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The Production of Cloud
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Waste Heat

The Value of Heat: From Waste to a Collective Spatial Resource

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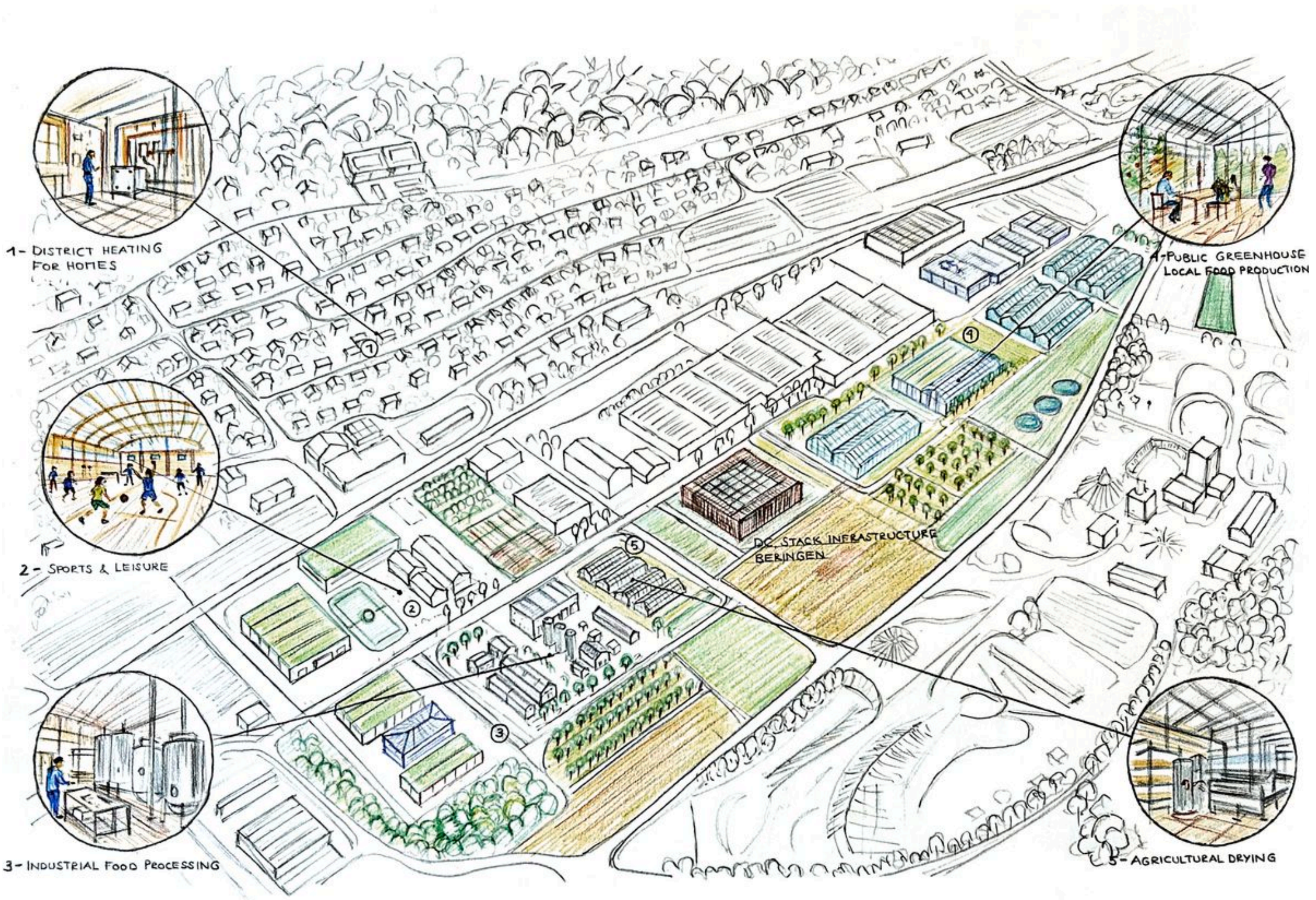
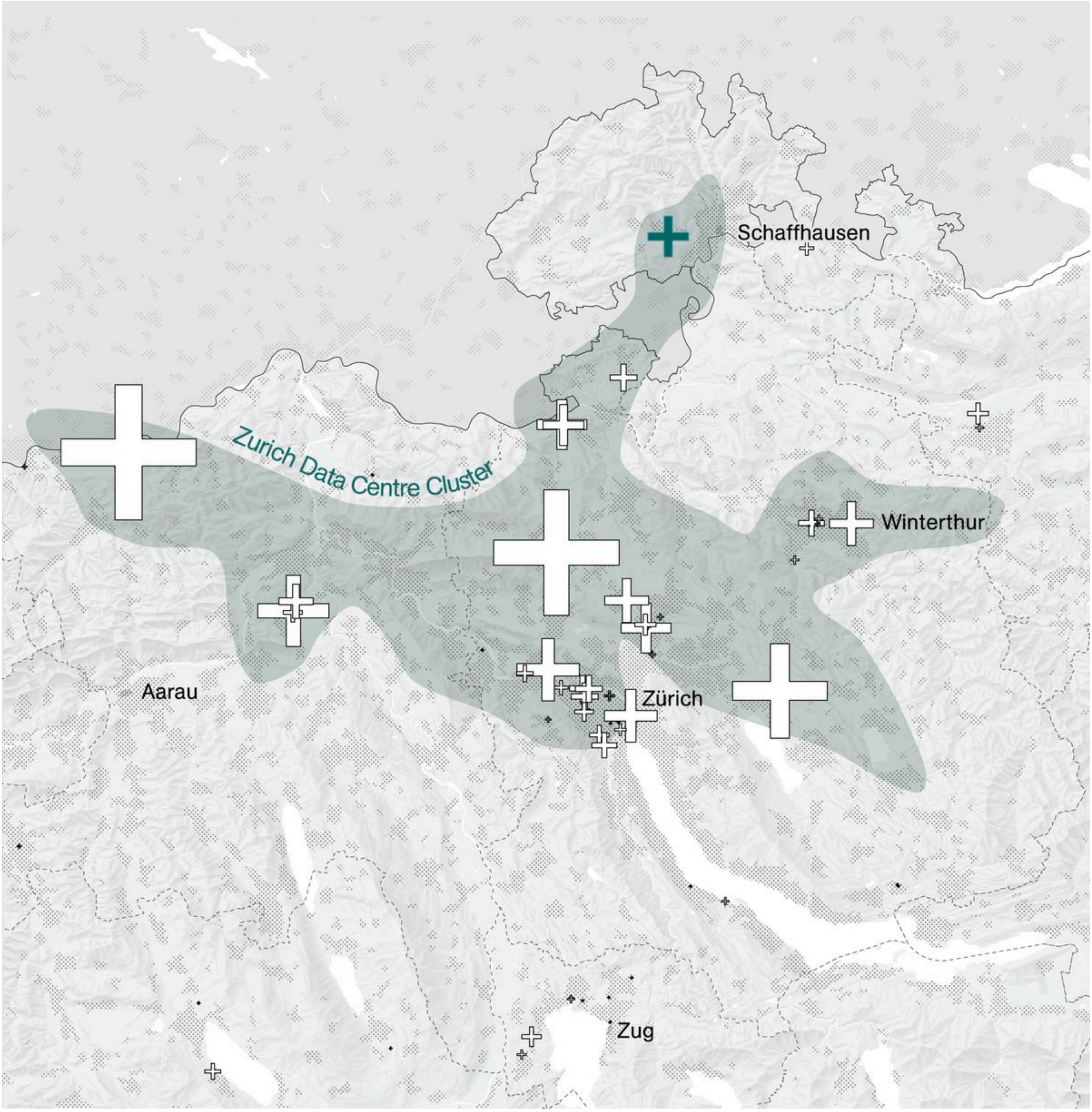


Waste heat is often treated as an invisible byproduct of data centres. Based on the case study of Beringen, Canton of Schaffhausen, this project explores how waste heat could become a shared spatial resource connected to local production, public life, and ecological processes.

