

# FTI Initiative Energy Model Region

Publishable final report

**Programme control:**

Climate and Energy Fund

**Programme management:**

The Austrian Research Promotion Agency (FFG)

Final Report

created on  
30/11/2024

Project title: Heat Highway

Project number: 880797

## FTI Initiative Energy Model Region - 3. Call for Projects

Federal Climate and Energy Fund – Handling by The Austrian Research Promotion Agency FFG

Call	3. Call FTI Initiative Energy Model Region
Project Starting Date	2021-03-01
Project Ending Date	2024-08-31
Total duration of project (in months)	42 months
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# Heat Highway

Interregional heat transmission networks to enable industrial  
waste heat usage and fossil-free industry

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## 1 Introduction

This report is the publishable final report for the Heat Highway project, which was carried out by 17 project partners between March 2021 and August 2024. The Heat Highway project focussed on supra-regional district heating networks and the resulting opportunity to make better use of industrial waste heat.

Heat Highway was funded by the Klima- und Energiefonds as part of the 3rd call for proposals of the FTI Initiative Energy Model Region and co-funded by the regional government of Upper Austria. The project was handled by FFG Österreichische Forschungsförderungsgesellschaft mbH. The project is assigned to the Energy Model Region New Energy For Industry. The Heat Highway project contributes to the innovation fields of the New Energy For Industry Energy Model Region, namely in the areas of 'Industry to Grid', 'System Solutions & Infrastructure' and 'New Business Models'.

Supra-regional district heating networks and the resulting opportunity to utilise industrial waste heat more effectively are the central themes of Heat Highway. This results in two major topics: Firstly, it is about the feasibility and realisation of supra-regional district heating networks. These exist in practice in a few individual cases, but are either smaller than those considered in the project or involve fewer players. The Heat Highway project is the first major research project to address the theory of supra-regional district heating networks, while at the same time aims to advance practical use cases towards implementation. Secondly, industrial waste heat is underutilised. This is also due to the fact that waste heat is increasingly generated in the summer and local heating networks mainly need waste heat in the winter. In addition, the capacity that local heating networks can absorb is often limited; supra-regional connections can increase the sales volume, which provides the thematic link between the two areas.

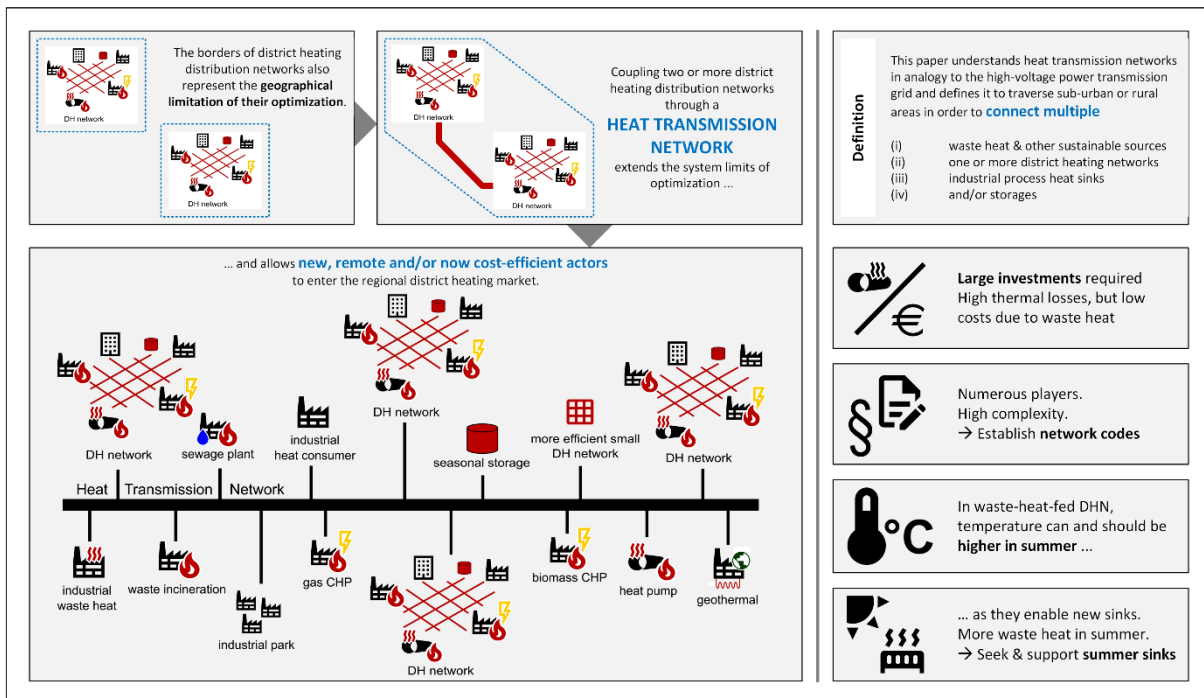


Figure 1: Overview of the concept of a supra-regional heating network and the derived objects of investigation. Illustration taken from: Moser, Puschnigg (2021). Supra-Regional District Heating Networks: A Missing Infrastructure for a Sustainable Energy System. *Energies*. 14(12):3380. <https://doi.org/10.3390/en14123380>

The use of industrial waste heat is essential for the decarbonisation of the heat supply. While the electricity transmission network connects many generation, storage and consumption units, the current options for waste heat feed-in and (supra)regional exchange are limited. Heat Highway is therefore investigating (supra)regional heat transmission networks (HTNs) that connect four areas: industrial waste heat and other sustainable sources, district heating networks, industrial process heat sinks and storage. These HTNs connect consumption centres and industrial sites and thereby cross areas with other heat sources and sinks. The project reduces risks by incorporating many supply and demand nodes and creating innovative business models. The concept goes beyond state of the art in terms of the number of players, (supra)regionality and networking.

Heat Highway is developing two 100 km long HTNs in Upper Austria and Styria and is driving forward three sections for practical implementation, particularly in the central region of Upper Austria and in Linz. Furthermore, Heat Highway analysed an HTN in Styria, especially in the Mur-Mürz area, and initiated the next steps and stakeholder participation. The analyses in four 'follower regions' ensures the reproducibility. Various areas/disciplines are considered theoretically. These include regulatory, systemic-technical, economic and legal analyses. The HTN implementation is evaluated using all of these analyses/tools. Heat Highway aims to develop an interdisciplinary toolbox for anticipating the medium-term utilisation of waste heat from innovative processes and to develop a cost-effective pipe system. A highlight of the project is the prototype, which is a large district heating pipe with illustrative elements, designed

for the exhibition, as well as a virtual HTN demonstrator, which demonstrates the technical controllability of a system with several players.

The following chapters describe the work carried out in the Heat Highway project and the results achieved. The division into sub-chapters in this report essentially corresponds to the work packages of the project and their underlying tasks. All work packages and tasks follow their own specific methods, which is why these are also presented in the content presentation. In Heat Highway, the aim was to disseminate scientific results in the best possible way, and therefore several research papers and conference contributions were produced. As these publications shall not to be repeated here in their entirety, short summaries are included or reference is made to the publications. This means that although the content and results are fully accessible, larger work packages or tasks can sometimes be relatively short. A central and integral part of the project was dissemination to the general public. This work is described in more detail in the chapter dissemination.

Table 1: Overview (Sub)-Chapters corresponding to Work Packages and Tasks

<b>(Sub)-Chapters</b>	<b>Work packages/Task</b>
2.1	T2,1 Review of national/international best practice T2,2 Legal requirements T2,3 Development of characteristic model case T2,4 Competing solutions, further potentials s
2.2	T3,1 Toolbox development T3,2 Semi-dynamic flow calculation tools T3,3 Control algorithms T3,4 HTN organization (network codes) T3,5 Business models and new players T3,6 Lean HTN pipe technology
2.3	WP 4 Case 1: HTN Upper Austria – section LINZ (T4,1 – 4,5)
2.4	WP 5 Case 2: HTN Upper Austria – section WELS-LINZ (T5.2 – T5,5)
2.5	WP 5 Case 2: HTN Upper Austria – section OTHER AREAS (T5,1)
2.6	WP 6 Case 3: HTN Styria (T6,1 – 6,5)
2.7	WP 7 Follower Cases & Replicability (T7,1 INN TAL)
2.8	WP 7 Follower Cases & Replicability (T7,2 INNVIERTEL)
2.9	WP 7 Follower Cases & Replicability (T7,3 – T7,4)
3.1	WP 8 Virtual demonstration & Dissemination (T8,4 Lessons learned)
3.2	T8,1 Virtual demonstrator T8,2 Stakeholder participation & local involvement T8,3 Dissemination & international visibility T3,6 Prototype

## 2 Content presentation

This chapter contains the central work content of the Heat Highway project. It is structured in the work packages or underlying tasks, each of which represents a subchapter. The content presentation therefore describes the objectives, methodology and results of the individual work packages or tasks. The results, particularly for tasks that deal with company-specific data, can only be presented to the extent that the required confidentiality of the data allows. Please note that reference is made to available publications such as scientific papers or conference contributions if the results have already been disseminated in this way by the project team before.

### 2.1 Framework assessment for heat transmission networks

The results from the work package on the framework conditions for heat transport networks are presented in this subsection.

#### 2.1.1 Review of national/international best practice

In the effort to decarbonize energy systems, long-distance heat transport networks (HTNs) have emerged as a critical infrastructure for the efficient distribution of waste heat and renewable energy over large areas. Countries such as Austria, Germany, Denmark and the Netherlands are pioneering these systems and showcased different models of successful implementation.

Further information can be found in the deliverable “Heat Highway - Review of Best Practice Examples” (see chapter 6 Appendix).

Heat transport networks, classified here into unidirectional pipelines (HTP) and bidirectional transmission systems (HTN), allow for the movement of thermal energy across extended distances. These networks serve multiple regions and cities, integrating industrial waste heat, renewable energy, and biomass to provide a stable heat supply. They also contribute to a significant reduction in emissions by replacing traditional fossil-fuel-based heating systems.

Table 2: Overview of long heat transport networks with basic information. In some cases, different parameters were found for identical networks (values in brackets). HTP = unidirectional transport pipe, HTN = heat transfer network.

Location	Country	Type	Length in km	Rated Power in MW	Annual heating demand in GWh/a	Pipe diameter in mm
Dürnrohr-St. Pölten	AT	HTP	31	50	200	450 / 400
Hallein-Salzburg	AT	HTP	14 (19)	7,5	120 (80)	200
Pöls-Judenburg HTP Aichfeld	AT	HTN	18	30	100	300 / 250

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Location	Country	Type	Length in km	Rated Power in MW	Annual heating demand in GWh/a	Pipe diameter in mm
Sappi - Graz	AT	HTP	12 (15)	40	170	400
Mellach-Graz	AT	HTP	19	300	900 (from 2021: max. 600)	650 / 550
Innsbruck-Wattens	AT	HTN	20 (16)	-	147,5	-
Donawitz - Trofaiach	AT	HTP	8,2	-	32	250
Arnoldstein-Villach	AT	HTP	16	19	100	-
Chur-Trimmis	CH	HTP	9,2	18	31	-
Melnik-Prague	CZ	HTP	32	340	-	1200
Lippendorf-Leipzig	DE	HTP	15	300	900	800
Mannheim-Speyer	DE	HTP	21,2	48	-	-
Aachen	DE	HTP	20	85	-	-
Boxberg-Weißwasser	DE	HTP	16	40	-	400
Zolling-Munich Airport	DE	HTP	28	150	-	500 / 400 / 350
Lower Rhine	DE	HTN	40	550	786	400
Ruhr	DE	HTN	42	430	1.600	800 to 300
Saar	DE	HTN	35	686	943	600 / 500
Triangle region Denmark	DK	HTN	123	-	1.658	660 - 220
Copenhagen	DK	HTN	189	-	8.000	-
Viborg	DK	HTP	12	58	-	-
District heating Fyn	DK	HTN	120	950	3.600	-
District heating Aarhus	DK	HTN	-	-	3.100	-
Kozani	EL	HTP	16,5	137	-	500
Helsinki	FI	HTP	20	490	-	1.000
Turku	FI	HTP	25	340	-	800
Akranes	IS	HTP	62	60	-	400
Nesjavellir-Riykjavik	IS	HTP	27	290	-	800
Rozenburg-Rotterdam	NL	HTP	16,8	160	-	700
Tilburg	NL	HTP	25	170	-	500
Diemen-Almere	NL	HTP	8,5	260	-	700
Almere	NL	HTP	10	170	-	500
Rotterdam-The Hague	NL	HTN	23	250	-	700
Oslo	NO	HTP	13	275	-	600
Oradea	RO	HTP	86,3	546	-	-
Linkoping-Mjolby	SE	HTP	28	25	-	-
Lindesberg	SE	HTP	17	26	-	-
Gothenburg-Kungälv	SE	HTP	22	19	-	-

### 2.1.1.1 Austria

Austria has developed several successful long-distance heat transmission systems. A notable example is the Pöls-Judenburger Wärmetrasse Aichfeld, a system that transports heat from the pulp industry over 18 km and supplies up to 15,000 households. This network efficiently integrates industrial waste heat and local biomass, optimizing the use of available energy sources. Another notable system, Innsbruck-Wattens, connects industrial waste heat sources with several local heating networks. The 20 km system is operated by TIGAS and serves several municipalities, demonstrating the benefits of regional cooperation in heat distribution.

### 2.1.1.2 Germany

Germany's Fernwärmeschiene Niederrhein and Fernwärmeschiene Ruhr are examples of large-scale heat transport networks utilizing industrial waste heat. The Niederrhein system, spanning 40 km, integrates heat from steel production and the chemical industry, connecting cities like Duisburg, Dinslaken, and Moers. Similarly, the Fernwärmeschiene Ruhr covers 42 km and has a capacity of 430 MW, integrating heat from multiple sources, including the soon-to-be-converted gas-fired power plant in Herne.

### 2.1.1.3 Denmark

Denmark operates some of the most extensive and advanced heat transport systems. Copenhagen's heat network, spanning 189 km, is one of Europe's largest. It integrates multiple renewable sources, including biomass, waste-to-energy plants, and industrial waste heat, to supply over 8,000 GWh of heat annually. Denmark's success in district heating results from strong political commitment, non-profit operations, and a focus on regional cooperation. The Dreiecksregion network (123 km) and Fünen's heat system (120 km) further exemplify Denmark's ability to leverage regional collaboration for optimal heat distribution.

Denmark's regulatory framework plays a critical role in the success of its heat networks. The Danish Heat Supply Act, introduced in the 1980s, mandates that heat networks operate on a cost-recovery basis, ensuring affordable prices for consumers. Moreover, the integration of diverse heat sources, including biomass, waste incineration, and industrial waste heat, makes Danish systems resilient and cost-effective.

### 2.1.1.4 Netherlands

The Netherlands is currently planning the WarmtelinQ project, a 23 km pipeline that will connect Rotterdam to The Hague, utilizing waste heat from industrial processes in the port of Rotterdam. Scheduled for completion in 2023, the system will supply up to 250 MW of heat, providing heating for approximately 120,000 households. This initiative is part of the Netherlands' broader efforts to transition away from natural gas heating, aligning with its climate-neutral goals for 2050. The system also features an open-access structure, allowing multiple energy suppliers to utilize the network, promoting competition.

## 2.1.1.5 SWOT Analysis

Based on the findings from the literature research and the interviews, a SWOT analysis was carried out on long transport networks, which compares the strengths, weaknesses, opportunities and threats.

Table 3: SWOT Analysis

STRENGTHS	WEAKNESSES
Enables the optimal integration and utilization of regionally available (industrial) waste heat sources that are not directly located in district heating areas	High investment costs for building the infrastructure
Possibility of providing district and process heat to customers outside urban centres	High complexity due to the size of the system, requiring more detailed planning and monitoring
Lower dependency on individual producers due to the variety of connected generating plants	Sluggishness in adjusting system parameters (e.g., reducing system temperature)
Diversification of the used heat generation technologies	Permanent reduction of transmission temperatures is only possible with corresponding adjustments in distribution networks and at end customers
Connecting individual networks enables cost-optimized heat generation, ensuring that only the most economical plants are in operation	Provision of peak load should be managed locally at the distribution network level to limit infrastructure costs
Resilient and price-stable heat supply for connected municipalities	High coordination needs between various stakeholders: heat producers, transmission network operators, and distribution network operators
Promotes cooperation between municipalities and the optimal use of available resources	For distribution network operators with their own production facilities, connection to a transmission network could displace their own production
Costs for pipelines in suburban areas are significantly lower than in densely built urban areas	-
OPPORTUNITIES	THREATS
Possibility of integrating (seasonal) heat storage on cheap land	Due to the long planning timelines for major infrastructure projects, critical conditions affecting economic viability may change (e.g., development of connection rates, will of local decision-makers)
Cost-covering, non-profit network operator ensures the lowest possible heat prices	Challenging investment decisions for new infrastructure in light of transitions in the energy system (shift from large centralized to small decentralized generation plants)
Political commitment and favourable legal and regulatory frameworks (e.g., tax reductions,	-

STRENGTHS	WEAKNESSES
subsidies for connection costs, connection obligations, etc.) support the development and economic viability of the infrastructure	
Many stakeholders enable the establishment of a heat market, analogous to the electricity market, for cost-optimized use of available heat sources	-

## 2.1.2 Legal requirements

The integration of waste heat into European energy systems faces significant legal, technical, and policy challenges, as highlighted in the three written papers: *Waste Heat Inconsistencies in the EU’s Energy Legislation*<sup>1</sup> and *Renewables vs. Waste Heat? Legal Provisions on the Original Energy Source*<sup>2</sup>. Together, these works emphasize the critical need for clearer policies and improved alignment of waste heat utilization with renewable energy (RES) targets under EU legislation, specifically the Renewable Energy Directive (RED II and III) and the Energy Efficiency Directive (EED III).

### 2.1.2.1 Legal Challenges and Definitions

A major barrier to the effective utilization of waste heat lies in its legal definition. According to RED II and III, waste heat is characterized as “unavoidable heat [...] generated as a by-product in industrial or power generation processes, or in the tertiary sector, which would be dissipated unused in air or water without access to a district heating [...]”, but this definition includes limitations that exclude many practical applications. For instance, internal reuse within industrial processes or bilateral heat exchanges via direct line between companies may not be recognized under current definitions. As highlighted in *Waste Heat vs. Renewables?*, the focus on district heating systems narrows the scope of waste heat utilization, preventing its adoption in other contexts. The report corroborates this, noting that the legal linkage of waste heat eligibility to district heating networks and cogeneration further restricts its practical deployment. Such definitions fail to account for the broader technical potential of waste heat, particularly when district heating is not a feasible option.

From a technical perspective, waste heat is well-defined by three key characteristics: it is unavoidable, unused (in the absence of internal use), and an unintended by-product of processes. This definition aligns with the technical understanding of waste heat, emphasizing its potential to avoid resource wastage when internal usability or external feed-in is absent. However, practical challenges often limit its further utilization. While electricity generation through steam turbines or ORC processes can be an option for high-temperature waste heat,

<sup>1</sup> Holzleitner-Senck/Moser/Denk (2024). *Waste Heat Inconsistencies in the EU’s Energy Legislation*, Utility Policy <https://doi.org/10.1016/j.jup.2024.101880>.

<sup>2</sup> Holzleitner/Moser (2022). *Renewables vs. Waste Heat? Legal Provisions on the Original Energy Source*, ISEC 2022, <https://doi.org/10.32638/isec2022>.

it is generally inefficient for lower-temperature levels (below 300°C), achieving electrical efficiencies below 25 %. As such, electricity generation should be a last resort, with priority given to more efficient uses such as process heat in external plants or district heating, which can achieve near-total efficiency.

The sector-specific definition of waste heat under RED III introduces exclusions that overlook smaller or non-district heating applications, despite evidence suggesting that even sources below 1 MW can be viable for district heating under suitable conditions. Moreover, the exclusive focus on district heating systems deviates from the general technical understanding of waste heat, limiting its recognition in other applications like internal reuse within the same company or bilateral exchanges between companies. A broader legal definition could enhance legal certainty and better support diverse waste heat applications.

Additionally, the emphasis on cogeneration (CHP) as a criterion for waste heat eligibility under RED III creates inconsistencies and inefficiencies. While CHP is often integral to district heating networks, its use should be prioritized when no sustainable energy sources like waste heat are available. Requiring CHP for waste heat utilization risks excluding efficient projects and undermines flexibility in achieving energy efficiency goals. Policies could benefit from promoting CHP alongside thermal energy storage for electricity-oriented operations, particularly where waste heat is unavailable, rather than limiting waste heat recognition to CHP-compatible systems.

The rigidity of waste heat definitions also leads to inconsistencies in its treatment relative to RES. The Renewables vs. Waste Heat? paper notes that waste heat, even when derived from renewable energy processes, is not classified as renewable under EU law. This creates unnecessary complexity, as industries must navigate unclear boundaries between waste heat and RES contributions. Such ambiguities hinder project implementation and discourage investment by introducing additional legal and administrative risks. Moreover, the restrictive requirements of RED III disproportionately may impact smaller-scale waste heat projects, where the economic feasibility of district heating connections or cogeneration is limited.

An overarching theme across the two papers is the imbalance in how EU legislation prioritizes RES over waste heat. While both energy sources are essential for achieving decarbonization goals, the current framework emphasizes renewable energy at the expense of waste heat's potential contributions. For instance, waste heat can according to Art 22a RED III only account for up to 40 % of annual target increases in industry decarbonization, with the remaining share coming from RES. This cap may diminish the incentive to invest in waste heat recovery, even though it represents an efficient and cost-effective means of reducing primary energy demand.

The preference for RES creates a perception of waste heat as a transitional solution. This may particularly be problematic for waste heat derived from fossil processes. As noted in the report, such projects face additional risks due to the uncertainty of their eligibility under future EU

targets. The Waste Heat vs. Renewables? paper echoes this concern, arguing that the focus on RES neglects the broader climate benefits of utilizing waste heat, regardless of its origin. By failing to fully integrate waste heat into the decarbonization framework, EU policy might miss an opportunity to maximize energy efficiency and reduce emissions across industrial sectors.

### **2.1.2.2 Policy Implications and Recommendations**

The definition of waste heat in RED III has notable shortcomings that complicate its application and reduce its effectiveness in promoting energy efficiency and decarbonization. It is overly complex, narrowly focused on district heating networks, and misaligned with technical understandings of waste heat. Key issues and proposals for improvement include:

#### *2.1.2.2.1 Complexity and Sectoral Limitations*

The current definition restricts waste heat to certain sectors (industry, power generation, and the tertiary sector) and links its eligibility to district heating systems with cogeneration (CHP). This approach excludes other viable sources of waste heat and limits its utilization to district heating, disregarding internal reuse or bilateral industrial exchanges. To address this, the definition should include a broader range of sectors and eliminate unnecessary references to CHP and district heating, making it more inclusive and adaptable.

#### *2.1.2.2.2 Limited Applicability Beyond District Heating*

By tying waste heat to district heating, RED III excludes its use in other contexts, such as internal company processes. This limitation also impacts funding mechanisms and regulations like the General Block Exemption Regulation (GBER), creating barriers for adopting efficient technologies. Aligning RED III and EED III to allow broader interpretations of waste heat could unlock its potential across diverse applications.

#### *2.1.2.2.3 Recognition of Waste Heat from green processes*

Waste heat from renewable energy processes is currently not fully recognized within the definition of renewable energy under RED III. Including such waste heat as part of renewable energy could incentivize cascaded uses of renewable energy and improve overall energy efficiency. Additionally, clarifying the relationship between renewable ambient heat and waste heat would reduce ambiguity.

#### *2.1.2.2.4 Preventing Underutilization*

Waste heat from fossil processes should not be neglected, especially in the short to medium term, as using this heat avoids the need for additional primary energy. Integrating waste heat into district heating networks early can encourage industrial stakeholders to consider waste heat recovery in their transition to green energy systems. Furthermore, lowering network temperatures and aligning industrial and district heating planning would improve the feasibility of using low-temperature waste heat.

