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ENERGY TRANSITION PlanHeat

PlanHeat

User-friendly data collection method for LHP

Improving data provision and access

National Energy Conservation Agency

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Content

Acronyms

BSR – Baltic Sea Region

CSR – Coordinate reference system

DH – District Heating

EED – EU Energy Efficiency Directive

GDPR – General Data Protection Regulation

GIS – Geographic Information System

LHP – Local Heat Planning

QA/QC tests – Quality Assurance /Quality Control tests

Executive Summary

This document provides practical guidance on building and maintaining a repeatable data workflow for Local Heat Planning (LHP). Its core message is simple: without a structured approach to data collection, integration, and upkeep, heat plans become one-off exercises–costly to reproduce, difficult to update, and of limited value for investment decisions. The recommended approach focuses on creating an operational “planning data asset” (datasets + metadata + quality rules + update routines), rather than producing a static package of files compiled only for the purpose of the plan.

For decision-makers (municipal leadership, utility management, heads of units)

Local Heat Planning requires cooperation across municipal administration, municipal companies/utility entities (e.g., district heating), infrastructure operators (heat, gas, electricity), and public bodies that can enable standardisation and access to data. The municipality’s key role is to act as the process owner and data integrator–setting the mandate, ensuring coordination, and establishing clear rules for data governance. Decision-level priorities should be: (1) agreeing on the scope and expected outputs (maps, zones, investment priorities, monitoring indicators), (2) enabling lawful and secure access to data–especially operator and consumption-related data–preferably in aggregated/anonymised forms, and (3) ensuring that the plan leaves behind a maintained dataset with a defined update cycle. The value proposition is reduced repetition, improved consistency, and a plan that can support real implementation over time.

For coordinators and implementers (LHP lead, GIS/IT teams, analysts, contractors)

The operational objective is to build an updateable planning repository that can continuously support analysis and reporting. A minimal end-to-end workflow includes: defining analytical outputs and minimum data requirements; compiling a source register (owner, format, coverage, update frequency, constraints); collecting data using agreed templates and standards; harmonising and integrating layers in GIS (reference systems, identifiers, units, definitions); conducting quality checks and documenting limitations; and establishing maintenance routines (versioning, responsibilities, and update schedules). The "definition of done" for the data stage is not only the final maps, but also a coherent set of integrated layers with metadata, a short quality report, and a practical update plan.

Data sensitivity and feasibility

Some datasets–particularly consumption information and detailed network asset data–are sensitive and may relate to critical infrastructure. The default approach should therefore be to work with spatial and temporal aggregation (zones/grids, typical profiles), apply data minimisation, and implement controlled access and secure handling whenever more detailed data are necessary. Where data are complex to obtain (operator datasets, waste heat potential, consumption), the recommended strategy is phased completion: start with a feasible baseline that supports planning decisions, and improve coverage and quality over successive update cycles. This ensures the plan remains implementable from the outset while becoming more robust over time.

To support practical implementation, the document concludes with role-specific checklists (Annex ES-A) for decision-makers and for coordinators/implementers, summarising the minimum actions needed to establish an updateable planning data asset and a repeatable data workflow.

Part A. Survey report

A1. Introduction

This document was prepared as a practical response to a key challenge in implementing Local Heat Planning (LHP). It aims to guide through the lack of an organised, repeatable data workflow, building on the (necessary) information many municipalities already possess. In practice, data (e.g., building datasets, selected Geographic Information System (GIS) layers, fragments of infrastructure information) are often dispersed across institutions, provided in different formats and standards, and sometimes collected only once "for the purposes of the document" and then neither maintained nor updated after the work is completed. This not only leads to costly and repetitive planning efforts, but also resulting maps and analyses that are of limited value for investment decision-making.

This report was developed within the PlanHeat project, a transnational initiative that brings together municipalities and expert organisations from seven countries in the Baltic Sea Region (BSR) to strengthen local capacities for Local Heat Planning (LHP). PlanHeat responds directly to the growing climate and energy-policy pressure on cities, as the heating sector remains a major source of greenhouse gas emissions across Europe, and the recast EU Energy Efficiency Directive (EED 2023) introduces new expectations for municipalities–particularly those above 45,000 inhabitants–to prepare robust local heat plans. By combining municipal practice with expert knowledge, the project is jointly producing a comprehensive manual that helps cities move from ad-hoc planning efforts to structured, repeatable approaches. The manual is organised into five complementary "sub-solutions" covering data access, technologies, staff and skills, stakeholder participation, and financial and organisational arrangements, with strong engagement of key actors such as heat suppliers, energy consultants, and national/regional authorities. This report contributes to that effort by translating project experience into a practical, implementation-oriented resource that can be replicated across the BSR and beyond.

The document aims to fill this gap by delivering two complementary outputs that together form a "bridge" between regulatory requirements and the realities of implementation at the municipal level:

- a diagnostic component – a survey-based report presenting the level of readiness of municipalities/partners, typical data gaps, and access barriers (organisational, legal, and technical), and
- an implementation component – a set of guidelines and a checklist that guide users through the data-preparation process: from identifying data needs, through

acquisition and harmonisation, to quality control, metadata, and the preparation of a dataset that can be reused and updated.

Within the PlanHeat project logic, the document serves a "diagnostic-and-design" function: it first determines what data municipalities have and what barriers prevent their acquisition, and then translates these findings into an implementation tool that can be applied across different countries and institutional contexts. This approach is particularly important because one of the most frequently reported problems is limited access to energy-related data and the fact that, and the information required for LHP is distributed among many stakeholders (including network operators).

The document is addressed to the PlanHeat target groups, i.e. the actors that, in practice, must cooperate to make Local Heat Planning (LHP) work: (Target group 1) *local and regional public authorities* (municipal administrations and their units responsible for energy/climate policy, spatial planning, and digitalisation/GIS), who lead the planning process; (Target group 2) *infrastructure and public service providers* such as district heating companies, heat-network owners and grid operators (heat/gas/electricity) as key data holders and implementation partners; (Target group 3) *sectoral agencies* including energy consultancies, engineering/planning offices and other external service providers that support municipalities with analysis, data integration and modelling; (Target group 4) *interest groups* (e.g. citizens' associations, energy communities, neighbourhood initiatives, and business organisations) whose early involvement is essential for acceptance and effective participation; and (Target group 5) *national public authorities*, primarily ministries responsible for energy and climate policy, together with other framework-setting public bodies that can enable LHP by clarifying rules, standardising approaches, and providing financial/technical support and mechanisms for improved data access ("support institutions").

The scope of the document includes the regulatory context and its implications for data, GIS fundamentals "for LHP needs" (formats, data quality, system components and the data lifecycle), survey analysis; GIS fundamentals "for LHP needs" (formats, data quality, system components, and the data lifecycle); survey analysis; and an end-to-end description of the data acquisition process with minimum requirements. At the same time, the document is not a technical specification of an IT platform nor a comprehensive modelling handbook – modelling and analytics appear only insofar as to the extent that they justify data requirements.

The conclusions in the diagnostic section are based on a survey conducted among partners/municipalities, which examined: the availability of GIS and descriptive data, access barriers, process maturity (updates, standardisation, documentation), that examined: the availability of GIS and descriptive data; access barriers; process maturity (updates, standardisation, documentation); and support needs (tools, standards, competencies). A key feature of the approach is that survey results do not remain purely "descriptive"–they are synthesised and translated into concrete checklists and guideline elements so that the report is directly useful for implementation.

A2. Regulatory context

A2.1. The EED Directive (EU) 2023/1791 – purpose, operating logic, and "what's new"

The revised Energy Efficiency Directive (EED 2023/1791) strengthens the role of planning as a systemic tool: Member States are to not only implement energy-efficiency improvement measures, but also identify and mobilise potential in sectors, including heat. In practice, this means a shift from a project-by-project approach (individual investments) to an approach based on diagnosing the current situation, analysing potentials, and programming actions in one based on diagnosing the current situation, analysing potential, and programming actions over a multi-year horizon.

In regards to heat, Article 25 is pivotal. It requires Member States to prepare a comprehensive assessment of the national heating potential, to be incorporated into national energy and climate plans. This assessment is to be based on standardised elements set out in Annex X of EED Directive (including, among others, a balance of heat/cold demand and supply, a technology analysis, scenarios, and the identification of potentials).

A key novelty for the local level is that the Directive strengthens planning obligations for local and regional authorities–not as a "good practice", but as a required element linked to data and participatory processes. Importantly, the requirements concern not only drafting a document, but also: (a) basing it on data from national assessments, (b) involving stakeholders and the public, (c) considering infrastructure, and (d) indicating financing mechanisms and progress-monitoring arrangements.

A2.2. Local heat plans – the role of local governments and Member State support

Article 25(6) obliges Member States to ensure that local and regional authorities prepare local heat plans in municipalities, if the total population exceeds 45,000.

The Directive specifies a minimum scope for such plans. In particular, the plans should:

- be based on information and data from comprehensive national assessments and include estimates and mapping of the potential to increase energy efficiency and deploy low-emission solutions (including low-temperature networks, high-efficiency cogeneration, waste-heat recovery, and renewables in heating),
- respect the "energy efficiency first" principle,
- include a strategy for using the identified potential,

- be prepared with the participation of stakeholders and the public, including operators of local energy infrastructure,
- take into account existing energy infrastructure and the needs of local communities,
- include elements on financing, implementation pathways for achieving targets, progress monitoring, and synergies with plans of neighbouring units.

The Directive also allows for territorial cooperation: local plans may be prepared jointly by several neighbouring local authorities where/if justified by geographical context and infrastructure. In addition, the plans are subject to assessment by the competent authority (with the possibility of implementing measures).

From the perspective of practical feasibility, it is also important that the EED places a practical feasibility perspective, it is also important that the EED imposes an obligation on Member States to support local and regional authorities. It explicitly mentions preparing recommendations and providing support (including financial and technical), as well as striving to align LHP with other local planning requirements in the fields of climate, energy, and the environment – so as to reduce administrative burdens/effort and increase the effectiveness of implementation.

In the PlanHeat project documents, the requirements of Article 25(6) are indicated as one of the key reference points for the final "manual" and for activities addressed to local governments and infrastructure partners.

A2.3. Implications for data: why EED requirements cannot be met without spatial data

EED requirements–especially regarding "mapping potentials", taking infrastructure into account, and planning the transition pathway–mean that LHP becomes a process that is strictly data-driven. The plan is not merely a description of actions; it must follow from identifying: (a) where demand for heat/cold occurs, (b) what the building stock characteristics are, (c) where and how infrastructure runs, (d) what technological potentials exist and where they are located (renewables, waste heat, cogeneration), and (e) what spatial and functional barriers to implementation exist.

In this context, spatial data are the "integrating language" for serve as the "integrating language" across different data domains: buildings, land use, functional zones, infrastructure networks, locations of sources and consumers, development areas, and environmental and as well as planning constraints. GIS enables:

- mapping potentials (as required by the EED) as an analytical operation rather than merely an illustration,
- linking demand and supply data to location (e.g., demand-density zones, areas where networks are cost-effective, locations of waste-heat sources),

- analysing options and scenarios (e.g., introducing low-temperature networks, modernising sources, gradually phasing out fossil fuels), which the Directive links to progress monitoring and the pathway for achieving targets.

As a consequence, a systematic approach to data acquisition, harmonisation, and quality assessment is needed. PlanHeat indicates that, at a minimum, the following are crucial: building data (e.g., energy performance, size, age, heating systems), energy-consumption data, energy-infrastructure data, and data on renewable energy potentials–datasets which in practice come from many institutions and often exist in different formats and standards.

For this reason, this document is not limited to describing requirements. Its role is to translate the EED into a practical, user-friendly way of organising data collection and to facilitate local governments' access to dispersed information sources, so that meeting planning requirements (including potential mapping) is feasible under real organisational and capacity constraints.

A3. Geographic Information System fundamentals

A3.1. What GIS is and why it is needed in local heat planning (LHP)

A Geographic Information System (GIS) is a set of tools and methods for collecting, organising, integrating, analysing, and presenting data linked to spatial dimensions. A key feature of GIS is that it allows work on different "layers" of information (e.g., buildings, networks, heat sources, land use) and links them through a common an everyday spatial context. So technical, statistical, and descriptive data can become a single, coherent analytical resource. In practical heat planning, GIS is the tool that enables a shift from a general description to evidence-based planning: identifying priority areas, assessing potentials general descriptions to evidence-based planning: identifying priority areas, assessing potential, and comparing scenarios.

