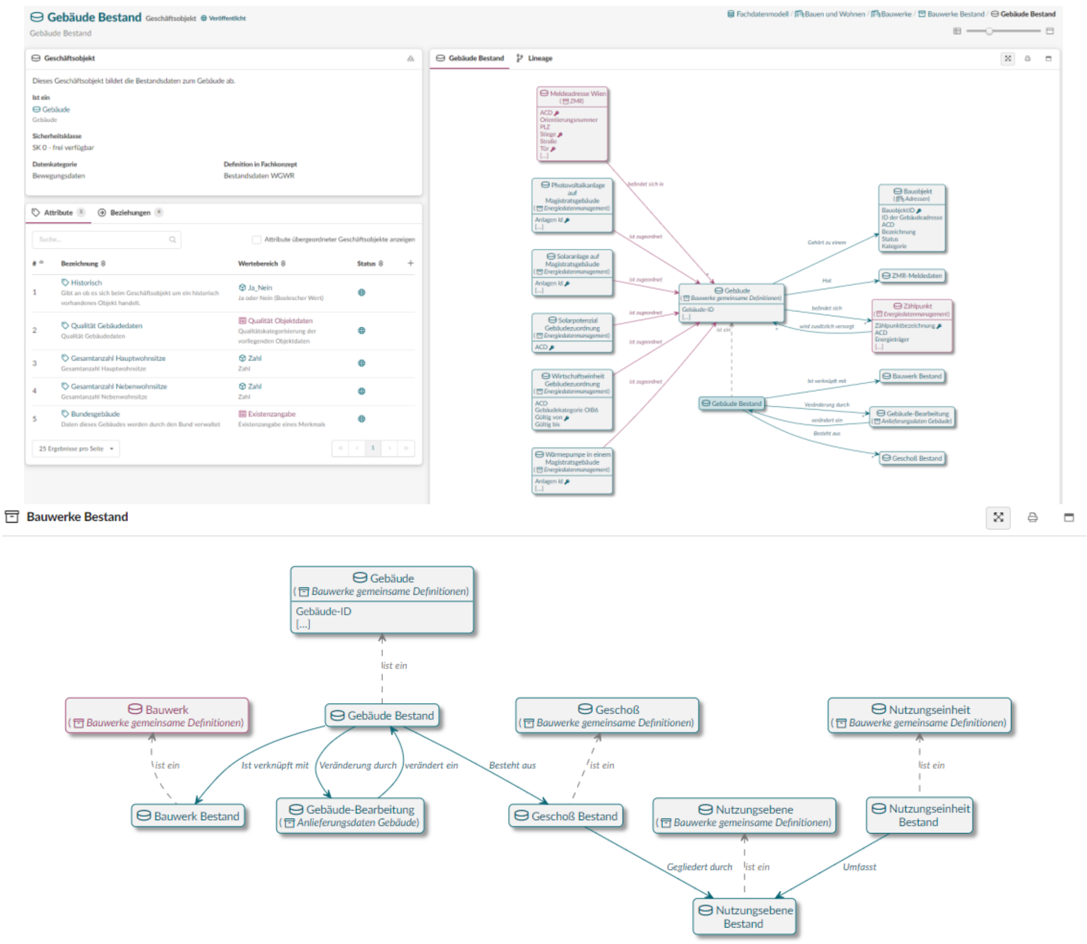

FIGURE 5 : METAINFORMATION OF THE DATA ELEMENT « BUILDING » WITHIN THE METADATA MANAGEMENT TOOL OF THE CITY OF VIENNA

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[5] Cambridge Dictionary 2022: Metadata. Accessed on 13.06.2022 from https://dictionary.cambridge.org/de/worterbuch/englisch/metadata.

Geodata & GIS infrastructure

As already indicated before, there is a centralised geodata base available in Munich, to which staff of the planning department have access to. However, due to safety reasons, writing access is limited to administrators of the central IT unit. Geo-analyses are carried out by the planning department itself. However, if the tasks exceed the scope or resources of the department, external parties can be commissioned. This was done for the energy use plan of Munich (Energienutzungsplan). It is important, that the import and export format, required for the geodata pool, is defined in advance with external parties.

Vienna operates two main geodatabases – one for specific data which is highly protected (including work in progress) and another one for "read only" data like OGD[6] or other basic information which is accessible for all departments. The geodata bases are operated by the IT department. The customer management is done by the department for "Surveying and Mapping" which is also the holder of most of the geodata. This department decides which geodata will be available for the users. For some specific data, the approval of the responsible department is required. An Advisory Board called "Vienna GIS" comprises all responsible geodata leaders of each department coordinated by the IT department. Every three months, relevant issues and projects about geodata are discussed by this consortium. For example, the Energy Planning Department demonstrated the energy data model used for the heat atlas. Also, the underlying data such as the calculation of gross floor area at the building level have been discussed.

In Winterthur, direct changes within the geodata base can be carried out depending on the respective role of the editor. Similar to Munich and Vienna, geo-analyses are partly carried out by external parties, including work for the solar cadastre, the energy plan or the road noise cadastre.

The following GIS software solutions are used in Munich and Vienna: ArcGIS 10.7.1, ArcGIS Pro and partly QGIS or WebGIS solutions. Similar software is also used in Winterthur, namely AutoCADMap, QGIS, ArcGIS and different types of Intranet WebGIS.

Data Outputs

Of special interest for the project Decarb City Pipes 2050 and for the planning department in Munich is output data about the building stock and the energy data from the energy use plan. In Vienna the department of energy planning is responsible for energy related (geo)data, including data on solar, geothermal or wind potentials, innovative energy projects or data on energy generation plants. The most essential output geodata relevant for the project is an energy demand model based on different kinds of building data as well as infrastructure.

Winterthur highlights outputs from the solar cadastre, the energy plan and outputs from the road noise cadastre as the most essential and relevant geodata outputs for heating and cooling plans and related measures.

Data protection/privacy

Data protection/privacy issues are significantly relevant within in the city administrations, especially when dealing with energy-relevant geodata. Hence, Munich addresses data privacy with an own data protection officer in the planning department, who is consolidated according to the urgency of the matter. In addition to the officer in the department, there is also a city-wide data protection officer in place, responsible for the entire city of Munich. In Munich, the legal requirements for collecting the relevant data for the energy use plan were clarified in advance. In addition, the IT unit carries out a so-called risk assessment for each geodata set, which defines and clarifies the data protection requirements. In Vienna each department has one data

[6] OGD = Open Government Data

protection officer who assesses the data and reports to the responsible department for data protection issues. Finally, this department decides which data has to be protected in which way based on an assessment. Winterthur consults the municipal data protection officer for relevant assessments of data protection issues. This was also done for the used geodata in the case of energy planning or energy consulting. The processing of personal data requires a specific legal basis or authorisation.

Data Availability & Quality

The following chapter shows detailed results of data availability and quality from the participating cities of the project. For generating the results, extensive peer-to-peer (P2P) sessions were carried out in two tranches. The first P2P data session was carried out in March 2021 under the title of “Mapping data availability, quality & access in our cities”. In this session, city partners were asked to answer specific questions dealing with energy demand modelling, building specific attributes and energy-related infrastructure. The results of the P2P session were gathered and summarised by the task-lead. After further minor bilateral exchanges, a second P2P series was carried out during the end of 2021 and early 2022.
Each city partner was interviewed separately in the second round of P2P sessions. Based on the previous P2P sessions, the goal was to deepen the knowledge about data availability and data quality in each city. Therefore, the interviews were carried out as guideline-based expert interviews, separately with each city partner. The interviews were split into four blocks. The first block addressed the (i) energy demand, the second the (ii) specific building data, the third the (iii) energy-related infrastructure questions. The last block dealt with (iv) energy supply in the participating cities.

(i) Energy Demand

The availability and quality of an energy demand model, the aggregation levels, the potential calibration with real consumption data and scenario calculations were part of this first block of questions on energy demand:

- Do you have an energy demand model? If yes, on which spatial level? Raster data (meter * meter) or on block or building level?
- How is the energy demand separated or aggregated? Which categories for the kind of energy demand you will use? Space heating, hot water, electricity (also by categories), further categories?
- Does the demand calculation distinguish between building categories (residential buildings, office buildings, public buildings, …)? If yes which categories? How good is the quality of data in each of the categories?
- Is your demand calibrated by real consumption data? If yes, which kind of consumption data (spatial and time level) and who provides it?
- Scenarios: Do you have scenarios for the development of the energy demand? If yes on which level do you have this calculation and how detailed and for which years (2030, 2040, 2050)?
- Which further information or data will you need for energy demand modelling and scenarios to develop your "H/C plan"?

(ii) Building Data

The energy demand of buildings is the cornerstone of the city's models. In this context, the modelling approaches of the cities was further assessed. Furthermore, a main goal of the following questions was the evaluation of the data quality of building data:

- Which data sources for buildings are you using? Do you have direct access to this data?
- Which attributes do you need to calculate the energy demand? Do you need to combine different data sources for calculating the energy demand?
- Which of the following attributes/information do you have and what is the quality of them (0 = not available, 1 = low, 2 = middle, 3 = high)? If one of the following information is not available for buildings, which spatial level do you have?
    - Construction age or period
    - Gross floor area (or other area parameters)
    - Compactness (volume to surface)
    - Main use of the building
    - Other uses of the building
    - Number of apartments/flats in the case of residential buildings
    - Number of inhabitants in the case of residential buildings
    - Condition of the building (refurbishment/retrofit)
    - Energy supply

In order to assess and better compare the quality of the data between the cities, a so-called building data attributes quality matrix was introduced. Each city partner was asked to assess the availability and quality of the attributes listed above. The results are presented in the building data attributes quality matrix in each city section of this chapter.