### 2.1.2.2.5 Status and Terminology of Waste Heat

Waste heat, though not renewable energy, is equated with renewables in district heating assessments under RED III. However, its classification remains unclear, particularly when associated with fossil-driven processes. Introducing a unified term, such as "low-carbon heat," to encompass both waste heat and renewable energy-based heat could simplify its categorization and emphasize its climate-friendly potential.

The proposed adjustments aim to clarify and expand the definition of waste heat, making it more inclusive, practical, and aligned with the goals of energy efficiency and decarbonization. These reforms would enable waste heat to play a more prominent role in transitioning to a sustainable, low-carbon energy system.

### 2.1.3 Development of characteristic model cases

To facilitate the classification and derivation of different model cases for district heating networks, four key distinguishing features have been identified. These key characteristics are the generation, topology, network level, and structure of a district heating network. These characteristics are thoroughly analysed and detailed in Steinegger (2025)<sup>3</sup>. For an overview, they are briefly subdivided below.

- Generations
  - First generation of district heating
  - Second generation of district heating
  - Third generation of district heating
  - Fourth generation of district heating
  - (Fifth and Sixth generation)
- Topology
  - Radial grid
  - Ring grid
  - Meshed grid
- Network level
  - Primary network level
  - Secondary network level
- Structure
  - One central location
  - Central base load
  - Large integrated network
  - Peripheral base load
  - Common transmission pipe

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<sup>3</sup> Steinegger (2025). Assessing the Technical and Economic Feasibility of Supra-Regional District Heating Networks. Doctoral thesis, currently under review.

A Heat Highway, as outlined and planned in this project, represents a supra-regional district heating network. This type of network can be described by the four key characteristics mentioned earlier and classified into different model cases, depending on how the characteristics outlined below are implemented. The supra-regional district heating network can exhibit characteristics of the second-generation district heating and higher, with the final generation level largely dependent on the temperature of the transmission line. This temperature is determined by the specific use case, as it must be sufficient to meet the highest temperature requirements of any connected district heating network within the supplied region.

In terms of topology, the transmission line in a supra-regional district heating network typically follows a radial grid, while a ring grid may be used in special cases. Meshed grids are unlikely, as transmission lines carry the highest temperatures in the network, and minimising the length of these lines helps reduce temperature losses. The network level of the transmission line corresponds to a primary network level. The implementation of a supra regional district heating network may introduce an additional, previously undefined network level. This is because the transmission line could connect to DHNs that already have both primary and secondary network levels, requiring the reclassification of these networks as secondary and tertiary levels.

Since a supra-regional district heating network is established by linking various DHNs and heat generation units through a heat transmission line, its structure would resemble that of a common transmission pipe. Furthermore, Moser et al.<sup>4</sup> define a supra-regional district heating network as one that spans large distances by using extended heat transmission lines. This network would link sources of industrial waste heat and renewable heat with heat sinks, such as district heating systems or large individual consumers, in a manner similar to the high-voltage grid in the electricity sector.

### **2.1.4 Potentials in addition to industrial waste heat: solar thermal, geothermal**

Within this project, a tool was developed to perform an approximate economic sensitivity analysis for large-scale solar thermal systems. The main purpose of the tool is to compare the economics of solar-supported district heating systems with those of conventional district heating systems. This includes the calculation of the levelized cost of heat (LCoH) of the solar thermal system and a comparison with the LCoH of conventionally operated district heating systems. The calculation of the LCoH considers the energy prices, lifetime of the components, costs for CO<sub>2</sub>-emissions, investment costs etc. As the initial calculation of investment costs is often a challenge, the tool provides the ability to estimate these with specific cost curves. This enables an initial estimation of the economic viability to be obtained at the outset of planning activities or feasibility studies with minimal effort. The comparison between the solar-supported

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<sup>4</sup> Moser (2021). Supra-Regional District Heating Networks: A Missing Infrastructure for a Sustainable Energy System. doi.org/10.3390/en14123380.

and conventional district heating system is done via the cost ratio (CR) of the two calculated LCoH., see Figure 2.

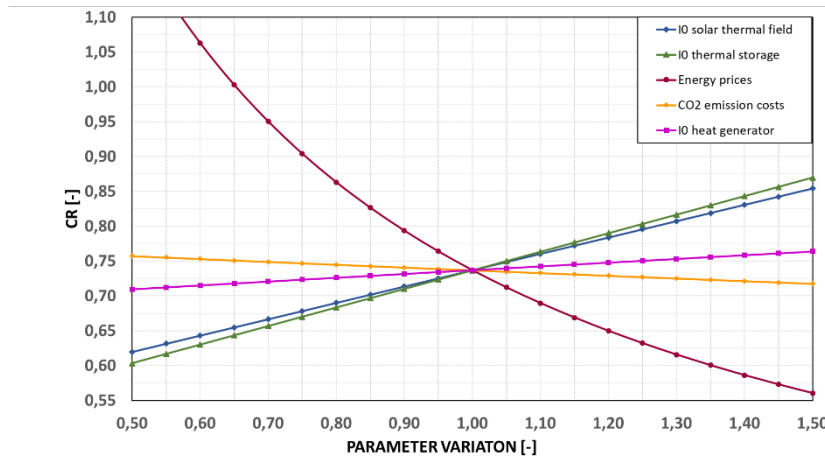


Figure 2: Result of the sensitivity analysis.

In this manner, the parameters with the most substantial impact on the LCoH can be identified. In the shown case in Figure 2, the most significant parameters are the energy prices. In order to validate the developed tool, it was applied to real projects. The results show a consistent correlation between the individual project results and the calculation methods used in the developed tool. More details on this topic can be found in Wagner and Dehner (2024)<sup>5</sup>.

### 2.1.5 Competing solutions: mobile energy storage systems

District heating networks (DHN) are contributing to an efficient and reliable heat supply, mostly for residential applications in urban areas. The energy sources for DHN are various, with a decreasing share of fossil fuels, as renewable energy technologies like biomass are steadily rising their contribution. Industrial waste heat can be considered as another renewable energy source with high potential for supplying DHN, however, industrial plants are usually located in the periphery, outside the economic range of DHN. The concept of mobile thermal energy storages (M-TES), as depicted by Figure 3, aims to bridge this distance between industrial heat source and DHN or other heat sinks by transporting the heat on already available infrastructure like roads or railways, and therefore, avoiding the need for extending the DHN.

<sup>5</sup> Wagner, Dehner (2024). Sensitivity Analysis Of Solar District Heating Systems. Conference Proceedings EuroSun 2024, Paper accepted.

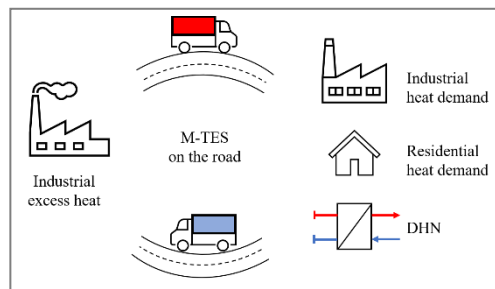


Figure 3: Schematic illustration of the M-TES concept<sup>6</sup>

During the project Heat Highway, the M-TES concept was thoroughly investigated, with the main goal to assess its economic viability in comparison to DHN. Therefore, three different kinds of storage technologies were considered, which were sensible storages, phase change materials (PCM) and thermochemical storage materials (TCM). Moreover, several types of storage material were analysed for each storage technology, with regard to their meaningful application in terms of temperature range, which is usually defined by the available heat source and the demanding heat sink. An economic model based on VDI2067 was developed that takes into account all boundary conditions given by the particular combination of storage technology and storage material, e.g. the energy density, which determines the number of required runs for transporting a certain amount of energy.

The results of this economic analysis are illustrated by Figure 4. The considered M-TES configurations are categorised in three temperature ranges, defined by the source and sink temperatures. For each case, the costs of transported heat (COTH) are presented in €/MWh. The costs of heat provided by conventional DHN in Austria in 2022 serves as benchmark for the results of heat transport by M-TES. This comparison reveals that M-TES working with PCM and TCM, namely Sodium Acetate Trihydrate (SAT), Erythritol, Zeolite 13X and Zeolite 4A, can provide lower COTH than DHN. The cheapest solution would be the M-TES configuration using Zeolite 13X, resulting in COTH of 89.5 €/MWh, equal to a relative economic benefit of 40.3 % compared to DHN.

<sup>6</sup> Resch, Dehner (2023). Economic Analysis of Mobile Thermal Energy Storages as Complement to District Heating. Environmental and Climate Technologies, Jg. 27, Nr. 1, S. 516-531. <https://doi.org/10.2478/rtulect-2023-0038>.

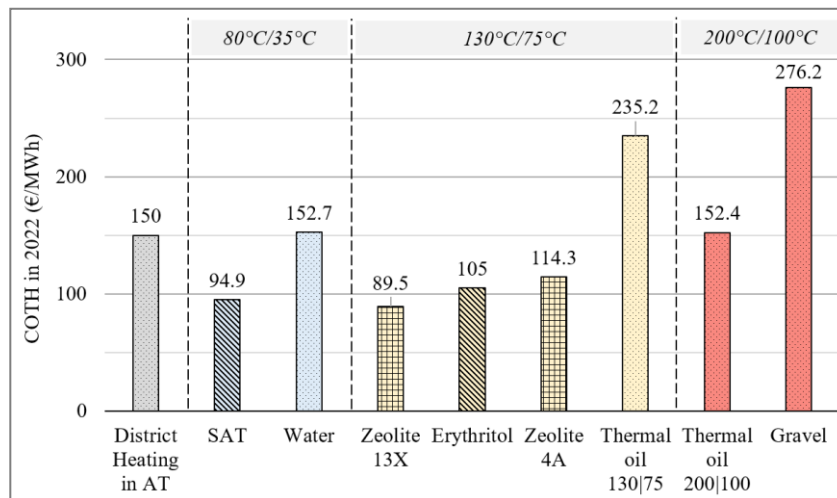


Figure 4: Costs of transported heat (COTH) for the analysed M-TES configurations, in comparison to the heat costs of conventional DHN in Austria in 2022<sup>7</sup>.

However, these results are only valid for a distance of 7 km between heat source and sink, with a transported amount of energy of 1092 MWh/a. More detailed results, all economic parameters and considered material properties are documented in the corresponding publication from Resch and Dehner (2023)<sup>8</sup>. This investigation revealed that M-TES can be economically competitive to conventional DHN for distances below 10 km. Therefore, M-TES can serve as complementary technology to accelerate the integration of industrial excess heat as energy source for DHN.

## 2.1.6 Replicability in Austria and Europe

Each region must be examined in detail to determine its suitability for a supra-regional district heating network. However, some regions are more favourable due to a high concentration of energy-intensive industries and the proximity of large district heating networks. Based on this, individual regions were analysed, focusing on existing heating networks near significant energy-intensive industries with substantial waste heat potential in Europe. For this purpose, many of the largest district heating networks in Europe, which are described in detail in Steinegger (2025)<sup>9</sup>, are analysed, along with the European heat road map<sup>10</sup>.

Based on the potential length of the transmission lines for a supra-regional district heating network, the maximum annual heat consumption of district heating networks near industrial waste heat sources, and the technical potential (assumed to be 6% of the theoretical potential) of industrial waste heat, considering 3,000 full load hours, rough estimates for linear heat

<sup>7</sup> Resch, Dehner (2023). Economic Analysis of Mobile Thermal Energy Storages as Complement to District Heating. *Environmental and Climate Technologies*, Jg. 27, Nr. 1, S. 516-531. <https://doi.org/10.2478/rtuect-2023-0038>.

<sup>8</sup> Resch, Dehner (2023). Economic Analysis of Mobile Thermal Energy Storages as Complement to District Heating. *Environmental and Climate Technologies*, Jg. 27, Nr. 1, S. 516-531. <https://doi.org/10.2478/rtuect-2023-0038>.

<sup>9</sup> Steinegger (2025). Assessing the Technical and Economic Feasibility of Supra-Regional District Heating Networks. Doctoral thesis, currently under review.

<sup>10</sup> Europa-Universität Flensburg and Halmstad University (2018). Pan-European Thermal Atlas 4.3.heatroadmap.eu/peta4/ (Abgerufen am: 17.12.2024).

density were made, and potential regions were identified. These regions are listed in the following table:

Table 4: Analysed regions

Large Sinks	Nation	Heat Demand in GWh	Theoretical Potential in GWh	Technical Potential adjusted to 3000 FLH	Length transmission line in km	linear heat density in MWh/(m*a)
Berlin	GER	9578	7463	155	99	1.6
Warsaw	POL	9472	11491	239	110	2.2
Espoo-Helsinki-Vantaa	FIN	9987	5655	118	58	2.0
Ruhrgebiet	GER	Researched but not realised (still high potential)				
Bucharest	ROU	5533	1933	40	65	0.6
Paris	FRA	5500	9500	198	203	1.0
Munich	GER	4800	5186	108	95	1.1
Gothenburg	SWE	4400	5278	110	106	1.0
Krakow	POL	2631	4844	101	33	3.1
Budapest	HUN	2184	2653	55	27	2.0
→ Leipzig	GER	1735	5219	109	52	2.1
→ Milan	ITA	1226	6933	144	78	1.8
→ Rotterdam	NED	Has already been partially implemented				
→ Saarland	GER	808	5139	107	6	17.8
→ Breda-Tilburg	NED	722	2042	42	21	2.0
→ Amsterdam	NED	611	5186	108	27	4.0

Due to the more precise data available on industrial waste heat in Austria compared to the rest of Europe, potential supra-regional district heating networks regions are identified by combining data from the Austrian Heat Map<sup>11</sup> with the calculation of the potential linear heat density. The given technical potential is standardised to 3000 full load hours, and only sources with temperatures above 50°C are considered. Regions previously identified and analysed in the Heat Highway Project, such as Lower Inntal in Tyrol, Innviertel, St. Pölten–Krems, Vienna South, Linz, and Styria, are excluded from this analysis. The results are presented in the following table:

<sup>11</sup> Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (2021). Austrian Heat Map. [www.austrian-heatmap.gv.at](http://www.austrian-heatmap.gv.at) (Abgerufen am:17.12.2024)

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Table 5: Additional potential supra-regional district heating networks regions in Austria

<b>Location</b>	<b>IWH Technical Potential in GWh</b>	<b>IWH Technical Potential adjusted to 3000 FLH</b>	<b>Length transmission line in km</b>	<b>LHD in MWh/(m*a)</b>
Salzkammergut	299.9	102.71	34	3.02
Deutschlandsberg	102.4	35.07	21	1.67
Völkermarkt	163.2	55.89	12	4.66
St. Veit an der Glan	119.6	40.96	36	1.14

## 2.2 Tools for developing and evaluating heat transmission networks

The results from the work package on developed tools for heat transport networks are presented in this subsection.

### 2.2.1 Toolbox development

To establish a consistent and structured framework for utilizing and interacting with the various simulation and calculation models from Work Package 3, the toolbox was developed as an overarching task. This toolbox aimed to ensure coherence within the work package and provided a unified starting point for the development of individual tools. These tools include the semi-dynamic flow calculation tool, control algorithms, HTN organization (network codes), business models and new players, and the lean HTN pipe technology & prototype.

During the project, we identified that a bottom-up approach was most effective in gaining a comprehensive understanding of data and information requirements. Because of the heterogeneous of the tools, the critical questions were addressed within the individual tools, and the findings were discussed and consolidated in joint Work Package meetings and feedback loops.

This collaborative process focused on defining data requirements, selecting appropriate databases, and ensuring interfaces and interoperability between the tools. Additionally, potential barriers and boundary conditions were evaluated that might impact the application of the tools and methodologies.

By analysing the requirements of each individual tools, it has turned out that completely different data is required in the different tools. However, if you are dealing with the topic of industrial waste heat feed-in and/or supra-regional heating networks and would like to approach the topic, the following data should be analysed in advance as a very positive initial input, because this can help in almost all tools:

- What is the situation regarding heat source or waste heat?  
Parameters:
  - Quantity
  - Performance
  - Profile
  - Temperature
  - Time horizon: all year vs. summer, all week vs weekend, weekdays, 24 hours per day vs 8 hours by day
- Are there heating networks nearby? And if yes, what size do they have, what temperature level and what is the annual sales?
- What alternative heat sources are available in the area (possibilities such as geothermal energy, solar thermal energy, etc.)?

- What alternative sources of waste heat are there in the area?
- Are there any legal restrictions that can be circumvented by using waste heat?
- Are there hydraulic guidelines that must be observed?
- Which economic efficiency parameters are available individually and collectively?
- Are there summer sinks? Who could take the waste heat in summer in order to utilise it all year round?

### 2.2.2 Semi-dynamic flow calculation tools

For the following simulations of the different scenarios in the use cases, a new load flow calculation tool was developed, as detailed in Steinegger et al. (2022)<sup>12</sup> and Steinegger (2025)<sup>13</sup>. This tool was designed to meet the key requirements for calculating supra-regional district heating networks:

- An easy implementation into existing multi-energy-system (MES) simulation frameworks, especially the HyFlow<sup>14</sup> framework.
- The accurate calculations for small and large district heating networks, highly branched district heating networks, or district heating networks with long transmission lines, considering that these properties can occur individually or in combination.
- The capability to consider temporally varying temperature changes within the district heating networks.
- The ability to incorporate changes in the directions of the volume flows within the district heating network over various time steps.
- Ensuring sufficiently fast calculation speeds.
- The inclusion of typical elements of a heating network in the calculations.
- The availability of a freely accessible code that allows for the integration of new operating strategies.

The developed tool is based on a quasi-dynamic approach that satisfies all the mentioned requirements. Compared to other tools in the literature, this method offers lower calculation times than dynamic approaches and higher accuracy than steady-state approaches.

### 2.2.3 Control algorithms

The report discusses technical challenges in implementing interregional heat transmission networks for the Heat Highway project. It focuses on the development and validation of control algorithms and operational strategies, incorporating available flexibility options.

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<sup>12</sup> Steinegger (2022). A new quasi-dynamic load flow calculation for district heating networks, [doi.org/10.1016/j.energy.2022.126410](https://doi.org/10.1016/j.energy.2022.126410).

<sup>13</sup> Steinegger (2025). Assessing the Technical and Economic Feasibility of Supra-Regional District Heating Networks. currently under review.

<sup>14</sup> Greiml (2022). Modelling and simulation/optimization of Austria's national multi-energy system with a high degree of spatial and temporal resolution, <https://doi.org/10.3390/en15103581>.

Further information can be found in the deliverable “Heat Highway - Control Algorithms (general)” (see chapter 6 Appendix).

### 2.2.3.1 Key Control Strategies for Heat Transmission Networks

There are six basic control strategies<sup>15</sup> which operate simultaneously in a traditional DH network. These are usually implemented in the form of classical control such as rule based or PID. A graphical depiction is shown in Figure 5. (A to E are implemented at the production and pumping station level, whereas the control strategy F is implemented at the user substation level.)

Basic Control in District Heating (DH) Systems:

- Supply temperature control: Modulates heat generation to maintain a fixed supply temperature based on external conditions.
- Minimum supply temperature control: Ensures sufficient supply temperature during low-demand periods.
- Pressure controls: Maintain minimum and maximum pressure limits to avoid system damage.
- Heat demand and flow control: Implements climatic control at substations, ensuring proper heat delivery.

Temperature Management in HTNs:

- Heat exchange between industrial sources and HTNs requires balancing differing temperature levels, often needing heat pumps or post-heating systems to raise the temperature before heat enters the main network.
- Managing multiple heat sources of varying temperatures can be optimized with additional lower-temperature lines and centralized post-heating to reduce energy loss.

Thermal Energy Storage (TES):

- Centralized TES can balance fluctuations in heat demand, while decentralized TES systems at substations or buildings enhance flexibility and reduce the need for larger distribution infrastructure.
- TES is essential in long-distance heat transfer networks (LDHTNs) for decoupling production from demand, aiding in response to peak demands.

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<sup>15</sup> Buffa, Fouladfar, Franchini, Lozano Gabarre, Andrés Chicote (2021). Advanced Control and Fault Detection Strategies for District Heating and Cooling Systems—A Review, Applied Sciences, vol. 11, no. 1, p. 455, doi: 10.3390/app11010455.

## Hydraulic Switch:

- Used to decouple components with different response times, enabling smoother transitions and consistent temperatures when systems with varying dynamic responses operate together.

## Heat Pumps (HPs):

- HPs operate with constant mass flow rates, adjusting compressor power and flow rates to optimize heat transfer. They play a crucial role in lifting the temperature of return flows to meet demand.

## Demand-Side Management (DSM):

- DSM strategies such as peak shaving and load management are employed to flatten demand curves and reduce the need for centralized TES. Price-based and incentive-based DSM programs incentivize consumers to adjust their heat usage.

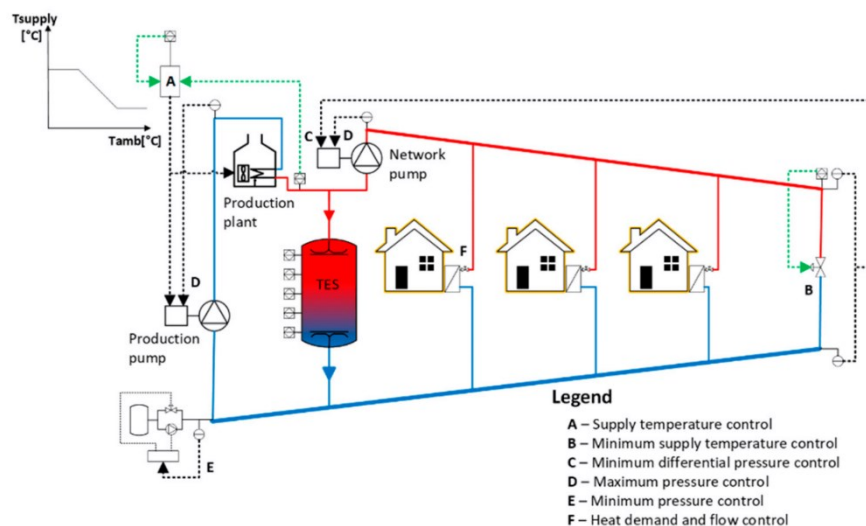


Figure 5: Basic control strategies in traditional district heating (DH) systems

### 2.2.3.2 System-Level Control Methods

Challenges such as weather uncertainty, user behaviour and customer-sited substation operation need smart control strategies at centralized and decentralized levels, which need to be applied on top of basic control strategies.

The implementation of advanced control strategies in DH systems is challenging, since they are affected by time-varying nonlinear dynamics, time-varying set-points and disturbances. Advanced control strategies applied in DH can be classified as hard, soft and hybrid control.

## Fault Detection and Diagnosis (FDD):

- Faults such as leakage or incorrect temperature levels can reduce system efficiency. FDD methods, including both physical models and data-driven approaches, are essential for identifying and addressing faults early.

Model Predictive Control (MPC):

- MPC optimizes system performance by anticipating future demand and adjusting control actions accordingly. It has been shown to reduce operating costs, improve heat storage management, and handle fluctuating loads.

Linear and Mixed-Integer Linear Programming (MILP):

- MILP optimizes system components and scheduling, reducing energy costs and improving system efficiency.

Meta-Heuristic Algorithms:

- These optimization algorithms, including genetic algorithms and particle swarm optimization, help solve complex, nonlinear system control problems.

Multi-Agent Systems (MAS):

- MAS allows decentralized agents to manage parts of the system autonomously, improving system flexibility and fault tolerance.

### 2.2.3.3 Case Study: Heat Highway in Linz

For the Linz Heat Highway, a control strategy was developed to increase return temperatures by using low and medium temperature waste heat through heat pumps. In the "Heat Highway short" variant, waste heat sources at different temperature levels are integrated into the district heating network and raised to the required temperatures by a cascade of heat pumps. A key challenge in this system is to manage the rapid fluctuations of the low temperature waste heat output, which varies faster than the cooling capacity of the heat pump cascade can adjust, while maintaining stable input and output temperatures.