In the context of Local Heat Plans (LHPs), GIS is not just as one might say: "nice map at the end". It is first and foremost a coherent data structure and analytical environment that makes it possible to enables answering planning questions such as: where demand density is highest, where infrastructure exists, where renewable and waste-heat potentials occur, and what the implementation constraints are.

A3.2. How a GIS system works: data, software, infrastructure, people, and process

GIS functions as an ecosystem in which data, IT tools, and organisational processes are equally important. In practical terms (relevant for municipalities), one can distinguish:

- Data: spatial layers (e.g., buildings, networks) and descriptive data (e.g., consumption, technical parameters), linked through identifiers and geometry.
- Software: tools for editing, integrating, and analysing data; these may be desktop systems, map servers, or web platforms.
- Infrastructure: databases, file repositories, network services, backup mechanisms, and versioning.
- People and roles: data owner, system administrator, GIS analyst, energy specialist, and a person responsible for legal aspects/data sharing.
- Processes: acquisition → standardisation → quality control → publication/sharing → update (i.e., the data life cycle).

In district heating and networks, GIS can also act as a reference system for infrastructure (asset inventory), and in more advanced applications it forms the basis for thermo-hydraulic modelling and optimisation (e.g., planning network routes, varying pipe diameters, analysing system operation over time).

A3.3. GIS data types and formats relevant to LHP

From an LHP perspective, three categories of spatial data are key:

- Vector data – represent objects as points/lines/polygons (e.g., point: heat source; line: network segment; polygon: building or zone). This data type underpins infrastructure analyses and links to attributes (e.g., year built, building type, pipe diameter). In practical integration, formats such as Shapefile or GeoJSON (especially in web environments) are often used; what matters most is a consistent attribute structure and unambiguous object identifiers.
- Raster data – represent phenomena as a grid of cells, where each cell has a value (e.g., heat-demand density, solar potential). In heat planning, demand/potential maps with a resolution of 100×100 m are common, enabling area comparisons and the identification of high-need clusters.
- Service data (web services) – provided as map/data services (e.g., for viewing and downloading). This is important for inter-institutional cooperation and for building a "shared data space" for LHP, especially mainly where data are distributed among different providers. (In practice, this is crucial, as surveys indicate fragmentation and lack of standardisation as one of the main barriers.)

Regardless of format, a prerequisite for combining layers is a common standard spatial reference (coordinate reference system and georeferencing). Without it, layers will not overlay correctly and distance/area calculations will be error-prone–, and distance/area calculations will be error-prone, which directly affects planning and resulting economic conclusions.

A3.4. Data quality and metadata: why this is critical for a credible plan

Because LHP is meant to support investment and regulatory decisions, GIS must rely on data which quality can be assessed and defended. In practice, this means checking at least five dimensions:

- **Completeness**: does the layer cover the entire area and all objects (e.g., all buildings, all network segments)?
- **Currency:** when were the data updated, and do they reflect the current situation?
- **Accuracy:** geometric (location, network alignment) and attribute accuracy (e.g., capacities, technical parameters).
- **Consistency:** absence of contradictions between layers and within a layer (e.g., consistent identifiers, units, classifications).
- **Provenance and constraints:** who the source is, what the terms of use are, and what legal constraints apply (e.g., sensitive data, operator data).

In European practice, one of the most common problems is integrating heterogeneous, inconsistent datasets: building data, statistics, energy registers, and operator networks often exist simultaneously at different aggregation levels and in different data, statistics, energy registers, and operator networks often exist at different aggregation levels and under various standards, forcing the use of approximations and increasing uncertainty.

Therefore, metadata are an indispensable element of every layer in LHP: a description of content, extent, quality, acquisition date, spatial reference, responsibilities, and sharing conditions. Metadata is not a "formality"–it is the mechanism that makes a plan auditable and updatable, and allows data to be reused in subsequent plan iterations.

A3.5. GIS in LHP: from inventory to analysis, scenarios, and modelling

In LHP, GIS supports the entire process–from diagnosis to implementation–through three main functions:

- **Integration and a "shared picture" of the situation**
  GIS links buildings (demand), infrastructure (transfer capability), sources (supply), and potentials (renewables/waste heat). Survey results in the PlanHeat project show that, in partner municipalities, building layers and data on district-heating networks (routes, lengths, losses, age) are the most strongly developed, providing a solid foundation for demand and infrastructure analyses. At the same time, a systemic weakness was identified in the area of waste heat–both identification and information on availability or seasonality are lacking, often due to organisational and legal constraints.

- **Spatial analysis and delineation of priority areas**
  A typical GIS product is a "heat map" – a demand-density map, often built by aggregating building data to a grid (e.g., 100×100 m). This makes it possible to indicate areas with the most significant potential for networks or for intensive efficiency actions. Such maps are widely used as decision-support tools (for municipalities, operators, investors) because they simplify the identification of high-demand clusters and comparison of action variants.
- **Scenarios and modelling (where data maturity allows)**
  In more advanced applications, GIS provides the basis for network modelling and option testing: from automatically determining network routes based on street layouts to analyses that account for technical parameters and system operation over time (e.g., annual simulations, optimisation of diameters and temperatures). The key point is that GIS ceases to be "background" and becomes a set of variables and constraints in the design process.

GIS is the fundamental tool that enables LHP to be carried out in a coherent, comparable, and iterative manner. Its effectiveness, however, depends on whether a municipality can establish a repeatable data workflow (acquisition–harmonisation–QA/QC–metadata–update) and whether it has real access to data from key stakeholders (in particular operators and entities holding consumption and potential data).

A4. The landscape of data and GIS systems in Europe (current state)

A4.1. What the "data ecosystem" looks like in practice: organisational models and typical flows

In most EU countries, the data needed for local heat and cool planning are not compiled in a single place. Instead, there is an ecosystem of distributed registers and institutions that provide different pieces of the picture: building geometries and addresses, statistical data, information on infrastructure, consumption, and renewable and waste-heat potentials. This dispersion means that preparing an LHP is largely essentially an integration task: datasets with different scales, formats, and aggregation levels must be combined, often filling gaps with intermediate methods (e.g., downscaling, grid meshes, proxy indicators).

In practice, two dominant models occur:

- A distributed model ("data silos") – each stakeholder maintains its own datasets, and the municipality collects data ad hoc for planning purposes. While such datasets are *in principle* connectable, in practice integration is often only partial due to differing standards and definitions, uneven data quality, and inconsistent maintenance cycles across organisations (a challenge observed particularly in smaller municipalities). As a result, integration work is repeatedly duplicated, inconsistencies are more likely, and the process becomes highly dependent on individual contacts and local know-how–especially where there are no clear rules or routines for data sharing by infrastructure operators.

- A platform model ("shared database / planning repository") – data are aggregated and maintained in one place (typically at national or regional level) in a form designed for reuse. The literature commonly points to this approach as a way to reduce access barriers and manual work, improve comparability, and support harmonised standards and update routines.
- In both models, GIS plays a key enabling role as the "connecting layer": it can structure and document inputs (layers + metadata + harmonisation rules), support interoperability and quality checks, and translate heterogeneous source data into the analytical outputs required for LHP (e.g., maps of demand, infrastructure, potentials, and zoning).

A4.2. Who provides the data: typical sources and their specifics

In simplified terms, the data used in local heat planning can be divided by provider:

Cadastral/topographic administration (central or regional)
Usually responsible for the most "stable" reference datasets: buildings (geometry), addresses, administrative boundaries, and the street network. In the EU context, it is important that geodata harmonisation is supported by the INSPIRE framework, which facilitates obtaining comparable building/address geometries and reduces integration costs for municipalities.

Public statistics / demographic registers
Provide data on population and social structures, but often at aggregation levels that do not "fit" the building scale (e.g., statistical zones vs. individual objects). The PlanHeat survey shows that while population data are widely available, they are not always effectively operationalised in GIS layers used directly for demand analyses.

Local governments and municipal units
Contribute planning data (land uses/functions, investments, degraded areas), often critical for actually "implementing" scenarios. The survey shows that planning data are widely used (e.g., planned investments, functional areas), indicating the growing integration of heat planning with spatial and regeneration policies.

Operators and companies (heat, gas, electricity) and industry
The most important source of "energy" data: actual consumption, network and source parameters, flow information, and the potential for waste heat. At the same time, these data are most often difficult to obtain because they may be considered sensitive,

commercial, or not subject to mandatory disclosure. The literature indicates that a lack of access to consumption data from operators forces estimations and reduces plan precision; it also shows examples of systemic solutions where sharing has been regulated (e.g., data-sharing mechanisms in Denmark and France).

A4.3. Availability and maturity of GIS layers: what typically works well and where the gaps are

The PlanHeat survey results discussed later in the report clearly show that the "data problem" is rarely a total lack of information–partial gaps dominate, resulting from dispersion, varying levels of detail, and access constraints.

In practice, the highest maturity is usually found in:

- building layers (type, floor area, heating system; often also year built), which form the basis of demand maps;
- district-heating network layers (routes, lengths, losses, age; often also diameters and temperature regimes), suggesting that DH infrastructure is relatively well inventoried and amenable to GIS analysis.

There are typically two weaker links:

- major customers – location is often known, but load parameters and annual consumption are usually available, which limits the precision of balancing and network planning;
- waste heat – the survey indicates low completeness even for basic attributes (source/location/availability/seasonality) and highlights organisational and legal barriers on the industry side.

In the descriptive part of the survey, respondents explicitly indicate that the main barriers include institutional fragmentation, the lack of an obligation for operators to share data, the lack of format standards, and limited integration competencies. These are typical barriers in countries where a "system layer" for LHP has not yet been developed (platforms, standards, and enforceable access to data).

A5. Entities covered by the obligation and the stakeholder ecosystem – introduction to the survey analysis

A5.1. For whom is data collection required, and why this is the starting point of the survey

EED requirements for local heat planning translate into particular organisational consequences: local and regional authorities are to prepare local plans and therefore also organise the acquisition, integration, and maintenance of the data on which those plans are based. The Directive indicates that plans should be prepared at least in units where the population exceeds 45,000, and that Member States should provide support (including organisational, technical, and financial) enabling this obligation to be fulfilled.

In practice, this means that the obligation to "collect data" does not rest with a single institution in isolation. It is a systemic obligation implemented by the local government, but reliant on cooperation with entities that possess data or co-create it (operators, municipal companies, public institutions, industry, building-stock managers). This is why the PlanHeat survey was designed as a diagnostic tool: whether and to what extent these entities are ready to provide data, what resources they have, and what barriers block information flows.

A5.2. The responsible entity: local governments preparing local plans (main user and "data integrator")

The primary group for whom the data-collection process is created (and for whom this report is produced) are: city municipal offices and–depending on the national division of competences–regional authorities that organise the preparation of local heat plans.

From a data perspective, the local government serves as an integrator in this process: it combines spatial and descriptive information from multiple sources into a coherent set used for analyses, potential mapping, and scenario development. In a typical organisational structure, this means cooperation of at least several functions/units:

- the unit responsible for energy/environment/transition (the substantive owner of the plan),
- the spatial planning and investment unit (coherence with spatial policy and investment projects),
- the GIS/IT team (data integration, quality, publication, maintenance),
- legal/GDPR General Data Protection Regulation support (sharing conditions, anonymisation, licences),

- municipal companies and units (public buildings, transport, housing, municipal services).

This "multi-unit" nature is precisely why–regardless of data availability in a given country–municipalities often need a procedure and checklist so that the process does not end with a one-off collection of files, but leads to data that can be updated and reused.

A5.3. Key data providers: who really "own" the information needed for LHP

Survey analysis requires a clear distinction between the entity obliged to prepare the plan (the local government) and the entities that possess the data. In local heat planning, the following provider groups are key:

- **Infrastructure operators and utilities (heat, gas, electricity)**
  This is the most "critical" stakeholder from the planning perspective, because it holds data on networks, sources, operating parameters, and–depending on the case–information on a planning perspective, because it holds data on networks, sources, operating parameters, and–depending on the case–consumption and load profiles. At the same time, access barriers most often arise in this group (data sensitivity, commercial secrecy, lack of sharing standards), which directly affects the quality and level of detail of the plan. In the PlanHeat survey, the topic of access to operator data is one of the key diagnostic areas.
- **Public entities maintaining spatial and reference registers**
  These are institutions responsible for reference datasets, without which energy data cannot be tied to space (buildings, addresses, boundaries, transport layout). For LHP, this is the foundation enabling geocoding, aggregation into zones/grids, and the creation offor geocoding, aggregating into zones/grids, and creating demand/potential maps.
- **Building-stock managers (public and private)**
  For local planning, information on building characteristics (type, function, size, technical/energy condition, heating system) is important because it determines demand and retrofit scenarios. In many cities, a key subset is public buildings (managed by municipal units), where data are relatively more straightforward to obtain and can serve as a "first step" toward building a high-quality data resource.
- **Industry and entities generating waste heat / holding local potentials**
  This group is crucial for identifying potentials (especially waste heat), but is often the hardest source from which to obtain data due to information sensitivity and lack of established cooperation channels. Therefore, the survey analyses not only "whether data exist", but also "whether they are accessible" and in what form (aggregation level, sharing conditions).