(iii) Energy-related infrastructure

As a connecting link between energy demand and energy supply, energy-related infrastructure is essential. The following questions specifically address grid-bound infrastructure:

- Do you have data about the pipe/grid infrastructure for the following categories?
    - Gas, district heating, electricity
- What do you know about it? Width/size, capacity, kind of construction (material?), age, …?
- Do you have further information about the energy infrastructure such as transformation stations for district heating, storages and so on?
- Do you know the energy supply system of each building? How detailed is this information? Do you know the age and power of the energy supply system within a given building?

(iv) Energy supply / Renewable energy potentials

From heat recovery from sea water to solar energy potentials, renewable energy potentials in the participating cities are very diverse. The questions below, thus, tried to shed some light on what data on energy potentials is available in the cities:

- Do you have data on renewable energy supply in your city (e.g. solar, geothermal, wind or waste heat)? If yes, for which resources?
- On which spatial resolution is the energy supply data available (City, district, raster data, plot/parcel, building level)? What kind of potentials: Physical and/or technical and/or economic-social?
- On which temporal resolution is the energy supply data available (annual, monthly, daily, hourly, every 15 minutes, live data)?
- Do you have information on potential future (scenarios) energy supply solutions?
- Does the energy provision data in any way match with the energy demand data (in order to calculate e.g. the supplied demand)?
- Which further information or data will you need for your “H/C plans”?
- Which data sources are you using? Do you have direct access to this data?
- Do you need to combine different data sources for calculating the respective renewable energy supply or do you get finalized data sets?

Important notes:
The questions served as a guideline. Not all questions were always answered. Due to the survey methodology and the different educational and professional backgrounds of the respondents, the depth of the results differed. The following explanations therefore do not claim to be exhaustive. Additionally, it needs to be noted that if not otherwise specifically stated, in the following, energy demand always addresses heating demand.

Bilbao

Energy demand

Bilbao has recently established a building stock-based energy model, which includes detailed data at building level. The most essential data for developing the energy model is derived from the building register, the city cadastre, energy performance certificates (EPC) and the Spanish building code. For instance, the building register contains typological data, including the type of use, such as commerce, education, health care, residential or sports buildings, as well as the construction period, number of floors and the heights of each building. The cadastre provides the building footprint from which the building shapes and the thermal characteristics are derived. Approximately 80 % of Bilbao's buildings contain one or more energy certificates. If only one energy certificate is available for a single apartment within a building, the characteristics are extrapolated to the entire building. The Spanish building code is used to derive key energy figures. Hence, for the calculations within the energy model, a combination of different data sources is necessary. As an example, Figure 6 shows the energy system of each building in the city of Bilbao.

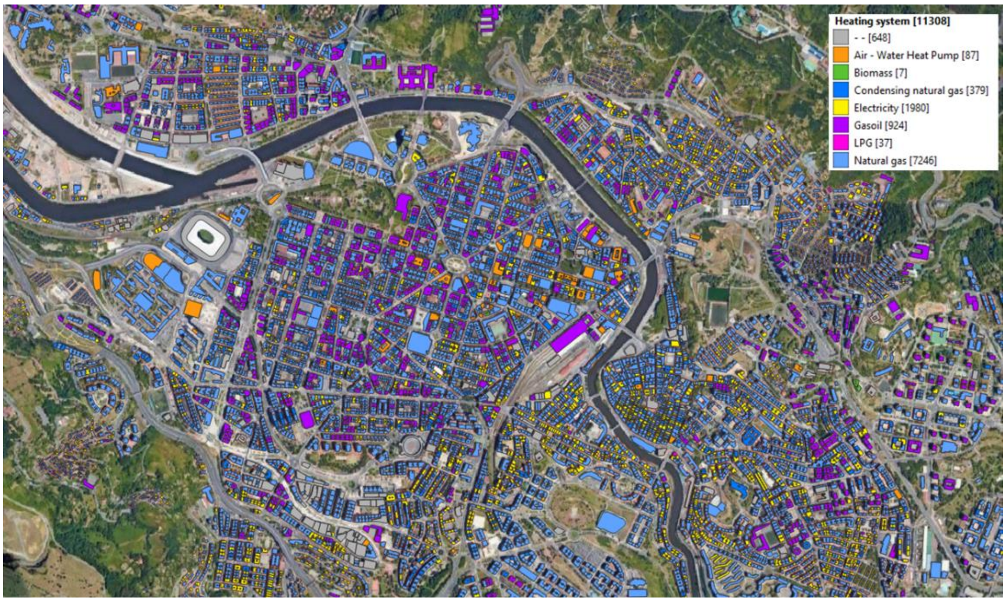

FIGURE 6 : BUILDING ENERGY SYSTEM DISTRIBUTION FOR BILBAO (TECNALIA'S ENERKAD® MODEL)

When it comes to building categories, the following differentiation is available in Bilbao:

- Residential blocks
- Single family houses
- Educational buildings
- Office buildings
- Buildings of public administration
- Health care buildings or hospitals
- Sport buildings
- Restaurants and hotels

For public and administrative buildings, direct access to the demand data is provided. Some of the buildings are owned by the municipality or the Basque government. This specific data can help to calibrate the energy demand of other buildings. With the exception of the cadastre data, all relevant data, including for instance gas data or EPCs data, is not freely available and is primarily gathered via the city council of Bilbao.
Due to modelling experience and due to the availability of consumption data, the best quality within the model is appraised for residential buildings. The energy demand of industrial buildings is not specifically calculated.

Energy demand data Bilbao:

Energy demand model	**Available ✓**
Differentiation	**Space heating, hot water and cooling demand**
Spatial resolution	**Building level**
Metered data	**Available city wide (gas consumption available on postcode level)**
Required data for model	**Partly public**
Data availability	**Sufficient**
Data quality	**Good**

Within the energy demand model, there is a differentiation between heating, cooling and hot water preparation. Annual values are currently used in the energy demand model, although the application of hourly demand profiles is possible and carried out for specific purposes. The basis for hourly demand calculations are climatic parameters, including temperature and solar radiation. The demand model consists of final heating demand values. Figure 7 visualises the specific heat demand in kWh/m2a.

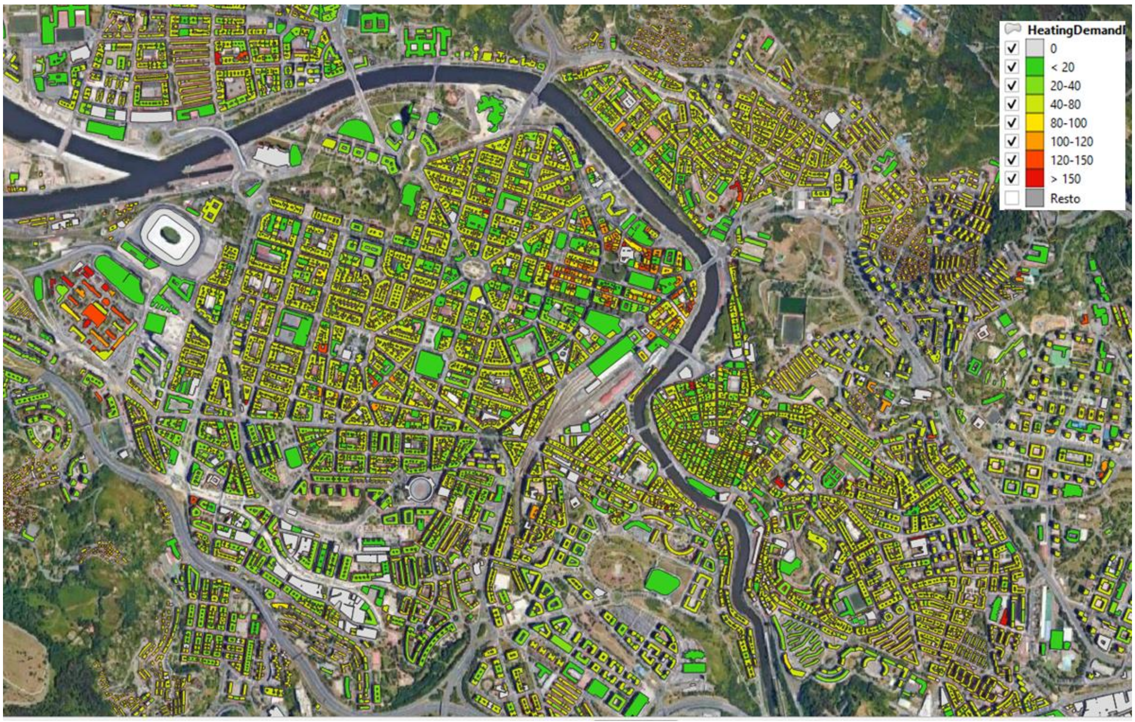

FIGURE 7 : HEATING DEMAND RESULTS IN KWH/M²A (TECNALIA'S ENERKAD® MODEL)

Regarding the energy supply of each building, gas, oil, heat pump and electricity use for heating is modelled for each building in Bilbao. This is done by dividing the calculated energy demand values by the efficiency of the heating systems. The details of the heating systems are again taken from the EPCs. Annual consumption data is provided from the energy supply companies. In this context, it has to be mentioned, that the gas supply grid is available for practically all of the building stock. Approximately 70% of the residential buildings in Bilbao currently still use natural gas for heating. The model is then calibrated with real consumption data of the entire city, except for gas, where consumption data is available only at the postal code level.
The calibration of the cooling energy use is more difficult, as electricity supply is not disaggregated in the city by final energy uses. It needs to be taken into account that there is very few air conditioning systems in the residential sector in Bilbao, so their energy use is currently practically irrelevant.