Further information can be found in the deliverable "Heat Highway - Control Algorithms (Use Case Linz)" (see chapter 6 Appendix).

The primary objectives were to gain a deeper understanding of the design and control behaviour of the Heat Highway short system, and to improve the control strategy and operational efficiency of the hydraulic switch and heat pump cascades. A detailed simulation was created using Dymola and the Modelica modelling language, modelling components such as low and medium temperature heat pump cascades, hydraulic switches, heat exchangers and pumps. This simulation allowed the analysis of different control strategies and operating conditions, providing valuable insights into the dynamics of the hydraulic switch and the system behaviour.

One of the key findings highlighted that optimising the hydraulic switch by adjusting its target level proportionally to the mass flow of the associated pump reduced the required switch volume and significantly improved control, potentially halving the required volume. Furthermore, the simulation results showed that at high power levels, there were minimal

performance gains and only minor adjustments to the switch fill levels. Similarly, at low power conditions, the system response remained stable with limited fluctuations, highlighting the need for refined control strategies. Taken together, these findings suggest targeted approaches to improve the efficiency and stability of the system.

The study also identified several directions for further research. Firstly, incorporating data from commercially available heat pumps would support more accurate modelling of the coefficient of performance (COP) under different scenarios. Integrating the Linz Mitte power plant and its storage would provide insight into the impact of industrial waste heat under different conditions. In addition, refining the model to accurately represent the storage and piping network would deepen the understanding of pressure dynamics within the system. Real-time monitoring data could then be used to simulate dynamic behaviour more realistically, while the integration of the district heating network would require comprehensive heat output and pressure demand datasets to effectively address system complexity.

The Linz Heat Highway project is an example of a significant step towards improving the efficiency of district heating networks by integrating industrial waste heat. Further research and optimisation of control strategies and system components are essential to maximise the potential of these inter-regional heat transfer networks and pave the way for sustainable urban energy solutions.

### **2.2.4 Organizational aspects of heat transmission networks (network codes)**

In this task, the network codes of the electricity industry were analysed and compared, with the goal of identifying the necessary key points for a potential cooperation agreement between a (fictional) association of heat distribution networks and a heat transmission network. Various topics and headings were collected, which were further discussed in a workshop with consortium stakeholders, held on May 19th, 2022 in Linz. The responses from the workshop were then clustered and divided into different categories. Based on this, the contents and key points of the agreement were prepared to ensure a structured and precise elaboration. The summary of the collected basics and analysis results provides a valuable basis for further discussions and decisions regarding the cooperation agreement. The results can help to ensure that the agreement meets the requirements and needs of all parties involved, thus enabling successful collaboration.

#### **2.2.4.1 Network codes of the electricity industry**

The European Commission's Network Codes form a comprehensive set of regulations for the electricity industry. These are legally binding EU regulations that define and harmonise numerous rules in the areas of market integration, network operation and network connection. Thanks to the direct applicability of these regulations, they form the basis for an efficient and Europe-wide integrated internal electricity market. The Network Codes contain time-bound obligations for all market participants, from transmission system operators to consumers. The

implementation requires far-reaching cooperation between the individual participants, beyond the borders of individual member states.

Some of the existing network codes include, for example, the Demand Connection Code, which defines harmonised requirements for connecting large renewable energy generation plants to the transmission grid; the Cybersecurity Code, which creates a European standard for the cybersecurity of cross-border electricity flows; and the Network Code on Forward Capacity Allocation, which regulates requirements for the allocation of long-term capacities. In this context, the extent to which and whether these regulations can be adapted for the district heating sector was analysed. Attention should be drawn to the lack of liberalisation and the resulting differences in the distribution of roles in the district heating market, which is one of the main obstacles to such a project. However, certain aspects and directions from the network codes of the electricity industry can certainly be utilised for the district heating sector. Such elements can be incorporated into the co-operation agreement, which corresponds to the legal link in the district heating transmission network.

### **2.2.4.2 The co-operation agreement as a legal link for district heating networks that merge to form a district heating transmission network**

The cooperation agreement forms the legally binding basis of a district heating transmission network. In this constellation, it replaces the network codes in the electricity industry, among other things. Accordingly, the quality of the cooperation agreement plays a decisive role on the one hand and the actual enforceability between the contracting parties on the other. Furthermore, the private law nature of the contract must be taken into account, which inevitably means that it can only be successfully implemented if it is sufficiently favourable for all parties.

In the course of the project, a number of key contractual elements and necessary contracting parties were identified, which were to be included in the cooperation agreement:

### **2.2.4.3 Essential elements of the contract**

With regard to the essential contractual elements, the focus is on drafting the contract in a form that fundamentally enables all eligible contracting parties to participate. To this end, the contract must be sufficiently general.

The essential contractual elements can be categorised as follows: Elements of a legal nature, which consist of legal-organisational requirements and core contractual elements, such as compensation for damages and liability conditions; technical elements, which in turn contain organisational requirements relating to processing and establish specification requirements that are necessary for grid management and security of supply; elements relating to the flow of information; and elements relating to economics and accounting.

Some of these elements concern, for example, general operational management, the duration of the contract, liability provisions and compensation, the chosen medium, quality assurance processes and many more.

As the cooperation agreement must fulfil numerous roles beyond the classic contract design in order to enable the operation of a district heating transmission network, its creation is accompanied by a certain degree of responsibility. The interests of all parties must be given equal importance and a well-founded set of rules for good cooperation must be created between them.

### 2.2.4.3.1 Contracting parties

In order for a district heating transmission network to function effectively and at the same time correspond to an efficient co-operation, many potential contracting parties must be taken into account. Probably the most important party to the cooperation agreement is the transmission system operator, who is primarily responsible for the operation and maintenance of the district heating transmission network. Without the transmission system operator (Also Transmission District Heating Network Operator/TDHNO), neither the cooperation agreement nor the district heating transmission grid can be realised. The transmission system operator also ensures the safe operation of the network and ensures compliance with the applicable legal situation and other regulations. Another important role of the transmission system operator is the management of grid access and exit. Furthermore, it works closely with all other stakeholders, especially with regard to compliance with all provisions of the cooperation agreement.

The operators of the various district heating networks involved will work particularly closely with the transmission system operator. Depending on demand and capacity bookings, they will feed into the transmission grid or take from it. The district heating network operators are each responsible for the operation and maintenance of their own networks.

Other contracting parties that need to be taken into account are both (industrial) feeders/extractors and pro-consumers (ProSumers are customers who both feed district heating into the transmission grid and withdraw it.). Their activities in connection with the transmission grid are particularly relevant in the area of capacity management.

For the efficient operation of the district heating transmission network, it is also necessary to integrate large heat storage facilities into the network. These act as a buffer to regulate the demand for and supply of district heating.

It also makes sense to set up a supervisory body as part of the cooperation agreement or to commission an existing one. On the one hand, this would ensure compliance with the contract internally and, on the other hand, it would be responsible for ensuring that the cooperation agreement complies with the applicable legal provisions and would thus reduce the responsibility and workload of the transmission system operator to a certain extent. In addition,

it would be possible to set up a contracting party whose competences would be similar to those of the balance group representatives in the electricity industry. This party would be responsible for all matters relating to cost accounting.

### **2.2.4.4 Conclusion**

A cooperation agreement, which in the district heating sector takes the place of network codes among other things, is essential for the effective and economic operation of a district heating transmission network. If carefully designed, the cooperation agreement can bring added value to all parties involved in the form of cooperation and fair competition. Although the implementation and realisation of such a project is associated with some obstacles, the resulting advantages outweigh them.

The cooperation agreement must be adapted in advance to all those parties that make the operation of the transmission grid possible. In addition, the key contractual elements mentioned above are more important than in conventional contracts under private law because the cooperation agreement contains a number of regulatory components by its very nature. Great care must be taken to ensure the neutrality of the contract so that none of the contracting parties is disproportionately disadvantaged or favoured.

In view of the purpose of the cooperation agreement, the essential contractual elements examined and the contracting parties in question are a cornerstone for the creation of district heating transmission networks.

### **2.2.5 Business models and new players**

#### **2.2.5.1 Summer heat sinks**

District heating (DH) systems provide both space heating and hot water, resulting in significantly higher energy consumption during the winter months due to lower outdoor temperatures. In Central Europe, the infrastructure is designed to handle consumption levels up to ten times higher in winter compared to summer. However, during the summer, a substantial amount of waste heat is produced, which largely remains unused due to lower demand. The goal of the analysis in task 3.5 was to explore how waste heat can be actively and economically utilised during the summer months. This was achieved through comprehensive research and a case study focused on Linz, which examined the following summer heat sinks:

- Domestic and commercial hot water use
- Heat-to-cold / waste heat-to-cold
- Low temperature process heat
- Seasonal heat storage
- Supply of new DHN or substitution of fuel-based DH energy
- Heat-to-power / waste heat-to-power

### 2.2.5.1.1 Domestic and commercial hot water use

In Linz, DH for space heating and hot water can be obtained separately. According to DH experts, the potential of hot water to be utilized as a summer heat sink in the central Linz area is limited. This assessment is based on the fact that more than 80 % of heat consumers use DH for both hot water and space heating. The remaining share of customers obtain hot water from electrically operated boilers. It is possible to supply these consumers with hot water as part of a large-scale retrofit campaign, which is already being implemented in some cases. However, this conversion involves a great deal of effort (many buildings/flats to be retrofitted in comparison to low hot water demand) and investment costs.

### 2.2.5.1.2 Heat-to-cold / waste heat-to-cold

During the summer months, waste heat could be harnessed by generating cold and feeding it into a district cooling network. The waste heat can power thermally driven absorption chillers, providing cooling for end customers. Linz already has some district cooling systems in place that utilize electrically driven chillers. In recent years, the demand for cooling in the city centre has grown significantly. As a result, there are plans to further expand the existing district cooling network and its generation capacity to meet the rising demand. Thermal chillers are technically complex and involve high investment costs, while the supply of cold is still limited to a low number of full load hours.<sup>16</sup>

### 2.2.5.1.3 Low temperature process heat

Waste heat generated during industrial processes can be utilised both inside and outside the production plant. The excess heat generated by primary industrial processes at higher temperatures can be recovered and utilised for secondary processes at lower temperatures. In this way, waste heat from primary processes can be used to replace other (fossil) fuels. It was shown that bilateral connections to provide process heat are feasible.<sup>17</sup> In order to deliver the waste heat at the highest usable temperature and to actually replace fossil process heat, DH networks would need to run at higher temperatures in summer, which is contradicting the current state of the art, as low temperatures decrease losses and increase pipeline lifetime.<sup>18</sup>

### 2.2.5.1.4 Seasonal heat storage

The FutureDHSsystem Linz project<sup>19</sup> investigated how a large-scale heat storage system can contribute to shifting thermal energy from the summer to the winter period and whether this

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<sup>16</sup> Kapeller et al (2023) The effects of climate change-induced cooling demand on power grids. Energy Reports, Volume 11, June 2024, Pages 674-691. <https://doi.org/10.1016/j.egy.2023.07.028>

<sup>17</sup> Moser, Lassacher (2020). External use of industrial waste heat - An analysis of existing implementations in Austria, Journal of Cleaner Production, Volume 264, 10 August 2020, 121531, <https://doi.org/10.1016/j.jclepro.2020.121531>.

<sup>18</sup> Moser, Puschnigg (2021). Supra-Regional District Heating Networks: A Missing Infrastructure for a Sustainable Energy System. Energies. 14(12):3380. <https://doi.org/10.3390/en14123380>

<sup>19</sup> Moser et al (2017). FutureDHSsystem Linz - Sondierung neuer Konzepte für zukünftige Energietransformationen im Linzer Wärmesystem. Final project report. Available: <https://energieinstitut-linz.at/wp-content/uploads/2023/04/Future-District-Heating-System-Linz-Endbericht.pdf> (Abgerufen am: 19.12.2024).

large-scale heat storage system can be operated economically. The results found there and methodology applied are still valid, given an update to changed price levels.

### *2.2.5.1.5 Supply of new DHN or substitution of fuel-based DH energy*

The DH network in Linz supplies the city's consumers with thermal energy. The majority of the city area is supplied by LINZ AG. In addition to this large DH network, the company operates other smaller decentralised local heating networks in Haid and Marchtrenk. These local networks primarily use biomass and gas for heat generation, which could theoretically be substituted by industries' excess heat. However, the extent of these networks' summer heat demand is limited.

### *2.2.5.1.6 Heat-to-power / waste heat-to-power*

Linz and the central region of Upper Austria are home to many heat-intensive industries. These include, for example, the chemical industry as well as food, paper and cement production, among others. In the course of these industrial processes, the temperature level drops until waste heat is finally available. If this waste heat cannot be further utilised for the primary process due to the low temperature level, it can potentially be used for other internal processes. Another alternative is to convert the low-value thermal energy contained in the waste heat into electrical energy. The electrical energy generated can be utilised internally or fed into the local power grid. Low-temperature ORC processes are expensive and exhibit low efficiency levels while electricity prices are expected to be lower in summer. However, a Heat Highway can collect waste heat from multiple sources and may provide economies of scale.

### **2.2.5.2 Business models for industrial waste heat cooperations**

The aim of the national research project Industrial Excess Heat (INXS)<sup>20</sup> was to record and evaluate the existing waste heat potential of Austrian industry as completely as possible. As part of this effort, a national survey on existing waste heat cooperations was conducted. INXS was carried out in conjunction with the work and insights gained of the project Heat Highway; thus, the survey results are attributed to both projects and are presented below. The detailed scientific findings can be accessed in Moser and Jauschnik (2023)<sup>21</sup>.

In order to obtain information on existing implementations of external waste heat utilisation in Austria, a questionnaire was created to generate a database for further analyses. The 45 waste heat cooperations surveyed by Moser and Lassacher (2020)<sup>22</sup> in 2018 served as the basis for establishing contacts. After publication of the paper, six further case studies were added to the list by December 2021, also by extending the system boundary applied.

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<sup>20</sup> More information on the project: <https://energieforschung.at/projekt/industrial-excess-heat-erhebung-industrieller-abwaermepotentiale-in-oesterreich/> (Abgerufen am: 17.12.2024).

<sup>21</sup> Moser, Jauschnik (2023). Using Industrial Waste Heat in District Heating: Insights on Effective Project Initiation and Business Models, Sustainability, Volume 15(13), 4 July 2023, 10559, <https://doi.org/10.3390/su151310559>.

<sup>22</sup> Moser, Lassacher (2020). External use of industrial waste heat - An analysis of existing implementations in Austria, Journal of Cleaner Production, Volume 264, 10 August 2020, 121531, <https://doi.org/10.1016/j.jclepro.2020.121531>.

The original questionnaire is five pages long and, in addition to an information sheet and general information on the cooperation, is divided into the following sections:

- Section 1: How did the cooperation come about?
- Section 2: How does the external heat supply work from a technical point of view?
- Section 3: How does the external heat supply work from an economic point of view?
- Section 4: How could risks and uncertainties be overcome?

The questionnaire was sent out in December 2021, and responses were provided by means of written entries in the questionnaire or via a web or telephone interview, which made it possible to go into more detail on causality (internal validity). The survey was closed at the end of March. In total, responses were obtained for 24 of the 51 implementations, with 4 companies responding for more than one case and responses from 16 companies in total.

It should be emphasised in advance that these were individual projects and the solutions are correspondingly specific. This also means that the limited number of cases means that the results are not statistically significant - however, the questions asked and the fact that interviews were also used to obtain the answers guarantee an argumentative causality. The following success factors and business models can be derived from the answers received.

### 2.2.5.2.1 Success factors

- Open handling of information gives the cooperation partners certainty about the business model and allows them to better weigh up risks.
- Major changes on the part of one of the cooperation partners prompt the active search for partners and the pursuit of the necessary negotiations. Only very good, existing relationships between the cooperation partners make it possible for projects to be initiated even without the impetus of such major changes.
- Third parties can also initiate co-operations: Municipal politicians, interest groups, agencies are in some cases decisive for initiation.
- External waste heat utilisation takes place between two partners. As soon as one partner does not feel fairly treated in the allocation of profits, failure is likely. A high level of transparency regarding the necessary costs and achievable savings increases trust.
- Existing generation systems bridge planned production downtimes and act as a backup in the event of unplanned outages of the waste heat supplier. Their presence also provides a cost reference.
- It is necessary to recognise the risks of waste heat utilisation and that they are difficult to outsource in a joint project.

### 2.2.5.2.2 Business models

- The majority of implementations creates clarity through an exact interface, e.g. a heat exchanger or heat metering. At this point, the separation of investment, responsibility (maintenance) and billing takes place. This is not an obligation for success but increases clarity.
- In most cases, billing is primarily in euros/MWh, often (but not always) supplemented by individual special provisions such as minimum quantities. Rents allow the heat network operator to locate its property on the industrial premises.
- Fairness is created on the one hand by covering the costs and on the other - which can be observed almost everywhere - by indexing the value of the waste heat.
- ‘Risks lead to contractual content’: this includes the aforementioned indexation and minimum quantities, but also prohibitions on potential alternatives, rights of first refusal on land or generation plants, etc.
- Taking fewer risks, giving fewer guarantees or making fewer investments than the cooperation partner leads to a lower share of the joint revenue. The heat network operators often invest ‘into’ the industrial company via the interface, which also reduces the price of the waste heat. If industrial companies act as full-service suppliers of a heating network, the price of the waste heat increases.

### 2.2.6 Lean HTN pipe technology

Selecting the right combination of DH pipeline technologies is key to efficient district heating systems. Planners and engineers must consider factors like area layout, energy demand, available resources, environmental impact, and economic feasibility. Each choice affects system efficiency, maintenance needs, and costs. Recent advancements in DH pipeline materials, such as high-density polyethylene and cross-linked polyethylene, are offering alternatives to traditional steel, valued for their corrosion resistance and flexibility. This task consolidates research and case studies to guide stakeholders in optimizing DH pipeline design and management for sustainable, energy-efficient heating. Another objective is to construct a lean, physical Heat Highway demonstrator at the Ars Electronica Center, highlighting sustainable district heating’s role in modern energy systems and raising public awareness.

Further details are available in deliverable “Heat Highway - DH pipeline technologies” (see chapter 6 Appendix).

An overview of the pipe technologies regarding their characteristics is shown in Table 6, and illustrated in Figure 6. The existing pipe technologies are:

- KMR: Plastic composite pipe (Kunststoffverbundmantelrohr)
- PMR: Plastic medium pipe (Kunststoffmediumrohr)
- MMR: Metal medium pipe (Metallmediumrohr)
- GRP: Glass fibre reinforced plastic pipe (Glasfaserverstärktes Kunststoffrohr)

- HTR: Pre-insulated high-temperature pipes (Hochtemperaturrohr)
- SMR: Steel casing pipe (Stahlmantelrohr)

Table 6: Overview of the pipe systems and their most important properties<sup>23</sup>

Tube system	Scope				Available lengths		Double pipe design up to DN	Feature
	Maximum permissible operating temperature	Continuous operating temperature	Nominal pressure PN	Nominal diameter DN	Rods	Rollers		
	°C	°C	bar	-	m	m	-	-
<b>PMR</b>	95	80	6	20-150	12*	Up to 780	DN50	Relatively favourable Limited pressure and temperature resistance
<b>KMR</b>	160	Up to 130 (140 only for peak temp.)	25	20-1200 (usually DN20 - DN800)	6/12/16*	-	DN200	Due to the standardization and robustness the most widely used pipe system
<b>GRP</b>	160	160	16	25-1000	6*	-	-	Relatively expensive, only for special corrosion resistance requirements
<b>MMR</b>	180	Up to 160	25	20-150	12*	Until 1000	DN50	Relatively expensive, justified if the laying conditions make it necessary
<b>HTR</b>	-	250	-	20-400	-	-	-	Relatively expensive, only if temperature

<sup>23</sup> Nussbaumer, Thalmann, Ködel (2017). Planungshandbuch Fernwärme, Schweiz: Energieschweiz und QM Fernwärme Logstor Industry, "Vorgedämmte HT-Rohre – wie geschaffen für hohe Temperaturen," [Online]. (Abgerufen am: 27 01 2020)

Kremsmüller A., Interview zu Projekterfahrungen. 2023

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Tube system	Scope				Available lengths		Double pipe design up to DN	Feature
	Maximum permissible operating temperature	Continuous operating temperature	Nominal pressure PN	Nominal diameter DN	Rods	Rollers		
	°C	°C	bar	-	m	m	-	-
								conditions make it necessary
<b>SMR</b>	400	400	64	25-1200	16*	-	**	Relatively expensive, only if the pressure, temperature or installation conditions make it necessary

\*Standard length/s, other lengths available on request.

\*\* Special designs possible on request (e.g. multiple tube design).

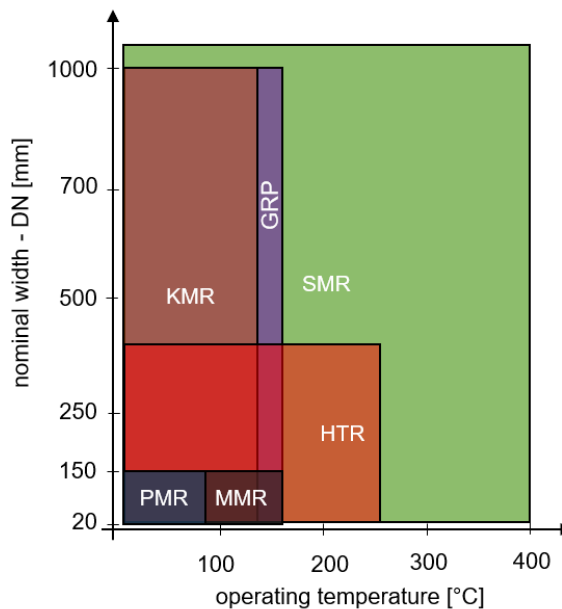


Figure 6: Existing pipe technologies on the market

Constructing a lean district heating pipe system involves optimizing various factors to achieve minimal heat losses, temperature requirements, ease of installation, cost efficiency, and reliable welding processes. To minimize heat losses, it is essential to select pipe diameters that balance minimal heat loss with manageable pressure losses. Effective insulation is crucial, and using high-performance materials like polyurethane foam or mineral wool with optimized

thickness helps balance heat loss reduction and cost, but they must be economically viable. Consequently, the design and implementation of DH pipes and systems involve a careful balance of various factors to optimize efficiency, cost, and reliability. The critical aspects of district heating pipes include:

- Pipe dimension and heat losses
- Insulation thickness
- CAPEX
- Pressure losses
- Buried vs. above ground laying
- Flexibility and parallel pipes
- Installation under pre-tension
- Integration with heat pumps
- Operational processes
- Economic considerations

Cost comparisons were based on the KMR pipe technology. PMR pipes are approximately 20% less expensive, while MMR pipes are roughly twice as expensive. No general pricing data is available for glass fibre pipes (GRP). HTR pipes are estimated to cost 5 to 10 times more, and SMR pipes about 10 times more. Although pipe technology prices provide a rough estimate for cost calculations, they need to be evaluated on a case-specific basis.

In addition, a physical "Heat Highway" prototype was developed and constructed, incorporating the technical characteristics and requirements discussed. The prototype was exhibited at the at the Ars Electronica Center (AEC) in Linz. This prototype, in combination with a developed virtual demonstrator, showcases cutting-edge thermal energy technology and engineering innovation, offering visitors an engaging and interactive experience. Designed with key characteristics in mind, the prototype aligns with exhibition standards to effectively communicate the basic principles of sustainable district heating and raise awareness of heat supply. Its design enables visitors to easily comprehend the core concepts of sustainable district heating, emphasizing its critical role in modern energy systems and its potential to reduce environmental impacts. The prototype integrates the fields of energy engineering, research, and exhibition design, providing visitors with an optimal learning experience. This collaborative effort ensures that the prototype is both informative and accessible, making complex engineering concepts easy to understand and relatable for a broad audience. More information to the virtual and physical prototype can be found in the chapters 3.2.1 and **Fehler! Verweisquelle konnte nicht gefunden werden.**, respectively.