- **Supporting institutions (national/regional level)**
  The EED emphasises the role of the state in providing tools and support state's role in providing tools and support to local governments. In practice, this group includes entities that can standardise the approach, prepare guidance, provide data platforms or funding programmes, reducing entry costs for individual municipalities.
  Accordingly, the PlanHeat project and its deliverables are directed to these provider groups; in particular, they address the PlanHeat target groups of local and regional public authorities, infrastructure and public service providers (including network operators), and national public authorities responsible for energy and climate policy.

A6. The Survey

A6.1. Introduction

Objectives of the Survey

The primary objective of the survey is to identify and systematise municipalities' data needs for heat supply planning (LHP), focusing on both spatial (GIS) and non-spatial (descriptive) data. The survey is designed to support the development of transnational guidelines and analytical tools that meet the requirements of the EED and are adaptable to diverse national and local contexts.

More specifically, the survey aims to:

- assess the availability, scope, and quality of GIS data used for analysing heat demand, supply systems, and infrastructure;
- identify data sources and acquisition mechanisms currently used by municipalities and their expert partners;
- examine the extent to which renewable energy sources (RES) and low-temperature technologies are supported by spatial data analyses support renewable energy sources (RES) and low-temperature technologies;
- identify institutional, technical, legal, and organisational barriers to accessing and using relevant data;
- determine capacity-building and support needs related to data integration, standardisation, and analytical competence.

The survey has a research and diagnostic character and does not aim to evaluate individual municipalities. Instead, it provides an aggregated knowledge base for the developing project outputs that support local heat planning (LHP) in the Baltic Sea Region.

Survey Scope and Target Group

The questionnaire was distributed to all project partners participating in the PlanHeat project, covering municipalities and expert organisations from Poland, Lithuania, Latvia, Estonia, Finland, Germany, and Sweden. In the case of Poland, two partner cities were surveyed; their responses were analysed and reported separately due to the different specific characteristics and planning contexts of the two municipalities. The survey was addressed to national tandems, consisting of:

- a partner city or municipality involved in the project, and
- a content or expert organisation supporting the municipality in local heat planning matters.

Respondents were encouraged to prepare answers collaboratively within each tandem to ensure that both local administrative perspectives and technical expertise were adequately reflected. The survey was disseminated to all partners of the project partners, ensuring providing comprehensive territorial and institutional coverage within the project consortium.

Structure of the Questionnaire

The questionnaire is organised into three main thematic sections, each addressing a distinct dimension of municipal heat planning and data usage.

Part I – Background Information

The first section collects contextual and organisational information about the responding tandem. It covers:

- general information on the municipality and country;
- the current status of Local Hea Plans (or LHPs), including whether such plans exist and when they were prepared or updated;
- identification of contact persons from both the municipality and the expert partner;
- prior experience of cooperation between partners and municipalities;
- key thematic areas of ongoing joint activities related to heat planning.

This section provides the institutional and strategic background necessary to interpret subsequent responses regarding data use and needs.

Part II – GIS Data Analysis

The second section constitutes the core analytical part of the survey, focusing on the use of spatial data in local heat planning (or LHP). It is explicitly structured around data categories derived from the EED requirements and best practices in spatial energy planning.

This part addresses:

- spatial data on heating demand, including building characteristics, urban structure, and primary heat consumers;
- data on heat sources and distribution systems, such as district heating networks, heat generation units, and waste heat sources;
- spatial assessment of renewable energy sources and low-temperature technologies, including geothermal energy, solar potential, biomass availability, and heat pump resources;
- infrastructure and planning data, such as local development plans, degraded areas, and critical infrastructure;
- statistical and modelling data used to support demand forecasts, demographic analysis, and scenario development.

For each category, respondents are asked to indicate which data layers and attributes are used, and to identify additional datasets, redundancies, or data-related challenges. This structure enables a detailed assessment of how GIS supports the different stages of local heat planning.

Part III – Descriptive Data in Local Heat Planning

The third section complements the GIS-focused analysis by addressing non-spatial (descriptive) data used in heat planning. It examines:

- key sources of descriptive data, such as energy consumption statistics, technical parameters of networks, waste heat information, and energy price data;
- accessibility of these data, their institutional sources, and limitations related to timeliness, completeness, or legal constraints;
- perceived sufficiency of currently available data for preparing comprehensive heat plans;
- main barriers to data access, including legal, organisational, technical, and financial factors;
- types of support most needed to improve data availability and quality, such as training, data integration platforms, legal instruments, or funding.

This section provides insight into the non-spatial data environment that conditions the effectiveness of GIS-based analyses.

A6.2. Analysis of Survey Results

This section presents a descriptive analysis of the questionnaire responses, structured according to the survey layout. The study highlights key trends, patterns, and constraints identified by municipalities and their expert partners regarding data availability and the use of GIS in local heat planning.

Part I – Background Information

Status of Local Heating Plans

(Question: "Does the municipality/city have an approved local heat plan (LHP)?")

The responses reveal a polarised level of preparedness regarding LHP development. Out of eight valid responses:

- 37.5% (3/8) report having a *fully approved* LHP,
- 25.0% (2/8) indicate a *partially developed* plan,
- 37.5% (3/8) report *no LHP* in place.

Rather than forming a gradual continuum of maturity, municipalities tend to cluster at two ends: either with an established planning framework or without a formal heat plan. This indicates uneven readiness for meeting the requirements of the Energy Efficiency Directive (EED) and suggests that a significant share of municipalities will require foundational support before moving to more advanced planning stages.

Prior Cooperation within National Tandems

(Question: "Have the partner and the city worked together on heat-related topics before?")

Only 37.5% (3/8) of respondents report any prior cooperation between the municipality and the expert partner, while 62.5% (5/8) indicate no prior collaboration. This suggests that, in many cases, the PlanHeat tandem structure is establishing cooperation from scratch, rather than building on long-standing partnerships.

This has practical implications for the pace of LHP development, as newly formed tandems may initially need to invest time in coordination, mutual understanding of data resources, and clarification of roles and responsibilities.

Current Focus of LHP-Related Activities

(Question: "What areas are currently the focus of joint LHP activities?" – multiple answers allowed)

The most frequently indicated focus areas are:

- Evaluation of data and information resources – 5/8,
- Technical planning of the district heating system – 5/8,
- Integration with strategic documents – 5/8,
- Organisational and competence support – 5/8,
- Consultation and participatory action – 4/8.

Overall, LHP-related activities are clearly data-driven and engineering-oriented, with a strong emphasis on technical planning and information assessment. Participatory and consultation activities are present but slightly less dominant, suggesting that stakeholder engagement often follows, rather than precedes, technical analysis.

Part II – GIS Data Analysis

II.1 Spatial Data on Heating Demand

Buildings

(Question block: "Buildings – attributes used")

There is very strong consistency in the use of building-level GIS data:

- Building type – 100% (8/8),
- Floor space – 100% (8/8),
- Heating system – 100% (8/8),
- Year of construction – 87.5% (7/8),
- Thermal requirements – 87.5% (7/8).

These results indicate that **building stock characterisation constitutes a robust and widely adopted foundation** for spatial heat demand analysis. In most municipalities, GIS-based building datasets are sufficiently developed to support detailed demand mapping.

Urban Zones

(Question block: "Urban zones – attributes used")

At the level of urban zones or districts, the following attributes are most commonly used:

- **Dominant function** – 100% (8/8),
- **Energy consumption** – 87.5% (7/8),
- **Housing density** – 87.5% (7/8),
- **Number of inhabitants** – 50% (4/8).

The relatively low use of population data at the zone level is notable. While demographic data generally exist, they are not always operationalised within GIS layers used directly for heat planning, indicating a **disconnect between statistical datasets and spatial demand analysis**.

Major Customers

(Question block: "Major customers – attributes used")

Data availability decreases significantly for large individual heat consumers:

- Location – 75% (6/8),
- Annual consumption – 50% (4/8),
- Maximum heat load – 37.5% (3/8),
- Power source – 37.5% (3/8).

While most municipalities can identify where major customers are located, quantified demand parameters are much less consistently available, limiting the precision of load balancing and infrastructure planning.

II.2 Heat Sources, District Heating Systems and Waste Heat

Heat Sources

(Question block: "Heat sources – attributes used")

A high and relatively uniform level of data availability is reported for heat generation assets. Key attributes such as type, capacity, technology, efficiency, fuel, and cogeneration share are present in 87.5% (7/8) of responses. This suggests good visibility of existing heat sources, often supported by cooperation with system operators.

District Heating Systems

(Question block: "District heating systems – attributes used")

District heating networks are among the best-documented elements in GIS:

- Network routing, lengths, losses, and age – 100% (8/8),
- Diameters and temperature regimes – 87.5% (7/8).

This indicates that GIS-based representations of district heating infrastructure are relatively mature and can support both strategic and operational analyses.

Waste Heat

(Question block: "Waste heat – attributes used")

Waste heat emerges as a systemic weak point:

- Source – 50% (4/8),
- Location – 50% (4/8),
- Availability – 37.5% (3/8),
- Seasonality – 37.5% (3/8).

Even basic identification of waste heat sources is incomplete, and temporal or operational feasibility is rarely documented. Respondents repeatedly point to legal and organisational barriers, for example:

"It is up to industries if they are willing to share this data. Not publicly available."

II.3 Renewable Energy Sources and Low-Temperature Technologies

Clear differences in GIS maturity are visible across technologies:

- Solar energy shows the highest level of development, with radiation and roof exposure used by 75% of respondents.
- Heat pumps are also well represented, particularly with respect to air temperature (87.5%) and low-temperature water sources (75%).
- Geothermal energy is assessed at a moderate level, typically using depth and temperature data.
- Biomass potential is very weakly represented, with only 25% using land area data and just 12.5% identifying organic waste locations.

Overall, GIS support is strongest for solar and heat pump technologies, moderate for geothermal solutions, and very limited for biomass-based heating.

I.4 Infrastructure and Planning Data

Spatial planning data are widely used:

- Planned investments – 75% (6/8),
- Functional areas – 50% (4/8).

Information on degraded areas and energy modernisation needs is used by 62.5% of respondents, indicating growing integration of heat planning with urban regeneration objectives.

For critical infrastructure, heat demand (75%) is more commonly considered than explicit spatial identification (50%), suggesting that some assets are analysed conceptually rather than through dedicated GIS layers.

II.5 Statistical and Modelling Data

Demographic data usage shows a strong imbalance:

- Population data – 100% (8/8),
- Income structure – 25% (2/8).

Similarly, while demand forecasts are used by 62.5% of respondents, broader energy trend analyses are used in only half of cases. This indicates that socio-economic differentiation and long-term scenario integration remain underdeveloped components of GIS-supported heat planning.

Part III – Descriptive Data, Barriers and Needs

Data Sufficiency

(Question: "Is the currently available data sufficient to produce a complete heat plan?")

- 87.5% (7/8) respond "*Partly*",
- 12.5% (1/8) respond "*Yes*",
- 0% respond "*No*".

The dominant perception is therefore not an absence of data, but rather partial sufficiency, driven by fragmentation, inconsistent access, and limited enforceability. Typical comments include:

"Low level of detail in some data, data comes from multiple sources…"
"…not supported by sanctions (no consequences if data is not provided)."
"No information about waste heat; lack of cooperation with service provider…"

Main Barriers to Accessing Descriptive Data

(Multiple answers allowed)

The most frequently identified barriers are:

- Data dispersed across multiple institutions – 75% (6/8),
- No obligation for operators to share data – 50% (4/8),
- Lack of technical capacity for data integration – 37.5% (3/8),
- Lack of standardisation of data formats – 37.5% (3/8),

- Lack of staff competence – 37.5% (3/8).

Additional context-specific barriers include security considerations and the lack of sanctions for non-compliance with data-sharing obligations.

Support Needs

(Question: "What support would be most needed…?" – multiple answers allowed)

Respondents most frequently indicate the need for:

- Data integration platforms – 62.5% (5/8),
- Training for employees – 50% (4/8),
- Legal support to enforce data sharing – 50% (4/8),
- Financial resources for data acquisition – 37.5% (3/8).