A key challenge for better model calibration is obtaining energy consumption data from the energy provider. Theoretically, it is possible to get data from the provider on a contractual basis, especially for planning purposes. In the case of Bilbao, though, no data has yet been made available.
And yet another challenge remains – the consideration of buildings in the model, which have undertaken retrofitting measures since their construction date. This is not yet implemented. However, the city council has a registry of licenses for major refurbishment activities available, but those are not yet georeferenced. In addition, data on listed monument buildings (mostly historic buildings) is available but not yet implemented in the energy model.
Bilbao is currently working on scenario calculations for 2030 and 2050. For these calculations, the spatial resolution is not yet specified. Based on strategic developments the spatial level will be concretised.
In order to further develop the H/C plans, real consumption data on a higher spatial resolution (e.g. on the building block level) would be helpful. Another specific issue and challenge for further developing the energy demand model is data protection. In addition, new development areas and refurbishment areas should be jointly considered in the future.
Table 1 indicates the data quality of attributes in Bilbao. Highest quality is assessed for the construction period, the gross floor area, the main use and further uses as well as for the number of apartments/flats. Lowest available quality is seen in the condition of buildings. The number of inhabitants is not available on the building level.

TABLE 1 : BUILDING DATA ATTRIBUTES QUALITY MATRIX OF BILBAO

Attributes/information	Rating
Construction period	3
Gross floor area	3
Compactness	2
Main use	3
Further uses	3
Number of apartments/flats	3
Number of inhabitants	2
Condition of building	0-1
Energy supply	2

Question: Which of the following attributes/information are available and what is the quality of them (0 = not available, 1 = low, 2 = middle, 3 = high)?

Energy-related Infrastructure

Due to the large share of gas supply in the city of Bilbao, the gas infrastructure is currently the most important energy-related infrastructure. Besides the supply of a hospital, there is no other district heating network established in the city. In addition, the location of the electricity grid is available for the planners.
A gas storage is planned in the port of Bilbao. Besides, there is no additional information on storage systems available. Interestingly, the availability of public space was specifically mentioned for the construction of required infrastructures, such as district heating or geothermal probes.
For the identification of energy supply systems for the buildings, the EPCs database and an additional database on public buildings from the city council have been used.

Energy-related infrastructure Bilbao:

Grid-bound infrastructure	**Gas and electricity**
Energy storage	**Not available**
Energy supply system	**Available for buildings of the EPCs and public buildings, otherwise estimations based on spatial proximity to respective infrastructure**

Energy potentials

There is no identified large-scale waste heat potential within the city of Bilbao. However, building-scale waste heat potentials (e.g from supermarkets) have been evaluated. Waste heat potential of large industrial sites outside the city centre have also been assessed. As visualised in Figure 8, solar energy potentials have been calculated for building integrated installations (mainly used for self-consumption).

FIGURE 8 : SOLAR RADIATION ON ROOFTOPS (TECNALIA'S ENERKAD® MODEL)

Geothermal potential still needs to be explored and might be an important source for the future heat supply of Bilbao. Another promising solution refers to the application of heat exchangers in the Estuary of Bilbao. The potentials have not yet been evaluated, but could be another essential renewable energy source for the city. Estimation of potential energy resources on a high spatial level is currently promoted and will be established in the near future.

Dublin

Energy demand

The energy demand model in Dublin is available on different spatial scales. For the commercial and public sector, the energy demand model is prepared on the building level, whereas demand data of residential buildings is available on an aerial level. Besides, a heat density map is available in TJ per square kilometre.
In general, the city follows an approach to separate the energy demand into residential, commercial and public buildings, from which the heating demand is further split into heating and hot water demand. For the calculation of the total heating demand of residential buildings, Building Energy Rating (BER) (= Irish version of Energy Performance Certificates) data, in case available, is used as a basis. BER cover approximately 50% of the residential building stock. For the remaining residential stock without a BER, its demand is estimated based on BER data of nearby dwellings of the same age and archetype. For commercial buildings, the total gross floor area is used. In addition, the residential energy demand model is based on archetypes, whereas the commercial buildings are based on benchmarks from the Chartered Institution of Building Services Engineers (CIBSE). The most detailed information is available for public buildings, since electricity and fuel demand are metered in detail. Further data sources are the Building Energy Rating Certificate dataset (BER) and the full census dataset for residential building. Census data is used for retrieving attributes such as the building period and the gross floor area.
Additional metered data of consumed gas at postcode level is used for calibration purposes. This way the model was validated. Individual metered data of residential buildings is also available. However, due to the challenge of data protection, it is difficult to get access to the gas consumption data. Regarding district heating, since there is hardly any supply in Dublin, no data on existing systems is available to planners.

Energy demand data Dublin:

Energy demand model	**Available ✓**
Differentiation	***Space heating, hot water demand***
Spatial resolution	**Building level and aerial level**
Metered data	**Only for public buildings**
Required data for model	**Partly public**
Data availability	**Good**
Data quality	**Good**

Concerning the commercial and industrial sector, information from for instance data centres and industrial sites is gathered. Similar to the energy demand model of commercial buildings, the demand of the industry is based on benchmarks. This demand model is further split into low and high temperature demand. The benchmarks are based on literature and are available per building type.
Unfortunately, there is no data on cooling demand in Dublin besides those identified also as heat sources (data centres and cold storage warehouses).
Furthermore, there is also the challenge to combine different data sources for calculating the energy demand in Dublin.
With respect to energy demand scenarios there are predictions available for residential, commercial and data centres. A rather detailed scenario is available for 2030 and a less detailed scenario for 2050. The current demand model is adjusted with potential population, retrofitting and refurbishment developments. Interestingly, the scenario calculations in Dublin include a so-called "rebound factor", which describes the theoretical savings (accomplished by retrofitting etc.) that are never realised due to human behaviour of increased energy consumption (Aydin et al. 2013). It has to be mentioned, that information on retrofitting is only available for residential buildings and not for commercial buildings.

For future planning purposes, the availability of metered data to enable further calibrations as well as a better integration of this with the Building Energy Rating Certificate (BER) dataset would be beneficial. Furthermore, detailed knowledge on cooling demand for all building types in Dublin as well as on scenarios would be beneficial for strategic planning purposes of the future energy demand.
The following Table 2 shows an estimation of the data quality of attributes in Dublin. Highest quality is assumed for the different types of usages and for the number of inhabitants. Lowest available quality is seen in the compactness of residential dwellings (data provided for areas which include 100 dwellings on average but these areas vary significantly in size) and the type of energy supply for the commercial buildings.

TABLE 2 : BUILDING DATA ATTRIBUTES QUALITY MATRIX OF DUBLIN

Attributes/information	Rating
Construction period	2
Gross floor area	2
Compactness	1
Main use	3
Further uses	3
Number of apartments/flats	2
Number of inhabitants	3
Condition of building	2
Energy supply	1

Question: Which of the following attributes/information are available and what is the quality of them (0 = not available, 1 = low, 2 = middle, 3 = high)?

The highest quality of data on the construction period is given for commercial buildings. Data on apartments/flats are available in a good quality but lacks the exact location.

Energy-related infrastructure

In Dublin, geodata about the entire gas and electricity grid is available, whereas data about district heating is only partly available (general location rather than exact pipe routes). The existing DH infrastructure is in the form of smaller communal networks typically on university campuses. Based on the BER dataset it is possible to evaluate how many buildings are connected to which type of infrastructure.

Energy-related infrastructure Dublin:

Grid-bound infrastructure	**Gas, electricity and district heating**
Energy storage	**Hot water storage of domestic buildings available**
Energy supply system	**Available for buildings within the BER database, otherwise estimations based on spatial proximity to respective infrastructure**

Every three months geodata on the gas and electricity grid are updated. Unfortunately, the age of the infrastructure and the remaining capacities are not available, which would be beneficial for planning purposes. However, due to the regular updates there is a very detailed knowledge on newly built infrastructure.
Information on the gas grids is also relevant for future hydrogen provision. Regarding energy storage systems, there are only estimations on hot water storage in domestic dwellings available. There is also no information gathered on gas storage.
Knowledge on the energy supply system of the buildings is provided for buildings within the BER database. Otherwise, there is an evaluation based on the proximity to and age of buildings for which this information is known. It is assumed, that industrial and commercial buildings are entirely supplied by gas.

Energy potentials

Energy potentials Dublin:	
Types of renewable energy sources	• **Photovoltaic** • **Solar thermal** • **Geothermal** (deep and shallow) • **Wind** • **Waste heat** • **Biomass** • **Sea water heat recovery** • **Surface water**
Temporal resolution	**Annual** (except waste heat)
Direct access of planner to the data	**Yes**

Data on already existing renewable energy installations are partly derived from the BER data. The database does not provide a full picture. Decentral installations such as photovoltaic or solar thermal units are, however, included. Additional data is directly retrieved from electricity supply companies that operate wind farms and solar farms or from planning applications (from permission certificates).