## 2.3 Use Case #1: HTN Linz

### 2.3.1 Identification and Description of Heat Sinks

There are two district heating networks in Linz – the Linz AG and the Kelag network. As the Kelag network is already supplied with waste heat by voestalpine, the focus was on the Linz AG district heating network.

The identification and description of suitable heat sinks in the Linz AG network is a decisive step in order to better utilise the potential for the use of waste heat and renewable energy. This requires a detailed analysis of the existing infrastructure, consumption profiles and heat demand dynamics. It is important to analyse the Linz AG plants so that they can be used as a benchmark.

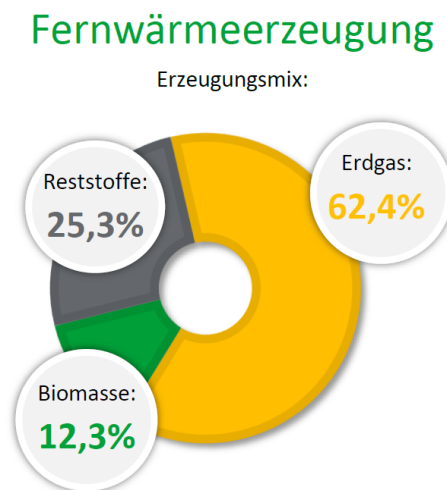


Figure 7: Illustration of the Linz AG district heating generation mix<sup>24</sup>  
(Financial year 2023, district heating mix changes annually depending on the operation of the systems)

#### 2.3.1.1 Brief overview of two Linz AG heating plants

##### 2.3.1.1.1 District heating plant Linz-Mitte<sup>25 26</sup>

- District heating power plant with storage facility, gas and steam turbine plant, biomass plant and waste-to-energy plant

<sup>24</sup> Linz AG (2023). Aktualisierte Umwelterklärung. Für den Bereich Energieerzeugung GJ 2023. <https://www.linzag.at/media/dokumente/linzag/energieerzeugung/umwelterklaerung-gj23.pdf> (Abgerufen am: 26.09.2024).

<sup>25</sup> Linz AG (ohne Jahr): Fernheizkraftwerk Linz-Mitte. [https://www.linzag.at/portal/de/ueber\\_die\\_linzag/unternehmen/gesellschaften/linz\\_strom\\_gas\\_waerme\\_gmbh/energieerzeugung/fernheizkraftwerk\\_linz\\_mitte#](https://www.linzag.at/portal/de/ueber_die_linzag/unternehmen/gesellschaften/linz_strom_gas_waerme_gmbh/energieerzeugung/fernheizkraftwerk_linz_mitte#) (Abgerufen am: 26.09.2024).

<sup>26</sup> Linz AG (2022). Pressekonferenz: Ein Öko-Turbo für mehr Erneuerbare Energie. [https://www.linzag.at/portal/de/ueber\\_die\\_linzag/unternehmen/gesellschaften/linz\\_strom\\_gas\\_waerme\\_gmbh/energieerzeugung#](https://www.linzag.at/portal/de/ueber_die_linzag/unternehmen/gesellschaften/linz_strom_gas_waerme_gmbh/energieerzeugung#) (Abgerufen am: 26.09.2024). // Linz AG (ohne Jahr): Energieerzeugung. [https://www.linzag.at/media/dokumente/presse\\_2/linz\\_ag\\_gas\\_waerme\\_5/PK\\_Erneuerbaren\\_Offensive\\_Startschuss.pdf](https://www.linzag.at/media/dokumente/presse_2/linz_ag_gas_waerme_5/PK_Erneuerbaren_Offensive_Startschuss.pdf) (Abgerufen am: 26.09.2024).

- Annual electricity generation: 741 GWh and annual district heating generation 906 GWh
- Storage facility: With a height of 65 metres and a storage volume of 35 million litres, the district heating storage facility at the FHKW Linz-Mitte is one of the largest storage facilities in the world. The storage system is used to reduce the utilization of peak-load boilers.
- The waste-to-energy unit has a thermal capacity of 47 MW and an electrical capacity of 15 MW. The biomass unit provides a thermal capacity of 21 MW and an electrical capacity of 9 MW.
- The total capacity of the gas-fired CHP unit is 171 MW thermal (unit 1a: 85 MW<sub>th</sub>, unit 1b: 86 MW<sub>th</sub>) and 227 MW electrical. The electrical capacity is divided into 73 MW from the gas turbine and 30 MW from the steam turbine at unit 1a, and 77 MW from the gas turbine and 47 MW from the steam turbine at unit 1b. The overall efficiency of the Linz-Mitte gas CHP unit is 88%, with an electrical efficiency of 50%.

### 2.3.1.1.2 District heating plant Linz-Süd<sup>27 28</sup>

- The main components are three gas turbine units with an electrical output of 40 MW each, three downstream waste heat boilers (to utilise the waste heat from the gas turbines and to generate steam) and two steam turbine units with an electrical output of 36 MW and 16 MW respectively.
- Annual electricity generation: 490 GWh and annual district heating generation 350 GWh
- The total thermal capacity of the gas CHP unit is 150 MW.
- The overall efficiency of this gas-fired CHP unit is 87%, with an electrical efficiency of 46%. To meet additional heat demand, a gas heat only boiler to cover peak-demand with a total capacity of 116 MW<sub>th</sub> is also available.

Looking ahead, a flue gas heat exchanger is planned to address Linz's growing district heating demand. With an additional capacity of 25 MW<sub>th</sub>, producing approximately 130,000 MWh of heat annually, this system will further increase the share of renewable energy in district heating production.

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// Moser et al (2017). FutureDHSsystem Linz Sondierung neuer Konzepte für zukünftige Energietransformationen im Linzer Wärmesystem, "Energieinstitut an der Johannes Kepler Universität Linz. *Linz AG, Linz und Wien: AIT Austrian Institute of Technology GmbH*.

<sup>27</sup> Linz AG (ohne Jahr): Fernheizkraftwerk Linz-Süd. [https://www.linzag.at/portal/de/ueber\\_die\\_linzag/unternehmen/gesellschaften/linz\\_strom\\_gas\\_waerme\\_gmbh/energieerzeugung/fernheizkraftwerk\\_linz\\_sued#](https://www.linzag.at/portal/de/ueber_die_linzag/unternehmen/gesellschaften/linz_strom_gas_waerme_gmbh/energieerzeugung/fernheizkraftwerk_linz_sued#) (Abgerufen am 26.09.2024).

<sup>28</sup> Linz AG (2022). Pressekonferenz: Ein Öko-Turbo für mehr Erneuerbare Energie. [https://www.linzag.at/portal/de/ueber\\_die\\_linzag/unternehmen/gesellschaften/linz\\_strom\\_gas\\_waerme\\_gmbh/energieerzeugung#](https://www.linzag.at/portal/de/ueber_die_linzag/unternehmen/gesellschaften/linz_strom_gas_waerme_gmbh/energieerzeugung#) (Abgerufen am 26.09.2024). // Linz AG (ohne Jahr): Energieerzeugung. [https://www.linzag.at/media/dokumente/presse\\_2/linz\\_ag\\_gas\\_waerme\\_5/PK\\_Erneuerbaren\\_Offensive\\_Startschuss.pdf](https://www.linzag.at/media/dokumente/presse_2/linz_ag_gas_waerme_5/PK_Erneuerbaren_Offensive_Startschuss.pdf) (Abgerufen am 26.09.2024).

// Moser et al (2017). FutureDHSsystem Linz sondierung neuer Konzepte für zukünftige Energietransformationen im Linzer Wärmesystem, "Energieinstitut an der Johannes Kepler Universität Linz. *Linz AG, Linz und Wien: AIT Austrian Institute of Technology GmbH*.

## 2.3.2 Defining the waste heat potential

An important step in the joint preparation of the situation for waste heat recovery and waste heat reintegration was the agreement on waste heat terminology. This chapter provides an overview of various potential concepts, focusing on the definition of potential. In his fifth excursus, Michael Piot offers detailed definitions of individual potentials to ensure consistent use of terminology. His excursus serves as an excellent summary, which will be briefly presented in the following chapter.<sup>29</sup>

- **Theoretical potential:** 'The theoretical potential of a renewable energy describes the energy supply that can theoretically be physically utilised within a given region at a given time or within a given period of time.'<sup>30</sup>
- **Technical potential** (see Figure 8): 'It is the proportion of the theoretical potential that can be utilised, taking into account the given technical restrictions.'<sup>31</sup>

The following diagram is intended to provide an overview of how the various concepts of technical potential can be differentiated.

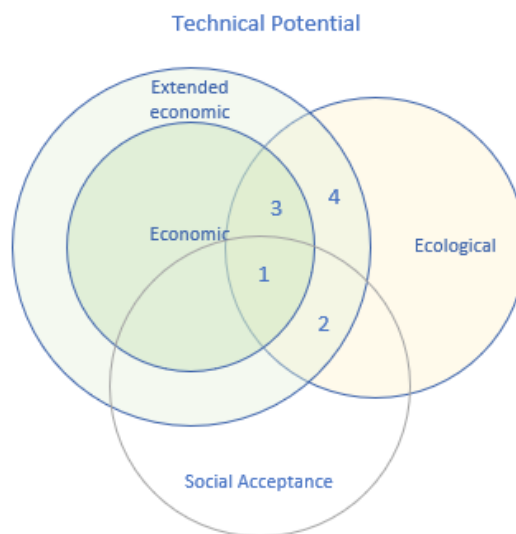


Figure 8: Technical Potential - terms in graphical representation (numbers = partial areas)

Source: Michel Piot (2006) 5. Exkurs: Potenzialbegriffe. In: Schweizerisches Bundesamt für Energie (2007) Die Energieperspektiven 2035 – Band 4. Exkurse.

<sup>29</sup> Piot (2006). 5. Exkurs: Potenzialbegriffe. In: Schweizerisches Bundesamt für Energie (2007) Die Energieperspektiven 2035 – Band 4. Exkurse. Link: [https://inis.iaea.org/collection/NCLCollectionStore/\\_Public/43/004/43004108.pdf](https://inis.iaea.org/collection/NCLCollectionStore/_Public/43/004/43004108.pdf) (Abgerufen am: 09.12.2024).

<sup>30</sup> Kaltschmitt, Streicher, Wiese (2005). Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, Springer, Berlin.

<sup>31</sup> Kaltschmitt, Streicher, Wiese (2005). Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, Springer, Berlin.

- **Ecological potential:** The ecological potential is the proportion of the technical potential that does not lead to any additional irreversible impairment of the habitat in terms of diversity and interactions both between living organisms and between living organisms and their environment.<sup>32</sup>
- **Economic potential:** 'Is the share of the technical potential that is obtained when the total costs (this includes the investment, operation and disposal of a plant) for the energy conversion of a renewable energy source are calculated and lie within the same range as the total costs of competing systems.'  
*'The extended economic potential is the share of the technical potential that is obtained when the total costs (investment, operation and disposal of a system) are calculated taking into account possible subsidies for the energy conversion of a renewable energy source and are in the same range as the total costs of competing systems.'*
- **Exploitable potential:** 'Exploitable potential is defined as the intersection of ecological and expanded economic potential [...] see Areas 1, 2, 3, 4 of Figure 8
- **Realisable (expected) potential:** 'The expected potential is defined as the intersection of the ecological, extended economic and social acceptance potential [...]' Areas 1, 2 Figure 8
- **Expansion potential:** 'The theoretical (technical, ecological, economic, exploitable, expected) expansion potential is the difference between the theoretical (technical, ecological, economic, exploitable, expected) potential and the potential that has already been realised.'

### 2.3.3 Identification of future waste heat sources

#### 2.3.3.1 LAT Nitrogen 60 MW Electrolysis<sup>33</sup>

Ammonia production is currently based on grey hydrogen, using natural gas as an input factor. The grey hydrogen can be replaced with green hydrogen produced with renewable electricity. This saves a significant amount of CO<sub>2</sub>.

The Green Ammonia Linz project aims to deploy a large-scale electrolyser to produce green hydrogen for the on-site production of green ammonia, melamine and fertilizer.

Green Ammonia Linz plans to construct an industrial-scale electrolysis plant with a capacity of 60 MW. This facility will produce green ammonia, supporting the decarbonization of industrial processes and enhancing flexibility in an increasingly stressed electricity grid. By integrating green hydrogen into production workflows, the project aims to facilitate the transition to low-carbon products.

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<sup>32</sup> Volken (2005). Internes Arbeitsdokument, BFE, Bern.

<sup>33</sup> Verbund AG: <https://www.gramli.at/en> (Abgerufen am: 25.11.2024)

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It is powered by electricity from renewable sources and deionised water. The green hydrogen produced will be the raw material for the sustainable production of fertilisers, technical nitrogen and melamine. The oxygen obtained from the water electrolysis will be used directly in other LAT Nitrogen production processes. The electrolyser will also provide grid services for the transmission grid.

With a planned production of up to 7,000 tonnes of green hydrogen per year, this would be an Austrian pilot project and the first production of green hydrogen and ammonia on an industrial scale in the region.

### Key facts of the electrolyser:

- 60 MW PEM electrolyser
- H<sub>2</sub> Storage
- H<sub>2</sub> conditioning
- O<sub>2</sub> conditioning
- Substitution of up to 10 % of grey H<sub>2</sub>
- reducing up to 90,000t CO<sub>2</sub>/a

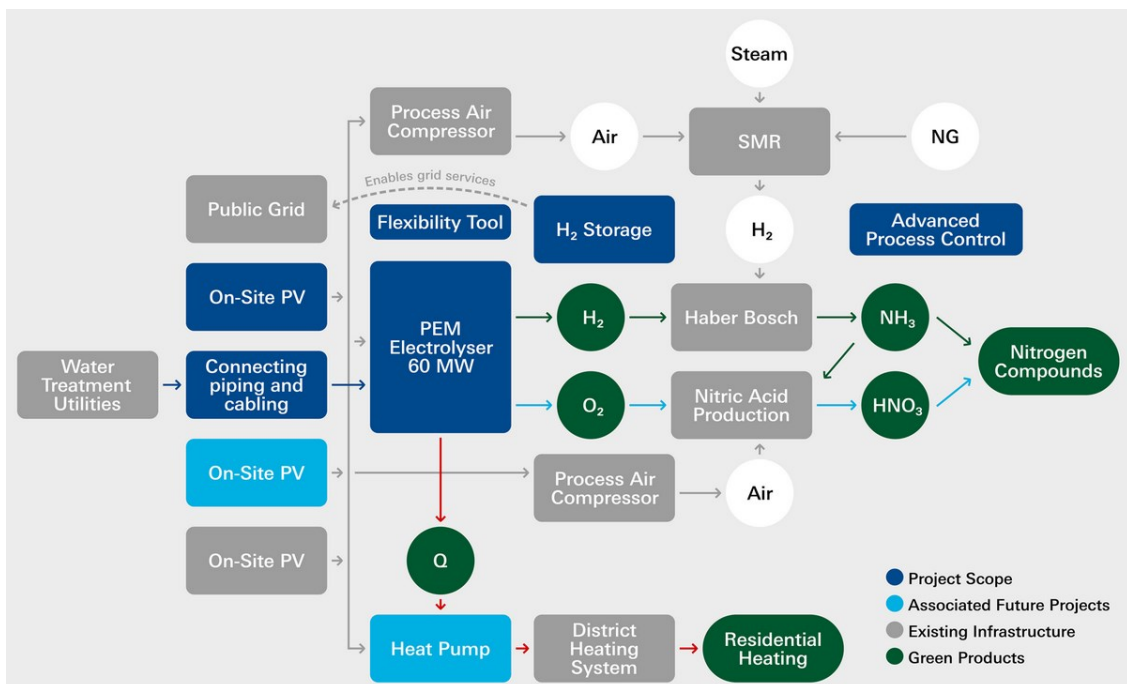


Figure 9: Green Ammonia Linz (Source: <https://www.gramli.at/en>; 25.11.2024)

If the temperature level is too low, heat pumps are required. With approx. 1/3 waste heat, this amounts to 20 MW. More detailed calculations on waste heat and in particular on usable waste heat were carried out in the project. There is the possibility of feeding it into the district heating network.

### 2.3.3.2 The future is green hydrogen from electrolysis

Numerous studies suggest that power-to-hydrogen (PtH2) will take a decisive part in future sustainable energy systems. District heating (DH) networks are also assigned a crucial role for the overall efficiency of such. In this regard, heat flows resulting from PtH2 may lead to synergies with the heat supply of DH systems.

High-temperature electrolysis is expected to become fully integrated into industrial utility operations and heat utilization addresses the known challenges of integrating industrial waste heat into district heating networks. The placement of low-temperature electrolysis depends on infrastructure constraints as well as to the economics of utilizing by-products. Operations are expected to be more aligned with electricity market dynamics and may vary seasonally, independent of heat demand. Nonetheless, its waste heat is adequate to supply modern low-temperature district heating networks and could cover up to 12 % of Austria's current DH demand by 2030 and up to 4% of the EU's demand for heat below 100° C.<sup>34</sup>

### 2.3.3.3 voestalpine Electric Arc Furnace<sup>35</sup>

An electric arc furnace (EAF) is a promising option for producing green steel, capable of melting both scrap steel and sponge iron. Voestalpine has decided to build at least one EAF at its Linz site. This should reduce the CO<sub>2</sub>-emissions by 50 %. The electric arc furnaces will enable voestalpine to produce around 1.6 million tons of CO<sub>2</sub>-reduced steel annually.

To ensure the process is genuinely "green", the operation requires a reliable supply of renewable electricity. A power line from the south, crucial for this purpose, has now been approved.

The EAF operates at extremely high temperatures to melt steel, generating significant amounts of waste heat in the process. Research has focused on the recoverable quantity of this heat, the temperature levels achievable, and potential applications for utilizing the recovered waste heat effectively.

Voestalpine has already cleared the land required for the site. This project is departed into 20 individual projects. Preparation includes installing a new raw material supply system, relocating various storage buildings, construct new roads and adaptations to the steel mill. They plan to build a micro tunnel for the new 220 kV power line.

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<sup>34</sup> Böhm, Moser, Puschnigg, Zauner (2021). Power-to-hydrogen & district heating: Technology-based and infrastructure-oriented analysis of (future) sector coupling potentials. *International journal of hydrogen energy*, 46(63), 31938-31951.

<sup>35</sup> voestalpine AG: <https://www.voestalpine.com/greentecsteel/en/green-steel-from-2027/greentec-steel-linz/> (Abgerufen am: 25.11.2024)  
voestalpine AG: <https://www.voestalpine.com/blog/en/sustainability/greentec-steel/arcs-in-green-times/> (25.11.2024)

voestalpine AG: <https://www.voestalpine.com/greentecsteel/en/> (Abgerufen am: 25.11.2024)

## 2.3.4 Identification of today waste heat sources

The industrial partners already have technical waste heat potential in the current situation. A more detailed analysis was carried out with regard to quantities, profiles, temperature, usability, distances, transport routes, etc.

Waste heat potentials without opposing own utilisation/own utilisation possibilities are mainly available in summer.<sup>36</sup>

There is a general preference among industrial companies for recovery at the highest possible temperature level, as this increases the (internal) reutilisation possibilities. Recovery at district heating level has therefore not been the focus of recovery efforts to date. There are alternatives for the recovered waste heat due to the utilisation options that are sometimes available, which district heating must outperform in terms of price.

In total, monthly technical waste heat quantities are available for the further calculations.

## 2.3.5 Pipe routing

The aim is to connect Linz-Mitte and Linz-Süd with a connection that can absorb the waste heat from the chemical park and voestalpine. To this end, various routes were first roughly defined, in particular an eastern route and a western route through and around the factory premises. A preferred route was derived. Property owners were identified and the technical feasibility was analysed. A calculation of the investment costs of the connection was also carried out at the end.

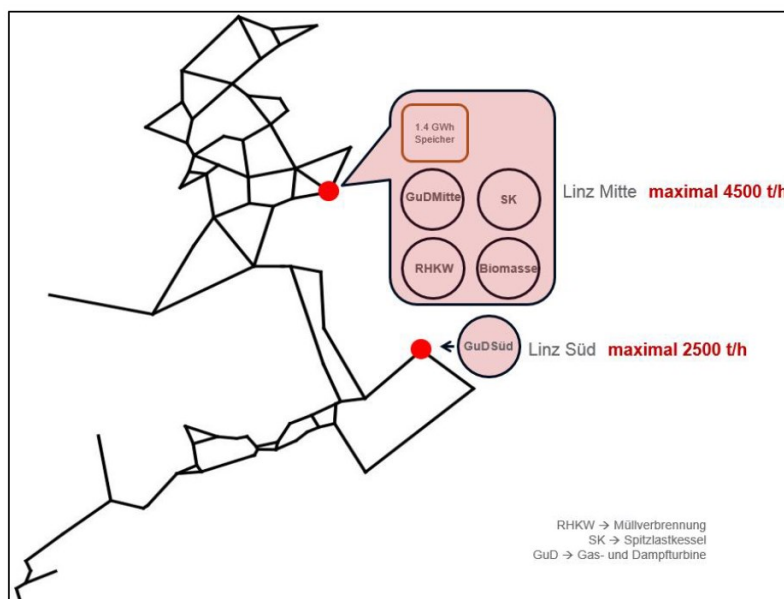


Figure 10: Simplified network diagram of the current system.

<sup>36</sup> Moser, Puschnigg (2021). Supra-regional district heating networks: A missing infrastructure for a sustainable energy system. *Energies*, 14(12), 3380.



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opportunities for heat-related cooperation. This route was explored as a pilot case for a Heat Highway, where companies could act as both suppliers and consumers.

To gather data, companies in the area were identified using maps and industry directories from the Upper Austria Chamber of Commerce. The defined geographical area extended from the intersection of B1 and A25 in the west, the A25 and A1 motorways in the south, the A7 motorway in the east, and the Westbahn railway line in the north. The geographic distribution of the surveyed companies, as shown in Figure 12, highlights the focus area between Wels and Linz, covering approximately 200 companies. These were prioritized based on their relevance resulting in 90 companies which were contacted and asked about their energy needs and waste heat potential. The survey also reviewed existing district heating networks in the area, such as those operated by Linz AG (Marchtrenk, Haid, and Linz to Traun) and the bioenergy network in Ansfelden, which could serve as sinks for the proposed Heat Highway.

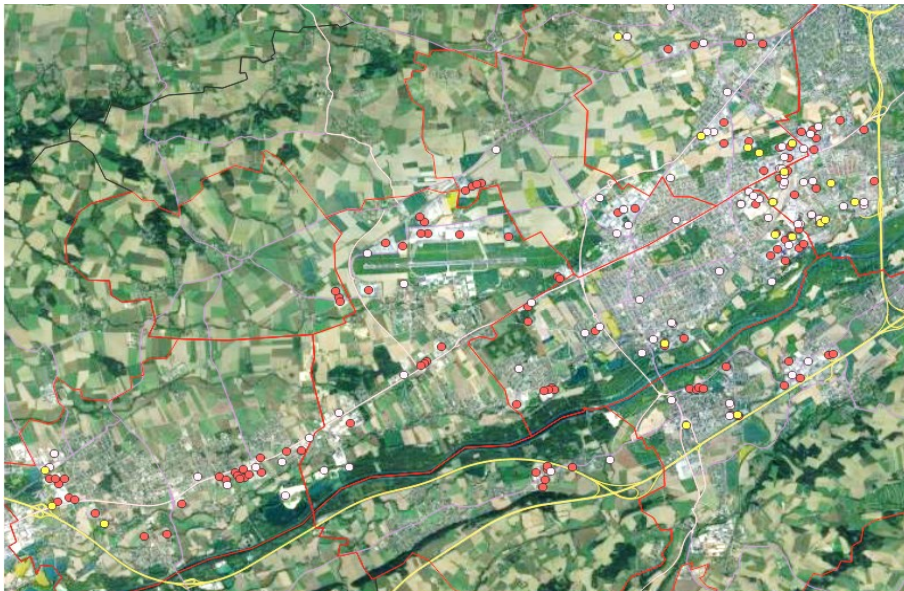


Figure 12: Map showing the locations of the companies identified and analysed in terms of their energy requirements and waste heat potential along the Wels-Linz route.