This demonstrates a clear preference for systemic enablers–institutional, legal, and organisational–rather than isolated technical fixes.

A6.3. Key Conclusions and Directions for Action

Key Conclusions

- The dominant constraint is partial data sufficiency (87.5%), caused by fragmentation and access limitations.
- GIS maturity is high for buildings and district heating networks, but weak for major consumer loads and waste heat.
- Spatial analysis of Renewable Energy Systems (RES) is strongest for solar energy and heat pumps, and weakest for biomass.
- Socio-economic modelling inputs are rarely integrated into GIS-supported planning.

Recommended directions for Action

- Establish a standardised GIS and data model for LHPs, defining minimum required layers and attributes.
- Develop and expand municipal or regional data integration platforms linking GIS with operator-held datasets.
- Strengthen legal enforceability and sanction mechanisms for mandatory data sharing, particularly for district heating and waste heat.
- Implement targeted training programmes for municipal staff in GIS integration, modelling, and scenario development.

- Launch a structured approach to waste heat inventories, covering location, availability, seasonality, and governance aspects.

Part B: Manual

B.1. Introduction to the manual

Why was this manual created?

- The survey results show that in most municipalities, the problem is not a complete lack of data, but rather its partial usability: data exists, but is dispersed, inconsistent, stored in different formats and levels of detail, and access to key information (especially energy data and data held by operators) is sometimes limited. As a result, LHP often boils down to a one-off data collection "for the purposes of the document," without a mechanism for maintenance and updating. This leads to costly, repetitive planning and to analyses of limited value for investment decisions and progress monitoring.
- Part B responds to these problems: it is a manual for collecting and structuring data and preparing them for the local heat supply plan. The manual guides a municipality through an end-to-end process: from identifying needs, through acquisition and harmonisation, to quality control, metadata, and preparing a dataset ready for use and updates.

Purpose of the manual: target variant and analytical module (extension)

The manual has been designed in two levels, corresponding to two different practical needs:

- **Target variant – complete coverage for preparing a local heat supply plan (LHP Full Coverage)**
  This is the core and intended pathway of the manual. Its goal is to ensure a complete process and a complete dataset that enable the preparation of the plan in full scope: mapping and diagnosis, an action strategy, inclusion of infrastructure, collaboration with stakeholders (including operators), identification of financing, preparation of monitoring mechanisms, and establishment of rules for data updates. This level is designed to be feasible in municipal practice and repeatable in subsequent iterations of the plan.
- **Extended pathway – mathematical modelling of district heating networks (DH Network Modelling & Forecasting)**
  This is an analytical module built on top of the target variant. Its purpose is not only to meet planning requirements, but to support development and forecasting of changes in district heating networks: expansion optioning, assessment of technical constraints, time-based network operation analysis, optimisation of selected parameters, and development of growth scenarios. This pathway requires additional technical and temporal data that are not always available at the plan-preparation stage–therefore, it is described as an extension rather than a prerequisite.

How to use the manual: the "baseline + upgrade" logic

The manual should be read as a set of modules that build data and analytical maturity in a logical sequence:

- First, the target variant (Full Coverage) is implemented: it creates an organised data asset and procedures on which the plan and its updates can be based.
- Then–if the municipality and partners have the relevant data–the extended pathway (DH Modelling) is launched: it uses the asset from the target variant and supplements it with technical parameters and time-series data needed for modelling.

In practice, this means the extended pathway is an "upgrade". If data and cooperation conditions are met, modelling can follow, but the plan itself should already be feasible at the target-variant level.

Roles and responsibilities: the municipality as the data integrator

The manual assumes a simple role model that reduces the risk of the process "getting stuck" between institutions:

- **Municipality/city (LHP process owner)** – responsible for scope, schedule, stakeholder coordination, and approval of final data deliverables.
- **GIS/IT team (integration implementer)** – responsible for data integration and harmonisation, quality control, metadata, versioning, and preparation of layers and indicators.
- **Operators and infrastructure companies (owners of energy data)** – provide key data on networks, sources, and (depending on conditions) consumption; they are a necessary partner in many elements of the plan.
- **Legal/GDPR function (condition for data sharing)** – supports the process with respect to the formal basis for data exchange, anonymisation/aggregation, and licensing constraints.
- **Additional stakeholders (e.g., industry, building managers)** – particularly important for data on large consumers and for waste heat inventories.

The manual describes roles operationally: who initiates, who provides, who integrates, who verifies quality, and who approves the outcome–so that the process is repeatable and maintainable.

Key barriers and how the manual addresses them

- The manual focuses on four areas that the survey identified as critical to LHP feasibility:
- **Access to operator data and enforceability of data sharing**
  The manual includes practical pathways for acquiring data, options for aggregation and anonymisation, and a set of elements that should be included in requests and agreements. It also indicates organisational solutions that can reduce the risk of data blockage.

- **Data dispersion and lack of integration standards**
  A minimal data model is introduced (layers, attributes, identifiers) along with harmonisation rules (formats, units, coordinate reference system, semantic consistency).
- **Data quality and metadata**
  The manual defines mandatory metadata for each layer and a simple set of QA/QC tests. This ensures data is not only collected, but also verifiable and ready for reuse.
- **Skills and tools**
  A minimum skill set and an implementation variant "for a small team" are specified, along with pointers to elements that may require external support.

Final outputs (Definition of Done). What must be produced after implementing the method

- The target variant results in a data and documentation package that forms the basis for building the plan and updating it:
- an integrated set of data layers (core for the plan; and–where available–extended data),
- metadata for each layer (source, currency/timeliness, quality, constraints, responsibility),
- a data quality report (test results, gaps, risks, and interpretative limitations),
- maintenance and update rules (who updates, how often, under what versioning approach).
- The extended pathway (DH modelling) adds further analytical outputs: technical and time-series datasets, calibration data, and scenario results (development variants and forecasts).

Entry condition for modelling (extended pathway)

To initiate mathematical modelling of district heating networks, it is necessary to have the "data backbone" from the target variant, along with additional technical and temporal information (e.g., network topology, segment and node parameters, source characteristics, load profiles, calibration data). Therefore, in the manual, the extended pathway is described as a module to be undertaken after defined data and quality conditions are met, rather than as a mandatory element of plan preparation.

B2. End-to-end process: from need to a ready LHP dataset

This chapter describes a practical, repeatable method for preparing data for a local heating supply plan (LHP) in the target variant (Full Coverage). The process covers the entire cycle: from defining needs and planning deliverables, through acquiring and integrating data from multiple sources, to quality control, metadata, and rules for maintenance and updates. The objective is to create a data asset that can be used not only to develop the plan but also to be updated in subsequent iterations and applied in decision-making processes.

B2.1. Defining the plan scope and final deliverables

The starting point is to determine what the plan must deliver precisely and at what level of detail. The LHP scope should be described in three dimensions:

- **Spatial scope:** the administrative area of the municipality/city, possibly a functional area or the scope of a joint plan for several units (if an inter-municipal approach is adopted).
- **Thematic scope:** heating and their links to infrastructure and spatial policy; the scope of additional data depends on national needs (e.g., links to electricity or gas).
- **Time scope:** the plan horizon and the update frequency (e.g., annual updates of baseline data + plan revision every few years).

At this stage, the final deliverables are also defined, i.e., the “definition of done” for data and analyses, for example:

- a set of (GIS) data layers for buildings, demand, infrastructure, sources, and potentials,
- diagnostic maps (demand, network coverage, potentials, constraints),
- indicators and summaries (e.g., demand density, technology shares, priority areas),
- quality and metadata documentation,
- a data source register and an update plan.
- Defining deliverables upfront reduces the risk of collecting data “because they exist,” rather than because they are necessary for analysis and decisions.

B2.2. Inventory of data sources (internal and external)

The next step is to identify and describe the data sources that will be used in the plan. In practice, a data source register should be prepared, covering at least:

- data owner and contact point,
- thematic and spatial coverage,
- available format and level of detail,
- update frequency,
- legal/licensing constraints and data sensitivity,
- minimum conditions of use (e.g., aggregation, anonymisation).

Data sources are typically grouped into:

- **internal (municipal):** spatial planning, investments, municipal assets and public buildings, municipal infrastructure, local registers,
- **external public:** buildings/addresses, boundaries, statistics, environmental data, planning data,
- **operator and utility/company data:** networks, sources, parameters, consumption and load profiles (sensitive and often critical),
- **industry and large consumer data:** particularly important for waste heat inventories and connection planning.
- The register should immediately indicate which datasets are **must-haves** for the target variant and which are **should-haves** (extensions that improve analytical quality).

B2.3. Data acquisition: pathways, formalities, privacy, and licences

Data acquisition should be planned as a process rather than a one-off action. It includes three groups of activities:

- **Acquisition pathways and delivery format**
  For each source, it must be agreed on how the data will be delivered (format, coordinate reference system, aggregation level, attribute scope). In practice, it is important essential to specify already in the request:
  For each source, it must be agreed on how the data will be delivered (format, coordinate reference system, aggregation level, attribute scope). In practice, it is essential to specify already in the request:
  - the minimum set of fields/attributes,
  - geometry and identifier requirements,
  - the reference period (year, season) and update frequency.
- **Formalities and conditions of use**
  Data may be subject to restrictions (licences, copyright, trade secrets). The manual assumes that each layer is assigned:
  - the source and rights for use,
  - restrictions on sharing and publication,
  - permitted processing (e.g., whether derivative products may be created).
- **Privacy and data sensitivity**
  Consumption and customer data often require aggregation and/or anonymisation. The standard approach should be to obtain data in a form that enables planning analyses but does not allow identification of individual consumers (e.g., spatial aggregation to zones or grids, temporal aggregation to typical profiles). This point is particularly important for district heating data, as information on heat network assets and operations may be considered sensitive and, in some contexts, part of critical infrastructure. If individual-level or

operationally detailed data are necessary for analysis, procedures for access restriction, data minimisation, and secure processing must be implemented, including controlled access roles, secure environments, and clear rules on what can be shared, stored, and published.

- It is crucial that acquiring data from operators is not improvised: it requires prepared request templates, agreed procedures, and aggregation variants that reduce barriers for data providers.

B2.4. Data harmonisation and integration in GIS

After data are/is acquired, the stage that most often determines success follows: harmonisation and integration. This includes:

- **Standardising spatial reference:** coordinate reference system, geometry validity, boundary alignment.
- **Standardising data structure:** field names, units, data types, value dictionaries.
- **Creating linking mechanisms:** building/address identifiers, relationships between layers (building–zone–network–source).
- **Aggregations and transformations:** e.g., aggregating demand to grids/zones, creating derived layers (demand density, priority zones).
- **Integrating attribute and spatial data:** tabular joins, geocoding, record matching.

It is important to **document integration decisions** at this stage: what transformations were applied, what assumptions were adopted, and which data are source vs. derived.

B2.5. Quality assurance (QA/QC) and metadata

Integrated but unverified data can lead to incorrect planning conclusions. Therefore, before data are used in analyses, a minimum set of quality tests (QA/QC) should be conducted, covering at least:

- **completeness:** missing features or attributes, spatial gaps,
- **geometry/topology consistency:** errors, overlaps, duplicates, network disconnects,
- **attribute consistency:** value ranges, units, inconsistent classifications,
- **cross-layer consistency:** e.g., buildings outside the boundary, networks without nodes, sources without an assigned zone,
- **currency and provenance:** whether the update date is known and fit for the plan's purpose.

In parallel, metadata are prepared and must be a mandatory element of every layer. A minimal metadata package should include:

- content description, scope, and intended use,

- source, data owner, and acquisition date,
- reference system and format,
- quality and limitation information,
- licensing terms and sharing rules,
- update responsibility.
- The output of the QA/QC stage should be a short data quality report (what is complete, what needs improvement, and what interpretative risks exist).

B2.6. Publication, maintenance, and updating: how to avoid a "one-off bundle of files"

The final step is to establish data maintenance rules to ensure the LHP can be updated and the data can operate in a continuous cycle. The manual assumes:

- a data repository (local or platform-based) with an agreed storage standard,
- versioning (what is the "current" version, what is working material, when changes take effect),
- an update schedule for key layers (e.g., buildings, consumption, networks, sources, investments),
- responsibilities (who updates, who approves, who publishes),
- a procedure for onboarding new sources and responding to changes (e.g., network modernisation, a new source, changes in spatial planning).
- The target variant therefore does not end with producing the plan: its outcome is a lasting municipal capability to work with data–an essential condition for monitoring progress and implementing actions in subsequent years.