In total, information on 18 different types of heat sources were investigated in Dublin, including deep and shallow geothermal, surface water, cold storage warehouses, industrial waste heat, waste heat from electrical transformers, power stations (including energy from waste plants), waste water treatment plants, CHP units, biomass installations, data centre waste heat and sea water heat source (shallow waters excluded and protected areas). There are also specific solar PV potential maps available and maps for onshore wind and offshore wind sites.

Currently, there are two areas in Dublin where district heating networks are being developed. The two district heating systems will be supplied from a waste incineration plant and from a data centre. More district heating systems are planned. Waste heat potentials from large industrial sites can be derived from the environmental protection agency licence information, which is based on respective CO_2 emissions and the temperature from the drainage system (obligation to monitor effluents). Other industrial sites such as cold storage warehouses have their waste potential estimated using cooling benchmarks.

The spatial and temporal resolution of the energy supply data depends on the corresponding resource.

In total, the supply potentials surpass the energy demand in Dublin. There is also direct access available to the energy potential data for planners. However, more than 70 different data sources are used to plot maps of the energy potentials in Dublin.

Some final remarks on energy potentials in Dublin: It is suggested, that waste heat potentials will change over time, particularly in the case of traditional thermal power stations (which will reduce significantly) and data centres (which will increase significantly). Additionally, limits are set for seawater heat recovery, due to theoretical unlimited potentials.

Munich

Energy demand

Munich has a comprehensive energy demand model at the building level, differentiating between primary energy demand and final energy demand. Another differentiation is done between space heating and hot water demand which are again both available in absolute numbers (kWh/a) and as specific indicators (kWh/m2.a). In addition to the total energy demand, the heat load is also filed. Cooling demand is only available for non-residential buildings. Furthermore, a differentiation between the following energy supply options is carried out: District heating, gas, oil and electric heating. Buildings supplied with either district heating or gas are modelled in accordance with the proximity to the corresponding supply infrastructure. Wherever gas and district heating systems are located close to the buildings, district heating was prioritised. For industrial buildings and schools, both district heating and gas networks were assigned. Remaining oil heating systems were derived from the Soil Protection Department, due to the authorizable character of this fossil-based supply option. Buildings that are currently supplied with either heat pumps or biomass (woodchips) are difficult to identify. Hence, data quality for these two supply options is rather poor. Some data gaps also occur for buildings with mixed use and non-residential buildings, whereas highest data quality is attributed to the residential buildings. Further data sources for the energy demand model are:

- Statistical data from the building register (building period, gross floor area, number of dwellings, type of use, building height etc.).
- Data from land survey (building dimensions).
- 3D data based on land surveys for energetic calculations (gross floor area, volume and compactness etc.).
- Reporting data on new buildings and building demolition from the statistical office.

The usable floor area is calculated from the building volume, which is derived from the land survey data; the number of floors origins from the building register. Hence, it is obvious, that a combination of different data sources for calculating the energy demand in Munich is necessary. Interestingly, there is no energy certificate database available in Germany.
In terms of buildings, the energy demand model distinguishes between residential and non-residential buildings. However, different categories for both residential and commercial buildings serve as a basis for the model:

- Residential buildings
  - Single-family house
  - Semi-detached house (two different types)
  - Multi-family house
  - Large apartment building
  - High-rise building
- Non-residential buildings
  - Trade and commerce (incl. restaurants)
  - Service and administration (incl. offices)
  - Education and science
  - Health, social and medical facilities
  - Industry
  - Storage and archiving
  - Culture
  - Sport
  - Accommodation

Energy demand data Munich:	
Energy demand model	**Available ✓**
Differentiation	**Space heating and hot water**
Spatial resolution	**Building level**
Metered data	**Only for city owned buildings**
Required data for model	**Partly public**
Data availability	**Good**
Data quality	**Good**

Real consumption data is only available for city-owned buildings. The Stadtwerke München (SWM) is the main energy providers of the city and holds consumption data of their customers. However, there is no access to this data for the planning departments.

In Munich, different refurbishment and energy supply scenarios are calculated. For the development of the energy demand, there is one scenario until 2030 and another one until 2050. The scenarios are based on retrofitting assumptions, which are again derived from the building refurbishment standards (KfW-Bank). These scenarios are applied to each building of the city. Unfortunately, no information is available for refurbishments that have already been carried out. Therefore, the refurbishments are allocated across all the buildings in the city. Detailed refurbishment data is only available for buildings, which were refurbished via the municipal funding programme, which is in fact a very low number of buildings compared to the total building stock.

For a better energy demand model, real consumption data and more information on the heating systems installed within the buildings would be helpful. Further, information or a database on retrofitting would also be beneficiary. This data is currently only available to the SWM. It is a challenge to get this data. One of the main reasons for SWM for holding back energy demand data refers to data protection issues related to consumers and the economic competition in general. The exact location and the demand of heat pumps as well as those of e-charging infrastructure would also be interesting for future energy demand modelling. In this context, some challenges may arise due to increasing electricity demands in the city.

As shown in
Table 3, data quality in Munich is in general very high. The quality of data on usable floor area and the compactness of the buildings that is to be found in the building register is, however, quite low, compared to the same data from the 3D model.

TABLE 3 : BUILDING DATA ATTRIBUTES QUALITY MATRIX OF MUNICH

Attributes/information	Rating
Construction period	3
Gross floor area	3
Compactness	3
Main use	3
Further uses	2
Number of apartments/flats	3
Number of inhabitants	2
Condition of building	1
Energy supply	1

Question: Which of the following attributes/information are available and what is the quality of them (0 = not available, 1 = low, 2 = middle, 3 = high)?

Lowest ratings were given to the data on the condition of the buildings and for the energy supply system of the buildings. Originally, there was no information available on building specific energy supply systems. Therefore, the energy supply of each building was calculated due to the proximity to the nearest grid-infrastructure. In this context, it has to be mentioned, that the quality of the results (output) depends strongly on data quality and availability on the input side.

Energy-related infrastructure

The location and the exact routing of pipelines of the gas and district heating network is provided by the SWM. However, no building connections are included in this dataset. This also means

that no data on width, size, capacity, construction material, age etc. is available to the planning departments in Munich. By using the grid infrastructure data, the grid-bound energy supply system of each building can be assessed. This way it is possible to distinguish between buildings supplied with either gas or district heating. Additionally, the number and the location of remaining oil boilers was derived from the Soil Protection Department.
Up to now, electricity infrastructure has not been part of the evaluations in Munich. Currently, only electricity generation potentials (for photovoltaic panels) are available. Besides the grid infrastructure, the location and the capacity of combined heat and power plants and heating plants are available.

Energy-related infrastructure Munich:

Grid-bound infrastructure	**Gas and district heating**
Energy storage	**Not available**
Energy supply system	**Calculated on building level (gas and district heating and oil boilers)**

Energy potentials

Information on already installed solar energy potentials are available for city-owned buildings. However, there is a solar cadastre (photovoltaic and solar thermal) for all other buildings in Munich. Additional energy potentials could be derived from the SWM and especially in terms of waste heat, from the Waste Management Corporation of Munich (Abfallwirtschaftsbetrieb München, AWM).
Data availability and quality is very good for groundwater and geothermal potentials. A high-resolution 3D subsoil model is available in Munich. However, the specific data is not stored in the planning department, but at other responsible departments such as the Climate Protection Department, the SWM or the Technical University of Munich. Data on shallow geothermal energy is available for the planning department; whereas the detailed results on deep geothermal energy is located at the SWM.
In general, some economic or social potentials have been evaluated in Munich. Annual balances were used for the evaluations.
For each building in Munich, the potential future energy demand is available, including scenarios on renewable energy supply solutions. Further details in this context can be found in the H/C maps of Deliverable 3.3.

Energy potentials Munich:

Types of renewable energy sources (spatial resolution if applicable)	• **Photovoltaic** • **Solar thermal** • **Deep and shallow geothermal** • **Waste heat**
Temporal resolution	**Annual**
Direct access of planner to the data	**No**

There is not yet a direct access to the potential data available to all members of the planning department. For the public, the access is aggregated at building block level and data is partly available via the public GeoPortal. The energy database is integrated in local GIS systems.

Rotterdam

Energy demand

From a spatial perspective, the energy demand model in Rotterdam is split into the building and postcode level. On the building level, the heating demand of residential and commercial buildings is available, whereas the gas and the electricity demand is only available on a neighbourhood and postcode level. Data at postcode level is provided by the network operator. Unfortunately, data on the building level from the energy suppliers is not made available due to data privacy issues. In Rotterdam, there are currently five test areas (focus areas) in which very detailed data collection is carried out. The collection is mainly done via site visits and surveys. This detailed data is especially relevant, because it is possible to extrapolate this data and to utilise it for the citywide energy demand model. It has to be highlighted, that the overall focus of the energy model is on space heating and on residential buildings.

For the calculation of the energy demand, certain attributes are essential. The main attributes are the gross floor area, the building period and the type of usage. Additionally, relevant guidelines (construction engineering regulations) are used to derive appropriate energy indicators. This is carried out for both residential and office buildings. Areas with many commercial and (semi) industrial buildings are difficult to include in the model. Thus, these are not the focus areas of the heating and cooling maps (see Deliverable 3.3). In addition, the gas grid (and to a less extend the district heating grid) are used to identify buildings that are centrally supplied via a grid system. The following differentiation is carried out:

- Buildings supplied with gas
- Buildings supplied with district heating
- Buildings supplied with district heating and gas
- Buildings without grid-based supply

The most valuable data concerning buildings are derived from the building register (available for the entire Netherlands) and the energy certificates (energylabels). Additional information for buildings is derived from the grid infrastructure and from shared data of the social housing associations. It can be concluded, that different attributes are derived from multiple data sources in order to calculate the energy demand in Rotterdam.