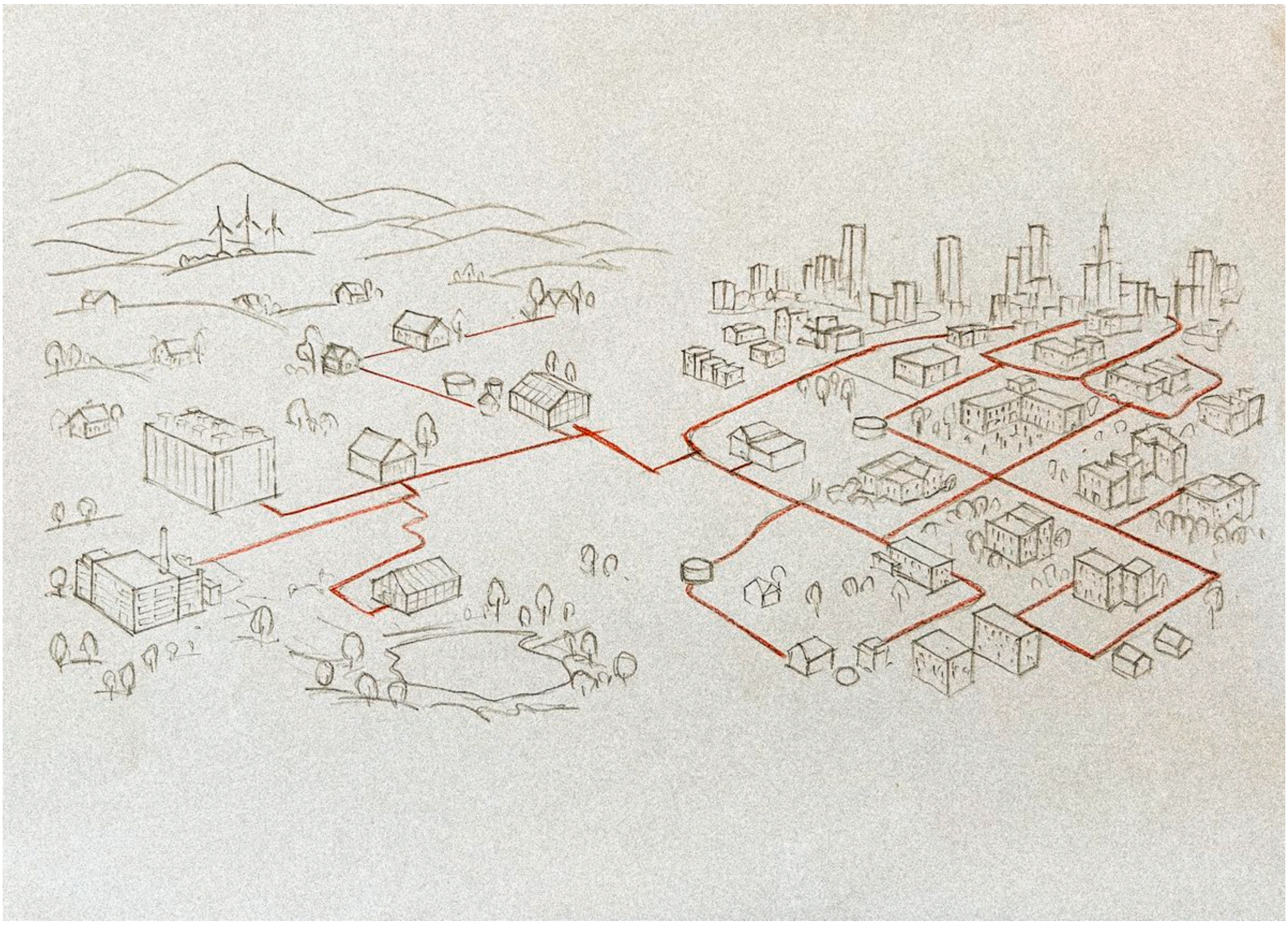
The research examines how distance, density, and infrastructure shape thermal networks across rural, peri-urban, and metropolitan territories. While metropolitan areas benefit from dense infrastructures and concentrated demand, rural territories such as Beringen face very different spatial conditions and challenges.

Based on these observations, the project proposes interconnected thermal systems linking data centres, agriculture, industry, and collective infrastructures. Through local reuse, storage, and clustered networks, waste heat becomes integrated into landscapes, local production, and everyday life.



Name Data Centre: STACK Infrastructure, ZRH 2
Commune: Beringen, SH
Type Data Centre: Hyperscale
Capacity: 36 MW
Operator: STACK Infrastructure
Year: Expected completion in 2027
Status: In planning
Energy Demand: approx. 350 GWh/year
Waste Heat Use: Planned district heating

Beringen and Glattbrugg: Two Concepts of Heat Distribution



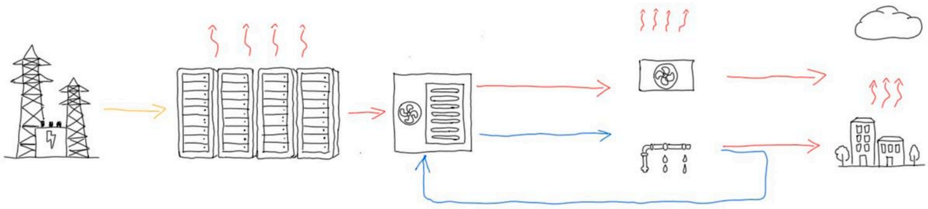
Whether and how waste heat from data centres or similar infrastructures is utilised depends heavily on the geographic context. In rural areas, long distances and dispersed settlements complicate heat distribution. Conversely, urban environments feature dense infrastructure and a high concentration of potential consumers, greatly facilitating the process. These spatial mismatches frequently prevent local waste heat reuse and its integration into everyday life.

How Data Centres Generate Waste Heat

The diagram illustrates how waste heat is generated within the data centre itself. Electricity powers the IT hardware, which continuously produces heat during operation. Cooling systems absorb this heat and transport it through warm and cooled water flows. Today, a large part of this heat is still released into the environment, while only a smaller part is reused through heating systems and local networks.

When related to the local context, another mismatch becomes visible. The amount of available waste heat exceeds the local heat demand in Beringen and even surpasses large parts of the demand in Schaffhausen. The challenge is therefore not only how much heat exists, but where it is produced, distributed and needed.

Waste heat therefore becomes a territorial question shaped by distance, infrastructure and the spatial organisation of supply and demand.



Generation of waste heat.

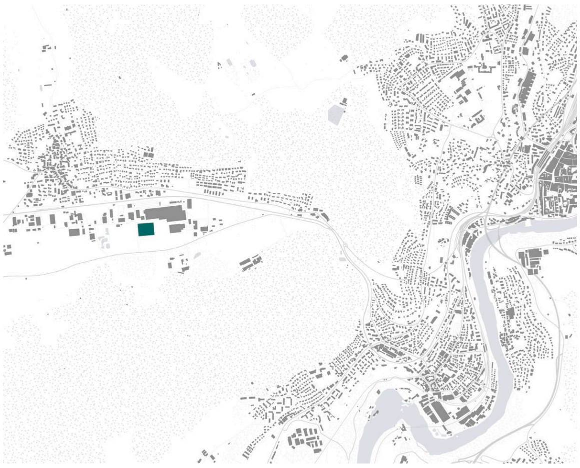
Data Centre Beringen

In Beringen, a small municipality nearby Schaffhausen, large-scale infrastructures meet agricultural and suburban landscapes. The data centre is located between industrial areas, open fields, and residential neighbourhoods.

The data centre is connected with Neuhausen and the city of Schaffhausen while remaining largely disconnected from its immediate surrounding, as an isolated technical object in the landscape.

To better understand these spatial relations, we documented the data centre and its surroundings through field observations and video recordings.

Aerial view of Beringen.
Source: Public Domain, 2009.



Site plan and future location of the STACK data centre in Beringen.

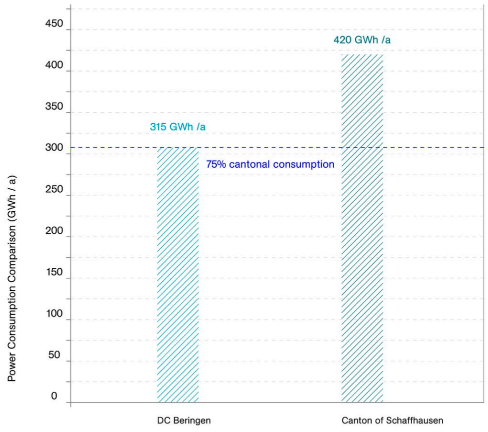
Data Centre Beringen: An Isolated Object in the Landscape, video essay, 2026.
https://www.youtube.com/watch?v=-9YrsU5KSaE

What becomes visible in Beringen is a landscape in which the data centre is present, but still largely disconnected from its surrounding territory. The data centre consumes land, electricity, and water at a scale that directly impacts its local context.

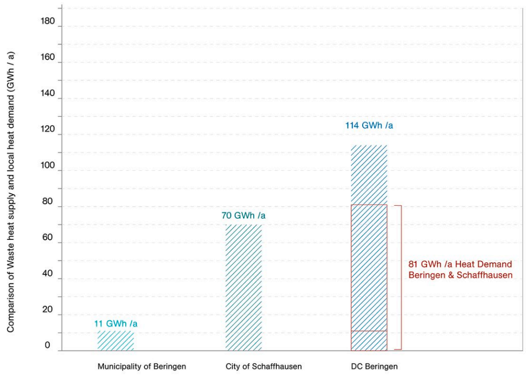
This raises a larger territorial question: since data centres operate at this scale, how can they return value to the landscapes and communities in which they are embedded?

At the same time, data centres are increasingly promoted as contributors to the energy transition through the reuse of their waste heat in district heating networks.

Yet, the scale of this system reveals a strong imbalance. The data centre alone consumes almost 75 % of the cantonal electricity demand—while most of this energy is ultimately transformed into heat—however, a large part of this future waste heat potential is expected to remain unused.



Power consumption of data centre Beringen in relation to the Canton of Schaffhausen. The data centre will consume 75 % of the total cantonal electricity consumption. Source: Amstein + Walthert, 2022.



Waste heat potential of the data centre Beringen in relation to the City of Schaffhausen and the Municipality of Beringen. The data centre could meet the demand of both. Source: Amstein + Walthert, 2022.

Data Centre Beringen: Why Waste Heat Remains Unused

Data Centre Beringen: The Complexities of Waste Heat Reuse, video essay, 2026.

https://www.youtube.com/watch?v=N5E5kJMdrUM

We interviewed energy providers, planners, and local authorities involved in the development of the system to understand the current state of waste heat reuse of the data centre in Beringen.

We found out that the reuse of waste heat is not only a technical challenge, but also a spatial and organisational one. Although the involved actors are working around and for the same issue, each of them approaches it from a different perspective and with different goals/incentives.

Based on the interviews, we were able to define four main reasons, why large amounts of waste heat still remain unused today: a spatial mismatch, an infrastructural gap, a seasonal mismatch, and a governance gap.

A SPATIAL MISMATCH

The spatial mismatch becomes visible through the distance between heat production and demand. While the data centre is located within an industrial area in Beringen, the highest heat demand is concentrated in Schaffhausen and Neuhausen.

Existing district heating networks currently operate at a local scale. Connecting these separate systems would require new transmission lines, larger infrastructural networks and additional storage systems across the territory.