The survey gathered information from participating companies to assess their energy needs and waste heat potential. Companies were asked about their energy consumption, including their annual heating and hot water demand and the types of energy sources they use. Furthermore, companies were questioned about the presence of processes that produce waste heat, the quantity and temperature of this heat, and whether it varies by season or operating schedule. They were also asked if the waste heat is utilized internally and whether certain processes require cooling to dissipate heat. Additionally, the survey explored the cooling requirements of the companies, both for room cooling and process-specific needs, including their annual cooling demand and the processes relying on cooling. This data aimed to provide insights into potential synergies for waste heat recovery and energy optimization along the Wels-Linz corridor.

## 2.4.1.1 Key findings

Out of the 200 identified companies, 90 were contacted and 25 responded, yielding a response rate of approximately 28%. As illustrated in Figure 13 the responding companies were predominantly from the metal and food industries. Most participating companies were large enterprises, with small and medium-sized enterprises accounting for only three of the responses.

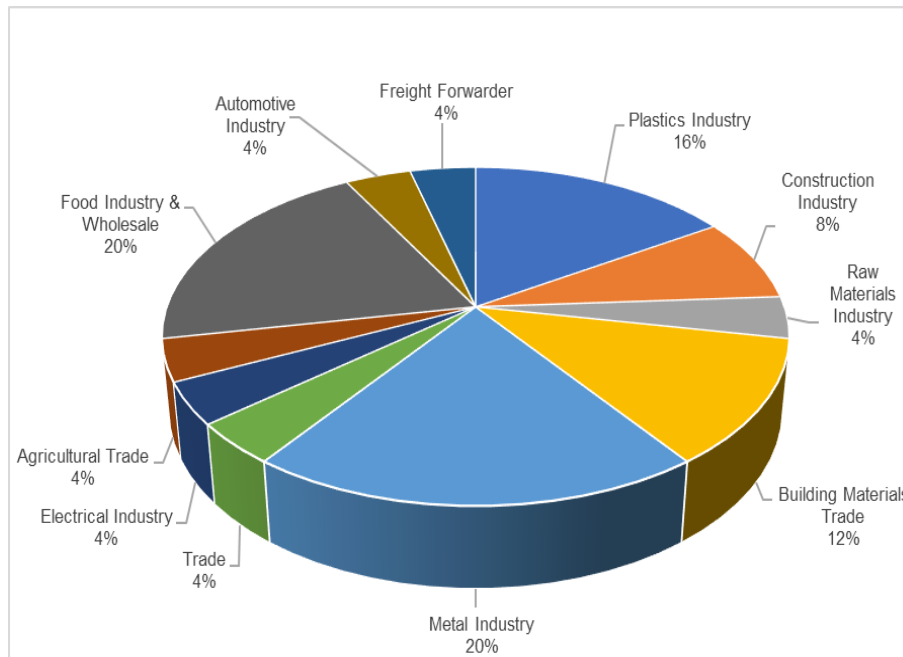


Figure 13: Sector distribution showing the percentage shares of various industries.

### 2.4.1.1.1 Heating Demand

The 25 responding companies reported a combined annual demand for heating and hot water of approximately 40 GWh/a. About 6 GWh/a of this demand is currently met by district heating networks. Extrapolating this data for the 90 relevant companies suggests a total heating and hot water demand of up to 150 GW/a. However, due to the greater focus on the more relevant companies, the actual total is probably lower.

### 2.4.1.1.2 Waste Heat Potential

Out of 25 surveyed companies, 18 indicated that their processes generate waste heat. Waste heat is generated from various operations such as chemical production, food manufacturing, compressor systems, cooling and refrigeration units, glass tempering furnaces, baking ovens, thermoforming, and drying processes. 11 companies already utilize the waste heat internally, while no external use was reported. Common applications include heat recovery from compressors, refrigeration systems, and production equipment. For most companies, waste heat is generated continuously. However, nearly none provided quantitative data on the temperature or quantity of waste heat, often due to a lack of measurements. There are minimal

operational differences between summer and winter, though waste heat utilization is mostly limited to winter months.

### 2.4.1.1.3 Cooling Demand

Among the surveyed companies, 11 out of 25 reported having processes that require cooling. These processes are primarily related to the cooling of machinery and casting systems, as well as the use of refrigerators and freezers. Nine companies provided information on their cooling energy requirements, which collectively amount to an estimated 8 GWh/a. However, the data indicates significant uncertainties regarding the exact quantities of cooling needed, the timing and duration of cooling operations, and the specific temperatures required. This underscores the need for more precise data collection to better understand and optimize cooling energy demands.

### 2.4.1.2 Conclusion

The surveyed companies showed a general interest in the Heat Highway project and in utilizing waste heat. The findings suggest that there is no significant waste heat potential in this area. However, there is a notable demand for space heating and hot water. The 25 responding companies reported a combined heating and hot water demand of around 40 GWh/a. When extrapolated to the 90 targeted companies, or the total of 200 companies in the region, the overall energy demand is estimated to be significantly higher. Additionally, there is further potential for waste heat utilization from smaller businesses and residential buildings.

Local district heating networks, particularly in Marchtrenk and Haid, present potential sinks for the Heat Highway. Their consumption should also be considered. Existing district heating networks could replace biomass with waste heat, although the heating plant capacities themselves must remain intact.

The combined heating demand of the surveyed companies, alongside the broader potential across all identified firms, underscores the significant energy needs in the area. However, precise quantification of waste heat and its characteristics remains challenging due to data gaps.

## 2.4.2 Heat Merit Order<sup>39</sup>

As part of the Heat Highway project, a tool was developed to economically analyse the integration and connection of multiple players in a district heating network, including the feed-in of renewable energy sources, waste incineration units and industrial waste heat. The so-called 'heat merit order' ranks the marginal costs of the generation units of the district heating system and thus represents the actual supply curve of the district heating network. The term

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<sup>39</sup> Moser, Puschnigg, Rodin (2020). Designing the Heat Merit Order to determine the value of industrial waste heat for district heating systems. Energy 200, 117579. // Rusch, Moser (2025) Economic feasibility of implementing supra-regional connections of existing district heating networks. Submitted/Forthcoming.

'merit order' is used to describe the ranking of power plants for operation in the electricity sector. Based on this term, the operating order of the heat generation units is referred to as the 'heat merit order'.

From the perspective of economic theory, the heat merit order represents the short-term supply curve or marginal cost curve for the local district heating market. The heat merit order is shown in a cost curve, where the price is shown on the ordinate and the current output is shown on the abscissa (MW) and not the amount of energy (MWh). The merit order curve orders the heat generation units according to their current variable costs, starting with the most cost-effective unit on the left. Due to the manageable number of relevant heat generation plants in a local district heating system, the individual generation units can be identified in the merit order curve.

The data used for the development and application of the heat merit order model mainly comes from publicly available sources. The capacities of the heat generation units are generally known or were collected as part of expert interviews with project partners from industry. The following variable cost parameters were identified and included in the development of the heat merit order: energy input costs of the heat generation plant (e.g. gas costs), electricity output revenues of cogeneration units (e.g. spot market for electricity), costs for CO<sub>2</sub> certificates (e.g. from the emissions trading system), energy taxes: taxes on energy inputs (e.g. gas tax), variable network tariffs for energy input (e.g. gas grid), variable grid charges for energy outputs (e.g. electricity grid), costs directly associated with generation (e.g. disposal of ash, operation-dependent maintenance). The marginal costs for the heat units were developed based on these cost parameters and adjusted with the technology-dependent efficiencies.

To apply the heat merit order, three steps must be followed. **(1)** First, the heat demand of a district heating network is calculated using a temperature-based approach, **(2)** then the marginal costs of each generation unit are calculated and **(3)** finally, the heat generation units are ranked for each hour in ascending order based on the marginal costs. Based on this, it can be determined hour by hour which heat generation units cover the specific heat demand. First, the unit with the lowest marginal costs is utilised up to its maximum capacity, followed by the next unit with the second-lowest marginal costs. Generation units are utilised in this order until the entire heat demand for the respective hour is covered. Finally, the total cost of meeting the heat demand is calculated by summing the costs for each hour. For each hour, the marginal cost value of a unit is multiplied by the amount of heat generated.

The following figures show two examples of an order of heat generation units in Linz. The examples are taken from the publication by Moser et al. (2020). In both figures, one Waste-to-Energy CHP, one Biomass CHP, two Gas CHP and three Gas Heat Only Boilers are ranked in ascending order based on their marginal costs. Figure 14 describes the scenario of one exemplary hour in winter. In winter, the demand for heat is high, so that the Waste-to-Energy CHP, the Biomass CHP and the first Gas CHP are utilised at full thermal capacity and the

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second Gas CHP is utilised at part of its thermal capacity in order to cover the heat demand in Linz. Figure 15, on the other hand, shows an exemplary hour in summer. As the demand for heat is low in summer, the Waste-to-Energy CHP is sufficient to cover the demand. Both examples are based on the price of a unit of heat, which is positive in Figure 14 and negative in Figure 15.

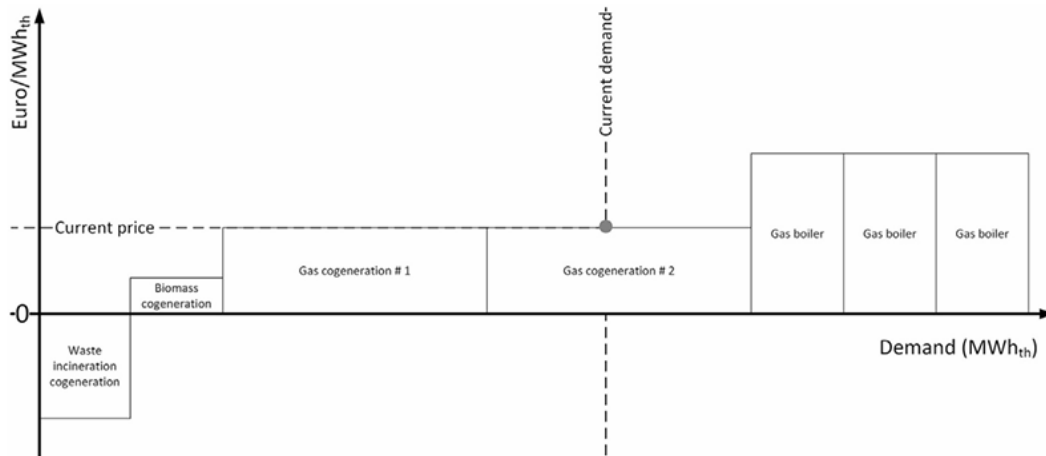


Figure 14: Order of units in the heat merit order model in an exemplary hour in the winter. According to marginal costs, the first three units are utilized to their full thermal capacity. The thermal capacity of the fourth unit is only partly used- until the total heat demand is fully covered. Source: Moser, Puschnigg, Rodin (2020). Designing the Heat Merit Order to determine the value of industrial waste heat for district heating systems. Energy 200, 117579.



Figure 15: Order of units in the heat merit order model in an exemplary hour in the summer. To cover the total heat demand, only parts of the thermal capacity of the first unit – according to marginal costs – is utilized. Source: Moser, Puschnigg, Rodin (2020). Designing the Heat Merit Order to determine the value of industrial waste heat for district heating systems. Energy 200, 117579.

The heat merit order is currently subject to restrictions that prevent the reflection of actual technical and economic conditions. These include the flexibility and ramp behaviour of heat generation units, heat losses, transport times among others. In addition, the fixed costs of heat generation units are not taken into account. Fixed costs include investment and construction costs as well as personnel, who are also indispensable during a shutdown. The fact that fixed

costs are not considered is the main difference between the heat merit order approach and the LCOE (Levelized Cost of Energy) approach. Moreover, electricity prices can become negative, which is not taken into account in the heat merit order.

As part of the Heat Highway project, the heat merit order was used to analyse the economic viability to create a Heat Highway, i.e. a connection by means of a Supra-Regional District Heating Network (SR-DHN) (Moser and Puschnigg, 2021) between Linz and Wels, cities 30 km apart from each other. SR-DHN link existing district heating systems and can thus increase the security of supply, reduce the risk of outages and make better use of sustainable and cost-effective energy sources. The heat merit order was applied to the use case ex-post over a period of four years, from January 2018 to December 2021. The system comprises a total of ten units, with the base load being covered by two Waste-to-Energy CHP units. These are supplemented by one Biomass CHP unit and five Gas CHP units in Linz and one Gas Heat Only Boiler unit in each city for peak loads and as a reserve. Essential for understanding the results is that the connection introduced in the simulation always enables optimisation, the savings are always  $\geq 0$ . In the worst case, the simulation would not use the SR-DHN and operate the local plants as before. It is therefore clear that the savings must first justify the construction and operation of the line and that no simple statement on the economic viability of the line can be derived from the result.

The substitution of units follows a clear seasonal pattern: when demand is high in winter, the units primarily cover their own district heating networks' heat demand, so there is little heat left to be shifted. In summer, the two Waste-to-Energy CHP cover local demand. Particularly in the transitional periods in spring and autumn, heat from the Wels is shifted to Linz in the simulation. In Linz the dispatch of Gas CHP is significantly reduced. Overall, the establishment of a SR-DHN leads to a reduction in the variable costs of heat generation by an average of 16.3% per year (other cost components of district heating provision such as network costs or fixed costs of the plants are not considered in the simulation; for economic feasibility, the cost reductions must outweigh necessary investment costs).

### **2.5 Use Cases #2: HTN Upper Austria – other potentials**

The Upper Austrian central region, which includes the cities of Linz, Wels, Steyr and Enns, as well as the northern Salzkammergut, is relatively densely populated. There is also a pronounced industrial structure along the main transport route, such as the A1 motorway, the B1 federal road and the Westbahn train corridor. In the analysis by Moser and Puschnigg (2021), a potential course of a heat transmission network in Upper Austria was analysed. This process is based on consumption centres, industrial waste heat potential and existing combined heat and power plants or district heating networks. The process is based purely on this information and does not take into account technical and economic feasibility or detailed data on the networks and companies. Moser and Puschnigg (2021) estimated that the total

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waste heat potential of the analysed companies is approximately 230 MW in the summer period and 130 MW in the winter. Additional potential comes from thermal power plants and waste incineration plants, contributing around 200 MW. Moreover, the two largest industrial companies were assessed with a minimum potential, as they report no (economic) waste heat potential. However, if their waste heat potential were to account for just 1% of their energy consumption, the total industrial waste heat potential would double.

The Heat Highway project also takes into account other possible decarbonised resources such as geothermal energy and solar thermal energy, which also have regional potential and would not be exploited without the Heat Highway.

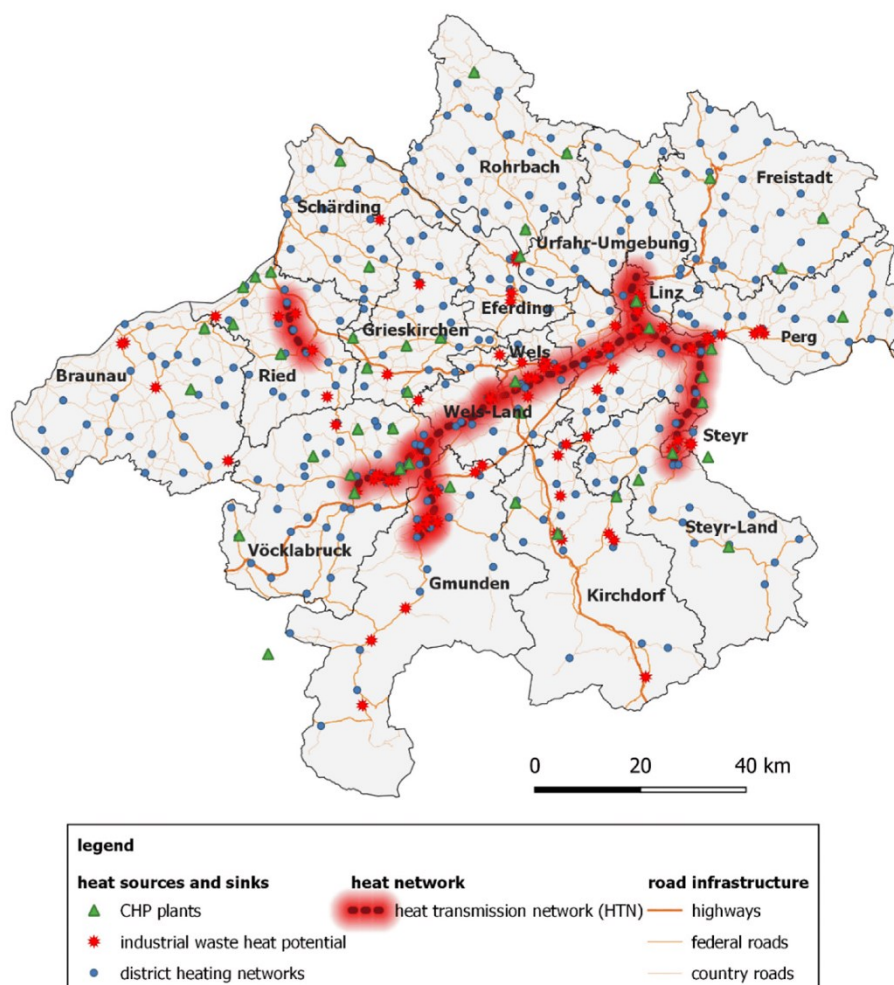


Figure 16: Case study results: possible routing of a SR-DHN in Upper Austria.

Illustration taken from: Moser, Puschnigg (2021). Supra-Regional District Heating Networks: A Missing Infrastructure for a Sustainable Energy System. *Energies*. 14(12):3380. <https://doi.org/10.3390/en14123380>

Three analyses are described in more detail below, which analyse specific topics (waste heat and demand from companies) and the implementation of certain potentials.

### 2.5.1 Potentials in Upper Austria (outside the Wels-Linz region)

#### 2.5.1.1 WKO survey on industrial waste heat potentials in Upper Austria

In May 2022, a survey on waste heat potentials of the Upper Austrian industry was sent out to around 600 industrial companies in cooperation with the Upper Austrian Chamber of Commerce. The goal of the survey was to assess the waste heat potential of local businesses and, ideally, identify opportunities for heat-related collaboration. Additionally, the questionnaire highlighted key aspects for the companies, such as the potential to utilise their waste heat externally or benefit from the waste heat generated by other companies.

The industrial companies surveyed were able to provide information in the following areas:

- General information about the company (e.g., name, address)
- Number of production sites
- Description of waste heat at production site(s)
- General questions (e.g., payback periods, energy cost)

An analysis of the survey results revealed that 47 out of 600 companies responded, with more than half being large enterprises. The remaining respondents were small and medium-sized enterprises (SMEs), highlighting that energy management is also a significant concern for smaller businesses. Half of the respondents, representing various sectors, reported that they do not utilize waste heat, either internally or externally. The sources of waste heat were highly specific to each company. While four of the responding companies are located within the city centre of Linz, the others are spread across Upper Austria. Although the limited data prevents drawing significant conclusions for Linz, the survey still provided valuable insights into the current waste heat management practices of local industrial companies.

##### 2.5.1.1.1 Conclusion & Results

The use of waste heat and the topic of energy are important not only for large companies but also for small and medium-sized enterprises.

**Waste heat at the main production site:** Around half of the responding companies have unused waste heat that they do not use internally or pass on to third parties (mainly district heating networks). Companies with waste heat come from all sectors of the economy, from the food industry to the non-ferrous metals, paper, stone and wood industries through to the chemical and steel industries.

The type of waste heat is very company-specific - from a few kW of heat output to high waste heat quantities in the double-digit GWh range and from low temperatures of 25°C to well over 300°C. Despite known efforts in some cases, there is still no customer for this. The temperatures and energy quantities recorded in the survey show that companies should consider using the waste heat of another company as a heat input for their own company.

**CO<sub>2</sub> neutrality:** Around 10% of companies state that their production is already CO<sub>2</sub>-neutral and around 50% state that they have a roadmap, strategy or concept for switching to CO<sub>2</sub>-neutral production. Compensation measures to fulfil CO<sub>2</sub> neutrality play a key role for around a third of the companies.

The years from 2027 to 2040 are primarily stated as the time horizon for achieving the target; only three of the companies define 2050 as the target horizon. Only a quarter of the companies would like advice on switching to CO<sub>2</sub>-neutral production.

**Energy prices, amortisation:** With regard to the current developments in energy prices (since the last year of the survey) and in Ukraine, the companies stated that there have been enormous price increases in some cases, although in some cases these are secured by longer-term contracts. This is also driving the implementation of measures. Although amortisation periods have decreased due to energy prices, the amortisation periods for energy-related projects have increased from approx. 5 years to 5.5 years according to the companies (2019-2022).

### 2.5.2 Salzkammergut

The potential for the extended, additional utilisation of an existing waste heat source was and the utilisation possibilities were analysed. This resulted in the utilisation of the waste heat, especially in the summer months for other customers outside of Gmunden (these are already supplied via the current district heating system based primarily on waste heat and natural gas), which have an almost constant heat consumption throughout the year. For the substitution natural gas-based district heating, there is the potential for a total of 16 GWh/a.

In order to expand the utilisation of the existing waste heat source and to ensure the required flow temperature of around 120 °C for the customers' technological processes, an expansion of the existing industrial heat extraction system was evaluated. The concept envisages further waste heat extraction parallel to the existing extraction for the Gmunden district heating network. The existing Gmunden network is primarily supplied by the existing recovery system. Further available waste heat can be utilised by other customers via the connecting pipeline.

The course of the route was optimised and defined. Route inspections were carried out on site for the realisation of the pipeline planning.

The project has the potential to achieve CO<sub>2</sub> savings of approximately 3,600 tons per year. Key investments include the expansion of waste heat recovery systems, the construction of a 5 km district heating pipeline (DN200), and the integration of the customer system. The total project costs are estimated at around €10.5 million.

Following main findings have been identified:

- CO<sub>2</sub> price has little impact on profitability

- Upcoming funding opportunity: transformation of the industry
- Real reduction in the amount of usable waste heat due to existing waste heat source in the target system
- Not economically viable due to falling natural gas prices (reference prices)

### 2.5.3 Ennshafen

This was a highly successful example in identifying potentials and initiating negotiations. An additional output of the WKO survey on industrial waste heat potentials in Upper Austria was, that companies responded to have a waste heat potential. Based on previous projects, neighbouring and involved companies were contacted. Potentials for industrial steam and/or hot water networks in Enns were assessed. The energy institute moderated the first joint meetings and first data provision. Finally, cooperation of two companies turned out to be most feasible and further assessments took place.

On 14 July 2022 a first meeting took place, where the Heat Highway project was presented. On 26 January 2023, a meeting took place in which the use case ‘Ennshafen’ business models for the use of industrial waste heat for external process heat were presented. Possible barriers were identified, success factors presented and the project group defined (specific companies as supplier, operator and customers as well as the constructing company). The individual situations of the companies were presented in order to create a basis for discussion. The project was clearly illustrated with examples. A total of 14 people from 6 companies from the Ennshafen area were present at the meeting.

This use case has made a significant contribution to business model development in WP3. The business model has benefited significantly as a result.