Unfortunately, no information on refurbishment is obtainable.

The calibration of the energy demand via real consumption data can only be carried out on the postal code and neighbourhood level. The data is originally derived from central data information databases and from local energy suppliers.

Efforts are underway to evaluate the cooling demand in Rotterdam. The city is currently working on that matter and first prototype models are already available.

Energy demand data Rotterdam:

Energy demand model	**Available ✓**
Differentiation	***Space heating and hot water***
Spatial resolution	**Building and postcode level**
Metered data	**Available on postcode level**
Required data for model	**Partly public**
Data availability	**Very Good**
Data quality	**Sufficient**

Scenario calculations are based on the premise, that the supply temperature is decreased to 70°C within the next 15 years. Another scenario is the trade-off between variations of higher heat recovery and/or higher heat demand cover via electricity.

A great challenge of energy demand modelling is the rather unknown matter of energy consumption patterns. This is one of the reasons for gathering concrete data from citizens. Therefore, and in order to establish a better database, the idea in Rotterdam is to go one-step beyond the index data and to take a closer look at the energy consumption behaviour of citizens. Therefore, residents are specifically asked about their energy consumption and their energy

behaviour in a specially designed program. In addition, a very detailed energy demand model is currently developed in the form of a digital twin. Together with the data gathered from citizens, this digital twin will be the future base for the energy demand model in Rotterdam. Asking citizens about certain data and their behaviour also offers the opportunity to provide energy advice (similar to energy consulting). Therefore, this a win-win situation for both citizens and the municipality.
Table 4 shows the estimated rating of the data quality for certain attributes. Overall, the quality of the data in Rotterdam is high. However, the condition of the buildings and the specific energy supply system gained the lowest ratings.

TABLE 4: BUILDING DATA ATTRIBUTES QUALITY MATRIX OF ROTTERDAM

Attributes/information	Rating
Construction period	3
Gross floor area	3
Compactness	3
Main use	3
Further uses	-
Number of apartments/flats	3
Number of inhabitants	privacy issues
Condition of building	2
Energy supply	2

Question: Which of the following attributes/information are available and what is the quality of them (0 = not available, 1 = low, 2 = middle, 3 = high)?

Information on further uses were not specified and the number of inhabitants are not available due to privacy issues.

Energy-related infrastructure

Energy-related infrastructure Rotterdam:

Grid-bound infrastructure	**Gas, district heating**
Energy storage	**n.s.**
Energy supply system	**Available on building level (gas and district heating)**

Data on pipe/grid infrastructure such as gas, district heating or electricity is available. Specifically, this data includes the type of infrastructure, the exact location and even a 3D underground map. Figure 9 shows a screenshot of the 3D map in Rotterdam, including a LOD2 building-model and a visualisation of the gas and district heating infrastructure.
The visualisation is freely available: https://www.3drotterdam.nl. Regarding the districting heating network, all relevant specifications are available, except two planning parameters: The remaining capacity and the temperature within the distribution network. However, the exact grid-bound supply system of each building can therefore be derived from the grid infrastructure.

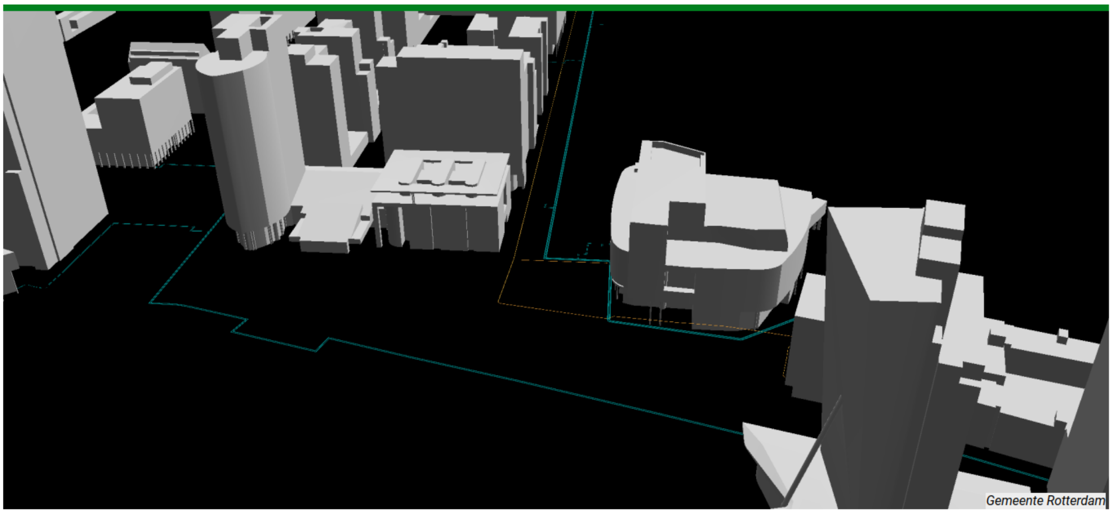

FIGURE 9 : VISUALISATION OF GRID INFRASTRUCTURE IN A 3D MAP OF ROTTERDAM (© GEMEENTE ROTTERDAM)

Energy potentials

In Rotterdam, renewable energy potentials of the following resources are available: Photovoltaic, geothermal, wind, residual heat and aqua thermal energy. Solar thermal energy for instance does not play an important role in the Netherlands. More specifically, photovoltaic potentials are available for rooftops, including qualitative (suitability categories) and quantitative parameters (e.g. solar hours per year). The visualisation is available for the public at https://klimaatdakje.nl/. Photovoltaic potentials are the only renewable energy sources that are publicly available. Continuous effort is put into evaluating geothermal energy and heat recovery potentials. Photovoltaic, wind and residual heat potentials are already integrated in local geoinformation systems.

So far, no comparison between energy demand and energy supply was carried out in the city. In addition, the availability of energy potentials in high temporal resolutions would benefit the planning processes but are not yet available (except for photovoltaic potentials).

Regarding future energy supply options, heat recovery from the harbour of Rotterdam for district heating is currently under discussion.

The idea behind the data evaluation is the goal of diversifying the energy mix of district heating in order to have a resilient and flexible heat supply for the future.

Finally, more specific energy data is required in order to answer some of the most challenging questions in Rotterdam. One challenge is the question of how to deal with heat surplus during summer and how to face the increase of cooling demand. Another challenge is the potential role of green gas in the future heating system.

Energy potentials Rotterdam:

Types of renewable energy sources (spatial resolution if applicable)	• **Photovoltaic** (roof area) • **Geothermal** • **Wind** • **Residual heat** • **Aqua thermal**
Temporal resolution	**Annual** (except Photovoltaic)
Direct access of planner to the data	**No**

Vienna

Energy demand

In Vienna, a comprehensive energy demand model is available, which is continuously improved. The energy demand model is available on the building-level, including approximately 180,000 buildings in the city area. Aggregation levels of the model are building blocks, statistical census areas or entire districts. In addition, the energy demand model is also obtainable at the raster level, more specifically in a 5x5m and 50x50m raster. Energy demand corresponds to delivered energy (heating together with space heating and hot water preparation as well as cooling demand) in kWh/a for each building. Delivered energy represents the energy demand of the building, whereby the losses of the energy supply (boiler, heat exchanger, etc.) are not taken into account. Additionally, the specific heat demand (kWh/m2) and the heat load (kW) is included. At this highly aggregated level, the electricity demand is not part of the model.
As already mentioned, the starting point of the energy demand model is building data. Therefore, all basic information of a building is essential. The most important attribute on building level is the gross floor area. Depending on the type of use and the construction period of each building, specific heat demand values are assigned. An additional differentiation into gross floor area and heated floor area is carried out. Further details on the model are presented below.
Building dimensions like the gross floor area, the surface area, the compactness were computed with the help of a digital surface model (DSM) and a digital terrain model (DTM). The necessary building footprints originate from the digital cadastral map (department of Surveying and Mapping – MA 41) which also includes important building related IDs. The type of use is based on information from the address and dwelling register (so called “building register”) and Point of interest from Open Government Data (OGD). Important uses like hospitals or schools complemented or replaced the information of the building register by using a priority order. Another essential information from the building register is the construction period. Direct access to the address and dwelling register is not provided to the energy planning department. However, individual extracts can be requested from this database.
Besides the type of use, the gross floor area and the construction period, additional information for calibrating the heat demand such as type of heat supply, funded refurbishment activities, compactness of the buildings, energy certificates (to identify the type of heat supply) or monument protection (list of historical buildings - protected zones) are also included in the calculations.
Energy certificates are available on address level and are provided by the city department of Building Inspection (MA 37). Refurbishment activities are derived from Wohnfonds Wien. The data were not georeferenced and needs to be prepared accordingly. Likewise, the data on monument protection is not geo-referenced, which means additional effort in processing and updating the data.

Energy demand data Vienna:

Energy demand model	**Available ✓**
Differentiation	**Space heating and hot water demand + cooling demand**
Spatial resolution	**Building level**
Metered data	**Partly available and based on real district heating consumption data**
Required data for model	**Partly public**
Data availability	**Good**
Data quality	**Good - sufficient**

With regard to the different building categories, the model distinguishes between the following main categories: Residential (single-family houses, apartment buildings, residences), office, commerce, accommodation, gastronomy, infrastructure, education, health, events, church, sport, production and other conditioned buildings. A major challenge arises in the allocation of

the specific heat demand to commerce and industry (production) buildings. In this case, further developments and improvements of the model are needed.
The energy demand model is based on real consumption data. Consumption data from multiple Austrian district heating networks was used as a basis. This data was then further aggregated into specific heat demand values of a building typology. This typology was in turn assigned to the different building types of Vienna. Main factors influencing the specific heat demand are:

- type of use,
- construction period,
- compactness and
- refurbishment level (existing state, state of construction or refurbished).