The proposed Energy Hub illustrates the scale of intervention needed to connect production, storage and consumption beyond municipal boundaries.

A spatial mismatch: the data centre Beringen is located at a distance from potential consumers in Schaffhausen and Neuhausen.

STACK data centre

Heat demand

Proposal for an energy hub system, overcoming the spatial mismatch.
Source: Renercon, 2026.

Energy Hub System
STACK Data Center
Seasonal Storage
Heating Central
Main Transmission Line Schaffhausen
Heat Supply Line
Local Transmission Line Beringen

AN INFRASTRUCTURAL GAP

Currently, there does not exist a heat network connection between Beringen, Schaffhausen, and Neuhausen. A new transmission line would have to be built.

An infrastructural gap: currently, there does not exist a heat network connection between Beringen, Schaffhausen, and Neuhausen.

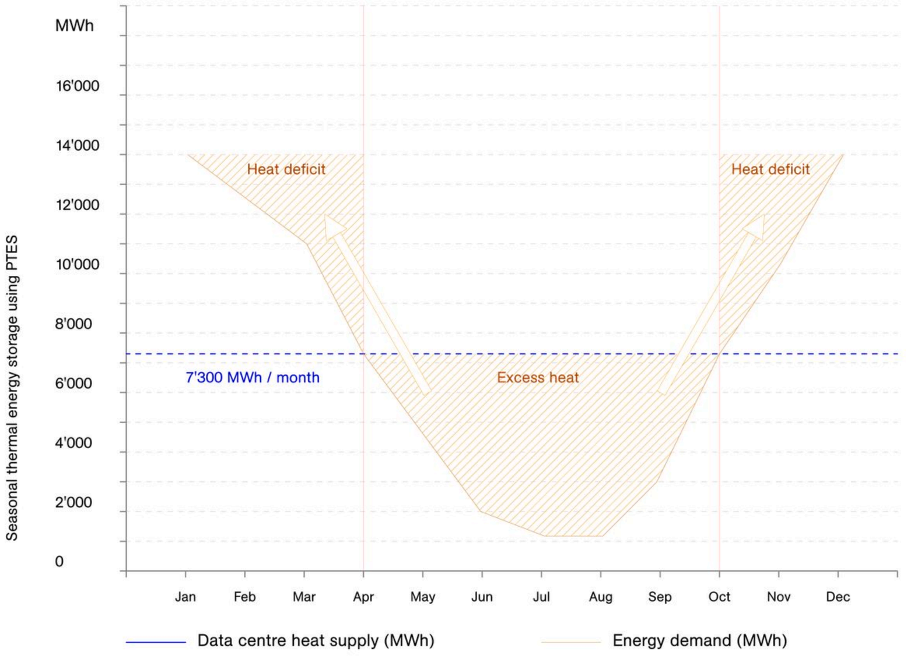
STACK data centre | Existing district heating | Heat demand

A SEASONAL MISMATCH

Heat demand changes seasonally, reaching its peak during winter, while waste heat from data centres is produced continuously throughout the year.

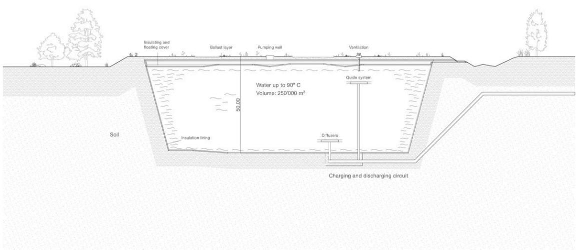
During summer, large amounts of surplus heat remain unused. Seasonal storage systems such as PTES make it possible to store this excess heat underground and reuse it during colder periods.

Rather than understanding storage only as technical infrastructure, the project interprets these systems as territorial and landscape interventions integrated into the surrounding environment. Existing examples in Denmark already demonstrate how seasonal storage can support larger district heating networks.



A seasonal mismatch: during the summer months, the need for heating is lower compared to the winter months, which creates a seasonal mismatch. Source: Renercon, 2026.

To overcome the seasonal mismatch, storage systems for the heat have to come into place, like this example of a seasonal storage PTES in Denmark. Source: Aalborg CSP, 2026.



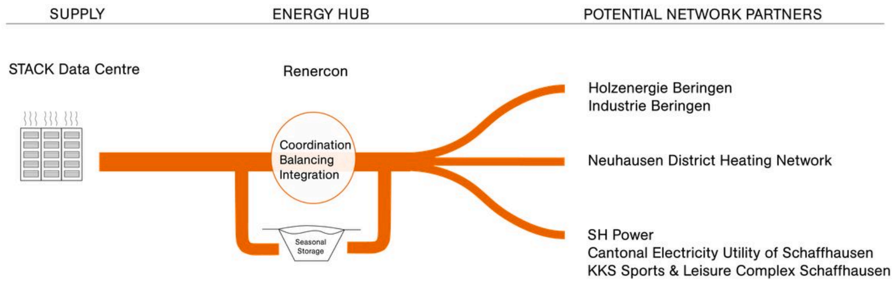
Section of a seasonal storage system. Source: Renercon, 2026.

THE GOVERNANCE GAP

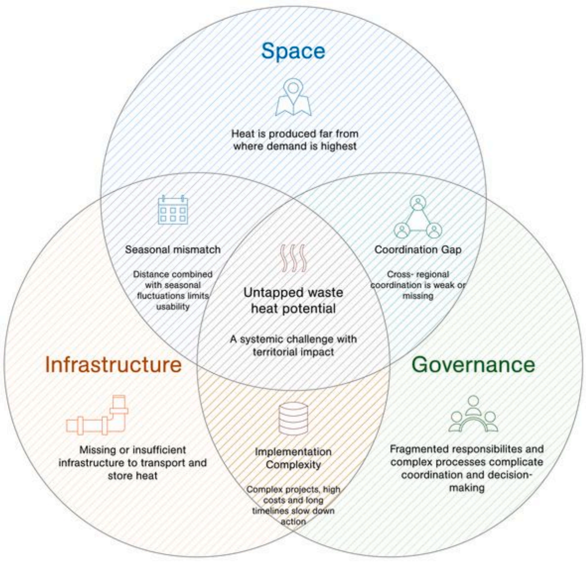
A large number of actors is involved in the system, operating with different responsibilities, interests and timeframes: energy providers, municipal utilities, public authorities, private companies, and the data centre operator.

While heat production and demand are closely connected spatially, their organisation remains fragmented. No single actor is responsible for coordinating the system across the territory.

As a result, responsibilities remain unclear, coordination becomes complex and the implementation of new thermal infrastructures slows down significantly.

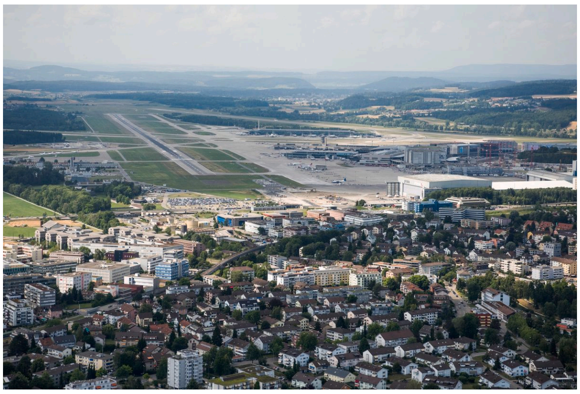


A large number of actors is involved in the project, operate with different responsibilities, interests, and timeframes: energy providers, municipal utilities, public authorities, private companies, and the data centre operator. Source: Renercon, 2025.



Data centre Beringen: why does waste heat remain unsued? It is precisely the confluence of a spatial mismatch, an infrastructural, and a governance gap that causes large amounts of waste heat to remain unused. Diagramme: the authors, 2026.

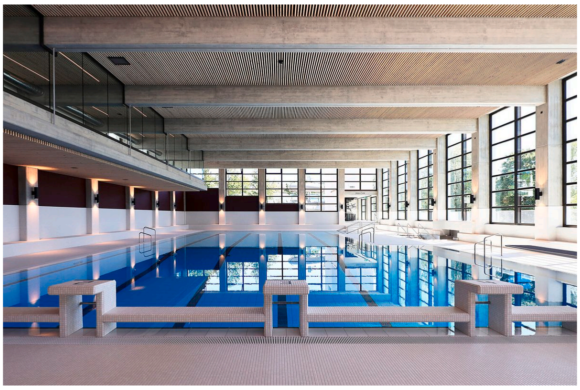
Data Centres Glattbrugg: Waste Heat Use Under Metropolitan Conditions