B3. Data catalogue for the LHP – target set (Full Coverage Data Catalogue)

This chapter defines the dataset required to prepare a local heating supply plan (LHP) in the target variant (Full Coverage). The catalogue is not just a list of layers–for each data category, it specifies the planning purpose, the minimum information scope, the recommended level of aggregation, typical sources, update frequency, and key risks (quality, availability, sensitivity). This enables a municipality to plan data acquisition, assess gaps, and manage uncertainty consciously.

How to read the data catalogue

For each data group, three levels are used:

- **Must-have (target minimum)** – essential to deliver the plan in full scope.

- **Should-have (recommended)** – significantly improves the credibility of maps and scenarios.
- **Nice-to-have (optional)** – supports prioritisation and deeper analyses, but is not critical.

In the target variant, it is recommended to achieve a complete **Must-have** set and as broad a coverage of **Should-have** as possible–especially for operator data, consumption, and potentials.

B3.1. Reference data (basemap and spatial consistency)

Planning purpose: provide a common spatial reference for all layers (boundaries, addresses, transport network) and enable linking attribute data to spatial objects.

Must-have

- Administrative boundaries of the municipality/city and auxiliary units (districts/precincts).
- Street network/transport layout (for accessibility analyses and potential network analyses).
- Addresses and/or address points (for geocoding consumption and customer data).
- Building geometries (footprints) – as the reference layer for integrating demand data.

Should-have

- Parcels/cadastral units (useful for organising ownership and linking registers).
- Building numbers/reference identifiers (if available), enabling joins without geocoding.

Typical sources: geodetic/topographic resources, address registers, municipal GIS/SIP, national/regional registers.
Updates: at least annually (addresses/buildings) or according to register update cycles.
Risks: inconsistent identifiers across sources; different coordinate reference systems; incomplete addressing.

B3.2. Buildings and heat demand (asset characteristics)

Planning purpose: build a picture of demand and identify priority areas (e.g., concentration of needs, building typologies, risk of energy poverty–if analysed).

Must-have

- Building locations (from B3.1) + basic functional classification (residential, services, public, industrial).

- Floor area/volume (or a proxy) enabling demand estimation.
- Heating type (e.g., individual, district heating, local boiler house) – if available.
- Construction year or typological age category (as a proxy for efficiency).

Should-have

- Energy efficiency parameters/retrofit status (if registers exist).
- Building density / urban indicators (e.g., intensity) supporting assessment of district heating viability.
- For public buildings: actual consumption data and planned upgrades (often easier to obtain).

Nice-to-have

- Planned building investments (feeding demand scenarios).

Typical sources include building/address registers, municipal records, public inventories, statistics, and building manager data.
Updates: annually or in line with investment/cadastral cycles.
Risks: lack of consistent identifiers; different definitions of "area"; gaps in functional classification.

B3.3. Energy and heat consumption (empirical demand)

Planning purpose: calibrate and validate demand maps, identify the highest-consumption areas, assess the effects of measures, and monitor progress.

Must-have

- Aggregated energy/heat consumption data (e.g., by zones/grid/cell, building groups) enabling analysis without identifying individual consumers.
- Reference period (year/heating season) and information on the aggregation method.

Should-have

- Seasonal/monthly profiles (supporting scenarios and load assessment).
- Breakdown by carrier (DH, gas, electricity for heating, other fuels) – where feasible.

Nice-to-have

- Daily/hourly profiles (usually constrained by access and sensitivity; mainly useful for modelling).

Typical sources: energy operators and suppliers, municipal utilities, public-building managers.

Updates: at least annually.
Risks: privacy and data sensitivity; inconsistent aggregation levels; difficulty linking consumption to geometry.

B3.4. District heating (DH) infrastructure and heat sources

Planning purpose: assess coverage and development potential, analyse connection areas, identify infrastructure constraints, and link demand with supply.

Must-have

- DH network routes (segments) and nodes (basic geographic topology).
- Basic network parameters: age, losses (if available), basic segment classes.
- Locations of heat sources and their type (e.g., CHP, boilers, RES), indicative capacity.

Should-have

- Supply zones/service areas, information on connection capacity (if available).
- Technical parameters of sources: fuel, efficiency, constraints, planned modernisations.
- Aggregated network customer data: number of connections/customer structure.

Nice-to-have

- Detailed network parameters (diameters, insulation, temperature regimes) – critical mainly for the modelling pathway (B7).

Typical sources: DH network operator, municipal utilities, infrastructure inventories.
Updates: at least annually + after major modernisation/expansion.
Risks: sharing restrictions; lack of data standards; inconsistencies between maps and parameters.

B3.5. Gas and power infrastructure (if nationally required)

Planning purpose: assess the feasibility of transition scenarios (e.g., heating electrification, fossil fuel phase-down) and identify infrastructure constraints.

Must-have

- Coverage and basic infrastructure parameters in a form suitable for spatial analysis (most often aggregated or simplified).

Should-have

- Information on planned investments and constraints (capacities, overload areas– if available).

Typical sources: gas and electricity operators, network development plans.
Updates: annually / in line with operators' planning cycles.
Risks: high sensitivity, varying detail levels, limited access.

B3.6. RES potentials and local energy sources for heating

Planning purpose: identify and map technological potentials that can replace conventional sources or support DH development.

Must-have

- Spatially referenced RES potentials (at least indicating areas/types of potential): e.g., solar (PV/solar thermal), shallow geothermal, biomass (regional level), heat pumps (environmental conditions).
- Constraints and implementation conditions (e.g., protected areas, planning constraints–linked to B3.8).

Should-have

- Quantified potentials (classes/values) enabling area comparisons.
- Data on existing RES installations and planned investments.

Typical sources: national/regional studies, environmental datasets, municipal resources, operators/sector institutions.
Updates: every few years or after significant planning changes.

Risks: high sensitivity, varying detail levels, limited access.

B3.7. Waste heat – mandatory module in the target variant

Planning purpose: identify waste heat sources as a transformational potential, especially in DH systems and industrial areas.

Must-have (minimum inventory profile)

- Source location (facility/plant/installation) and activity type.
- Indicative availability (whether the potential is realistically usable) and basic conditions (e.g., continuity/seasonality, qualitative).
- Information on the owner/manager and a possible cooperation model (contact, sharing conditions).

Should-have

- Quantitative estimate of potential (classes/values) and qualitative parameters (e.g., temperature level–if feasible).

- Initial “connectability” assessment (distance to network/consumers, spatial barriers).

Typical sources: industry data, business registers, local analyses, cooperation with operators and the region.
Updates: dependent on technological changes in facilities (in practice: periodic verification).
Risks: minimal access, reluctance to share, lack of standardised formats.

B3.8. Planning, environmental, and constraint data

Planning purpose: assess feasibility and spatial conflicts, identify priority areas and constraints.

Must-have

- Spatial development plans, development directions, and investment areas.
- Protected areas and key environmental constraints.
- Spatial conditions for infrastructure (corridors, barriers).

Should-have

- Risk datasets (e.g., floods, landslides–if they affect infrastructure).
- Data on planned public investments (roads, reconstructions–affecting network routing feasibility).

Updates: according to spatial planning cycles.

Typical sources (indicative)

- Municipal spatial planning departments and planning registers (local plans, strategic documents, investment areas).
- Regional/national spatial planning portals and open data platforms (where available).
- Environmental protection agencies and nature conservation authorities (protected areas, restrictions, permits).
- Water authorities / hydrology institutes (flood hazard and risk maps, water protection zones).
- Road authorities and public investment programmes (planned roadworks and reconstruction schedules).
- Cultural heritage authorities (heritage sites and buffer zones, if relevant).

Update cycle and maintenance

- Primary updates follow spatial planning cycles (plan adoption/amendment), but selected layers should be refreshed more frequently where they change faster (e.g., planned roadworks/investments–often quarterly/annually; risk layers when new assessments are published).
- Maintain a change log: plan version/date, legal status (draft/adopted), and applicability area.

Risks

- Strategic plans may be too coarse for routing; complement with local constraints/barriers and on-site verification at later stages.
- Investment plans and constraints may be held by different bodies; define a standard request list and a routine exchange format early.
- Corridors, easements, and barriers may not align with base maps; use GIS QA/QC (topology checks, snapping rules) and document harmonisation steps.
- Constraint maps can discourage options prematurely; use phased assessment–screening first, detailed feasibility later with operators and permitting bodies.

B3.9. Socio-economic data (optional, but strengthens prioritisation)

Planning purpose: prioritise actions (e.g., socially vulnerable areas), justify interventions, and support monitoring indicators.

Must-have (optional depending on country)

- Population and basic structure (usually aggregated to statistical zones).

Should-have

- Vulnerability/energy poverty indicators (if they exist and are available in aggregated form).
- Economic indicators supporting development scenarios.

Typical sources (indicative, country-specific in detail)

- National statistical office datasets and small-area census outputs (population, households, demographics).
- Municipal social services / welfare statistics (aggregated and privacy-compliant), where legally accessible.
- Energy poverty observatories or national/regional programmes (if such reporting exists).

- Municipal planning and development departments (local strategies, regeneration areas), plus regional development agencies.

Recommended spatial/temporal resolution

- **Spatial:** Statistical zones or planning units that are stable over time and large enough to protect privacy (avoid household-level).
- **Temporal:** Annual updates where possible; otherwise aligned with official statistical release cycles (often annual or multi-year).
- **Update cycle and maintenance**
- Align updates with the publication cycle of the statistical office; keep a simple "version log" (year, source, indicator definition).
- If indicators change definitions over time, store metadata and mapping rules to preserve comparability.

Risks

- Indicators differ across countries; use clear definitions and document proxies used.
- Some socio-economic and welfare data are sensitive; use aggregation, suppression rules (e.g., minimum cell counts), and access controls.
- Present results carefully (focus on targeting support, not labelling areas), and validate with local stakeholders.
- Where indicators are missing, use phased completion (start with basic demographics, add proxies later) and triangulate with qualitative input.

In the target variant (Full Coverage), the priority is completeness, not so much at the level of "every building has everything," but at a level that enables:

- mapping demand and potentials,
- assessing infrastructure and development directions,
- preparing an action strategy, financing, and monitoring,
- maintaining data on an update cycle.

Where data are sensitive or complex to obtain (consumption, operator data, waste heat), the catalogue assumes the use of aggregation, anonymisation, and phased completion methods–so that the plan remains feasible while still being improvable over time.

B4. Data model and interoperability standards

This chapter describes the recommended data model for the LHP in the target variant (Full Coverage) and a set of minimum interoperability standards that enable data from multiple sources to be combined into a coherent GIS asset. Its purpose is to reduce situations in which a municipality "has data" but cannot reliably integrate them, compare, or reuse them across years. The data model in this chapter is deliberately following a simple structure: it is meant to be feasible in municipal conditions while remaining rigorous enough to support analyses, mapping, and updates.

B4.1. Model structure: layers and relationships are key to the LHP

The LHP data model is based on the assumption that all analyses can be reduced to a consistent linkage of five main "objects":

- **Building/building stock** – the basic carrier of demand and the starting point for aggregation.
- **Zone/analysis area** – the aggregation unit (district, statistical zone, grid), used for handling sensitive data and for mapping demand/potentials.
- **Infrastructure (networks and nodes)** – primarily DH, and optionally gas and electricity, as elements of constraints and development opportunities.
- **Heat source** – generation facilities and local resources (including RES).
- **Potential (RES/waste heat)** – objects or areas describing possible energy sources and their parameters.

Relationships between layers should be maintained unambiguously:

- **Building → Zone** (each building assigned to a zone; the zone is the basis for demand aggregation).
- **Building → Network (DH)** (coverage/service information: on-network / off-network / potential connection area).
- **Source → Network / Zone** (a source supplies a network or serves a defined area).
- **Potential → Zone / Building / Network** (a potential is located and linked to its implementation area).

In the target variant, the model should support two types of analyses:

- **building-level analyses** (where the data allow),
- **zone-level/aggregated analyses** (especially for consumption and sensitive data).

B4.2. Identifiers and data-joining keys

The most common cause of integration problems is the lack of stable identifiers. The LHP model should rely on a hierarchy of keys that allow data to be linked even when sources are incomplete:

Level 1: Object IDs (preferred)

- building_id – a stable building identifier (if it exists in national/municipal registers).
- address_id – an address-point identifier (if it exists).
- dh_segment_id, dh_node_id – identifiers for network segments and nodes (from the operator).
- source_id – source identifier (operator/register).

Level 2: Intermediate keys (when IDs are missing)

- standardised address (street, number, postcode, locality) + geocode,
- parcel/cadastral identifiers (if present in the data),
- spatial relationships (e.g., "building within zone," "nearest node") – as a fallback.