Additional detailed consumption data is only available for public buildings. In the near future, the specific heat demand values will be calibrated together with the energy provider Wien Energie and network operator Wiener Netze. Energy scenarios for the development of the energy demand are only available for the entire city of Vienna. Up to now, only the refurbishment level was included in the building specific energy demand model.
A revised energy demand model would benefit from more information on each building's energy supply system, the condition of the buildings in general (especially the state of renovation) and from more information on commercial and industrial buildings. As mentioned above, a detailed calibration of the model is of utmost importance. Preliminary work on this topic is currently underway.
As Table 5 shows, highest quality is seen for the construction period, the gross floor area and the compactness of buildings.

TABLE 5: BUILDING DATA ATTRIBUTES QUALITY MATRIX OF VIENNA

Attributes/information on building level	Rating
Construction period	3
Gross floor area	3*
Compactness	3*
Main use	2
Further uses	1
Number of apartments/flats	1-2
Number of inhabitants	1
Condition of building	1
Energy supply	0-1**

*Question: Which of the following attributes/information are available and what is the quality of them (0 = not available, 1 = low, 2 = middle, 3 = high)? * The data quality of these attributes in the building register is low, but in combination with the geometry they result in high quality. ** only buildings which are supplied by DH are known. Furthermore, the energy certificates provide for some buildings the energy supply but there are not comprehensive available.*

Consequently, the lowest rating was given to the categories of further uses (other uses besides the main use), number of inhabitants, the actual condition of buildings and the energy supply system of the buildings. Currently under discussion is the relevance of the construction period – some experts argue that no building is in an original status of its construction year. Therefore, even older buildings will not have that high consumption as calculated while newer buildings need more energy as calculated.

Energy-related infrastructure

In the case of energy-related infrastructure, the exact location of the grid-based infrastructure is available to the Municipal Department 20 – Energy Planning. Specifically, geodata on the electricity, gas, district heating and district cooling networks are provided via a so-called central pipeline cadastre of the city. For the electricity grid and the gas grid, the materials used are available. For the gas network, the dimensions and a differentiation into pressure-levels (high and low pressure) are also provided. In Vienna, the district heating network is differentiated into a primary network (up to 160 degrees Celsius) and secondary network (between 65 and 85 degrees Celsius). In addition to the location of the infrastructure, the installation type (pressed, overhead line, etc.) is also included in the dataset. Further, the remaining capacities (qualitative differentiation into high, medium and low remaining capacity) of transformer stations/substation (links between primary and secondary network) are provided for the Energy Planning department. This information is especially relevant for energy zoning, since the remaining capacities are essential to delimit zones suitable for district heating: https://www.wien.gv.at/stadtentwicklung/energie/erp/aktuell.html

Energy-related infrastructure Vienna:

Grid-bound infrastructure	**Gas, district heating, electricity**
Energy storage	**Gas storage facilities available**
Energy supply system	**Buildings supplied with district heating available, modelled using gas grids for gas supplied buildings**

However, attributes like (remaining) capacities or age of the grid infrastructure itself is not available. In addition, small privately owned infrastructure is also not included in the central pipeline cadastre of Wiener Netze (net provider). As far as storage systems are concerned, the Energy Planning department only knows the location of gas storage facilities.
Grid infrastructure is also used to derive the energy carrier and likewise the heating system. Besides the central pipeline cadastre, energy certificates were also used to derive the energy supply system of buildings. An extra dataset about buildings already supplied with district heating was provided by Wiener Netze. No information is available for buildings supplied with gas. Moreover, it is not known in detail what kind of heating system is currently installed in buildings. Unknown is also the age of these systems as well as a differentiation between central and decentral supplied buildings. These would, however, be of vital interest for a coordinated phasing out of fossil energies in Vienna.

Energy potentials

- For renewable energy potentials, a distinction is made between publicly available data and internal data. On the city's own WebGIS application (https://www.wien.gv.at/umweltgut/public/) the following energy features are publicly mapped:
- Innovative energy projects related to education, energy-efficient buildings, energy production, refurbishments or urban development;
- Energy generation plants such as subsidised photovoltaic and solar thermal plants as well as other energy generation plants including hydropower plants, wind power plants, power plants based on biomass and landfill gas and conventional power plants;
- Energy potentials including wind potential cadaster (polygon-features), geothermal potential cadastre (polygons), wastewater heat potential (polyline features with a buffer), solar energy cadastre (polygon-features on building level) and aggregated waste heat potentials (polygon-features).

As an example, Figure 10 shows wastewater heat potentials based on dry weather flow (l/s) along the sewer (including a 100m and a 200m buffer along the polyline-feature) in the western part of Vienna.

FIGURE 10 : SCREENSHOT OF « WIEN UMWELTGUT » VISUALISING WASTEWATER HEAT POTENTIALS (VIENNAGIS, S.A.).

In addition to the publicly available potentials, more detailed geodata is also available to the Energy Planning department, for instance, detailed data on the capacity and location of heating plants is internally available. Another example is a detailed evaluation of open space photovoltaic potential and a detailed and updated roof-top cadastre. Both are not finished yet. In cooperation with the research facility Geologische Bundesanstalt (GBA) a very detailed map of shallow (near-surface) geothermal energy was developed, including results such as heat extraction potentials of groundwater use or the potential of shallow geothermal probes (for 30, 100 and 200 metres).

Energy potentials Vienna:

Types of renewable energy sources (spatial resolution if applicable)	• **Photovoltaic** (roof-tops and open space) • **Solar thermal** (roof-tops) • **Shallow geothermal** and **ground water** • **Aggregated waste heat** (per site) • **Wastewater heat** • **Wind** (only wind speed)
Temporal resolution	**Mainly annual** (monthly for solar energy)
Direct access of planner to the data	**Yes**

Features including data on operating hours, thermal conductivity, subsoil temperature or restriction areas were also generated. This was aggregated to a simplified map, which uses the traffic light colours to show where geothermal energy could be used, where possible limitation might occur and where it is not allowed (for instance water protection areas). Currently, efforts are being made to create a map for air source heat pumps based on sound levels.

Regarding energy potentials, the Energy Planning Department has direct access to almost all the geodata. It is also integrated in the local GIS servers. The spatial resolution varies, depending on the respective renewable energy source. In general, the energy potentials reflect the physical or technical potentials regarding some limitations like protection areas. Only the new solar potential cadastre for roofs are going more in detail about technical limitations. Nevertheless, all provided potentials don't replace detailed analysis.

It can be concluded, that there is still a lot to do, especially with regard to data quality and a further and more detailed resolution of renewable energy potentials, e.g. at the plot/property level. This way, it would also be possible to compare the renewable energy potentials with the energy demand on the plot level. Accordingly, coverage rates could be evaluated and spatially precise statements about the future energy supply on the building block, plot and building level could be made.

Winterthur

Energy demand

Energy demand data Winterthur:

Energy demand model	**Available ✓**
Differentiation	**Space heating and hot water demand together**
Spatial resolution	**Building level**
Metered data	**Partly available**
Required data for model	**Not public**
Data availability	**Good**
Data quality	**Sufficient**

In the city of Winterthur, a very detailed energy demand model is available. The model is prepared both on the building level and on the raster level (hectare). The building data contains space heating and hot water, but a separate preparation is not obtainable. Metered data is available for buildings that are supplied with either natural gas, district heating or heat pumps (used electricity). Gas data, district heating data as well as energy data for heat pumps is provided by the energy utility/provider. For heating systems operated with fuel oil or wood, data for the installed heating-power from chimneysweepers is gathered.

Wherever metered data is not available, information from the building and dwelling register is used to model the heat demand by applying a specific heat demand value (kWh/m2.a) for certain building typologies. The energy indicators are determined based on random samples via a survey of buildings in the canton of Zürich. The survey is conducted every two years.

In Winterthur, there is also a register of cooling units. Due to regulations, cooling units of a certain demand need to register, their cooling demand is, however, not available. The cooling demand is generally evaluated for commerce and industrial buildings and not for residential buildings. As a result, the cooling demand is aggregated on the hectare level using a qualitative classification.

The temporal resolution of all energy demand data is a year and the reference unit in the residential part of the model is always the dwelling unit. It also has to be highlighted, that the best data quality is available for residential buildings. In addition, there is no distinction between the residential, commerce and industrial energy demand on the building level.

For the city of Winterthur retrofitting rates and retrofitting successes (estimated insulation success) for each construction period is used to model future energy demand scenarios. Scenario calculations were made for 2035 and 2050.

However, there is a lack of data concerning the cooling demand. Additionally, there is a data gap on information of potential future developments (spatial planning). Finally, the pipe diameter of the district heating system would be essential in order to evaluate the feasibility of the extension of the network to certain areas.

In order to calculate the energy demand on the building level, data from different sources is required. As initially mentioned, there is metered data for certain buildings available (gas, district heating and heat pumps) and there is also the need to model the energy demand for those buildings without metered data. Hence, it is necessary to combine different data sources for the calculations.