## 2.6 Use Case #3: HTN Styria

The investigation of Styria was conducted in three key phases: a preliminary study, a main study, and a detailed study, all adhering to the standards of a techno-economic evaluation. The preliminary study focused on gathering relevant data and background information, as well as analysing the fundamental components required for developing a supra-regional district heating network. In the main study, both the technical and economic feasibility of the project were thoroughly examined. Finally, in the detailed study, the economic viability was further scrutinised, with a closer focus on critical influencing factors. The methodology used for the analysis in the preliminary study and the technical analysis in the main study is detailed in Steinegger et al. (2024)<sup>40</sup>. Similarly, the approach for conducting the economic analysis in the

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<sup>40</sup> Steinegger (2024). Revolutionizing heat distribution: A method for harnessing industrial waste heat with supra-regional district heating networks, doi.org/10.1016/j.apenergy.2024.123769.

main study, as well as the detailed study, is outlined in Steinegger et al. (2025)<sup>41</sup>. A comprehensive summary of these topics, along with additional results, can be found in Steinegger (2024)<sup>42</sup>.

As depicted in the following graphic, the preliminary study reveals a significant amount of already installed waste heat, along with substantial untapped waste heat potential, based on data from the waste heat cadastre<sup>43</sup>. This potential is categorised as follows:

- **High-temperature industrial waste heat (HTIWH):** Including the technical industrial waste heat (IWH) potential higher than 100 °C with a lower reference temperature of 100 °C.
- **Medium-temperature industrial waste heat (MTIWH):** Including the technical IWH potential between 50 °C and 100 °C with a lower reference temperature of 50 °C.
- **Lower-temperature industrial waste heat (LTIWH):** Including the technical IWH potential lower than 50 °C with a lower reference temperature of 0 °C.

Furthermore, the region contains numerous small and large heating networks. This combination creates an ideal scenario for implementing a supra-regional district heating network, as illustrated in the final section of the graphic.

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<sup>41</sup> Steinegger (2025) Assessing the Technical and Economic Feasibility of Supra-Regional District Heating Networks. currently under review.

<sup>42</sup> Steinegger (2024). Supra-Regional District Heating Networks: Harnessing Industrial Waste Heat for a Carbon-Free Heat Future, Current under review.

<sup>43</sup> Gruber-Glatzl (2021). Abwärmekataster III Steiermark: Öffentlicher Kurzbericht.

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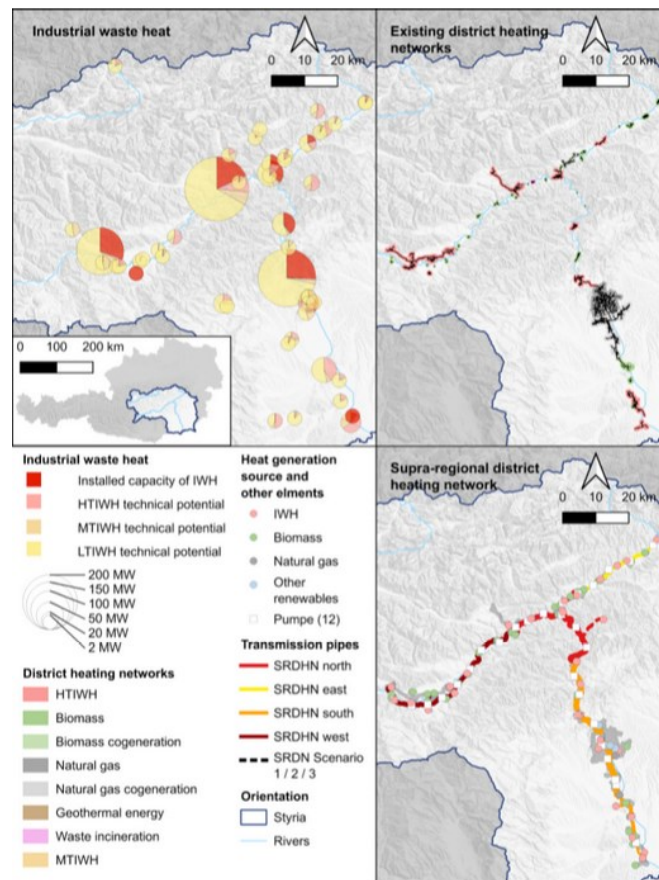


Figure 17: Overview - industrial waste heat, existing district heating networks and supra-regional heating networks

The available heat output and consumption in this region for 2022 are compared with the potential for IWH expansion in different scenarios in Figure 18. These technical IWH potentials, which can be harnessed using technologies such as heat pumps, are defined as follows:

- **State 2022:** Current installed capacities for heat generation in the examined region.
- **Scenario 1:** State 2022, additionally incorporating the use of high-temperature industrial waste heat (HTIWH), adjusted to a reference temperature of 50 °C (assumed return flow temperature).
- **Scenario 2:** Scenario 1, with the addition of medium-temperature industrial waste heat (MTIWH), adjusted to a reference temperature of 50 °C and assuming an enhancement of the usable temperature level to 110 °C using a heat pump (average coefficient of performance (COP) would be 5.6) or similar technology.
- **Scenario 3:** Scenario 2, further including low-temperature industrial waste heat (LIWH), adjusted to a reference temperature of 50 °C and assuming the temperature is raised to 110 °C with a heat pump (average COP would be 2.8) or similar system.

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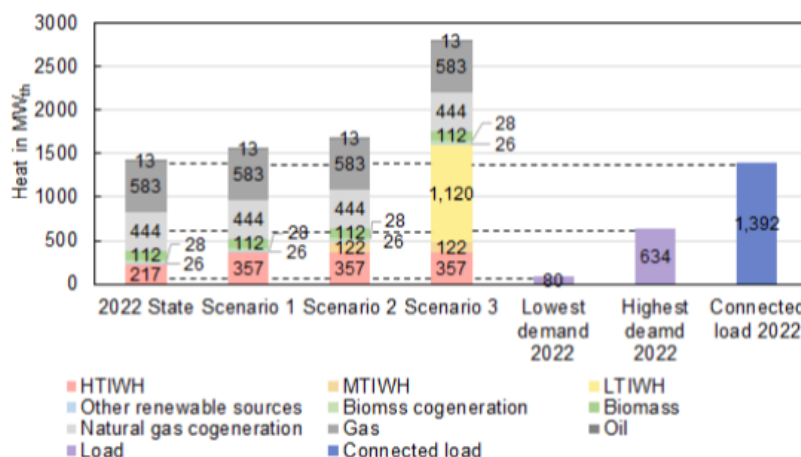


Figure 18: Technical IWH potentials

As shown in : Technical IWH potentialsFigure 18, from Scenario 2 onwards, it is possible to cover the maximum heat demand of the Mur-Mürz region in 2022 by combining all heat generation plants with a supra-regional district heating network, using heat generation from renewable and sustainable sources.

In the main study, the technical and economic feasibility of the district heating transmission line within such a supra-regional district heating network was assessed. For this, an investment cost estimate for the system to be constructed was determined using standard procedures in the district heating industry, amounting to 618 million euros for connecting the 2022 State with a supra-regional district heating network. Special key performance indicators were developed for the subsequent techno-economic analysis, and the potential system was evaluated based on these indicators. The economic evaluation is based on a newly introduced heat price model, which is explained in greater detail in the publications referenced at the beginning of this chapter and the developed load flow calculation tool described in Chapter 2.2.2. The results of the worked out key performance indicators are shown in the following table.

Table 7: Results of the worked out key performance indicators

Key performance indicator	Requirement	Value	Target Achievement
Temperature	Must reach a certain value at the heat substations	All temperatures are higher than the lower limit	Archived
Linear Heat Density	Must be higher than 1.5 MWh/(m*a)	**1.7 MWh/(m*a) & ***6.0 MWh/(m*a)	Archived
Carbon Footprint	The integration must reduce the original value	*Reduction of 191 ktCO <sub>2</sub> /a (78%)	Archived
Primary Energy Demand	The integration must reduce the original value	*Reduction of at least 42%	Archived
Unit costs	Must be equal to or lower than the value without a SRDHN	In the same range of LDHNS	Achieved

Key performance indicator	Requirement	Value	Target Achievement
Overall annual costs	Must be equal to or lower than it would be without a SRDHN	In the same range of LDHNs	Achieved
Net Present Value	Must be higher than the value without a SRDHN or higher than 0	The values are higher than 0 or higher than the original value	Archived
<p><i>*Based on the Finnish method</i></p> <p><i>**Based on the overall SRDHN length including the length of the LDHNs</i></p> <p><i>***Based on the SRDHN transmission line length</i></p>			

In the detailed study, the impact of external factors (e.g., electricity price, heat price, biomass price, useful life, etc.) on the heat price was assessed using the newly developed heat pricing model. The sensitivity analysis shows that gas and electricity prices, in particular, have a significant impact on the heat price. This is because, in the assumed scenario with the new pricing model, gas cogeneration plants are frequently used as the price setting heat generators during peak demand. The analysis also indicates that as more renewable and sustainable sources are integrated, the heat price would decrease to a level comparable to that of district heating networks which operate with biomass. Further details are available in the publications referenced at the beginning of this chapter.

In summary, the calculated results indicate that connecting the heat generation plants with the district heating networks in the examined area (Mur-Mürz) could be economically and technically feasible under certain conditions. The findings also suggest that further investigation with detailed ramp-up scenarios would be worthwhile.

## 2.7 Follower Case #1: HTN Inntal

The study assesses the potential for extending the current heat transfer network (HTN) between Wattens and Innsbruck or establishing separate district heating (DH) networks in the eastern Inntal region between Wattens and Kufstein. In addition, the feasibility of integrating existing biomass heating plants and resources from Fügen in the Zillertal will be investigated.

Further information can be found in the deliverables for Task 7.1 (see Inntal in chapter 6 Appendix).

The focus is on the use of existing infrastructure, such as biomass heating plants and industrial waste heat sources, and the evaluation of the potential of unused waste heat together with flexible suppliers such as large heat pumps and combined heat and power (CHP) units. These primary heat sources serve large consumers - such as cities, supermarkets, hotels and hospitals - which are critical for economic viability.

The study also addresses the economic risks associated with DH networks, particularly as they transition from fossil and biogenic fuels to alternative heat sources such as ambient heat, waste heat, solar and geothermal energy. This shift is driven by the declining availability or reutilisation of traditional fuels. The main uncertainties examined include fluctuations in energy prices (electricity and biomass) and the availability of alternative heat sources.

Using a Monte Carlo simulation based on seasonal energy balances, the study compares the economic resilience of district heating networks with that of individual heating systems. The results show that individual systems are subject to greater economic risk due to volatile energy prices. In contrast, HTNs mitigate this risk by optimising the use of waste heat, operating heat pumps when electricity prices are low and operating CHP plants to generate revenue when electricity prices are high. This adaptability gives HTNs a more stable economic base than individual heating systems with fewer supply options.

### 2.7.1.1 Identification of key heat sinks and sources

The identification of key heat sinks and sources for the proposed Heat Transfer Network (HTN) expansion in the Tyrol Inn Valley relied on extensive data collection using recognized open data tools. The Austrian Heat Map<sup>44</sup> was essential in providing insights into potential heat sources, while *tiris*<sup>45</sup>, the Tyrolean spatial information system, offered GIS-based heat density maps (Figure 19 **Fehler! Verweisquelle konnte nicht gefunden werden.**) and using the district heating potential economic assessment<sup>46</sup> feasible connection rates were estimated.

This analysis included a robust assessment of potential heat sources, such as industrial waste heat, heat pumps, biomass plants, and combined heat and power (CHP) units. Major demand nodes—including residential areas and large commercial consumers like hospitals, hotels, and supermarkets—were identified to comprehensively understand the region's heating requirements.

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<sup>44</sup> <https://austrian-heatmap.gv.at/karte/> (Abgerufen am: 17.12.2024)

<sup>45</sup> [https://maps.tirol.gv.at/synserver?user=guest&project=tmap\\_master&client=core](https://maps.tirol.gv.at/synserver?user=guest&project=tmap_master&client=core) (Abgerufen am: 27.12.2024)

<sup>46</sup> Fallahnejad (2020). in Hotmaps-Wiki, CM-District-heating-potential-economic-assessment (September 2020)

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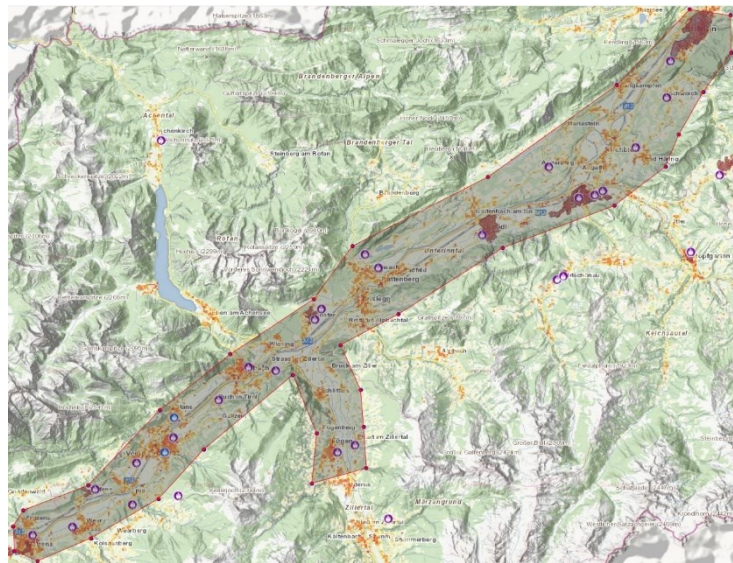


Figure 19: Study area Inntal

In total, 32 municipalities along the proposed HTN route were designated as demand nodes, focusing particularly on densely populated areas such as Wörgl, Schwaz, and Kufstein. These towns exhibit high heating demands driven by residential and service sector needs, making them essential anchors for the HTN’s distribution network. Also, other large consumers in the municipalities, which among others include hotels, hospitals, garden centres were mapped. The heating demand data for these municipalities, sourced from *tiris*, along with current connection rates and heating supply distributions, based on the study “Wie heizt Tirol 2050<sup>47</sup>” provided a solid basis for further calculations.

Furthermore, potential and existing heat sources of industrial waste heat (see **Fehler! Verweisquelle konnte nicht gefunden werden.**) were mapped and evaluated from sectors such as wood processing, pharmaceuticals, food production, and manufacturing, alongside existing biomass boilers and biomass CHPs. Public information, interviews with industrial companies and local stakeholders facilitated the identification of the most promising industrial waste heat suppliers.

Table 8: Industrial companies

Company	Municipality	Currently supplies a DH Network	Main Processes	Prognosis
<b>Swarovski Wattens</b>	Wattens	Yes	Melting processes - melting, surface treatment -	High-temperature waste heat remains but may decrease with efficiency improvements.

<sup>47</sup> <https://wasser.energieagentur.tirol/unternehmen/news/details/wie-heizt-tirol-2050-pilotgebiet-planungsverband-woergl-und-umgebung/> (Abgerufen am: 17.12.2024)

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Company	Municipality	Currently supplies a DH Network	Main Processes	Prognosis
			grinding (electricity-intensive)	
<b>INNIO Jenbacher</b>	Jenbach	Yes	Combustion engines	Waste heat potential remains steady and will be used more in the future.
<b>Montanwerke Brixlegg</b>	Brixlegg	No	Melting processes, electrolytic baths at 100°C	Waste heat potential may be higher than indicated, as melting operations typically generate significant heat. Waste heat recovery could be explored further, especially at lower temperatures suitable for pre-heating or DH.
<b>Sandoz GmbH</b>	Kundl	Yes	Electricity, steam generation, waste heat from drying equipment, compressed air compressors	Steam generation with a heat pump will likely reduce waste heat, but pharmaceutical manufacturing often has complex processes with waste heat at various levels, potentially suitable for DH.
<b>Pfeifer Holz GmbH &amp; Co KG</b>	Kundl	No	Drying	The company's drying processes can offer a waste heat potential. However, no district heating network is currently connected.
<b>Fritz EGGER GmbH &amp; CO. OG</b>	Wörgl	No	Drying, pressing, coating	Drying, pressing or coating processes may offer waste potential, however it is currently not in the focus.
<b>Tirol Milch</b>	Wörgl	Yes	Pasteurization, sterilization	Tirol Milch supplies Wörgl with waste heat. However, with efficiency increases and lower temperatures, the waste heat potential may drop.
<b>Adolf Darbo AG</b>	Stans	No	Cooking	Cooking processes generate relatively low-temperature heat, which may be useful for DH in limited applications. As efficiency improves, the waste heat availability might decrease further.
<b>Tyrolit Schleifmittel Schwaz</b>	Schwaz	No	Mechanical processes	Waste heat is limited since most of Tyrolit's mechanical processes are not high-temperature. Unless there

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Company	Municipality	Currently supplied as a DH Network	Main Processes	Prognosis
				are auxiliary systems like cooling that generate recoverable heat, the potential is low.
<b>Sandoz Schafteu</b>	Schafteu	No	Electricity, steam generation; waste heat: drying equipment, compressed air compressors	Steam generation by heat pump may reduce waste heat availability.

## 2.7.1.2 Basic Routing

A basic routing of the HTN was derived, based on the existing HTN between Innsbruck and Wattens in the western part of the Inn Valley, which follows the Inn valley highway (see Figure 20). The proposed HTN will also follow the Inn Valley highway, supplying all 32 municipalities along the way. For this purpose, existing district heating distribution networks and municipalities without networks, where it would have to be built, were taken into consideration. The preliminary route is shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** and depicts a total of approximately 82 km of heating pipeline from Wattens to Kufstein and to Fügen in the Ziller Valley. Approximately 34 km pass through urban areas, while 48 km pass through rural, unpaved terrain.



Figure 20: Proposed routing of the HTN in the eastern Inntal

### 2.7.1.3 Techno-economic feasibility evaluation

More details can be found in Marx et al. (2023)<sup>48</sup>.

To model and mitigate economic risks, a Monte Carlo simulation was used, analysing 10,000 scenarios with varying energy costs and waste heat availability and compares a maximum configuration where close to 90% of the heating demand in the municipalities is provided by the HTN, including the construction of new supply networks, to an individual configuration, where the existing district heating network remains unchanged. For individual heating systems, specific decarbonization pathways for heat supply to municipalities and regions at the building level were considered (shifting fossil fuel demand to decarbonized alternatives). The simulation considers fluctuations in energy prices for electricity, biomass, and waste heat, as well as potential shifts in waste heat supply. This probabilistic approach allowed for evaluating the network's levelized cost of heat (LCOH) and economic resilience under diverse conditions. Key findings from the simulation indicate that diversified heat sources, such as industrial waste heat, CHP, and biomass, provide a stable economic basis for the HTN. Flexible pricing mechanisms, such as a heat merit order (HMO), enable prioritized use of cost-effective sources, maximizing economic efficiency and reducing vulnerability to individual prices spikes.

Key cost components, besides the HTN and the construction and enlargement of the distribution networks, include heat supply units, such as combined heat and power (CHP) plants and heat pumps, along with storage facilities to support peak demand and ensure operational flexibility. Operational expenditures (OPEX) account for maintenance, auxiliary energy, waste heat costs, and network expansion, reflecting a balanced financial structure to sustain long-term network viability. General cost assumptions based on local information and databases were the basis for the individual heat supply.

Comparatively, the HTN model demonstrated a lower economic risk than individual heating systems, with LCOH variability of +/-4% versus +/-9% in individual configurations. This is due to the HTN's ability to optimize lower-cost waste heat and deploy heat pumps at low electricity prices, as well as CHP units at higher electricity prices, to manage costs effectively. The result is a more stable, resilient heat supply network that reduces reliance on volatile energy sources, offering substantial risk reduction and economic sustainability over isolated heating systems.

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<sup>48</sup> Marx, Blakcori, Forster, Maggauer, Schmidt (2023). Risk assessment in district heating: Evaluating the economic risks of inter-regional heat transfer networks with regards to uncertainties of energy prices and waste heat availability using Monte Carlo simulations. *Smart Energy*, Volume 12, November 2023, 100119, <https://doi.org/10.1016/j.segy.2023.100119>.

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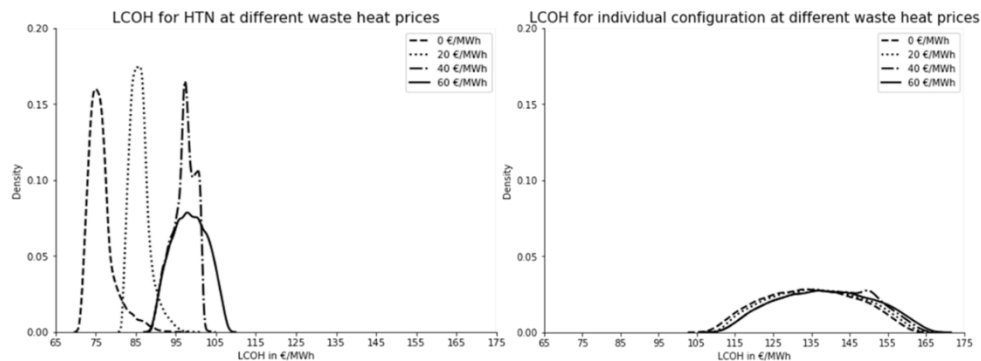


Figure 21: Comparison of the LCOH for the HTN and the individual configuration at different waste heat prices

## 2.7.1.4 Heat Highway WebApp<sup>49</sup>

To also compare possible configurations for different district heating demands, modelled with the district heating potential economic assessment, and energy price scenarios, an optimiser<sup>50</sup> was used to decide on the optimal supply infrastructure in the HTN Inntal, based on existing infrastructure, local potentials, energy prices, CAPEX and OPEX. Results were visualized in a web application (<https://ies-apps.ait.ac.at/hhw>) for different district heating demands and energy price scenarios.

Figure 22 below outlines the possibilities for the optimiser for the district heating supply. The town or municipality represents the overall heating demand, including residential and service sector demand. Supply elements can include:

- Biomass CHPs
- Waste heat sources
- Storages
- Large heat pumps
- Biomass boilers
- Connections to other towns and municipalities

<sup>49</sup> <https://ies-apps.ait.ac.at/hhw> (Abgerufen am: 17.12.2024)

<sup>50</sup> <https://github.com/ait-energy/iesopt> (Abgerufen am: 17.12.2024)

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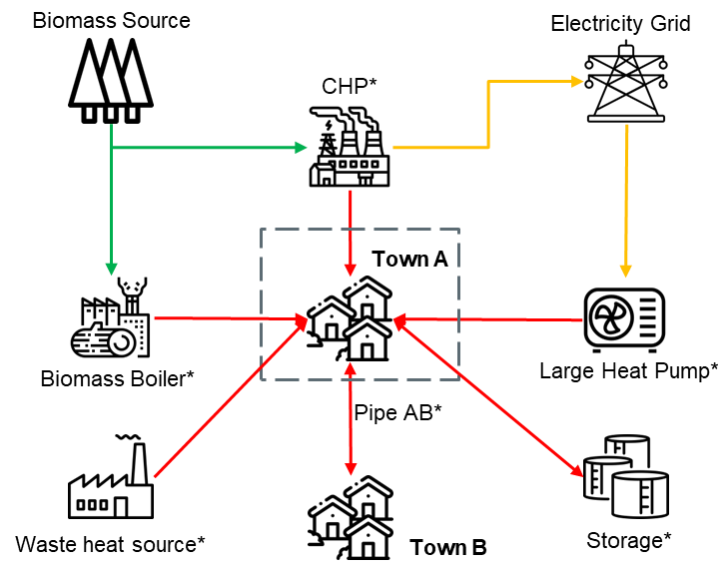


Figure 22: Potential heat supply setup

### 2.7.1.5 Business & Action Plan

The implementation of the HTN Inntal depends on a multi-faceted approach including funding, stakeholder engagement and a clear action plan.

More information can be found in the deliverable “Heat Highway - Follower Inntal (Business Case)”.