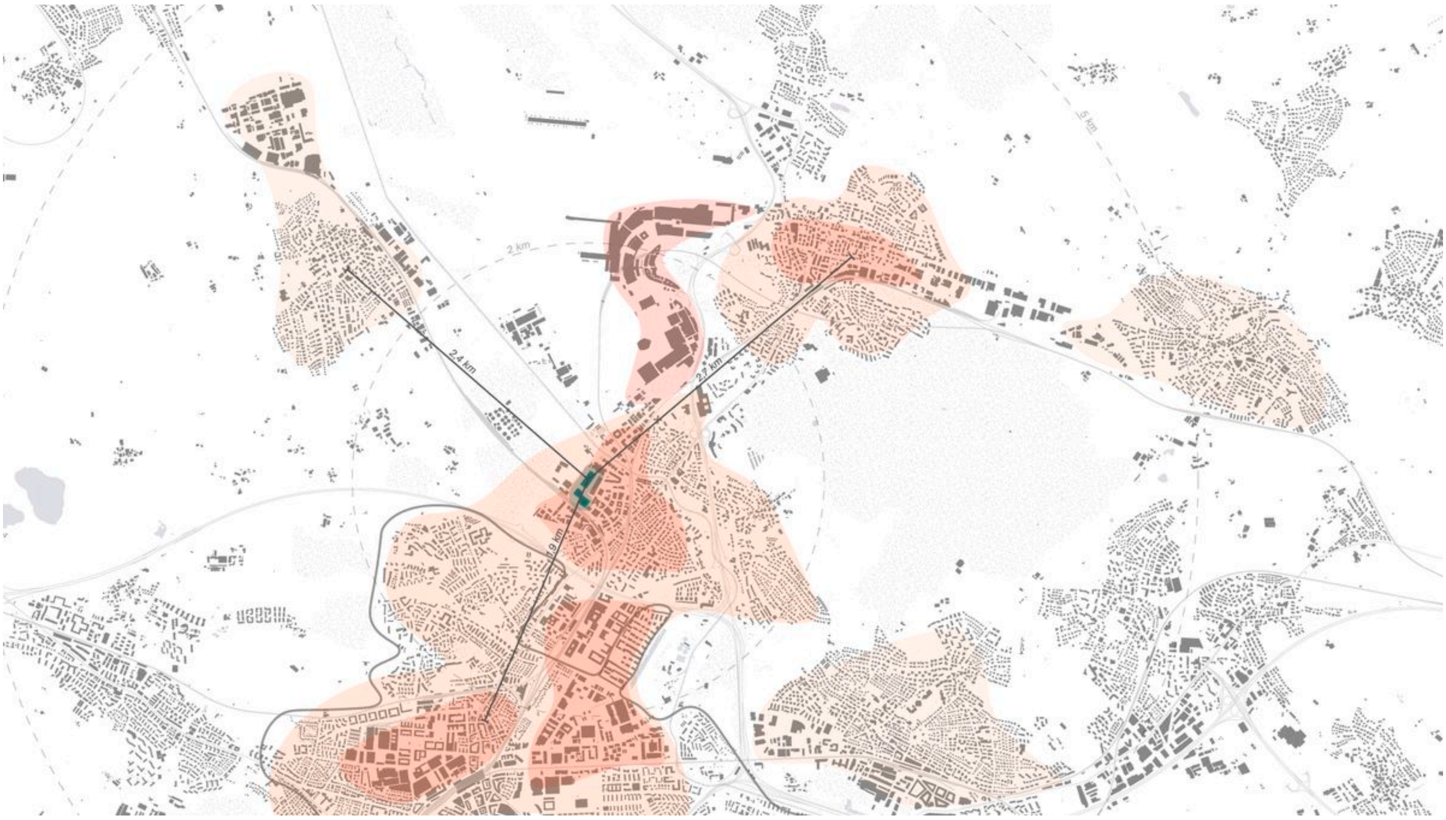
To compare the agricultural condition of Beringen, the research also looks at Glattbrugg as a representative metropolitan condition. Unlike Beringen, Glattbrugg already contains dense urban structures, concentrated heat demand and existing district heating systems. The area is connected to Zurich Airport, industrial zones and existing energy networks. Source: Tagesanzeiger, 2025.

Several large heat producers are located within a relatively small area, including data centres, waste incineration plants and other energy infrastructures. Photograph: Gruner&Friends, Basel.

At the same time, the surrounding urban areas create a continuous heat demand through housing, offices, industry… Glattpark. Source: Max Maurer, 2023.



…and public buildings: indoor swimming pool Glattbrugg. Source: RLC Architekten, 2020.



In Glattbrugg, the distances between heat production and consumers are much shorter and more efficient. Existing district heating systems already connect energy production and urban demand. Map: the authors, 2026.

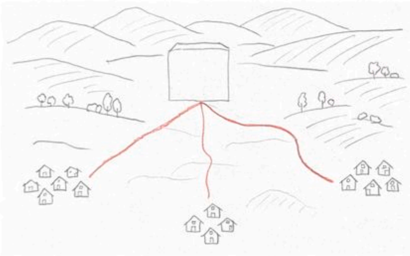
- Digital Realty data centres
- Heat demand
- Existing district heating networks (KVA)

Comparing Beringen with Glattbrugg

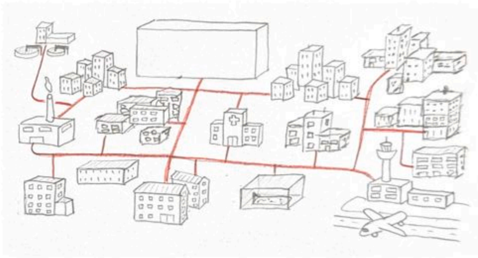
The comparison between Beringen and Glattbrugg reveals two different territorial conditions for waste heat distribution: rural territories operate through scattered settlements, fragmented systems, and long transmission distances. Metropolitan territories instead function through concentrated demand, dense infrastructures, and shorter distribution networks.

These territorial differences influence how waste heat can be produced, exchanged, stored, and distributed. Different territorial conditions therefore require different heat distribution systems.

AGRICULTURAL

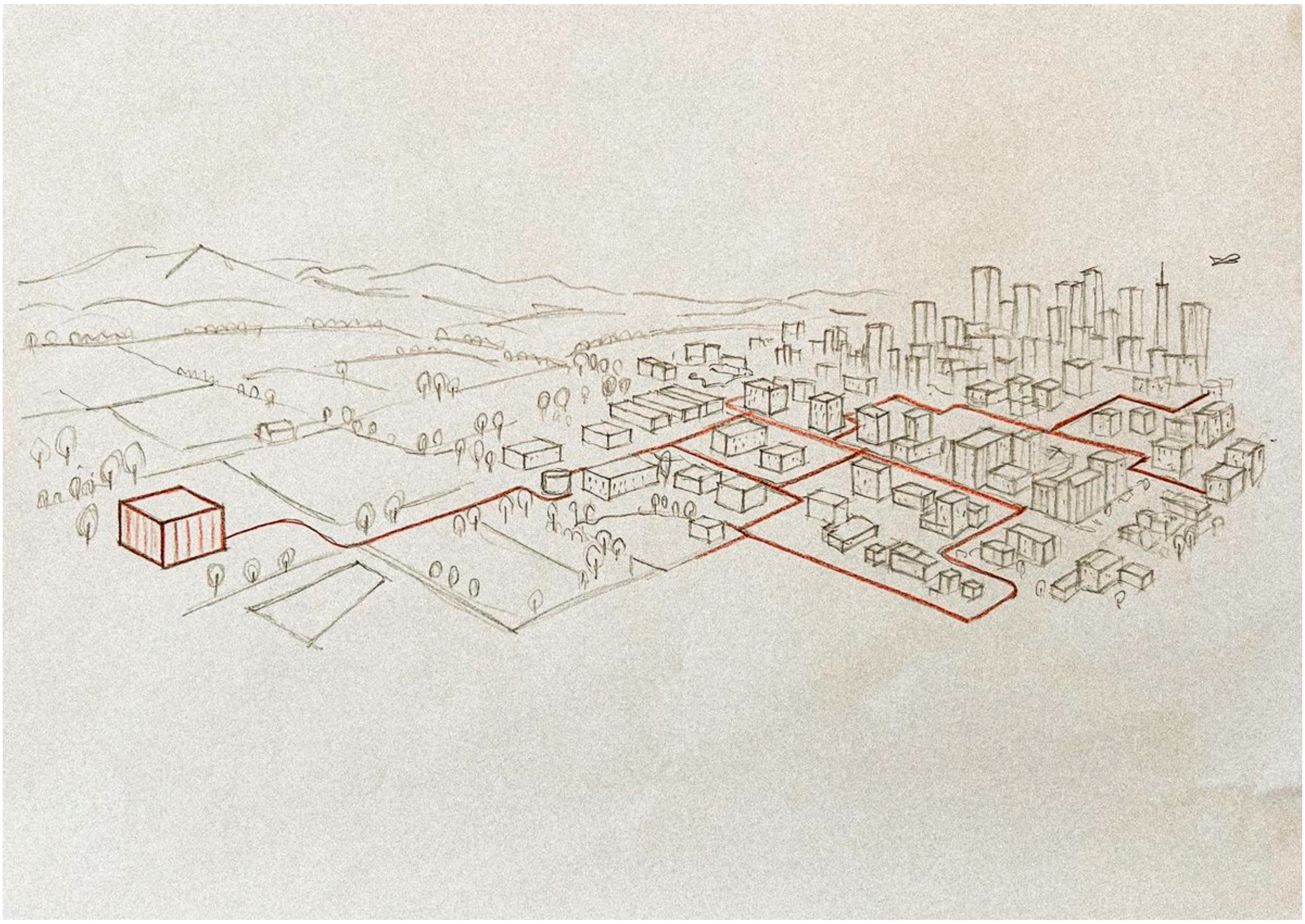


URBAN



SPATIAL DENSITY	low density	high density
SETTLEMENT STRUCTURE	scattered settlements	concentrated demand
NETWORK STRUCTURE	few connection points	central infrastructures
DISTRIBUTION DISTANCE	long distances	short distances
THERMAL EFFICIENCY	high heat losses	efficient distribution
SYSTEM DEPENDENCY	difficult coordination	dependence on central systems