Level 3: Aggregation (for sensitive data)

- zone_id – zone identifier (district/precinct, statistical zone, or grid).
  Consumption and customer data should, where possible, be linked at the zone_id level rather than at the individual building level.

The manual assumes that each layer in the B2 catalogue has a defined "preferred key" and a "fallback key." This makes integration robust to data gaps by design.

B4.3. Standards for formats, units, and spatial reference

For data to be interoperable, they must meet a minimum technical standard. In the target variant, the following rules apply:

1) Coordinate reference system (CRS)

- All spatial layers must have an unambiguously defined CRS.
- One working CRS should be selected at the project level and used consistently in all integration operations.
- Every CRS transformation should be recorded in metadata.

2) Data format

- Spatial data should be delivered in a format suitable for durable storage and integration (e.g., a spatial database or standardised files).

- Tabular data (consumption, parameters) should be delivered in a format suitable for automated processing (CSV/XLSX/ODS).
- Service-based data (WMS/WFS/WMTS or equivalent) are acceptable as a reference layer, but for key planning datasets, it is recommended to keep a copy of the source data in the LHP repository.

3) Units and naming

- Every numeric variable must have a defined unit (e.g., MWh/year, kW, MW, °C).
- Values should, where possible, be normalised to the project's adopted units.
- Value dictionaries (e.g., building type, source type, energy carrier) should be defined and applied consistently.

4) Semantic consistency

- The same term (e.g., "capacity," "consumption," "losses") must have a consistent definition across the entire asset.
- If data come from different institutions with different definitions, a concept-mapping dictionary should be introduced (e.g., source values → harmonised values).

B4.4. Minimum metadata package (mandatory for each layer)

In the LHP, metadata are critical: without them, it is impossible to assess data reliability or update the plan. The minimum metadata set for each layer should include:

- Layer name and description (purpose and use in the LHP).
- Source and data owner (institution, contact).
- Acquisition date and reference period (which year/season the data describe).
- Spatial coverage and resolution/aggregation (buildings/zones/grid; scale).
- CRS and data format (including transformation information).
- List of key attributes and units.
- Quality information (completeness, accuracy, known gaps).
- Legal/licensing constraints (whether it can be published and in what form).
- Update rules (frequency, responsibility, versioning).

In the manual (in B6), metadata are presented as a checklist and a template to be completed for each layer.

B4.5. Rules for integrating sensitive data (consumption, customers, operators)

The Full Coverage model assumes that some data (especially consumption) is sensitive. Therefore, interoperability standards also include "safe analytics" rules:

- Sensitive data should be acquired and stored in aggregated form (most often by zone_id/grid), unless there are formal grounds for processing detailed data and access-control mechanisms.
- If an operator provides detailed data, the LHP repository should contain:
  - a **working version** (restricted),
  - and a **planning version** (aggregated/anonymised) used in documents and published outputs.
- Every aggregation transformation must be described in metadata (method, parameters, implications).

This approach enables plan development that reflects real-world data-sharing constraints and reduces the risk of stakeholders blocking information.

B4.6. Definition of "Done" for the data model (what it means that the model works)

The data model is considered implemented if all conditions are met:

- each layer from the B2 catalogue has a defined key (building_id or zone_id or another agreed key),
- data are in a consistent CRS and have defined units and value dictionaries,
- metadata exists for each layer,
- basic QA/QC tests (B4) have been performed, and a quality report exists,
- the data repository has established rules for versioning and updates.

B5. Data quality (QA/QC) and metadata – procedures, thresholds, and reporting

This chapter describes a minimal, practical quality assurance system (QA/QC) and metadata rules for the LHP in the target variant (Full Coverage). Its goal is to ensure that data are not only "collected," but also reliable, comparable over time, and auditable. In an LHP, data quality directly affects planning conclusions (e.g., identifying priority areas, assessing potential, selecting measures), therefore QA/QC and metadata are mandatory elements of the method, not add-ons.

B5.1. General principle: "good enough for decisions" quality and controlled uncertainty

In municipal practice, achieving "perfect" quality is not always possible. The goal is quality that is sufficient for decision-making, while clearly describing limitations and risks. This implies three rules:

- transparency of assumptions and limitations (metadata + QC report),
- comparability (stable definitions, units, identifiers, CRS),
- repeatability (the same QC tests in subsequent updates).

As a result, the plan can be produced even with data gaps, but those gaps must be visible and managed–not hidden.

B5.2. QA vs QC: what we check and when

The manual distinguishes between:

- **QA (Quality Assurance)** – "preventive" actions: format standards, value dictionaries, required fields, integration rules (B3) that minimise the risk of errors already at acquisition and harmonisation stages.
- **QC (Quality Control)** – "control" actions: quality tests performed on already integrated data before they are used in analyses.

QC should be performed at least:

- after the first data integration (baseline version),
- after every significant layer update or change of source,
- before publishing results and maps in the plan.

B5.3. Minimum set of QC tests (for each layer)

Below is the minimum set of tests that should be applied to GIS and tabular datasets. Each test should yield a result (OK /Warning/Fail), a short description, and a corrective action.

A) Completeness tests

- **Spatial coverage:** does the layer cover the entire plan area (spatial gaps, holes)?
- **Feature completeness:** is the number of features consistent with expectations (e.g., buildings vs a reference register)?
- **Attribute completeness:** percentage of missing values (NULLs) in key fields (e.g., building function, area, source type).

- **Temporal completeness:** is the reference period known and consistent (year/season)?

Practical threshold (recommendation): for critical fields in Must-have layers, missingness should be minimal; if it exceeds what is acceptable for the analysis, apply filling (imputation/proxies) or move to zone-level aggregation and document it in the QC report.

B) Geometry validity tests

- **Valid geometry:** no damaged geometries (self-intersections, invalid polygons).
- **Empty/zero geometry:** no objects without geometry or with zero area/length (unless justified).
- **Boundary consistency:** objects should lie within the plan area (buildings outside the boundary, sources out of scope without justification).

C) Topology tests (essential for DH networks)

- **Duplicates:** duplicated segments and nodes (identical geometry or identical IDs).
- **Network disconnects:** segments without connections, nodes without segments (unless intentional).
- **Inconsistent crossings:** intersecting segments without a node (if required by the topology model).
- **Directionality/flow logic (if modelled):** consistency of direction attributes.

D) Attribute validity tests

- **Value ranges:** do numeric values fall within realistic ranges (e.g., capacity, consumption, temperature)?
- **Units:** are the same units used across the dataset (no mixing kW/MW, MWh/GJ)?
- **Value dictionaries:** do categorical fields conform to the dictionary (e.g., building type, source type)?
- **Data type consistency:** numbers stored as numbers, dates as dates, no text values in numeric fields.

E) Cross-layer consistency tests

- **Building ↔ zone:** every building has an assigned zone (zone_id), if zones are used.
- **Building ↔ DH network:** if supply zones or network coverage exist, building status (on-network/off-network) should not contradict geometry.
- **Sources ↔ network/zone:** sources have an assigned area/network; no “orphan” objects without context.

- **Consumption ↔ zone:** consumption data have a clear aggregation key (zone_id/grid) consistent with the zone layer.

F) Timeliness & lineage tests

- **Update date:** known and recorded in metadata.
- **Reference period alignment:** e.g., 2024 consumption vs 2018 buildings–if misaligned, it must be described and justified.

B5.4. Acceptance thresholds and corrective decisions (OK / Warning / Fail)

The manual assumes three decision levels:

- **OK** – data meet requirements; can be used without reservations.
- **Warning** – data can be used, but with limitations (e.g., attribute gaps, incomplete coverage); documentation in the QC report is required, including the impact on analyses.
- **Fail** – data cannot be used for planning in their current form (e.g., missing CRS, significant gaps in critical fields, severe geometry/topology errors). A correction is required, or a fallback variant must be applied (e.g., aggregation, proxy, or an alternative source).

For sensitive data (consumption), a typical corrective mechanism is to switch to spatial aggregation and restrict publication.

B5.5. Metadata: mandatory minimum package and maintenance rules

Metadata is an integral part of data quality. For each layer, at least the following information must exist:

- description and use (why the layer is in the plan),
- source and data owner (institution + contact),
- acquisition date and reference period (year/season),
- spatial scope and aggregation level (building/zone/grid; resolution),
- CRS and format (including transformation information),
- relation keys (building_id, zone_id, etc.),
- list of key fields and units,
- quality information (QC result + known gaps),
- legal/licensing constraints (publication/sharing, sensitivity),

- update and versioning rules (who, how often, how versions are labelled).

Metadata should be maintained in parallel with the data: each layer update requires metadata updates (date, source, changes, QC result).

B5.6. Data quality report (QC Report) – structure and minimum content

Each iteration of LHP data preparation should end with a QC report. The report can be tabular plus a short narrative and should include:

- list of layers (per the catalogue) and their status: OK/Warning/Fail,
- test results (completeness, geometry, topology, attributes, consistency),
- problem descriptions (what is wrong and where),
- corrective actions (what was done / what needs to be done),
- impact on planning analyses (which conclusions may carry uncertainty),
- publication restriction list (sensitive layers and aggregation level).

The QC report is a key element of plan auditability: it enables later assessment of whether changes in analytical results reflect real-world change (e.g., network modernisation) or changes in data and data quality.

B5.7. Quality over time: versioning and comparability across iterations

For the LHP to be a process rather than a one-off document, data must be comparable year to year. The manual recommends:

- maintaining layer versions (e.g., annual) with clear reference-period labelling,
- documenting changes in metadata (what changed and why),
- performing the same QC tests in subsequent iterations,
- preserving value dictionaries and units (changes only in a controlled, documented manner).

This enables reliable monitoring of progress (e.g., demand changes, network coverage changes, use of potentials) and scenario comparison.

B6. Implementation, organisation and stakeholder cooperation

This chapter explains how to organise the implementation of the LHP data collection method in the target variant under municipal conditions, where data are dispersed and key assets are held by multiple stakeholders (especially operators). The chapter's goal is to ensure the process is feasible through clear roles, cooperation rules, a minimal data-governance model, and mechanisms for maintenance and updating.

B6.1. Organisational model: the municipality as a "data integrator"

In the target variant, the municipality acts as the data integrator: it does not need to own all datasets, but it is responsible for ensuring that the data required for the plan are acquired, harmonised, verified, and maintained over time. In practice, this means four functions must be assigned (even if performed by the same people):

- **LHP process owner (Accountable)** – responsible for scope, schedule, decisions, and acceptance of deliverables.
- **LHP data owner (municipal data owner)** – responsible for the data catalogue, compliance with the methodology, and contacts with data providers.
- **Integration implementer (GIS/IT)** – responsible for integration, the data model, QA/QC, the repository, and publication.
- **Formal owner (Legal/GDPR)** – responsible for the legal basis for data sharing, aggregation/anonymisation, and licences.

To avoid a "grey zone" of responsibility, a simple **RACI** matrix (RACI matrix: Responsible, Accountable, Consulted, and Informed) is recommended for the key steps in the process (acquisition, integration, QA/QC, metadata, publication, updating).

B6.2. Minimum team and skills ("small town" vs "larger city" variants)

The manual assumes two typical organisational variants:

Variant A: small town (2–4 people + support)

- LHP coordinator (substance + schedule),
- GIS specialist (data integration, maps, QC),
- legal/GDPR support (part-time),
- support from operators and/or a consultant for sensitive data.

Variant B: larger city (multi-department team)

- LHP coordinator and thematic team (energy/environment),
- GIS/IT (integration, repository, data services),
- spatial planning/investments (alignment of measures and areas),
- municipal units (public buildings, assets),
- formal legal and information security support.

Minimum skills required for the target variant:

- GIS fundamentals (layers, joins, aggregation, CRS),
- integration of tabular and spatial data (identifiers, geocoding),
- data quality control and metadata,
- understanding energy data at a planning level (capacity, consumption, losses, technology types),
- formal competencies: licences, GDPR, rules for sharing sensitive data.

B6.3. Cooperation with operators and infrastructure companies: rules and scenarios

Operators (DH, gas, electricity) are a key source of data, but are also often the most challenging partners due to sensitivity and the lack of sharing standards. The manual adopts a pragmatic approach: cooperation should be agreed so that it provides data sufficient for planning, not necessarily "fully technical" data.

Recommended cooperation principles:

- a clearly defined planning purpose (why the data are needed and what product will be created),
- a minimum dataset and aggregation level (to reduce operator-side risk),
- agreement on a "data package" (what the operator provides once vs what is updated cyclically),
- defined publication constraints (what can be published vs analysed only),
- a contact point and an update mode (annual/seasonal cycle + post-modernisation updates).