In general, the required data for modelling the energy demand on the building level is not publicly available. In order to gather relevant data, contracts with the involved parties are necessary. However, the public utilities provide their data to the municipality. This data exchange takes place on a voluntary basis. It has to be mentioned, that the public utility in Winterthur is entirely owned by the city of Winterthur. Currently, a cadastre of buildings (development towards a digital twin) is foreseen for the city.

In the following table (Table 6) an overview of the estimated data quality is prepared. It can be seen that the highest data quality is available for the number of apartments/flats and the energy supply system of the buildings.

TABLE 6 : BUILDING DATA ATTRIBUTES QUALITY MATRIX OF WINTERTHUR

Attributes/information	Rating
Construction period	0-2
Gross floor area	0-2
Compactness	0
Main use	0-3
Further uses	0
Number of apartments/flats	2
Number of inhabitants	0
Condition of building	1
Energy supply	2

Question: Which of the following attributes/information are available and what is the quality of them (0 = not available, 1 = low, 2 = middle, 3 = high)?

The condition of the buildings is ranked with the lowest quality. The quality of the construction period and the gross floor area ranges from 0 to 2 and the main use from 0 to 3.

Energy-related infrastructure

In terms of infrastructure, the data quality varies significantly. There is GIS data available for the gas grid. The district heating network is only provided via pdf. Data of central heating plants, including the capacity (e.g. for incineration plants and large heat pumps), is also made available for planning purposes. Direct access to infrastructure data is not available. If data for planning purposes is required, a request has to be submitted to the public utility and, if necessary, a contract for the data exchange must be concluded.

Data of the energy supply system of each building is available. The data is available on the address point level. Only the information on the energy demand is available for the metered buildings that are served via gas, district heating or heat pump. Information on parameters such as the age or power of the energy supply system is only available for combustion heatings (gas, oil, wood).

Energy-related infrastructure Winterthur:

Grid-bound infrastructure	**Gas, district heating**
Energy storage	**Not available**
Energy supply system	**Available on building level (gas and district heating)**

Energy potentials

In Winterthur extensive data on different renewable energy sources (RES), such as photovoltaic, solar thermal, geothermal (shallow), ground water, waste heat, wind and biomass are available or roughly estimated. Solar energy potentials are available on the building level, including a qualitative and quantitative classification of roof-tops and facades (facades for PV only). Although areas for shallow geothermal and ground water heat recovery have been located, a detailed evaluation of its potential was not followed in the city. One possible area for deep geothermal energy extraction was evaluated within the city and two areas outside the city. Data on waste heat recovery is only assessed for certain industrial sites and/or companies, for which individual companies were surveyed. Wind potentials are available on a smaller-scale.

Energy potentials Winterthur:

Types of renewable energy sources (spatial resolution if applicable)	• **Photovoltaic** (roof area and front area) • **Solar thermal** (roof area) • **Shallow geothermal** and **ground water** (no potential, only permission or not) • **Waste heat** (per site, per source) • **Wind** (only wind speed) • **Geothermal** (per site) • **Biomass**
Temporal resolution	**Annual** (except waste heat)
Direct access of planner to the data	**Partly**

Whenever energy supply data is available, it is provided in an annual resolution, except the surveyed waste heat potentials (seasonal/daily). Similarly, there is no overall evaluation on future energy supply scenarios in the city of Winterthur except for waste heat potentials. An integration into the local GIS system has already been carried out for geothermal (shallow) energy, groundwater energy and waste heat potentials. RES data on photovoltaic, solar thermal, geothermal (shallow) and groundwater as well as wind energy is publicly provided (see Figure 11). A direct access to the energy supply data is not always guaranteed. Photovoltaic, solar thermal, geothermal (shallow) and groundwater and wind potentials are available online, whereas waste heat and geothermal resources are only available to planners.

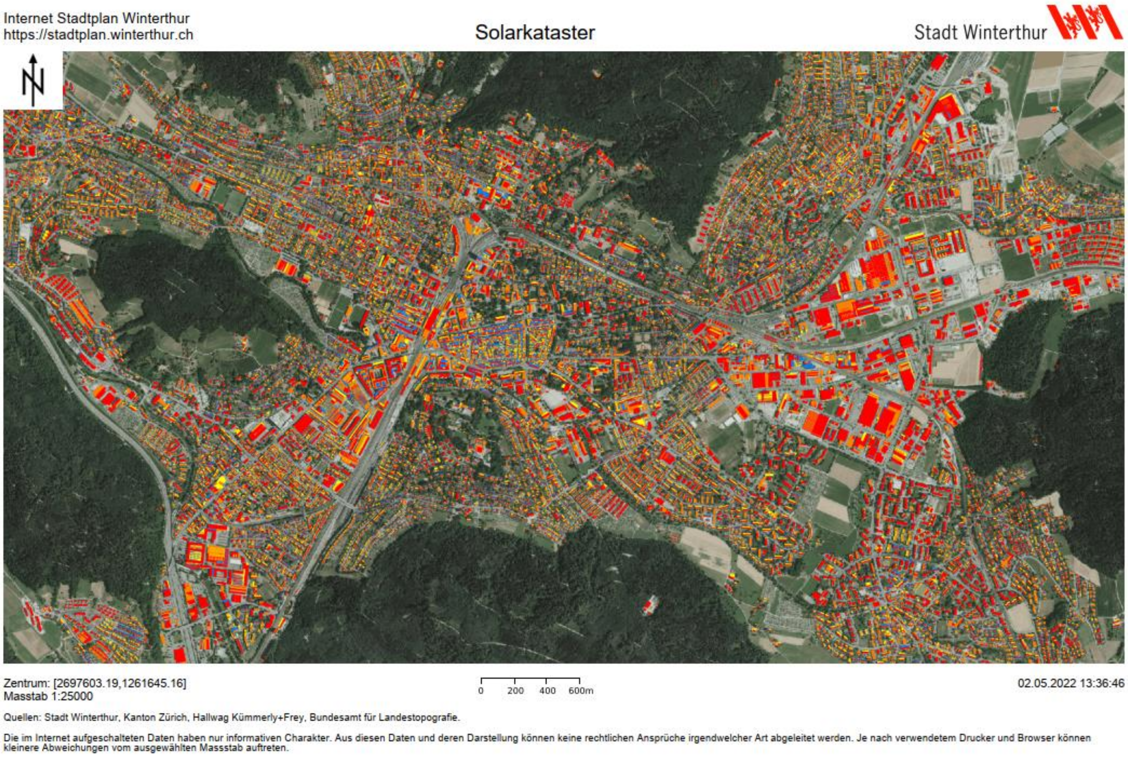

FIGURE 11 : SOLAR CADASTRE OF THE CITY OF WINTERTHUR (STADT WINTERTHUR, KANTON ZÜRICH, HALLWAG KÜMMERLY+FREY, BUNDESAMT FÜR LANDESTOPOGRAFIE)

In order to derive what part of the energy demand can be provided by local RES, a detailed comparison between the energy demand and the energy supply is intended in the near future. An interesting question that arises in this context is to which extend the district heating system can be entirely operated renewably in the future. In order to provide more detailed H/C maps the potential energy supply on each parcel would be quite helpful. Some data on RES is also available for the entire area of Switzerland (wind and solar), other data is provided by the canton (e.g. geothermal and groundwater) and some data, such as waste heat, is surveyed in detail by the municipality.

City synthesis

This chapter presents a city synthesis, taking the results of data availability and quality from all the participating cities of the project as a basis. Table 7 displays the results of the city synthesis in an easy-to-understand overview.

TABLE 7 : CITY SYNTHESIS AMONG THE MOST RELEVANT TOPICS

Topic	Synthesis
General information on energy demand models	▶ Every city has its own energy demand model which is based on multiply data sources ▶ Model are mostly based on the building stock ▶ Focus lies on residential buildings ▶ Focus lies on heat demand, including space heating and hot water demand ▶ Cooling and electricity demand are only sometimes included ▶ Temporal resolution is always annual ▶ Spatial resolution: Building, areal level (e.g. postcode), density maps (raster)
Composition of energy demand model	▶ Building data (type of use, construction period, gross floor area, …) ▶ Specific heat demand values such as kWh/m2.a or heat load in kW/m2.a ▶ Total heat demand values in kWh/a
Most common data sources	▶ Census data ▶ Building register ▶ Energy performance certificates ▶ Building cadastre from land survey ▶ Other land survey data including digital surface and digital terrain models ▶ Energy suppliers and public utilities ▶ Municipal buildings ▶ Registered refurbishment activities (mostly if subsidised) ▶ Monument buildings or zones ▶ Benchmarks for commercial buildings ▶ Metered data from public buildings ▶ Other departments/institutions/registers due to obligations to report certain installations ▶ Statistical offices ▶ Site visits and surveys ▶ Social housing associations ▶ Open Government Data (OGD) ▶ Central pipeline cadastre ▶ Chimney sweepers database