Spatial Relationships in Heat Distribution

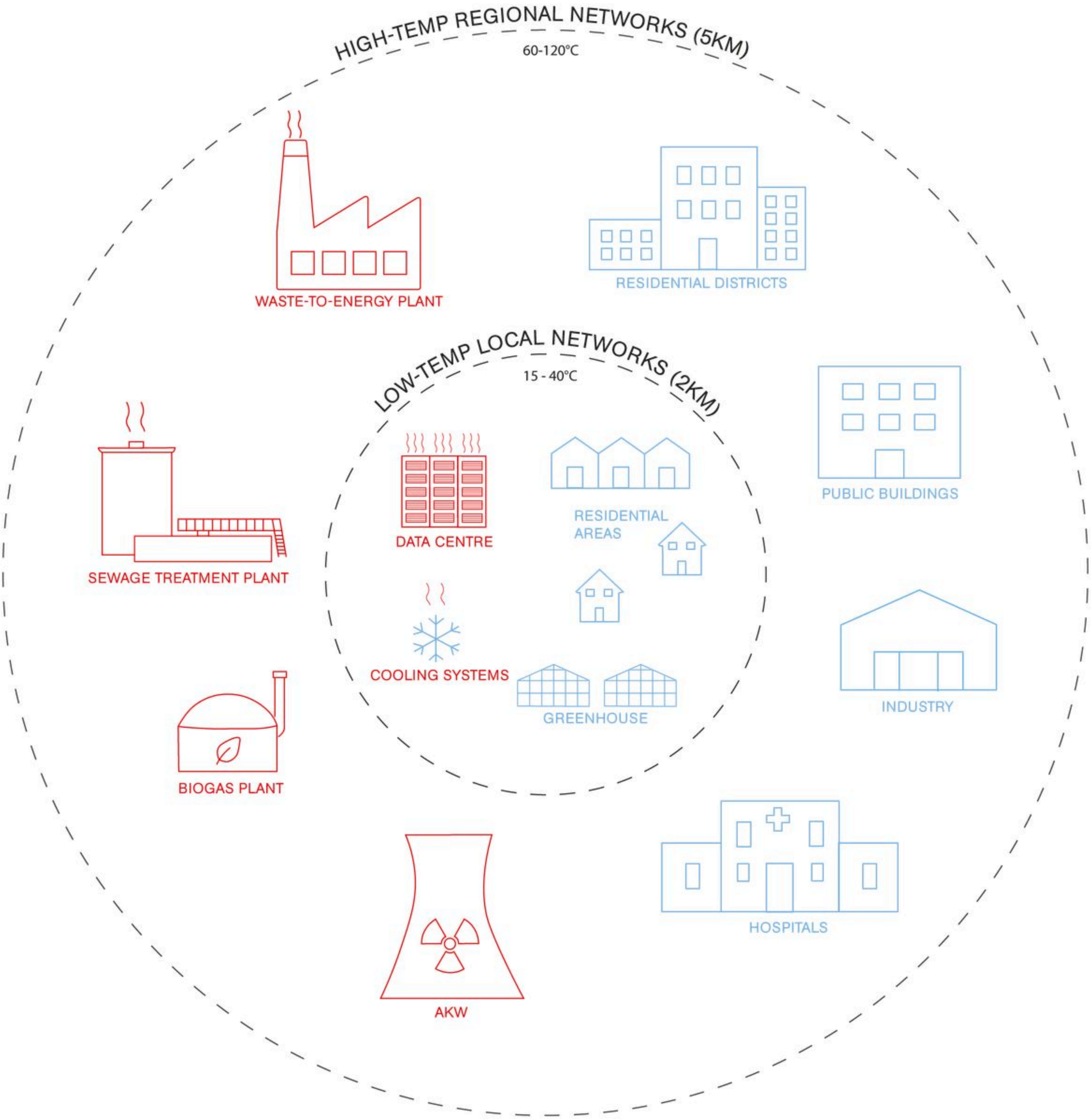


Density of end consumers, distances between producer and consumer, and existing infrastructures influence how and if heat is stored and distributed. While local systems often operate at a small scales, metropolitan areas rely on large and interconnected networks. Each thermal scale creates different spatial conditions and requires different forms of distribution and exchange.

Different heat producers generate different quantities and temperatures of waste heat. Data centres, waste incineration plants, sewage treatment plants, biogas facilities, and industrial infrastructures operate at different scales and capacities.

At the same time, heat consumers also vary depending on their thermal demand. Housing, industry, hospitals, food production, greenhouses, and public buildings all require different quantities and temperatures of heat.

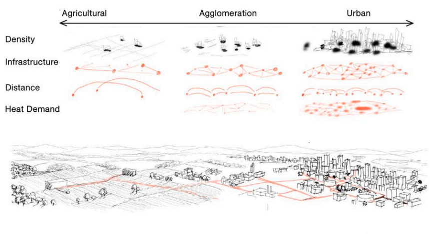
Low-temperature local networks mainly operate within shorter distances of around 2 kilometres, while larger high-temperature regional systems can extend up to approximately 5 kilometres. Beyond this distance, heat losses increase and distribution often becomes economically inefficient.



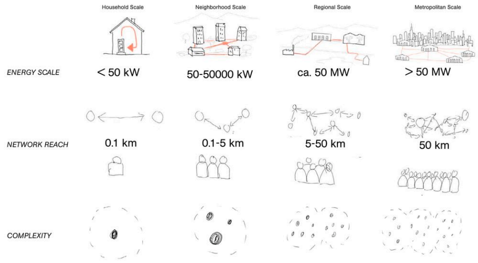
The 2 km and 5 km radii illustrate the approximate reach of different heat distribution systems. While local low-temperature networks mainly operate within shorter distances, larger regional systems can extend further through existing district heating infrastructures. Source: Own Map, 2026.

Heat producers

Heat consumers



Comparing different scales of waste heat distribution from household and neighbourhood systems to regional and metropolitan networks reveals that each system operates within different distances, infrastructures, and territorial conditions. Waste heat distribution therefore depends strongly on proximity, density, infrastructure and distance. Drawing: the authors, 2026.



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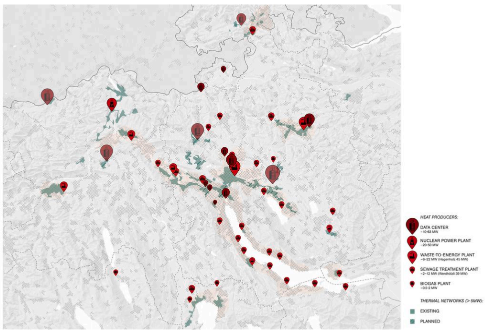
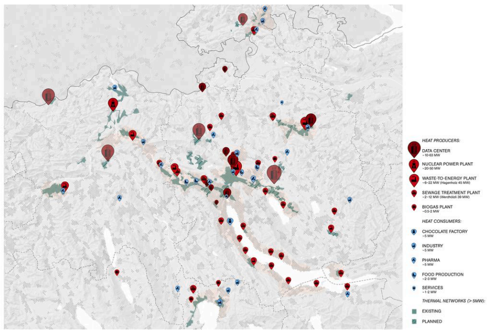
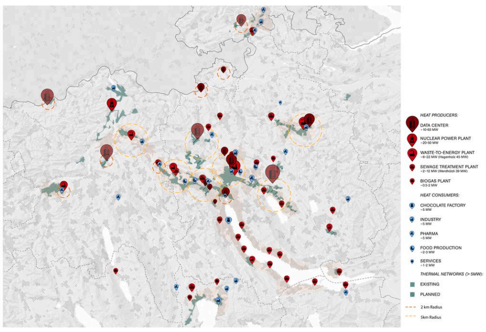
Spatial Heat Exchange Potentials



Industrial waste heat producers. Drawing: the authors, 2026. Source: geo.admin, 2026.



Industrial waste heat producers and consumers. Drawing: the authors, 2026. Source: geo.admin, 2026.



Spatial relationships between heat producers, consumers, and network reach. Drawing: the authors, 2026. Source: geo.admin, 2026.