Typical data-sharing scenarios:

- **Scenario 1 (full operational access):** the operator provides network and source data at great detail; consumption data in aggregated form.
- **Scenario 2 (limited access):** the operator provides geometry and basic attributes; technical details remain with the operator, while the municipality works with planning-level data.
- **Scenario 3 (no consumption data):** consumption is estimated from building data and indicators; the operator provides only infrastructure and connection-capacity information (where possible).

The manual assumes that variants should be prepared in advance so the plan remains feasible even with limited access.

B6.4. Sensitive data: aggregation, anonymisation, and access control

For consumption and customer data, the key is to reduce the risk of identifying individual entities. The manual recommends:

- acquiring data in aggregated form (zones, grid) as the default standard,
- creating two versions of the data: **working (restricted)** and **planning (aggregated)**,
- introducing minimum access-control rules for sensitive data (who, when, and for what purpose),
- documenting aggregation methods and their interpretative impact in metadata.

This approach increases the likelihood of obtaining data from operators and reduces the risk of process blockage.

B6.5. Data exchange models: agreements, licences, and "data packages"

To make the process repeatable, data exchange should be formalised and operationalised. Recommended elements include:

- data-sharing agreements (what, for what purpose, how often, in what format),
- provisions on rights to derivative products (e.g., maps, aggregates),
- publication constraints and data protection rules,
- agreed delivery standards (format, CRS, value dictionaries, identifiers).

A good practical solution is the concept of an **"LHP data package"**: a set that the operator delivers cyclically (e.g., annually) in an agreed standard. This reduces transaction costs for both sides.

B6.6. Data maintenance and lifecycle: updating, versioning, and audit

A core objective of the target variant is to avoid "one-off data collection." Therefore, B6 defines a minimal data maintenance model:

- an LHP data repository (a single source of truth–local or platform-based),
- versioning (e.g., annual layer versions with reference periods),
- an update schedule (which layers are updated annually vs less often),
- an update procedure (acquisition → integration → QC → metadata → publication),
- change audit (what changed and why–in metadata/QC reports).

The maintenance model should also cover onboarding new data (e.g., a new waste heat source, a change in the building register, a new DH investment) and a feedback loop: the plan generates data needs, and the data enable plan updates.

B6.7. Managing implementation risks: where the process most often "breaks"

Based on project experience and survey results, the most common failure points are:

- lack of agreement/mode for operator data sharing,
- lack of consistent identifiers and the need for manual matching,
- insufficient resources (time, people) for QC and metadata,
- no decision on what aggregation level is acceptable,
- treating the process as a one-off (no maintenance).

The manual proposes minimal mitigation measures: acquisition variants (scenarios), working with zones/grids for sensitive data, embedding QC and metadata as a "done" condition, and establishing an update schedule from the start.

B7. DH Network Modelling & Forecasting (optional extension)

This is an **optional advanced module** that extends the Full Coverage LHP baseline with **mathematical modelling of DH networks** to support network development and forecasting. It is **tool-agnostic**: it does not mandate a specific modelling software, but it defines the **minimum data standard and preparation workflow** required for credible modelling.

B7.1 Purpose and Scope

Purpose

Use DH modelling to:

- evaluate **network expansion/densification variants**,
- forecast network performance under **demand/supply changes**,
- identify **constraints and bottlenecks** (capacity, temperatures, pressure, losses),
- compare investment options via consistent **KPIs**,
- strengthen the technical basis of LHP actions and sequencing.

Scope boundaries

- B7 covers: data, preparation, QA/QC, scenario inputs, calibration/validation approach, reporting package.
- B7 does not cover: procurement, detailed software configuration, or full engineering design.

B7.2 Entry Gate ("Go/No-Go" Criteria)

Gate objective

Prevent modelling on incomplete, non-topological, or non-traceable datasets.

Go criteria (minimum)

- **Full Coverage baseline completed** for DH: network geometry, sources, demand representation (building/zone/grid), constraints layers where relevant.
- **Unique IDs** exist (or are created) for segments, nodes, sources, and zones.
- **Join logic works**: demand can be linked to zones and mapped to the DH service area (or connection points).
- **QC status** is **OK or Warning** (no critical failures) and documented.
- **Metadata** completed for modelling-relevant layers (source, CRS, units, reference year, processing steps, restrictions).
- **Data governance agreed**: access rules for restricted operator data; publication limited to aggregated outputs.

No-Go triggers

- missing CRS / inconsistent units,
- broken connectivity (network cannot be represented topologically),
- unknown reference year for demand/supply,
- inability to link demand to the network area (no mapping approach agreed),
- missing permissions/agreements for using operator data.

Output of B7.2: "Gate decision note" (Go/No-Go) + list of remediation actions if No-Go.

B7.3 Modelling Data Catalogue (What you need beyond Full Coverage)

A) Topology-grade network data

Minimum:

- **Edges (pipes)** with unique dh_segment_id,
- **Nodes** with unique dh_node_id (explicit or derived),

- Connectivity: each edge has from_node and to_node IDs (or equivalent)

Recommended:

- substations/connection points (or defined method to represent loads).

B) Technical parameters (values or classes)

Minimum (allow classes if exact values unavailable):

- pipe diameter (or diameter class),
- insulation/heat loss parameter (or class),
- friction/roughness parameter (or class),
- temperature regime assumptions (supply/return seasonal setpoints),
- sources: technology/fuel, nominal capacity, min/max constraints (or classes).

C) Time-dependent inputs (for forecasting / quasi-dynamic runs)

Minimum:

- annual demand baseline + scenario multipliers

Recommended:

- monthly profiles; representative daily/peak profiles

Optional:

- hourly profiles, weather normalisation factors.

Output of B7.3: "Modelling input inventory" confirming which parameters are exact vs class-based.

B7.4 Calibration & Validation Data (If available)

Calibration sources (preferred)

- SCADA/telemetry: plant outputs, flow/temperature measurements, pressure where relevant,
- aggregated delivered heat by zone/service area,
- metered load curves (aggregated).

Minimum credibility check (if detailed SCADA is not available)

- match annual heat delivery totals (by system or service areas),
- ensure plausible losses and temperature regime,
- test peak feasibility using representative peak assumptions.

Annex to Part Executive Summary (Ready-to-use Materials)

This document contains editable annex templates for direct use by municipalities and partners.

ES-A. Checklists for Executive Summary

Checklist A – Decision-makers (municipal leadership / utility management)

A1. Governance and responsibility

- Appoint a single LHP process owner in the municipality (role + mandate).
- Define the core partner set: municipal departments, municipal utility (e.g., DH company), grid/network operators, GIS/IT, data protection/legal.
- Agree who approves data releases, who signs data-sharing arrangements, and who decides on aggregation levels.

A2. Scope and "definition of done"

- Confirm which outputs must be delivered (demand maps, infrastructure maps, potentials, zoning, action strategy, monitoring indicators).
- Approve a minimum dataset scope (baseline) and a target scope (full coverage over time).
- Require that the project leaves behind a **maintained planning data asset** (integrated datasets + metadata + QA/QC + update cycle), not only a report.

A3. Data access and partnerships

- Identify key data holders (municipality, DH company, heat/gas/electricity operators, statistical authorities, large consumers/industry).
- Agree data-sharing rules with operators (what, at what aggregation level, how often).
- Ensure resources for coordination (staff time) and, if needed, budget for data preparation/cleaning.

A4. Compliance, sensitivity, and risk posture

- Confirm the default rule: work with aggregated/anonymised consumption data where possible.
- Define access control principles (who can see what; internal vs external dissemination).
- Approve a risk approach for sensitive/critical-infrastructure information (storage, publication, permitted outputs).

A5. Maintenance commitment

- Approve an update schedule aligned with planning/statistical cycles (annual / multi-year).
- Assign ownership for ongoing maintenance (unit/team) and a minimal annual workload.
- Require a simple change log and versioning approach for each plan update.

Checklist B – Coordinators & implementers (LHP lead / GIS-IT / analysts / contractors)

B1. Prepare the workflow

- Translate required planning outputs into concrete data needs (layers, attributes, resolution).
- Create a data source register (owner, coverage, format, legal constraints, update frequency, contacts).
- Set standards: CRS, file formats, naming conventions, metadata template, and identifier strategy.

B2. Collect data (baseline first)

- Acquire reference layers (administrative boundaries, addresses, base map, buildings).
- Acquire planning/constraint layers (plans, protected areas, corridors/barriers, investments).
- Acquire infrastructure layers (DH network where available, energy grids where relevant) at agreed detail.
- Acquire demand inputs (building characteristics and/or aggregated consumption proxies).
- Acquire potentials (renewables, waste heat candidates, available sites) where feasible.

B3. Harmonise and integrate

- Reproject to common CRS; check geometry validity.
- Harmonise attribute definitions, units, and categories (create a dictionary).
- Implement linking rules (building ↔ zone/grid ↔ network segments ↔ sources ↔ potentials).
- Document assumptions and transformations (aggregation rules, estimation methods).

B4. Quality assurance (QA/QC)

- Completeness checks (coverage by area, missing attributes, null ratios).
- Consistency checks (units, ranges, duplicated IDs, topology errors).
- Cross-layer checks (e.g., buildings within boundaries; networks intersect plausible corridors).
- Produce a short QA/QC log: key issues, fixes applied, and remaining limitations.

B5. Deliver the "planning data asset"

- Package integrated layers in a structured repository (folders, naming, versioning).
- Attach metadata for each layer (source, date, update cycle, constraints, owner).

- Provide an "as-built" data model summary (how layers relate, key IDs, join keys).
- Provide an update plan: what changes annually vs per planning cycle, and who does it.

B6. Enable continuity

- Define routine contacts with data providers (operators/statistics/planning units).
- Create repeatable request templates for future updates.
- Document onboarding notes so new staff can reproduce the workflow.

Checklist C – Sensitive data & critical infrastructure (applies to both groups)

C1. Default handling rules

- Use spatial aggregation (zones/grids) and temporal aggregation (typical profiles) by default.
- Apply data minimisation (only fields needed for planning questions).
- Avoid publishing detailed asset-level network information unless explicitly approved.

C2. Access and security

- Define user roles (viewer/editor/admin) and access boundaries (internal vs external).
- Store sensitive datasets in controlled locations (restricted repositories).
- Ensure secure transfer channels for operator data (agreed method, encryption if required).

C3. Documentation and accountability

- Record data restrictions in metadata (what can/cannot be shared).
- Keep a log of who supplied the data, when, and under what conditions.
- If detailed data are used, document why they were necessary and how they were protected.

Annexes to Part B (Ready-to-use Materials)

This document contains editable annexe templates for direct use by municipalities and partners.

B-A1. Data Catalogue Tables (Full Version)

Legend

- Priority: M (Must-have), S (Should-have), N (Nice-to-have)
- Geometry: PT (point), LN (line), POLY (polygon), GRID (grid), TAB (table/no geometry)
- Key: preferred relation keys (e.g., building_id, address_id, zone_id)
- Update: A (ad hoc), Y (yearly), Q (quarterly), S (seasonal), 2-5Y (every few years)

Full version covers the Full Coverage LHP baseline. Modelling-specific add-ons are referenced in B-A7.