#### 2.7.1.5.1 Financing Strategy

The financing will combine debt capital from banks, private investors, and national and European subsidies. Notable funding sources include the Climate and Energy Fund (KLIEN), the Umweltförderung managed by Kommunalkredit Public Consulting (KPC), and European programs like Horizon. Current funding schemes focus on capital expenditures (CAPEX) while offering limited support for operational expenditures (OPEX). A detailed review of available funding options is essential during advanced planning stages to ensure financial stability and sufficient capital for network expansion.

#### 2.7.1.5.2 Stakeholder Engagement

Engaging local stakeholders is crucial for the successful implementation of the HTN. This includes conducting consultations to align the project's objectives with community needs and securing commitments from industrial players to supply waste heat. The development of a collaborative business model involving operational stakeholders will help identify cost benchmarks and financing options.

#### 2.7.1.5.3 Action Plan

Possible next steps for the implementation of the HTN Inntal are listed below:

- **Market Analysis and Feasibility Study:** Conduct a detailed feasibility study to validate demand and supply data. The initial findings should guide further investigations into untapped waste heat sources and existing infrastructure.
- **Technical Planning:** Finalize the optimal routing of the HTN using GIS analysis to identify suitable locations and ensure compliance with environmental regulations, including necessary permits.
- **Securing Financing:** Intensively pursue funding from identified sources, emphasizing the establishment of clear collateral and payment structures to attract investors.
- **Construction Phase:** Execute the construction plan, ensuring the installation of pipes and auxiliary components, followed by rigorous testing to guarantee operational reliability.
- **Commissioning and Start-Up:** Upon successful commissioning, coordinate activities with local district heating networks to facilitate integration and optimize operating conditions.

By implementing these steps, the Inntal HTN aims to provide a reliable, climate-friendly heat supply to the region while fostering economic sustainability and community involvement.

### 2.7.1.6 Conclusion

The success of the existing heat transfer network (HTN) between Innsbruck and Wattens in the Inn Valley, Tyrol, has highlighted the potential of such systems. Consequently, several regional stakeholders are exploring ways to expand this concept throughout other parts of the Inntal, potentially achieving a continuous connection from Kufstein to Wattens. This expansion would allow for the utilization of otherwise unused waste heat, improve the reliability of heat supply, and open new economic opportunities for industrial companies in the region.

## 2.8 Follower Case #2: HTN Innviertel

As part of work package 7, task 7-2 “Follower case HTN Innviertel”, a concept, inspired by the method of a business model plan, was developed for the implementation of a potential heat transmission network (HTN) in the Innviertel region in Upper Austria. The concept aligns with the structure of a business model plan where applicable. A summary of the approach is provided below. The full report is available online.<sup>51</sup> Further information can be found in the deliverable for Task 7.2 (see “Innviertel” in chapter 6 Appendix).

The necessary steps and measures required to implement a HTN for the Innviertel region were outlined. The follower case HTN Innviertel is a conceptual HTN, which interconnects many industrial waste heat and other sustainable sources, district heating networks, and industrial process heat sinks. A presentation of the product, analysis of the market, marketing strategies,

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<sup>51</sup> Jauschnik, Rodin, Moser (2024) Heat Transmission Network „Innviertel“, Projekt Heat Highway, Task 7.2 Concept and Business Model. Final Task Report, August 2024. Available <https://energieinstitut-linz.at/wp-content/uploads/2023/04/Business-Model-Plan-HTN-Innviertel.pdf> (2024-12-09).

financial forecasts (with a focus on the capital expenditures) economic estimates and plans for implementation have been made.

First, a comprehensive analysis of the potential for implementing an HTN was carried out, including the identification of waste heat sources and potential heat sinks through the utilisation of both existing open data sources and first-hand information obtained from district heating operators and industrial companies. The Innviertel region, especially Ried im Innkreis and the municipalities in its North, is home to approx. 28,500 people, various industrial companies, commercial business and public entities. Furthermore, some municipalities already have district heating networks available, which could be connected in a HTN. These already implemented heating networks can be found in Mehrnbach, Ried im Innkreis, Tumeltsham, Utzenaich, St. Martin im Innkreis and Reichersberg. On the other hand, individual heating systems are still a common choice, e.g. based on oil and gas heaters but also biomass. The total energy consumption in the Innviertel region amounts to 1.07 TWh/year, of which almost 35 % is accounted for by the industrial and commercial sector and 26 % by the residential sector. The remaining energy consumption is split between the mobility (22 %), services (14 %) and agriculture and forestry (2 %) sectors. The heat demand has a share of about 36 % of the total energy demand, with households accounting for 22 % alone and 5 % by industry.

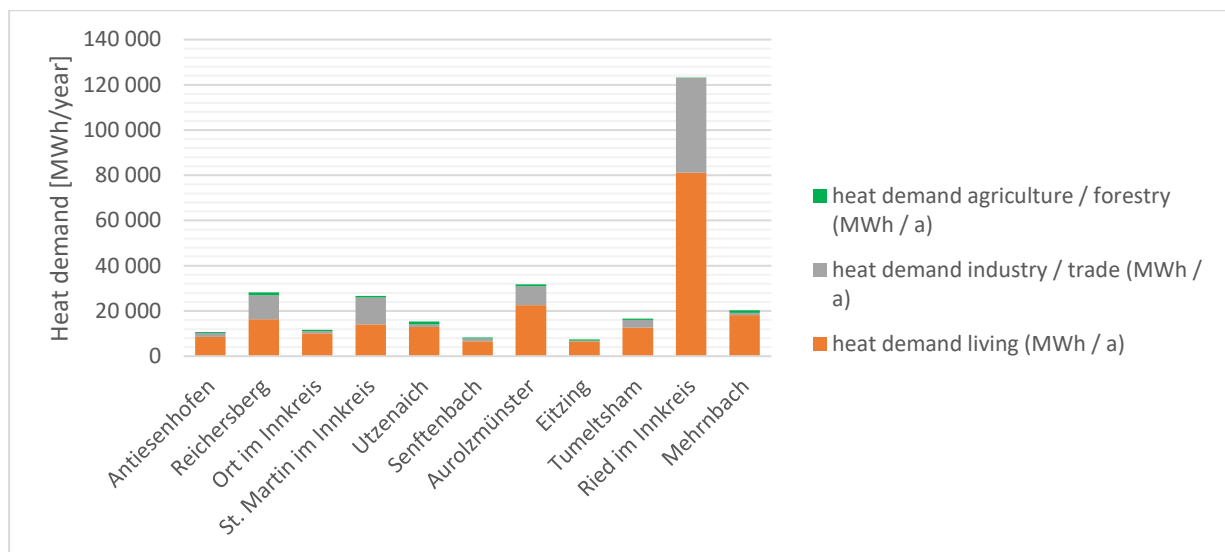


Figure 23: Heat demand of agriculture/forestry, industry and living in the different municipalities of the Innviertel region in 2019. Order of municipalities: North to South. Data source: Abart-Heriszt und Erker 2019, Datensatz Energiemosaik Austria.

In addition, there are numerous companies in the region that could represent further potential heat sources and sinks for the HTN (listed in the Appendix of the report). These include companies in the food, composite, wood, stone and ceramics, metal and chemical industries, among others.

From this assessment, a preliminary pipe routing plan from South to North was developed. The main route of the HTN is planned to connect Ried/Innkreis, Aurolzmünster (optional), St.

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Martin/Innkreis, Ort/Innkreis, Reichersberg and Antiesenhofen. In the South-West of Ried/Innkreis, a connection to Mehrnbach is also an option to be discussed as the geothermal source of the Ried/Innkreis DHN is in the Mehrnbach area, as regarding population Mehrnbach is in the top three of the eleven municipalities. The areas of Eitzing and Senftenbach are less populated, however, in Senftenbach a brick factory as well as the geothermal source of the DHN St. Martin are located. Thus, the main piping route ideally follows the B141 from Mehrnbach to Ried/Innkreis, then the B143 from Ried/Innkreis to Ort/Innkreis, followed by A8 and/or L522 to Antiesenhofen. The preliminary route is shown in Figure 24 and depicts a total of approximately 50 km in one direction of heating pipelines from Ried im Innkreis to Antiesenhofen. The existing main heating network in Ried extends approximately 13.5 km (blue), while the connection to Mehrnbach is just over 2 km (green). The main pipelines of the St. Martin DHN span about 8 km (purple). The new pipelines to be constructed (indicated in orange) will add a length of just over 27 km. All lengths are indicated in one direction only.

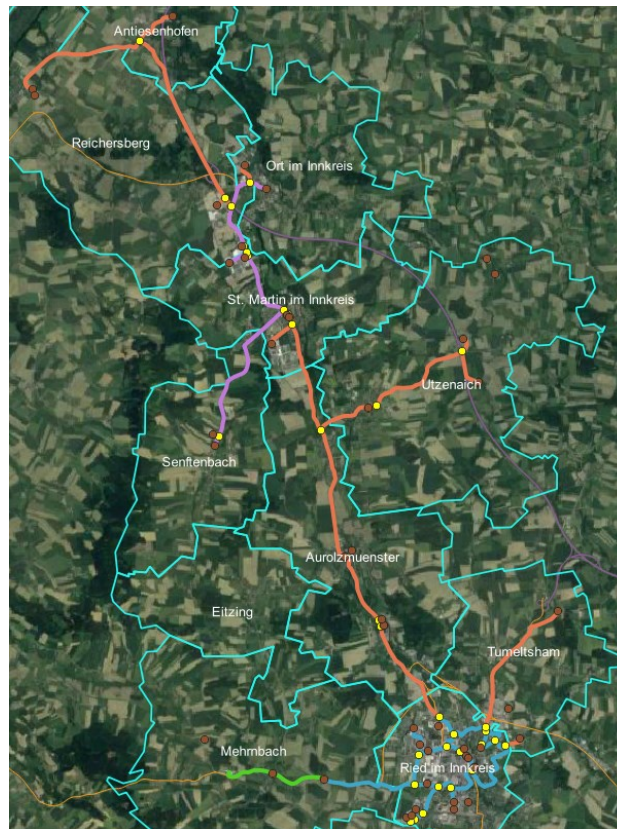


Figure 24: Proposed route of the HTN Innviertel. Source: Energieinstitut an der JKU Linz.

The capital requirements for a new HTN include a variety of large, long-term and up-front costs, and need to be carefully planned and calculated. Key CAPEX includes investments in the three system parts: heat generation facilities, distribution system including pipelines and substations, and installations at the consumer side. In addition, costs for setting up the company, including legal and administrative expenses as well as regulatory and administrative costs associated with complying with legal regulations and official requirements must also be included in the overall calculation. Detailed and careful planning of these capital requirements

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ensures that all financial aspects of the project are covered and potential risks are minimized. The length of the new heating pipeline to be constructed is approximately 27 km (one way) with an assumed DN 300 at a base cost of 350 € per meter (one way). **The cost for the pipeline itself excludes additional expenses such as installation, permits, and other relevant work. As a result, according to DH experts the actual cost per meter is likely to be two to three times higher when considering all associated factors.** A subsequent capital expenditure assessment was carried out to evaluate the feasibility of the proposed HTN in the follower region and resulted in investment cost for simple supply and return pipelines of around 19 million €, based on expert opinions. This estimation will need to be adjusted to account for the specific conditions and requirements of the project. The concept was presented to local stakeholders.

Table 9: SWOT-Analysis for the HTN Innviertel.

<b>Strengths</b>	<b>Opportunities</b>
Integration and combination of various sustainable energy sources	Rising demand for climate-friendly district heating
Increased flexibility, and thus, reliability and sustainability of the network	Financial incentives from the government to facilitate implementation of district heating
Use of currently unused but abundant resources such as waste heat from local industry, making optimal use of existing energy resources and reducing environmental impact	Possibility of building a new DHN in Auroldmünster (municipality in the north of the Innviertel region) in parallel to the HTN development
Contribution to achieving climate targets due to increased renewable (geothermal, biomass, solar) and waste heat utilization	Expanded use of the region's geothermal potential and high levels of solar radiation to integrate sustainable and renewable heat sources in the HTN
Reducing dependence on fossil fuels, such as gas and oil based individual heating systems	Bringing various stakeholders together in the HTN development and operation creates local value and win-win situations.
<b>Weaknesses</b>	<b>Threats</b>
High investment costs in the network infrastructure and the associated technology	The long-term planning horizons of DH projects could be jeopardized by changing factors such as political or economic conditions
Increased complexity of network management in terms of technical and organizational aspects	Changes in regulatory framework conditions
Currently, there is no existing DHN in Auroldmünster, leading to long distances between Ried and St. Martin. This could lead to high transport losses and low acceptance by third parties with no access on the route	Discordance of stakeholders
DHNs are long-term investments, which require careful planning and securing financing	Deteriorating competitiveness due to new, innovative or alternative (individual heating) technologies

The connection of existing DHN via the HTN might lead to technical challenges (direct/indirect connection, temperature and pressure levels, water quality)	Decreasing heating demand
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Further, a SWOT-analysis was carried out. The risks of an HTN can be reduced by including many supply and demand nodes, leading to increased flexibility and reliability of the network, as a large number of sustainable energy sources can be used in the event of supply failure by a single source or planned shutdown. Thus, a more robust and reliable heat supply for consumers is enabled.

Finally, a preliminary implementation plan for the HTN Innviertel was created, offering a recommended roadmap for the implementation process. The plan outlines the following key steps: conducting a market analysis and feasibility study, developing a business model, carrying out technical planning, navigating the authorization process, securing financing, moving into the construction phase, commissioning, start-up, and ultimately the official opening.

## 2.9 Follower potentials

### 2.9.1.1 Description of the Case Study / Region

Task 7.3 aims to identify and analyse the waste heat potentials in the regions of Southern Vienna and St. Pölten – Krems, focusing on energy-intensive companies where waste heat, a byproduct of industrial processes, often goes unused. The study's objective is to comprehensively quantify this waste heat potential and identify local heat sinks. Special attention is given to energy-intensive companies to gather precise data on the type and amount of waste heat produced and its potential uses. Direct contact with companies ensures an accurate information collection, providing detailed insights and a solid basis for future waste heat utilization decisions in these regions.

Further information can be found in the deliverable for Task 7.3 (see chapter 6 Appendix).

### 2.9.1.2 Methodology & Data Basis

The research began with a comprehensive literature review to standardize the definition and understanding of waste heat across various industrial sectors, such as steel, aluminium, chemicals, textiles, and food production.

Next, an industrial map of Lower Austria was used to identify companies that might generate waste heat, highlighting locations with a high concentration of industrial enterprises. Each identified company was thoroughly analysed to assess its waste heat potential based on its industry, size, and activities.

After identifying relevant companies, contact was initiated through emails and phone calls, including a customized Excel questionnaire to gather data on their waste heat potential. Due to low response rates, the Austrian Heat Map was used as an alternative to estimate waste heat potentials for power plants, district heating networks, and industrial sites, using 2019 data. In addition, research was conducted on potential heat sinks, such as large energy consumers (e.g., commercial buildings and institutions). Where data was unavailable, estimates were made based on building size from online atlases. The heating energy performance indicator was used to estimate energy demand, calculated by multiplying the building's floor area by energy performance indicators. This helped in planning efficient heating systems and integrating waste heat recovery solutions.

### 2.9.1.3 Results

#### 2.9.1.3.1 Contact Initiation

Upon contacting companies by phone, it became evident that staff at general telephone switchboards often hesitated to provide the contact details of responsible personnel. They typically requested a brief project description to be sent to the office email address. In rare cases, direct contact with a responsible person was established, enabling the exchange of contact details and transmission of informational material and distribution of the questionnaire. Despite these efforts, both direct telephone acquisition and email outreach resulted in an insufficient response rate regarding waste heat potential information. Only a limited number of companies responded with follow-up questions or completed questionnaires. Possible reasons for the low response rate include company distrust towards consulting firms and limited time resources.

#### 2.9.1.3.2 Waste Heat Potentials

Due to insufficient direct data collection, waste heat potentials were evaluated using heat map research.

Waste Heat Potential in the Southern Vienna Region: Heat map research identified several companies with waste heat potential, categorized into three levels: below 50°C, between 50°C and 100°C, and above 100°C. The identified waste heat potentials are as follow:

- Waste heat potential < 50°C: 111 GWh/a
- Waste heat potential 50°C – 100°C: 10 GWh/a
- Waste heat potential > 100°C: 5.5 GWh/a

Figure 25 displays the precise locations and temperature levels of the waste heat potentials using Power Map in Excel.

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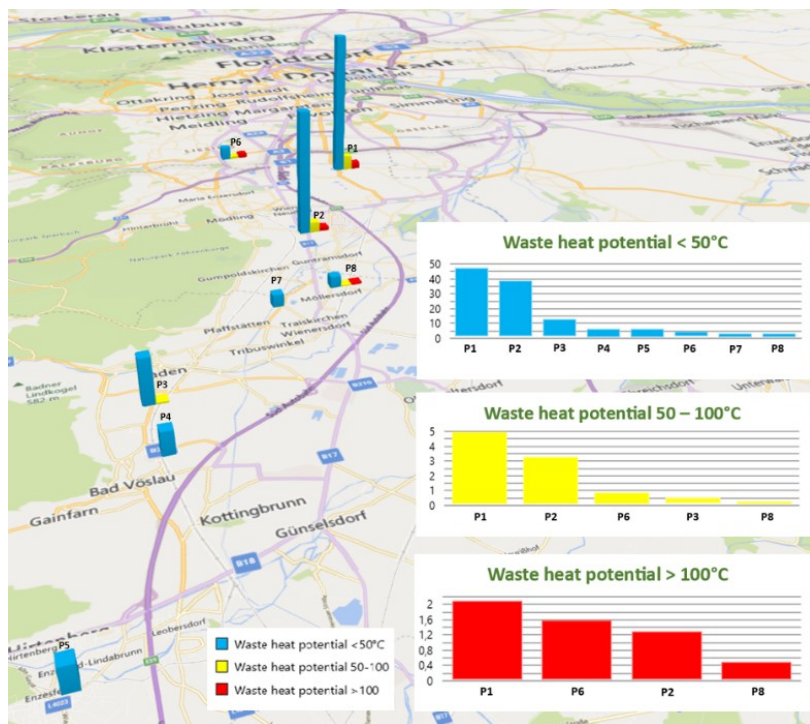


Figure 25: Waste heat potential map for the southern Vienna region

Heat map research identified companies with waste heat potential in the St. Pölten - Krems region, categorized into three temperature levels. The determined waste heat potentials are as follow:

- Waste heat potential < 50°C: 310 GWh/a
- Waste heat potential 50°C – 100°C: 30 GWh/a
- Waste heat potential > 100°C: 14 GWh/a

Figure 26 shows the precise locations and temperature levels of the waste heat potentials. This region has fewer locations with waste heat potential, but all locations exhibit waste heat potential across all three temperature levels.

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Figure 26: Waste Heat Potential Map for St.Pölten-Krems Region

### 2.9.1.3.3 Heat Sinks Research

Local heat sinks were identified in the studied regions, focusing on their potential size and function as significant energy consumers. The visualization of these heat sinks and waste heat potentials was carried out using a specially created map. Blue circles represent companies that declined or have no waste heat potential, while orange circles mark companies identified as potential heat sinks.

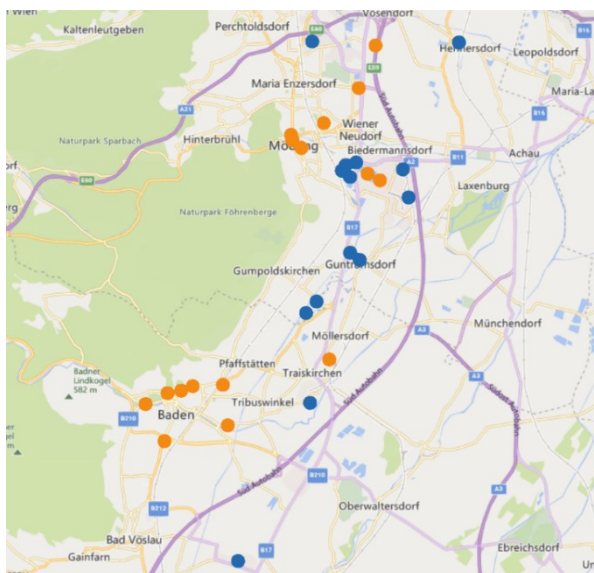


Figure 27: Heat Sinks Map for the Southern Vienna Region

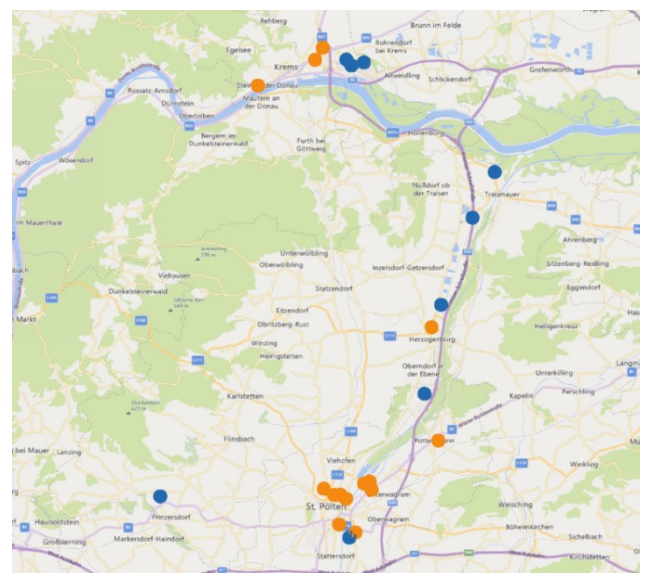


Figure 28: Heat Sinks Map for the St. Pölten – Krems Region

### 2.9.1.3.4 Waste Heat Potentials and Heat Sinks

A refined map was created to visually represent waste heat potentials and corresponding heat sinks, facilitating planning and design. Blue dots indicate the locations of heat sinks, while thermal images highlight areas with waste heat potential below 50°C. The intensity of waste

heat is color-coded: stronger red hues signify higher waste heat potential, while lighter shades indicate lower potential.

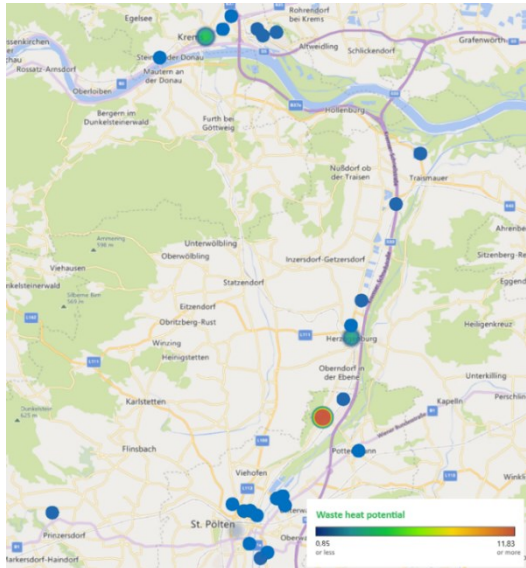


Figure 29: Waste Heat Potentials and Heat Sinks Map for the St. Pölten – Krems Region

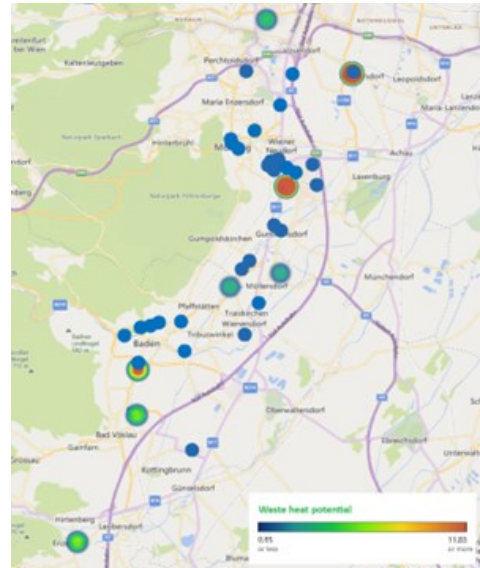


Figure 30: Waste Heat Potentials and Heat Sinks Map for the Southern Vienna Region

## 3 Results and conclusions

The very concrete knowledge gained from the theoretical tasks and practical use cases was presented in the sections of chapter 2. Additional insights and partner's recognition I summarized in the lessons learned.