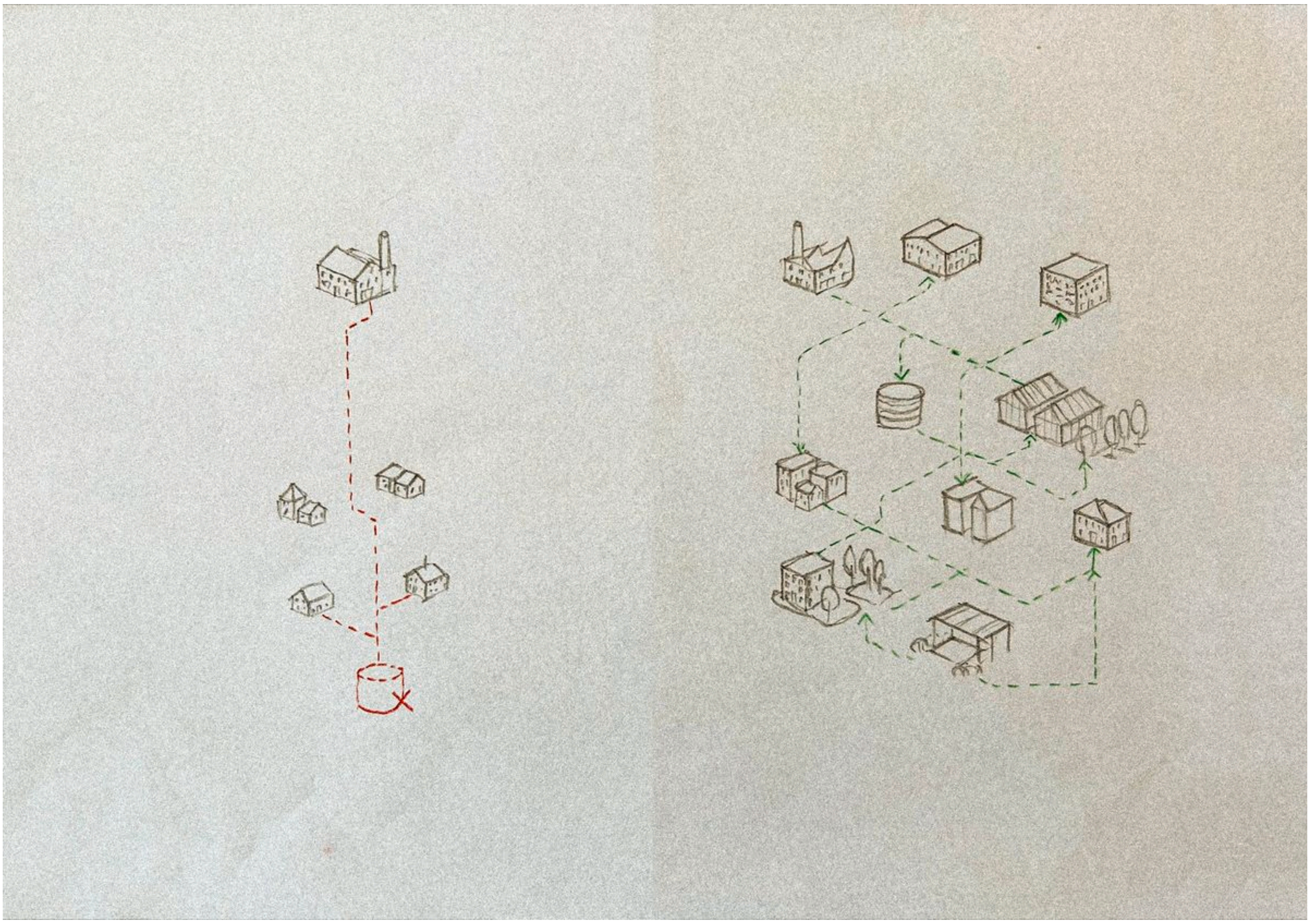
Design Hypothesis

The research proposes a shift in perspective. Waste heat should no longer be understood as an technical byproduct, but as a shared spatial resource capable of connecting infrastructure, settlement, agriculture, industry, and public life.

Based on these findings, the design hypothesis proposes that future data centre clusters should operate through interconnected and resilient heat networks adapted to different territorial conditions and scales.

Rather than relying on one universal system, waste heat distribution should support distributed and locally adapted thermal networks connecting local, regional, and metropolitan territories.

From Fragmented to Connected Heat Distribution Networks



Resilient thermal systems rely on connections between different producers, storage systems, and users. Instead of isolated infrastructures, clustered networks allow heat to be shared across neighbourhoods, civic infrastructures, and productive landscapes. By connecting multiple systems and scales, thermal networks become more adaptable, flexible, and collectively resilient.

The project proposes a shift from fragmented and isolated heat systems towards interconnected and resilient thermal networks. Waste heat from data centres, industry, and waste incineration plants should no longer be understood as a technical byproduct, but as a shared spatial resource connected to settlement, local activities and everyday life.

Based on this thesis, the project defines four main principles:

FIRST, waste heat should support local heat networks connected to housing, agriculture, industry, public programmes, and storage systems.

SECOND, waste heat distribution should operate across multiple scales from household and neighbourhood systems to regional and metropolitan networks.

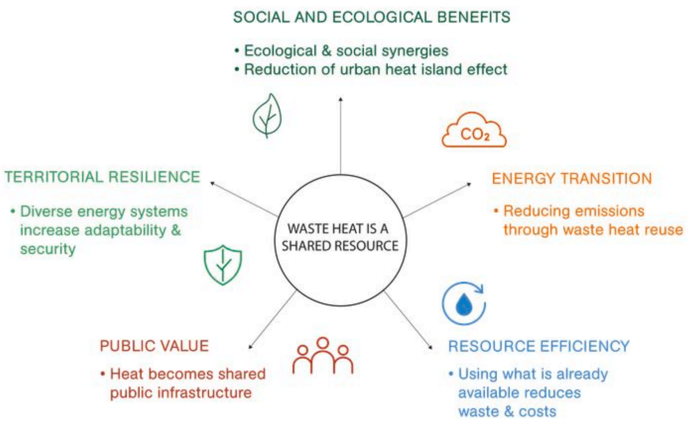
THIRD, thermal systems should become more resilient through diversified producers, diversified users, and seasonal storage systems capable of balancing changing heat demand over time.

FINALLY, future thermal systems should become interconnected, adaptable and integrated into existing territorial conditions rather than operating as isolated technical infrastructures.

Waste Heat as a Shared Resource

Waste heat can support the energy transition, improve resource efficiency and create public value through housing, agriculture, industry and public buildings. Interconnected thermal systems can further strengthen resilience through diversified producers, storage systems and shared infrastructures.

Waste heat can also create ecological and social benefits by supporting local food production, reducing urban heat island effects and enabling new forms of collective spatial use. Waste heat therefore becomes a spatial connector between infrastructure, settlement, and everyday life.



Potentials of collective waste heat reuse. Drawing: the authors, 2026.

Towards Connected Thermal Territories

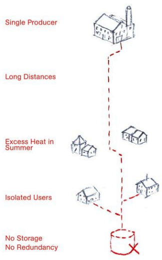
Today, many heating systems still operate through isolated infrastructures. Individual buildings often depend on separate oil, pellet, or heat pump systems with a one-sided relationship between one producer and one consumer.

Existing district heating systems already support more collective forms of heat distribution, often connected to waste incineration plants or industrial infrastructures. Many systems still rely on relatively centralised heat production with limited integration of multiple producers, storage systems, and diversified consumers.

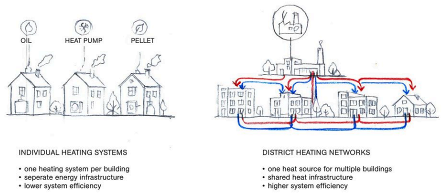
At the same time, waste heat reuse is increasingly included in the planning of data centres across Switzerland, including the data centres of Beringen, Volketswil, and Winterthur. However, many of these systems are not yet operational, as several data centres are currently under construction and the necessary heat networks are under development.

The case of Beringen shows that even the planned connection towards Schaffhausen and Neuhausen would not be able to fully absorb the entire waste heat potential of the future STACK data centre. Current planning proposals therefore also include large seasonal storage systems. Without storage and regional heat connections, the large amount of continuously produced waste heat could not be used efficiently. These systems can still suffer from long transport distances, excess heat during summer, and limited flexibility. As a result, large amounts of waste heat may still remain unused.

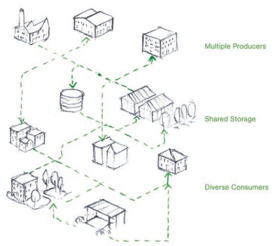
The proposal therefore explores how future thermal systems could become more interconnected through networks linking multiple producers, consumers, and storage systems. Connected systems increase flexibility, redundancy, and resilience while reducing heat losses through shorter and more efficient exchanges.



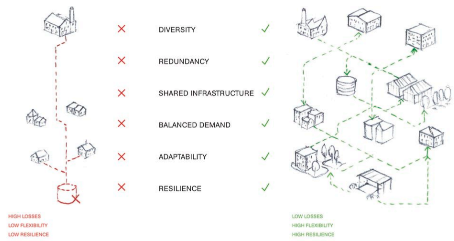
Isolated waste heat distribution network. Drawing: the authors, 2026.



Comparison of heat distribution systems. Drawing: the authors, 2026.

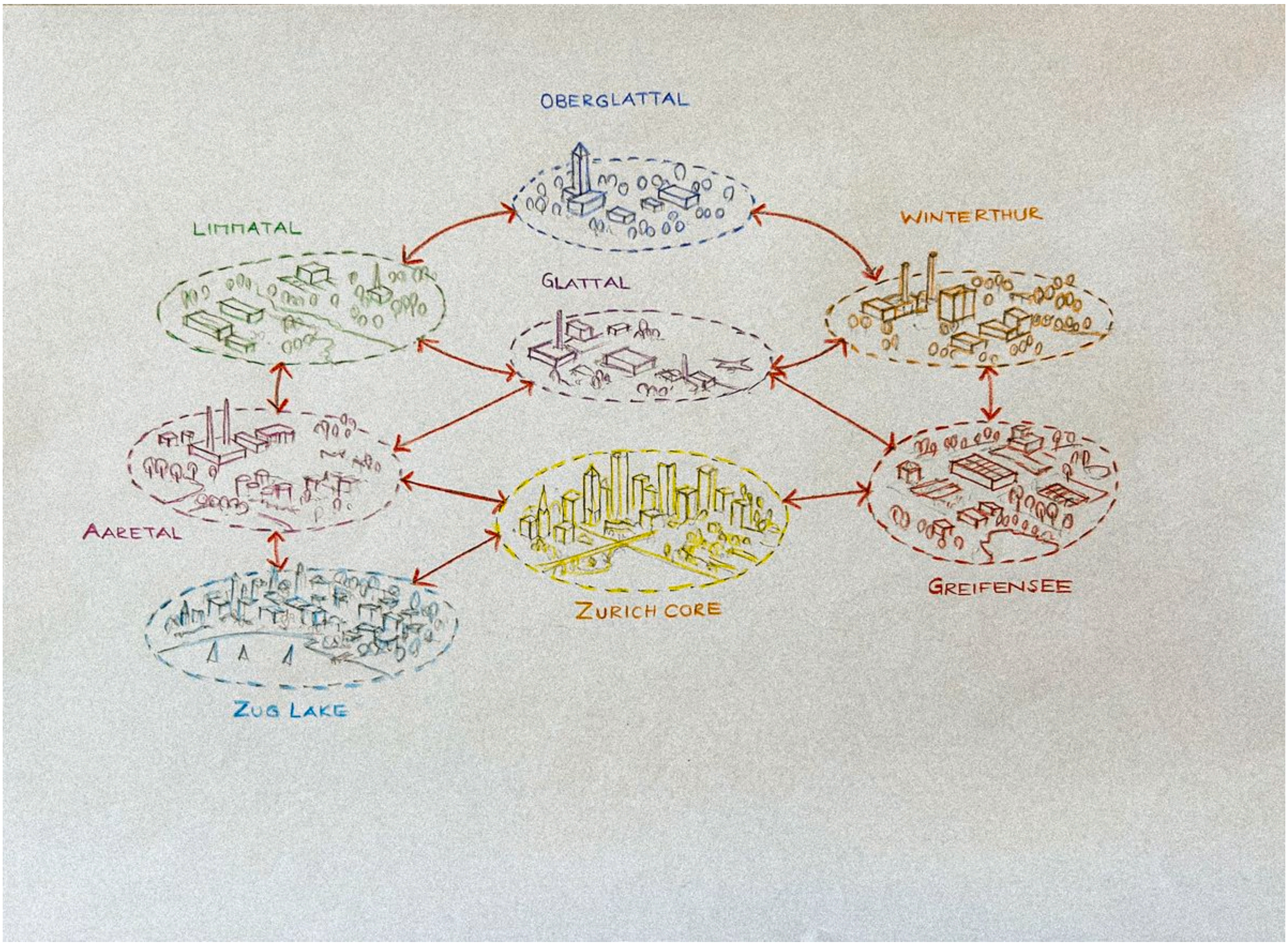


Connected waste heat distribution system. Drawing: the authors, 2026.