B-A1.1 Reference & Administrative Data

Layer / Dataset	**Priority**	**Geometry**	**Key**	**Minimum Attributes**	**Recommended Attributes**	**Preferred Format**	**Typical Source**	**Update**	**Minimum QC**
Municipal boundary	M	POL	admin_id	name, code, admin level	source/version, capture date	GIS	national/regional register	Y/A	valid geometry; CRS set
Sub-municipal units (districts/wards)	S	POL	unit_id	name, code	parent relations	GIS	municipality	Y/A	no gaps/overlaps
Road network	S	LIN	road_id	class, name	restrictions	GIS	municipality/national	Y/A	geometry validity
Address points	M	PNT	address_id	street, number, locality	postcode, source coords	GIS/TAB	address register	Y	duplicates; missing critical fields
Parcels (optional)	N	POL	parcel_id	parcel ID	ownership (if allowed)	GIS	cadastre	Y/A	valid geometry

B-A1.2 Buildings & Demand Typology

Layer / Dataset	Priority	Geometry	Key	Minimum Attributes	Recommended Attributes	Preferred Format	Typical Source	Update	Minimum QC
Building footprints	M	POL	building_id or address_id	use/function; floor area (or proxy)	year built; storeys; retrofit status	GIS	building register/municipality	Y	valid geometry; within boundary
Building use classification	M	TAB	building_id	use type	mixed-use share	TAB	municipality/statistics	Y	dictionary compliance
Heat/cool demand estimate (building or zone)	M	TAB/GRID	building_id or zone_id	annual demand (MWh/y); method flag	seasonal split; uncertainty band	TAB/GRID	model/municipality	Y/S	ranges; missing values
Heating system type	S	TAB	building_id	system category	fuel; efficiency class	TAB	surveys/registries	Y	dictionary compliance
Public buildings inventory	S	POL/TAB	building_id	owner/unit; function	measured consumption; planned retrofits	GIS/TAB	municipality	Y	completeness

B-A1.3 Energy Consumption (Sensitive Data)

Layer / Dataset	Priority	Geometry	Key	Minimum Attributes	Recommended Attributes	Preferred Format	Typical Source	Update	Minimum QC
Heat consumption (aggregated)	M	TAB/GRID	zone_id	annual heat use; reference year	monthly/seasonal profile	TAB/GRID	DH operator/energy supplier	Y	aggregation method documented

Gas use for heating (aggregated)	S	TAB/GRID	zone_id	annual consumption	monthly profile	TAB/GRID	gas operator/supplier	Y	aggregation & privacy check
Electricity for heating (aggregated)	S	TAB/GRID	zone_id	annual consumption	peak estimates; seasonal split	TAB/GRID	DSO/supplier	Y	aggregation & privacy check
Public buildings measured use	S	TAB	building_id	annual use; carrier	monthly data	TAB	municipality	Y	outlier checks

B-A1.4 District Heating (DH) Infrastructure & Sources

Layer / Dataset	Priority	Geometry	Key	Minimum Attributes	Recommended Attributes	Preferred Format	Typical Source	Update	Minimum QC
DH network segments	M	LIN	dh_segment_id	segment class; length	age; losses class	GIS	DH operator	Y/A	topology sanity; duplicates
DH nodes / substations (if available)	S	PNT	dh_node_id	node type	connection count	GIS	DH operator	Y/A	duplicates; missing coords
Supply zones / service areas	S	POL	dh_zone_id	zone name/type	capacity notes	GIS	DH operator/municipality	Y/A	overlap checks
Heat sources (plants)	M	PNT	source_id	type; fuel/technology; nominal capacity; CHP flag	efficiency; constraints; planned upgrades	GIS/TAB	DH operator	Y/A	attribute ranges
Planned DH investments	S	LIN/POL/TAB	plan_id	location; type; timeline	cost class	GIS/TAB	operator/municipality	Y/A	completeness

B-A1.5 Gas & Electricity Networks (Country-dependent)

Layer / Dataset	Priority	Geometry	Key	Minimum Attributes	Recommended Attributes	Preferred Format	Typical Source	Update	Minimum QC
Gas network overview	N/S	LIN/POL	gas_id	coverage/pressure class	constraint areas	GIS	gas operator	Y/A	CRS; geometry validity
Electricity network overview	N/S	LIN/POL	elec_id	coverage/voltage class	congestion notes	GIS	DSO	Y/A	CRS; geometry validity

B-A1.6 Renewable & Local Potentials

Layer / Dataset	Priority	Geometry	Key	Minimum Attributes	Recommended Attributes	Preferred Format	Typical Source	Update	Minimum QC
Solar potential (PV/thermal)	S	GRID/POL	zone_id or grid_id	potential class/value	roof suitability constraints	GRID/GIS	national/regional	2-5Y	method documented
Shallow geothermal / heat pump suitability	S	GRID/POL	grid_id	suitability class	constraints	GRID	regional/national	2-5Y	metadata completeness
Biomass potential (contextual)	N	POL	region_id	availability class	sustainability notes	TAB/GIS	regional	2-5Y	source documented

B-A1.7 Waste Heat Inventory

Layer / Dataset	Priority	Geometry	Key	Minimum Attributes	Recommended Attributes	Preferred Format	Typical Source	Update	Minimum QC
Waste heat sources register	M	PNT/TAB	wasteheat_id	location; activity type; owner/contact; availability (qualitative)	temperature level class; seasonal profile; estimated MWh/y	GIS/TAB	industry/municipality	A/Y	completeness; plausibility
Waste heat connectability pre-screen	S	TAB	wasteheat_id	distance to DH/demand	barriers; corridor notes	TAB	GIS analysis	A	logic checks

B-A1.8 Planning & Constraints

Layer / Dataset	Priority	Geometry	Key	Minimum Attributes	Recommended Attributes	Preferred Format	Typical Source	Update	Minimum QC
Land-use plans / zoning	M	POL	plan_zone_id	land-use category	development pipeline	GIS	municipality	Y/A	overlap/gaps
Protected areas / constraints	M	POL	constraint_id	constraint type	legal reference	GIS	national/regional	Y/A	geometry validity
Climate risk layers (optional)	N	GRID/POL	grid_id	risk class	return period	GIS/GRID	national/regional	2-5Y	source documented

B-A2. Data Source Register Template

Use this as the municipality's single list of all sources used in LHP.

Field	Description / What to fill in
Source ID	Unique ID (e.g., SRC-DH-01)
Data owner / provider	Institution/company and unit
Contact person	Name, email, phone
Dataset name	Official name
Dataset description	What it contains, why it matters
Coverage	Spatial coverage (municipality / area)
Time reference	Year/season the data describes
Update frequency	Y/Q/S/A/2–5Y
Delivery format	GIS file / DB extract / service / CSV/XLSX
CRS (if spatial)	EPSG code / definition
Join key(s)	building_id, zone_id, etc.
Licensing / usage	License, restrictions, publication rules
Sensitivity	Public / internal / restricted
Aggregation needed	Yes/No; if yes: target level (zone/grid)
QC status	OK/Warning/Fail + date
Notes / risks	Main issues, gaps, actions

B-A3. Data Request Template to an Operator (with Aggregation Options)

Subject: Data request for Local Heat Planning (LHP) – [Municipality], reference year [YYYY]

1. Purpose

We request the datasets below to prepare the municipal Local Heat Plan (LHP). Data will be used for spatial analysis and scenario building. Publication will be limited to aggregated outputs as agreed.

2. Requested datasets (choose relevant blocks)

A) District Heating (DH) – baseline package

- DH network segments (geometry + attributes): segment ID, length, class, age/loss class (if available)
- DH heat sources: location, technology/fuel, nominal capacity, CHP flag (if applicable)
- DH service areas (if available): polygons and identifiers
- Planned DH investments (optional): locations, type, timeline

B) Consumption/loads (sensitive) – provide in one aggregation variant below

- **Variant 1 (preferred): Aggregation by LHP zones (zone_id)**
  - Annual heat delivered per zone_id (MWh/year) for [YYYY],
  - Optional: monthly totals (MWh/month),
  - Optional: number of connections per zone_id.
- **Variant 2: Aggregation by grid (e.g., 250 m / 500 m cells)**
  - Annual heat delivered per grid cell (MWh/year), reference year [YYYY],
  - Provide grid definition (cell size, origin, CRS).
- **Variant 3: Aggregation by supply area/service zone**
  - Annual heat delivered per service area ID, with geometry of areas (or mapping table).
- **Variant 4 (restricted, only if required and legally feasible): Building-level / connection-level data**
  - Only if justified and covered by agreements; access restricted; publication prohibited.

3. Technical requirements

- Spatial data with CRS declared (EPSG code),

- Unique IDs for segments/nodes/sources,
- Attribute units (MW, MWh/y, °C) declared,
- Delivery format: GeoPackage/Shapefile/PostGIS export + CSV/XLSX for tables.

4. Confidentiality & publication

- Outputs published only in aggregated form (zones or grid)
- Raw restricted data stored under controlled access, if applicable.

5. Timeline & update

- Requested delivery date: [DD-MM-YYYY],
- Update cycle: yearly (preferred) or as agreed.

Attachments

- Zone layer/zone table (zone_id) and/or grid specification,
- Metadata template (B-A4).

B-A4. Minimum Layer Metadata Template

Use one metadata sheet per layer.

Layer name:	
Layer ID / code:	
Theme (Reference / Buildings / Demand / DH / Potentials / Constraints / etc.):	
Purpose in LHP (what analysis it supports):	
Data owner / provider:	
Contact:	
Reference year / period:	
Date received:	
Spatial coverage:	
Geometry type (PNT/LIN/POL/GRID/TAB):	
CRS (EPSG…):	
Format / storage location:	
Join key(s) (building_id, zone_id, …):	
Main attributes & units (list critical fields and units):	
Method / processing steps (transformations, aggregation, joins):	
Quality summary (OK/Warning/Fail + key issues):	
Known gaps / limitations:	
Sensitivity & access level (Public/Internal/Restricted):	

Licensing / publication rules:	
Update frequency:	
Responsible for updates:	
Versioning rule (e.g., YYYY_v1):	

B-A5. QA/QC Report Template

Project: [Plan name]

Municipality: [Name]

Reporting period: [YYYY]

Prepared by: [Name/Unit]

Date: [DD-MM-YYYY]

1) Executive summary

- Overall readiness: [High / Medium / Low]
- Key blockers: [operator data / missing IDs / low completeness / etc.]
- Major risks for conclusions: [short statement]

2) Layer status table

Layer	Source	Reference year	Sensitivity	QC status (OK/Warn/Fail)	Key issues	Action / Owner	Due date

3) QC test results (per layer)

For each layer, report:

- Completeness: missing critical fields (%)
- Geometry validity: invalid geometries (count/%)
- Topology (if relevant): disconnected segments/duplicates
- Attribute validity: outliers/unit inconsistencies
- Cross-layer consistency: join success rate (%)
- Timeliness: mismatched reference years (yes/no)

4) Publication restrictions

- Layers requiring aggregation before publication: [list]

- Restricted layers (no publication): [list]

5) Impact on LHP analyses

Describe analyses affected and mitigation steps (e.g., use zones/grid, proxy methods).

B-A6. One-Page Checklist

Goal: produce an LHP-ready dataset package (layers + metadata + QC report + update plan).

1) Scope & governance

[ ] Define plan scope (area, horizon, outputs)

[ ] Assign roles (Owner, GIS/IT, Legal, Operator contacts)

[ ] Create Data Source Register (B-A2)

2) Acquire core data

[ ] Boundaries, addresses, buildings (B-A1.1–B-A1.2)

[ ] DH network + sources (B-A1.4)

[ ] Planning/constraints layers (B-A1.8)

3) Sensitive & hard-to-get data

[ ] Request consumption data aggregated (zones/grid) (B-A3)

[ ] Prepare Waste Heat inventory (B-A1.7) with minimal profile

4) Integrate & standardise

[ ] Single CRS, units, dictionaries

[ ] Relation keys established (building_id / zone_id)

[ ] Aggregations documented (method + parameters)

5) QA/QC & metadata

[ ] Run QC tests (completeness, geometry, attributes, joins)

[ ] Produce QA/QC report (B-A5)

[ ] Fill metadata for each layer (B-A4)

6) Deliverables & maintenance

[ ] Final LHP dataset package stored in repository

[ ] Publication rules applied (aggregation/restrictions)

[ ] Update schedule agreed (yearly core layers + ad hoc changes)

B-A7. One-Page Checklist (Modelling – DH Network Modelling & Forecasting)

Prerequisite: Full Coverage package completed (B-A6), with OK/Warning QC status for DH layers and stable join keys.

1) Modelling scope

[ ] Define modelling purpose (expansion planning / constraints / forecasting)

[ ] Define model boundary and scenarios (baseline + variants)

2) Additional DH technical data (beyond Full Coverage)

[ ] Network topology: nodes/edges with connectivity (consistent IDs)

[ ] Pipe parameters: diameter, insulation class, roughness (or classes)

[ ] Temperature regime and/or pressure classes (as available)

[ ] Substations/connection points (if available)

[ ] Source curves/constraints: min/max, efficiency, costs (classes accepted)

3) Time-dependent data

[ ] Load profiles (monthly/daily/hourly) or representative profiles

[ ] Seasonal boundary conditions (if used)

[ ] Demand scenarios (growth/retrofit/connection plans)

4) Calibration & validation (if feasible)

[ ] Measurement points (flows/temperatures/SCADA summaries)

[ ] Calibration period selected and documented

[ ] Validation check performed (error bands reported)

5) Modelling QA/QC

[ ] Topology consistency (no disconnected critical segments)

[ ] Parameter plausibility checks (ranges)

[ ] Scenario inputs versioned and reproducible

6) Outputs

[ ] Expansion variants compared (KPIs, costs, constraints)

[ ] Forecast results documented (assumptions + uncertainty)

[ ] Modelling report + dataset package archived (versioned)