Distinctions between building categories	► Residential buildings (various differentiations) ► Commercial buildings ► Industrial buildings ► Office buildings ► Public and administrative buildings ► Health care buildings, hospitals ► Social facilities ► Educational buildings ► Sport buildings ► Cultural and event buildings ► Restaurants, gastronomy ► Hotels and accommodation ► Infrastructure buildings ► Religious buildings like churches
Calibration with consumption (metered) data	► Calibration is a main challenge in all cities ► Calibration with city owned buildings ► Calibration with consumption data of entire city, postcode level or if available from individual buildings ► Gas consumption data on postcode level
Scenario calculations	► Commonly not available on building level ► Partly adjustments of the model based on population developments, retrofitting and refurbishment measures or rebound effects
Data on (grid) infrastructure	► Differentiation into gas grid, district heating grid and electricity grid ► Grid infrastructure is used to determine the heat supply system ► Hardly any information on energy storage systems available ► Besides location, only little details on grid infrastructure available – data quality varies significantly between cities
Data on renewable energy potentials (number of cities specifically mentioning renewable energy source)	► Industrial waste heat IIIII ► Ambient heat (sewer, wastewater treatment plant, surface water, data centres etc.) IIIII ► Solar energy IIIIII ► Deep Geothermal IIII ► Shallow Geothermal IIIII ► Wind IIII ► CHP IIII ► Biomass III ► Waste incineration III ► Hydropower I
Availability of data (internal, external)	► Most data are not freely available (public) ► Requests for data from other departments often necessary ► Easy access to city owned buildings ► Data on industrial and commercial buildings often based on assumptions

	▶ Data from energy providers difficult to obtain
Strategies to gather relevant data	▶ Gathered via city council ▶ Requests to the energy supplier ▶ Requesting relevant data via agreements or contracts
Quality of data and data gaps	▶ Best quality mostly for residential buildings ▶ Poor quality for industrial buildings ▶ Poor quality for mixed-used buildings ▶ Lack of information on retrofitting/refurbishment of buildings ▶ Lack of data on cooling demand ▶ Lack of data on future developments
Future of data	▶ Better calibration of energy demand models ▶ Better and further integration of data into city's models ▶ Digital twin specifically mentioned by cities ▶ Better integration of scenario calculations ▶ Regular and automatic updates of the data model ▶ Further details on installed heating systems ▶ Better availability of data on refurbished buildings ▶ Better knowledge on consumption patterns
Others	▶ Dealing with strict data protection measures (specifically in relation to energy providers) ▶ No data on green gas ▶ Challenge of electrification of the heating sector ▶ Comparison of energy demand and provision on plot level

Recommendations for Cities

Based on the P2P sessions and extensive (bilateral) interviews with the city partners, many insights were gathered on data governance, sovereignty, data quality and of course data availability. The answers were compiled and evaluated and are presented in detail in the previous chapters.
The results further enabled the derivation of recommendations for cities on data-related issues. Therefore, a brief summary is presented below. Following the chapter division of this deliverable, the first part of the recommendations addresses data governance and sovereignty, followed by data quality and availability.

Data governance and sovereignty

Exhaustive knowledge on data governance issues

It is essential that the unit (department, institution) responsible for an energy data model fully understands the workings of data governance across the entire administration. This also includes a profound understanding of geodata management or geospatial data management. Thus, the following questions should be able to be answered:

- What city-wide strategy and structural set-up is there for dealing with data in general?
- What is the role/responsibilities of others (departments and units) and what is my role within the organisation?
- What data is available at what (spatial) level and who is responsible for the data?

Attribute enough time and staff resources

In a related step, it is also essential to set up a (geo)data management within the unit responsible for energy issues and to define adequate time and personnel resources. Especially the maintenance of data or data models requires considerable resources. Data acquirement for a subsequent model development is also quite time-consuming.

Ensuring a smooth data exchange

Another aspect refers to data exchange. Within a city, it may be necessary to set up a process of data exchange. This exchange can take place between different departments or between the city and the grid operator/energy providers. Sometimes it is also necessary to base the exchange on laws or legal contracts in order to create legal certainty. Some data could be provided as open data – this would then also need resources.

Data quality and availability

Following a checkbox-set of questions to ensure data quality

The first recommendation in terms of data quality and availability is to use or be guided by the initial questions already presented in the chapter on “Data Availability & Quality”. The questions are particularly interesting for assessing and gaining a better understanding of data available.
It is recommended to focus on the following questions for each data set:

- Which attributes are available and at which spatial level?
- Is the data available for all units or only partially?
- What is the quality of the data? Can they be used for the task at hand?
- Is the data trustworthy?
- Where does the data come from?
- Who is the holder/owner of the data?
- How often is the data updated?
- What is the exact definition of the data and the attributes (e.g. units, definition of energy demand, etc.)?
- What are the limitations of the data available?

Integrating data gathering into recurring, official procedures

In the context of data quality, it is emphasised that the quality of the models (outputs) is only as good as the underlying input data. In order to improve data quality, adequate resources are required. For instance, a comprehensive assessment of the building stock through on-site inspections could provide the highest data quality. However, due to time and resource constraints, this is usually not feasible. Therefore, a moderate level of data quality needs be achieved that meets the requirements of the respective project. It has to be decided which quality data level is necessary for which tasks. For instance, the heat demand could deviate of around 20% on building level and 10% on hectare level to be sufficient for district heating planning.
In the long term, it is advisable to integrate data collection into existing procedures, like e.g. in the case of building permits or other official notifications. It is then, for example, possible to integrate the data provided in a cross-departmental database/data warehouse.

Identifying data / knowledge gaps

To get a better overview of the data and to identify possible data gaps, it is advisable to first make a comparison between the data already available and the data still required. Some gaps could be filled by workarounds. For example, missing values for gross floor area on the building level can be derived from digital surface models (DSM) and digital terrain models (DTM). Points of interest (POI) data could also be included if the exact type of use of a building is not available. This information can also be used to improve, enhance or validate existing data.
Another challenge refers to population-related data. For example, this data is difficult to relate with building data. It needs also be noted that the personal register does not reflect the actual living situation.

Closing research gaps

Research gaps that still exist need to be closed. For example, the energy demand of non-residential buildings as well as adequate information about residual/waste heat (especially on low temperature levels) still pose challenges to pretty much all participating cities.
One approach to increase knowledge about the population is to use demand data such as water consumption or electricity consumption on building level.

Clear identification of data is crucial.

Energy data models need accurate data, specifically on building level. It is often challenging to identify the right ID (identifier) to link different data sources. Hence, the definition and the identification of data is crucial. For instance, the element “building” in the building register could denote a different physical object in another data source.
Thus, there needs to be a commitment to universal identification of data for different spatial levels or statistical units.

Towards specific data on building level

In the future, energy performance certificates could play an even more important role for energy-related information and energy models. Especially the information about the type of energy system[s] (including temperature level) is essential. Information like the construction period could be used in addition to or as comparison for the building register. If the database grows continuously and includes a large part of the buildings, then the quality of the data model will inevitably benefit.

Updating data on a regular basis

An essential question also arises when it comes to updating the data on a regular basis. Depending on the type of data this can range from immediate updates in a database to annual updates (or even longer periods). As a minimum, key dates or the periods should be agreed and communicated.

Energy data in a high spatial and temporal resolution

It is recommended to compare the energy demand with the energy supply in the future. Special attention should be paid to both, the spatial and temporal components of the comparison. Annual balances for an entire city often show a distorted picture of reality.

Validation of the energy model

Wherever possible, validation must be carried out with measured data. This way it is also possible to calibrate the energy model accordingly. To avoid data protection issues it is recommended to use anonymised data for a sufficient number of buildings for each type (residential buildings with 3 to 9 apartments, commercial buildings, etc.), construction period and compactness.

More on data concerning energy-related infrastructure

It is advisable to collect detailed data on gas infrastructure and specific information on cooking and process gas consumption. For district heating, it is not sufficient to only know the location of the grid infrastructure, the type of pipes or the hydraulic-dynamic system. Additional information about the remaining capacity is essential for planning purposes (e.g. information about substations/transformers). For electricity data, it is advisable to collect information on remaining capacities, especially for charging stations and heat pump applications.

Handling multiple data sources

Most energy models consist of a variety of different data sources. Therefore, knowing and accurately tracking the status of data is essential. A combination of data with different time stamps is often the case. Tracking the data status helps to explain the results in detail. Especially, when it comes to questions about the results of the model in the future. Metadata, such as the description of attributes, should also always be kept up-to-date to support the understanding of the data.

What is important for renewable energy potentials?

Data on renewable energy potentials are important. Assessments about these potentials should take into account any limitations on implementation (technical potentials). It is almost impossible to calculate potentials exactly while considering all economic, legal, static or other limitations for each building and property. Nevertheless, it is recommended to calculate all potentials on the "smallest" possible spatial level. For instance, the shallow geothermal potential could be calculated down to the property level (from 30 to 200 metres) regarding water protections zones and non-built up areas. Solar potential of roofs could be calculated only for useable areas of each roof, while including reducing factors well known from practice.
All calculated potentials should be easily accessible for everyone to trigger the use or the interest on renewable energy potentials.

Finally, it is emphasised once again that data – no matter whether its geospatial or non-spatial data - are the cornerstone of energy planning. It provides the basis for heating and cooling plans as well as transitions roadmaps.
Most important key element is appropriate and sufficient information about buildings (and properties) including the energy supply system.
Looking at all the information gathered in this project from six different cities (Bilbao, Dublin, Munich, Rotterdam, Vienna and Winterthur), it can be concluded that great efforts have already been made and continue to being made in terms of data governance & sovereignty as well as data quality & availability.

However, there is still a need to fill data and knowledge gaps. The future of energy-related data is seen, among other things, in

- more sophisticated calibration of models (usage of measured data),
- the development of digital twins,
- regular updates,
- enhanced data exchange between energy provider / net provider and the city administration,
- better integration of scenarios or better knowledge on consumption patterns.

Ultimately, each city needs to define its own structures. By looking at other successful examples, cities can, however, extract learnings for their own settings.

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