Comparison of spatial relationships in isolated and connected waste heat distribution systems. Drawing: the authors, 2026.

The Zurich Data Centre Cluster as a Resilient Thermal Ecology



The future cloud is no longer a hidden infrastructure operating in the background, but becomes part of everyday life through a waste heat network. Beyond technical efficiency, thermal networks can create new forms of collective space, ecological integration, and territorial resilience.

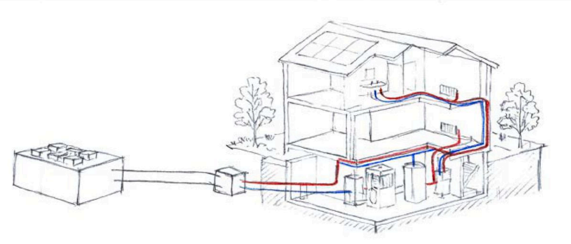
The project proposal develops waste heat distribution across four scales: household, neighbourhood, regional, and metropolitan systems.

Household systems support local reuse in the case of home servers with minimal transport losses and high user autonomy, but remains limited in scalability and heat volume.

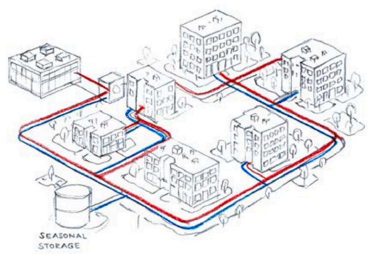
Neighbourhood systems increase resilience through shared loops, local storage, and shorter distribution distances. Heat is shared between several users.

Regional systems allow diversification, balance, and seasonal storage across larger territories. Larger networks require coordination between different producers, consumers, and infrastructures.

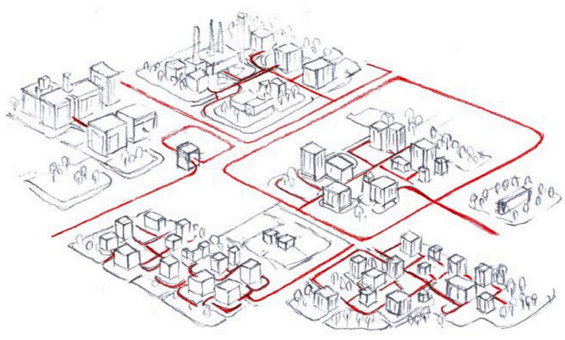
Metropolitan systems optimise efficiency through collective networks and stable year-round demand. At the same time, they require large investments and can become dependent on centralised infrastructures.



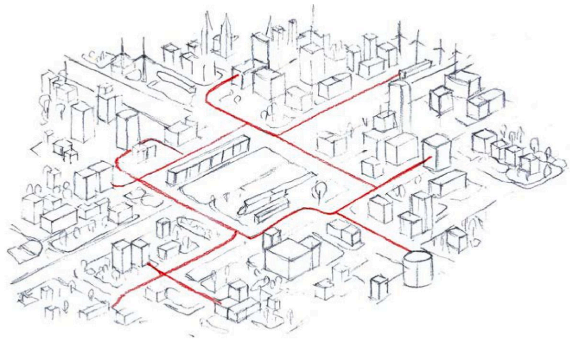
HOUSEHOLD SCALE
Autonomy—direct reuse of waste heat—low temperature
Pro: minimal transport losses, high user autonomy, simple and low cost. Cons: Limited scalability and heat volumes, dependency on constant heat supply. Drawing: the authors, 2026.



NEIGHBOURHOOD SCALE
Resilience—Anergie/district heating network—low/medium temperature
Pros: High resilience through redundancy, efficient local reuse, low distribution losses. Cons: limited scalability beyond the neighbourhood, dependent on local density. Drawing: the authors, 2026.

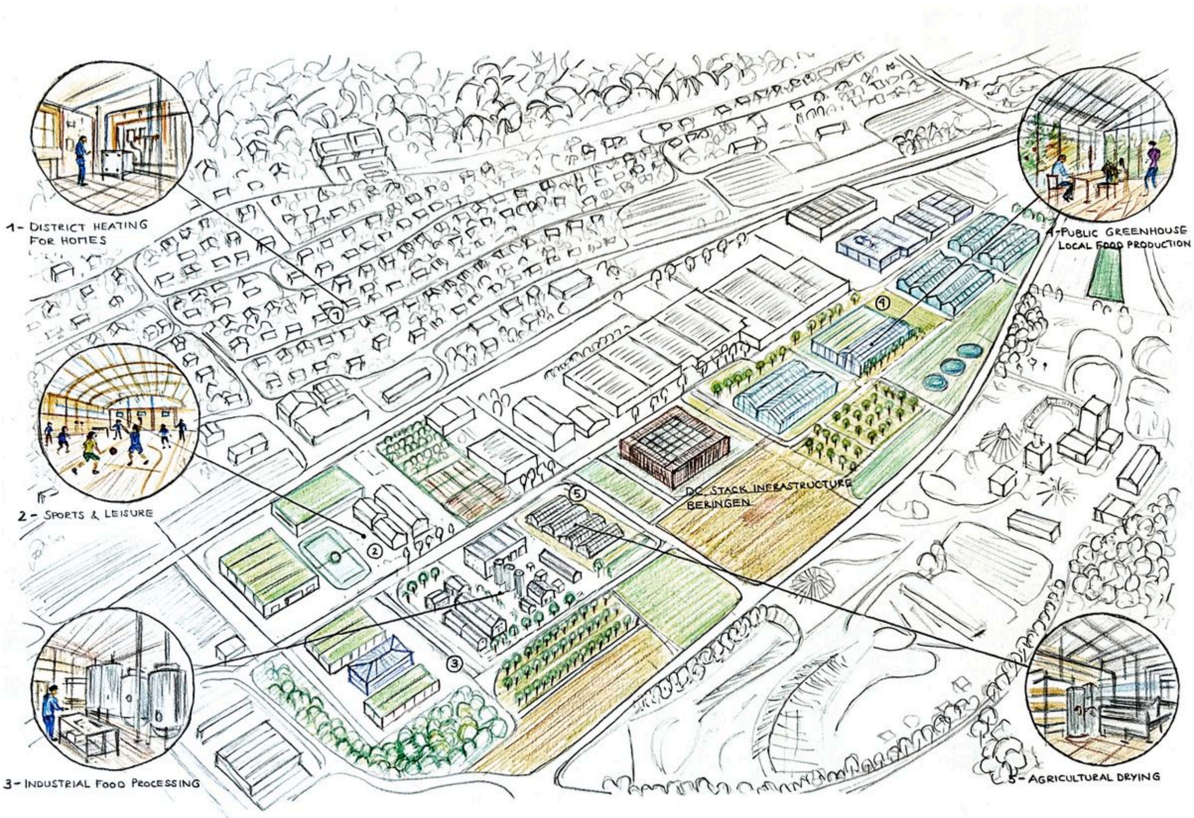


REGIONAL SCALE
Diversification—Anergie/district heating network—medium/high temperature
Pros: high efficiency and resource diversity, economies of scale, seasonal storage potential.
Cons: high investment and long distances, complex coordination and planning, space and infrastructure demands. Drawing: the authors, 2026.



METROPOLITAN SCALE
Efficiency—district heating network—high temperature
Pros: high efficiency and resource optimisation, economies of scale, stable year-round demand.
Cons: high investment, vulnerable to centralisation, space and infrastructure demands. Drawing: the authors, 2026.

Beringen: Local Thermal Relationships



New spatial uses enabled by the data centre waste heat in Beringen. Drawing: the authors, 2026.

In Beringen, the proposal responds to rural conditions and scattered settlements. The analysis shows that the municipality itself has only a limited local heat demand compared to the large amount of waste heat produced by the future STACK data centre.

One possibility would therefore be to connect the system towards Schaffhausen and Neuhausen through larger regional district heating systems, similar to existing planning proposals. At the same time, the project proposes to strengthen local thermal relationships within Beringen itself.