### 3.1 Findings & Results (Lessons Learned)

The lessons learned are additional insights to the very concrete knowledge gained from the theoretical tasks and practical use cases. Project statements that are specific, for example the given decarbonisation potential through a heat highway in Styria or the regulatory conditions for waste heat utilisation, are presented in the work package and task reports in chapter 2.

District heating transmission grids are comparable to electricity transmission grids in terms of their purpose: the aim is to be able to optimise the expanded portfolio of generation alternatives based on social, economic, energy and/or emission-related parameters. A better situation can be achieved with the additional options offered by the connection. Conversely, if the selected generation plants remain the same, the situation with regard to the optimised factor can remain the same in the worst case, but at least cannot get worse. For this analysis, however, the starting point is that the new plants (e.g. in the case of waste heat feed-in) or the connection lines already exist: the necessary investments and operating costs must be considered and counterbalanced in a second step.

The cost of the pipes is just as essential as the savings that can be achieved. The transport of heat in the form of steam or hot water is not only limited in terms of distance due to thermal losses, but also by the cost of the pipes. District heating pipes are cost-intensive due to their size and design (steel or plastic with insulation, etc.). Added to this are surcharges for construction and building work, which in some cases increase the pure cost of the pipes a lot.

As with normal district heating, which often connects main areas of consumption within a city or covers (shorter) distances, there is no standard answer to the question of the economic viability of district heating transmission networks. It therefore remains a challenge to assess whether certain locations/grids can be connected to a potential transmission grid. The economic efficiency is largely related to the use case and is defined by the existing (rather expensive) heat generation plants, the potentially added (rather cheap) generation plants, new sales markets (expansion of customers through the new heat source or development of new areas along the lines), as well as the lines including their size and the distances covered (investment costs). Other social requirements and needs, such as the proportion of renewable energy or the security of supply of the system, must be taken into account and to be considered in the price.

It has been proven that inter-regional district heating connections can bring significant benefits. The various research papers developed in the project have shown that the resilience of the regional system can be significantly increased in terms of price and supply, that CO<sub>2</sub> emissions can be greatly minimized, and that the economic efficiency of a supra-regional network is at least in a range that definitely justifies further consideration (taking into account possible subsidies). With regard to resilience, it should be added that locally existing heat generation plants are still needed, particularly in the cold winter periods: These should not necessarily be removed, but should be used for peak load or back-up, as well as continuing to act as a price benchmark.

Although waste heat as a concept is easy to grasp, the discussion needs to consider the definitions to be applied to the different categories. It has been shown that the distinction between theoretical, technical, economic and realizable potentials is very relevant for the joint discussion in order to achieve a common understanding (and to avoid exaggerated expectations). The discussion focused in particular on the technical potential as a starting point, as the economic and realizable potentials are a result of the joint discussion process. The temperature level of the waste heat is highly relevant and should be economically attractive for district heating. Temperatures that are too low (e.g. cooling water) would require investment and electricity cost-intensive processing with heat pumps, while temperatures that are too high enable alternative use, including electricity generation, which would make these alternative costs significant.

Although the actors are informed about the basic technical requirements and possibilities of the partners, it is the partly general, partly case-specific technical and economic details that prove to be relevant: what exactly are the technical requirements, to what extent are these requirements flexible, and which alternatives can be undercut with waste heat or via the connection line?

The survey of project partners on lessons learned shows that the networking role of third parties is sometimes seen as essential. External facilitation works and connects the different actors. Facilitation is a long and very personal process that does not end with the identification of potential or the initiation of a first contact. Neutral mediation between the actors is essential. The presentation of initial in-depth information, the optimal timing of information and networking, including actors at a higher decision-making level, and the (non-)postponement of economic issues as part of the initial technical considerations are essential cornerstones.

With regard to economic viability, it should be noted that discussions quickly focus on the purchase price of the new (waste heat) plants or the new plants connected via a transmission line. In fact, the overall economic viability of the project must be considered first. Only when the overall project is recognised as economically viable the allocation of costs, revenues and cash flows should be considered.

Payback periods play an essential role in economic efficiency. It has been proven that waste heat is generally preferable in summer. This also applies to surpluses from base load heat sources such as geothermal energy or waste incineration. The bathtub curve of district heating demand is also known, which follows the outside temperatures and results from the usually dominant, often exclusive consumption share of heating and hot water provision. This means that there is a period in the summer that does not generate revenue for either the district heating or the (new) systems providing the heat. The implementation of so-called summer sinks can increase the demand for district heating and thus improve the profitability of summer-heavy waste heat.

## **3.2 Communication & Dissemination**

### **3.2.1 Virtual demonstrator & Prototype**

The 3D simulation should show the routing, the innovative combination of best available technologies, the use of industrial waste heat and the positive effects on the entire energy system. It shall base on the WP3 toolbox (semi-dynamic flow calculation). The catchy illustrations should also represent the economic added value for the individual players. As a physical accompaniment to the 3D simulation, the prototype of the lean pipeline from WP 3 is shown. The exhibition is open to the entire public, raising awareness for the Climate and Energy Fund's initiative. However, at least two separate events are intended to motivate

personally invited experts. Thus, industry, energy suppliers and policy makers are motivated to support the HTN.

- **M8-1: Establishment of virtual demonstration and in use for public exhibition**
- **M8-2: Virtual demonstration stakeholder promotion events**

### **Finding ways to embed the topic in the exhibition**

There are many points of reference in the museum where the Heat Highway project comes into play - not only in the 'There is no Planet B' exhibition in cooperation with the Climate and Energy Fund.

Example: *Global Shift* exhibition

In the '*Global Shift*' exhibition, the human footprint is examined from an ecological and infrastructural perspective. Heat Highway could be one of the infrastructural networks needed to turn the 'Anthropocene' into an era with a positive human imprint.

### **Explaining important terms simply but correctly**

Very few visitors were familiar with the term 'sector coupling' - however, if it was explained right at the beginning which sectors could be involved, some visitors were able to deduce the term logically. If the basic idea of sector coupling was already known, only (smart) electricity grids were thought of. Terms such as 'process heat' require a brief explanation, but are easily understood by both young and older audiences and across all educational backgrounds and professional groups.

### **Creating meaning through personal everyday relevance**

This is increasingly proving to be a no-brainer. Climate and energy issues are perceived as the most important topics of our time. Particularly during the pandemic, which has probably overshadowed much of the media and politics, 'security of supply' and 'systemically relevant infrastructure' were probably discussed by the public for the first time ever.

The geopolitical upheavals of the present are contributing to the fact that energy policy, security of supply, the operational safety of different forms of energy generation (e.g. nuclear power plants) and climate protection have taken on enormous importance in the public perception. While the causes and problems seem to be widely known, there is less knowledge about potential solution strategies and ways out. Heat Highway is therefore definitely something that our visitors are very happy to learn about.

So far, the basic idea of the project has been presented during the 'Planet B' themed tours and during the site supervision (visitor supervision without a guided tour, in dialogue). For the themed tours, it can be assumed that the majority of visitors will have a certain level of prior knowledge and special interest in climate and energy issues. These are not only pupils and

students, but often also teachers on further education programmes or members of NGOs or educational initiatives.

### 3.2.1.1 Methods of presentation

- **Area mediation:** Info trainer colleagues convey the content of the exhibition in dialogue as required. All colleagues were trained in September 2022 and given a "study hour" to learn the content.
- **Highlight tour:** Heat Highway is often a favourite stop on guided tours as a representative station for the "There is no Planet B" area.
- **Planet B themed tour:** Heat Highway is an integral part of the themed tour. Industrial waste heat utilisation is presented as part of the energy transition and as a link to circular economy.
- **Teacher training programmes:** The Heat Highway project is discussed intensively in teacher training courses on climate and energy topics.
- **Heat Highway on the website:** Heat Highway is made available on the website in the exhibitions section, including an animation of the virtual demonstrator (AE Solutions) and images of the physical demonstrator. <https://ars.electronica.art/center/de/heat-highway/>
- **Heat Highway video shoot:** A video was produced as an internal training video. It provides a compact and comprehensible explanation. More detailed information is supplemented by written documents.

Showing complexity, price levels, ecological footprint of different sources of waste heat, the important players, the infrastructure/network and the heatsinks and suppliers at different situations around the year with summer season, winter season and spring/fall season. A suitable screen was purchased for the virtual demonstrator, as the project was added to an existing exhibition. The headphones and platform for the screen come from the existing inventory. For the pipe-demonstrator LED lights, power sources and additional material was purchased.

### 3.2.1.2 Virtual demonstrator

The following scenarios were developed, incorporating considerations for summer, winter, and spring/fall seasons, both with and without HHW integration:

#### 3.2.1.2.1 Scenario Summer:

- **Existing HHW:** The total heat demand in summer is the lowest, although the heat demand of the industry is rather constant over the year. Only the must-run waste incineration plant is in operation for heat supply. Companies feed waste heat into the HHW and thus support the heat supply. A seasonal storage is integrated to store excess heat. The average CO<sub>2</sub> footprint and marginal costs are the lowest.
- **No-built HHW:** Although the total heat demand is at its lowest, combined heat and power plants (gas, biomass) have to support the heat supply to cover peak demands. Reason:

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There is no HHW and thus companies can only partially feed waste heat into the local grid or not at all. This results in an unused waste heat potential and to an increase in the average CO<sub>2</sub> footprint and marginal costs.

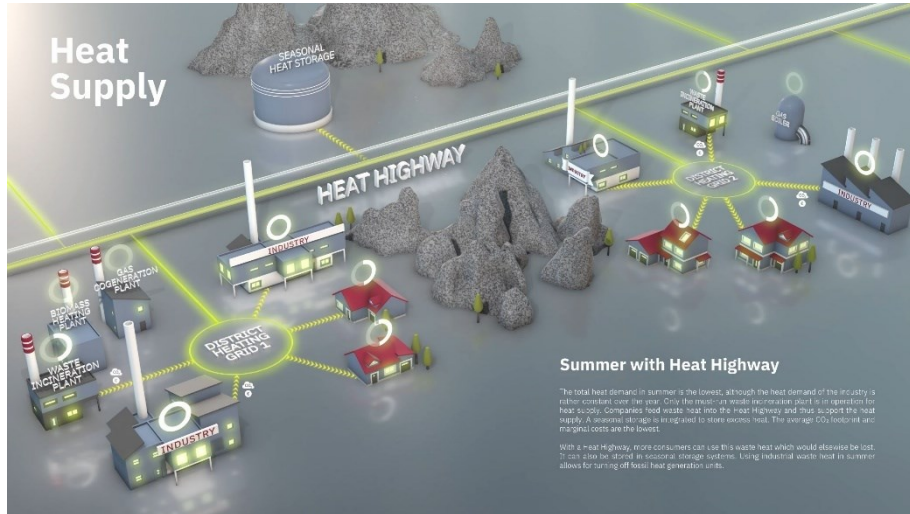


Figure 31: AEC Demo Heat Highway Summer Scenario existing Heat Highway

### 3.2.1.2.2 Scenario Transition:

- **Existing HHW:** Due to an increase in the heat demand of households, a medium heat demand exists. Whereas the must-run waste incineration plants are still in operation, companies providing waste heat and biomass fired combined heat and power plants are necessary to cover peak demands. The seasonal storage either supports in covering the peak demands or stores available excess heat. The average CO<sub>2</sub> footprint and marginal costs are on a medium level.
- **No-built HHW:** Without the HHW, an additional operation of the gas fired combined heat and power plant is required to cover the heat demand. This results in an increase of the average CO<sub>2</sub> footprint and marginal costs. In addition, an unused waste heat potential occurs, which could otherwise be integrated into the HHW. Compared to the HHW connection, the average CO<sub>2</sub> footprint and marginal costs become worse.

### 3.2.1.2.3 Scenario Winter:

- **Existing HHW:** The highest heat demand occurs in winter (sum from households and industry). Waste incineration, combined heat and power (gas, biomass), and industrial waste heat are necessary to cover the heat demand. The stored excess heat from the summer can be utilized now to support the heat supply. This results in a positive effect of the average CO<sub>2</sub> footprint and marginal costs.
- **No-built HHW:** Due to the highest heat demand in winter and the non-built HHW, the average CO<sub>2</sub> footprint of the heat supply is intense and costs are expensive. Companies can only partly feed into the local grid and an unused waste heat potential exists.

### 3.2.1.3 Prototype

A physical "Heat Highway" prototype was developed and constructed, incorporating the technical characteristics and requirements discussed. The prototype was exhibited at the at the Ars Electronica Center (AEC) in Linz. This prototype, in combination with a developed virtual demonstrator, showcases cutting-edge thermal energy technology and engineering innovation, offering visitors an engaging and interactive experience. Designed with key characteristics in mind, the prototype aligns with exhibition standards to effectively communicate the basic principles of sustainable district heating and raise awareness of heat supply. Its design enables visitors to easily comprehend the core concepts of sustainable district heating, emphasizing its critical role in modern energy systems and its potential to reduce environmental impacts. The prototype integrates the fields of energy engineering, research, and exhibition design, providing visitors with an optimal learning experience. This collaborative effort ensures that the prototype is both informative and accessible, making complex engineering concepts easy to understand and relatable for a broad audience.

In preparation for the design, construction, and installation of the demonstrator by Kremsmüller, it is crucial to establish the necessary framework conditions in collaboration with the AEC. The plan was to integrate the prototype into the "There is no planet B" exhibition. The following conditions were considered and discussed: positioning options, space requirements, dimensions, environmental considerations, logistics and accessibility, safety and compliance, integration with AEC infrastructure and visualization. This collaborative effort helped to determine the optimal location and setup for the demonstrator, ensuring it meets both practical and aesthetic requirements.

Based on the developed variants, two demonstrators were finally built, which also optimally fit in the exhibition "There is No Planet B."

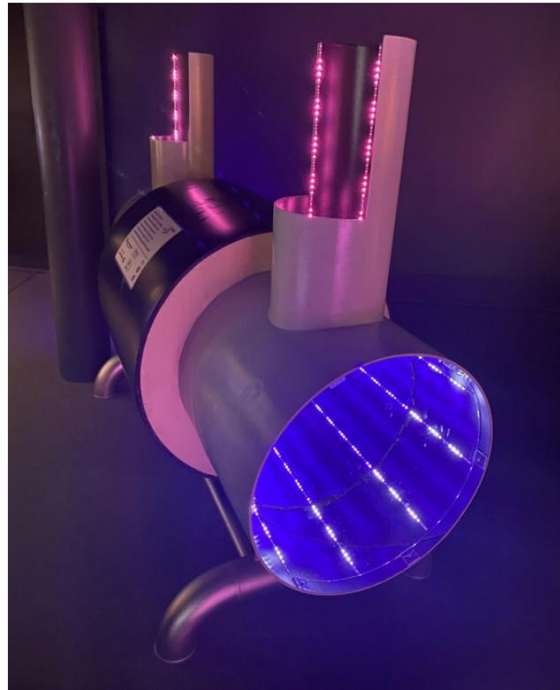


Figure 32: Demonstrator I at the AEC exhibition

The demonstrator itself includes several key components to illustrate the project concept:

- **Main heat transfer pipe (Heat Highway):** This serves as the primary pipe for transferring heat.
- **Feed-in of industrial waste heat:** This demonstrates how industrial waste heat is fed into the system.
- **Provision of process heat:** This section shows how the system provides heat for various industrial processes.
- **Section of heat transfer pipe structure:** A cross-sectional view of the pipe structure to explain its construction and functionality (pipe and insulation).
- **Feed into the district heating network:** This illustrates how heat is ultimately distributed into the district heating network.

### 3.2.2 Stakeholder participation & local involvement, Dissemination & international visibility

#### 3.2.2.1 Stakeholder participation & local involvement

Three workshops were conducted by partner BIZ, with a total of 69 participants.

##### 3.2.2.1.1 1<sup>st</sup> Heat Highway Workshop “Waste heat” at Business Upper Austria, 14.07.22

The main objectives of the workshop were to introduce the Heat Highway project, discuss the possibilities and challenges of industrial waste heat utilization, and provide a platform for experts and stakeholders to exchange ideas and experiences. The workshop aimed to bring together industry, academia, and policy-makers to facilitate collaboration and knowledge-sharing on the topic. The first session of the workshop focused on the theoretical and practical

aspects of operational-external use of industrial waste heat and the use of high-temperature steam-producing heat pumps for reusing waste heat in other companies. The second session was dedicated to practical examples of industrial waste heat utilization. After the expert-input presentations, the workshop provided a platform for discussions and exchange of ideas. The Heat Highway Workshop was a successful event that brought together experts and stakeholders from various fields and facilitated knowledge-sharing and collaboration among the participants. The discussions helped to identify potential solutions to the existing challenges and opportunities for further collaboration in this important area. The workshop was an excellent platform for networking and collaboration and helped to advance the goals of the Heat Highway project.

### *3.2.2.1.2 2<sup>nd</sup> Heat Highway Workshop “Summer sinks” at Business Upper Austria, 25.01.23*

In this workshop new insights into possible approaches in seasonal heat storage and usage were shown, namely summer sinks. It provided a platform for experts and stakeholders to exchange ideas and experiences. The workshop aimed to bring together industry, academia, and policy-makers to facilitate collaboration and knowledge-sharing on the topic, as well as the input of new expert knowledge into the consortium. After the expert-input presentations (on excess heat in summer, seasonal storage, waste heat for process heat, new and innovative concepts with absorption chillers, local heating networks as heat sinks in summer) the workshop provided a platform for discussions and exchange of ideas. The presentations brought new insights (feedback was great) to all participants and a lot of networking was done after the workshop.

### *3.2.2.1.3 3<sup>rd</sup> Heat Highway Workshop at Business Upper Austria, 25.06.2024*

The main objectives of the event were to present the results of the project and to bring all workshop participants up to the same level of knowledge. Additionally, the projects “Lessons learned” were collected, which provide valuable insights into which waste heat potentials could already be utilised technically and economically in the opinion of the companies and where there is still a need for further research and development

The **expert event** of the Ars Electronica Center "**Economic efficiency of energy storage**" held on 19.03.24, aimed to provide a platform for different energy storage areas to express their views, explain established and expected business models, present the economic viability in terms of costs and benefits, and discuss the requirements for economic establishment. During the event, the stakeholders also examined the demonstrator.

## **3.2.2.2 Dissemination & international visibility**

### *3.2.2.2.1 DHC+ Summer School*

From 25 to 30 August 2024, the 12th edition of the **DHC+ summer school** took place in Linz, focusing on "Industrial urban symbiosis as an enabler for climate-neutral district heating." The summer school was organised by Euroheat & Power in collaboration with the Energieinstitut an der JKU Linz. The event was designed to raise awareness of the main topic and make it

more approachable for participants. This year's edition brought together 40 participants from 21 countries and 33 different organisations. Throughout the immersive week, attendees gained valuable insights into the district heating and cooling sector, networked with peers, and learned from leading industry professionals and academics. The program encouraged collaboration and innovation, with lectures and workshops led by experts from DHC+ platform member organisations and Austrian partners.

The presentations covered a wide range of topics, starting with an introduction to district heating and cooling (DHC) including the current DHC situation in Austria. Further, relevant EU legislation and policy, industrial waste heat recovery, sector coupling and business models were presented. In addition, the lectures covered financing instruments, district cooling engineering, efforts to decarbonise DH systems, insights into the Austrian Heat Map, and the implementation of large-scale thermal energy storage solutions.

The summer school highlighted the project Heat Highway. In addition to the presentation by our experts on industrial waste heat recovery from existing and future processes, participants visited the Ars Electronica Center, the "museum of the future," to explore the Heat Highway virtual demonstrator and view the prototype first-hand.

### *3.2.2.2.2 International Workshop*

The online workshop "Heat Highway: Using Decarbonised Heat Sources via Supra-Regional Heat Networks" **online workshop** on 3rd March 2023 organised in the context of the international conference World Sustainable Energy Days ensured a wide dissemination of the project topics and international visibility. The workshop was attended by more than 50 participants and dedicated to the exchange of experiences with interregional heating networks in Europe. International speakers from Denmark (example Copenhagen) and the DHC+ Platform (Euroheat and Power) were part of the programme, thus contributing to the international visibility of the project.

### *3.2.2.2.3 International Conference*

Being part of the NEFI network offered manifold dissemination and networking opportunities at NEFI events (e.g. NEFI Technology Talks, Workshop 19th March 24). Especially the **second international NEFI conference** (13th-14th Oct. 2022, Linz), in which parallel sessions and workshops were included (e.g. IEA IETS Task 19 workshop), presented a unique opportunity for exchange and networking.

The Energy Institute at the JKU and the AIT delivered presentations at the international **Smart Energy Systems Conference 2023** in **Copenhagen** on the topic "How can industrial waste heat be used in district heating networks? Insights on effective project initiation and business models." and on the topic "Heat transmission network design optimization and robustness analysis for a case study in Tyrol – Methodology" The conference aims to serve as a platform for presenting and discussing both scientific findings and industrial experiences related to Smart Energy Systems. Over the years, it has evolved into a primary venue for impactful

presentations and stimulating discussions on the development and implementation of smart energy systems to meet national and international objectives.

### 3.2.2.2.4 *International Seminar*

The AIT held a seminar “**Séminaire Énergie - Environnement**” at the Université de Genève in March 2023 about “Risk minimization for decarbonizing heating networks via network temperature reductions: opportunities and challenges, Experience from Austria and outlook”. The seminar was for employees and students from the Université de Genève.

### 3.2.2.2.5 *Additional dissemination & broad visibility*

- Peer-reviewed scientific papers
- Scientific papers under review
- Doctoral thesis, master thesis, 6 bachelor theses
- Conference papers or posters
- Workshops, and presentations
- Award for innovation from the regional government of Upper Austria
- Broad visibility showcasing of the virtual demonstrator at the ARS Electronica Museum of future (guided tours, 1000s visitors (national & international) - visibility for the general public)

## 4 Outlook and recommendations

In particular, the following recommendations should be made for further research:

- Tools for the initial determination of techno-economic feasibility
- Tools for more detailed technical analysis
- Tools for detailed economic analysis
- Models for the description of the regional market including heat price and remuneration for reserve capacity

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## 6 Appendix

Attachments (Link):

- [Heat Highway - Review of Best Practice Examples](#)
- [Heat Highway - Control Algorithms \(general\)](#)
- [Heat Highway - Control Algorithms \(Use Case Linz\)](#)
- [Heat Highway - DH pipeline technologies](#)
- [Heat Highway - Follower Inntal \(Business Case\)](#)
- [Heat Highway - Follower Inntal \(Heat sinks and sources\)](#)
- [Heat Highway - Follower Innviertel](#)
- [Heat Highway - Further Followers](#)

## 7 Contact details

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<https://energieinstitut-linz.at/project/interregional-heat-transmission-networks-to-enable-industrial-waste-heat/>

### List of all project partners:

1. Energieinstitut an der Johannes Kepler Universität Linz
2. Allplan GmbH
3. Ars Electronica Linz GmbH & Co KG
4. Austrian Institute of Technology
5. Business Upper Austria
6. Energie AG OÖ Erzeugung GmbH
7. Energie AG OÖ Umwelt Service GmbH
8. eww AG
9. FH Oberösterreich F&E GmbH
10. Kremsmüller Anlagenbau GmbH
11. LAT Nitrogen Linz GmbH
12. Linz Strom Gas Wärme GmbH
13. MU Leoben – Lehrstuhl für EVT
14. OÖ Energiesparverband
15. Primetals Technologies Austria GmbH
16. voestalpine Stahl Donawitz GmbH
17. voestalpine Stahl GmbH