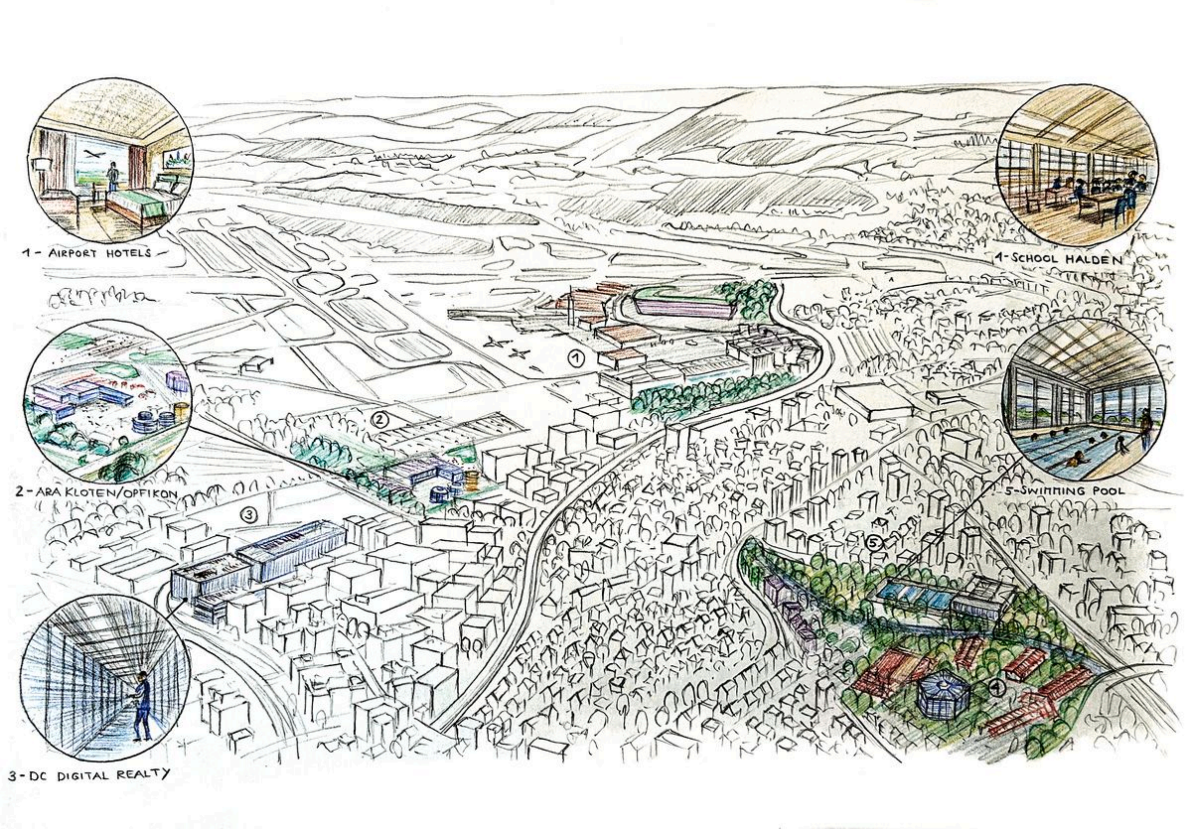
The proposal shows how waste heat could support greenhouses, food production, local industry, public programmes, and seasonal storage close to the data centre.

Rather than exporting the heat, the project explores how waste heat could generate local value and strong spatial relationships for the surrounding community.

Local thermal relationships in Beringen: the proposal investigates how different producers and consumers can become spatially connected through local and regional heat exchange systems. Drawing: the authors, 2026.

- STACK infrastructure
- Existing district heating network Hagenholz
- High industrial heat demand
- Low industrial heat demand

Glattbrugg: Metropolitan Thermal Networks

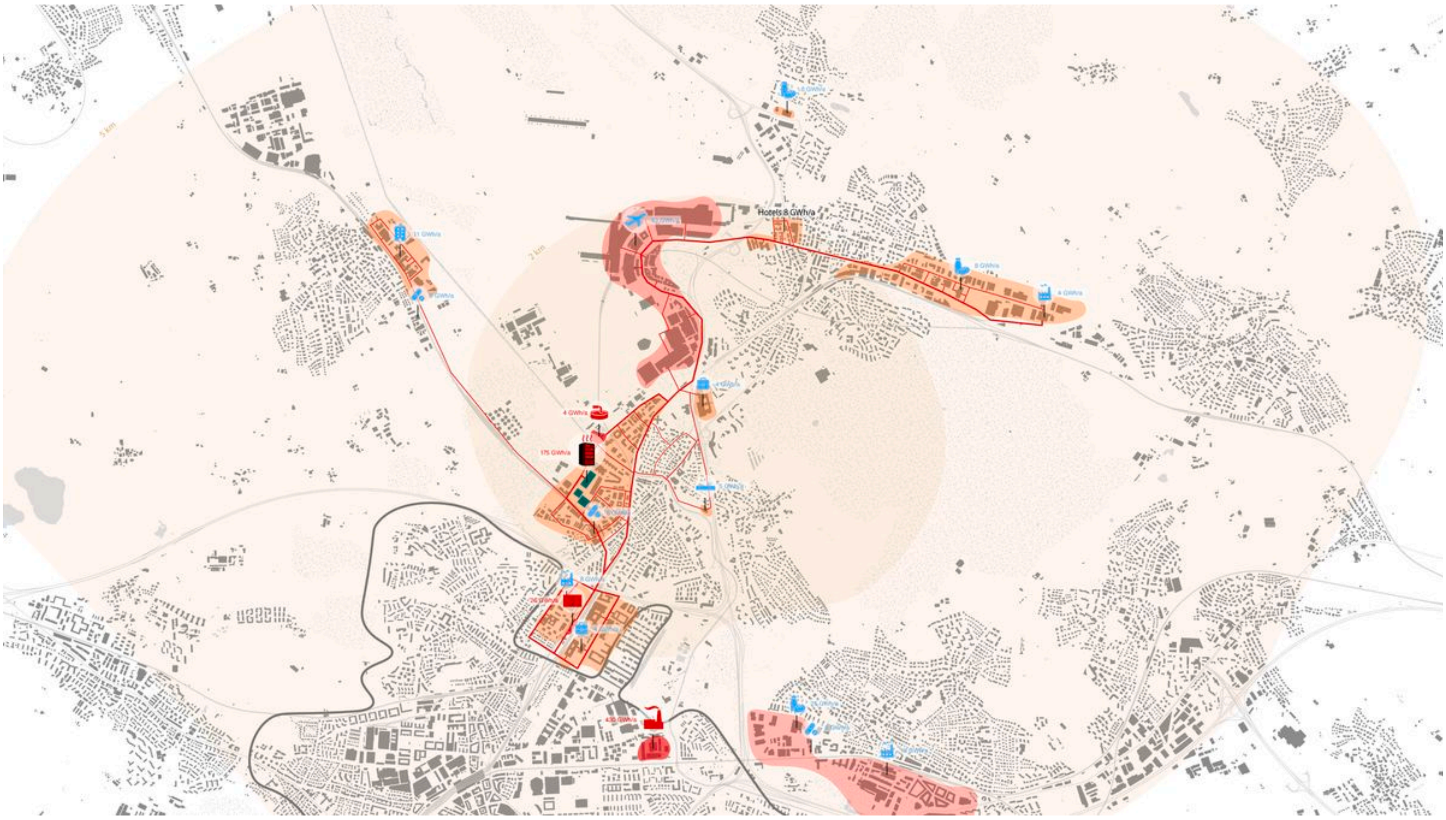


Spatial connections between waste heat producers and consumers in Glattbrugg. Drawing: the authors, 2026.

Unlike Beringen, Glattbrugg already contains dense urban structures, concentrated heat demand, and existing district heating systems.

The proposal therefore does not introduce entirely new heat networks, but rather expands and strengthens existing thermal relationships. The proposal identifies existing and potential producers and consumers already located close to one another.

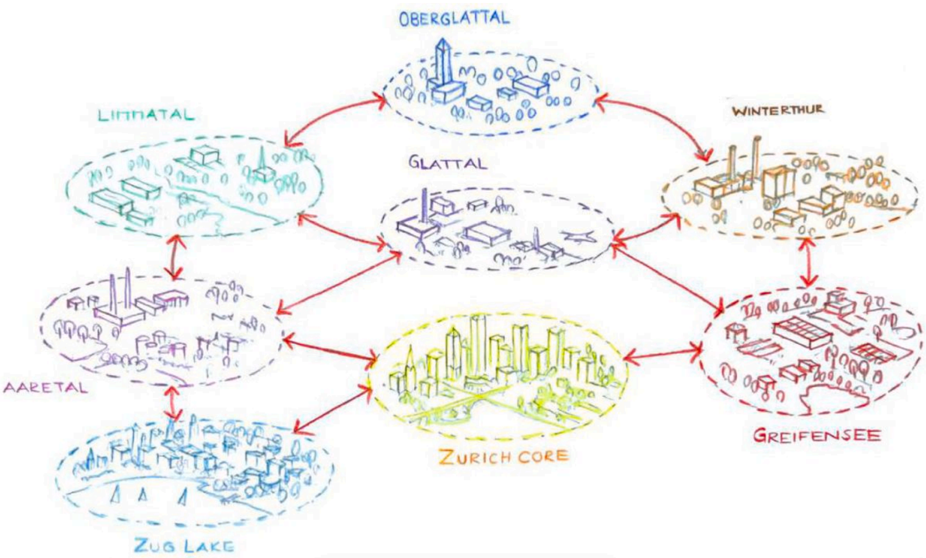
Existing district heating systems could be extended to connect additional data centres, industries, hotels, offices, and public buildings through larger interconnected metropolitan networks. In this sense, Glattbrugg operates less through local systems and more through collective metropolitan heat exchange.



Potential waste heat distribution zones and network reach in Glattbrugg.
Drawing: the authors, 2026.

- Digital Realty
- Existing district heating network Hagenholz
- Hagenholz potential interconnected thermal network
- High industrial heat demand
- Low industrial heat demand

From Local Proposals to Territorial Networks

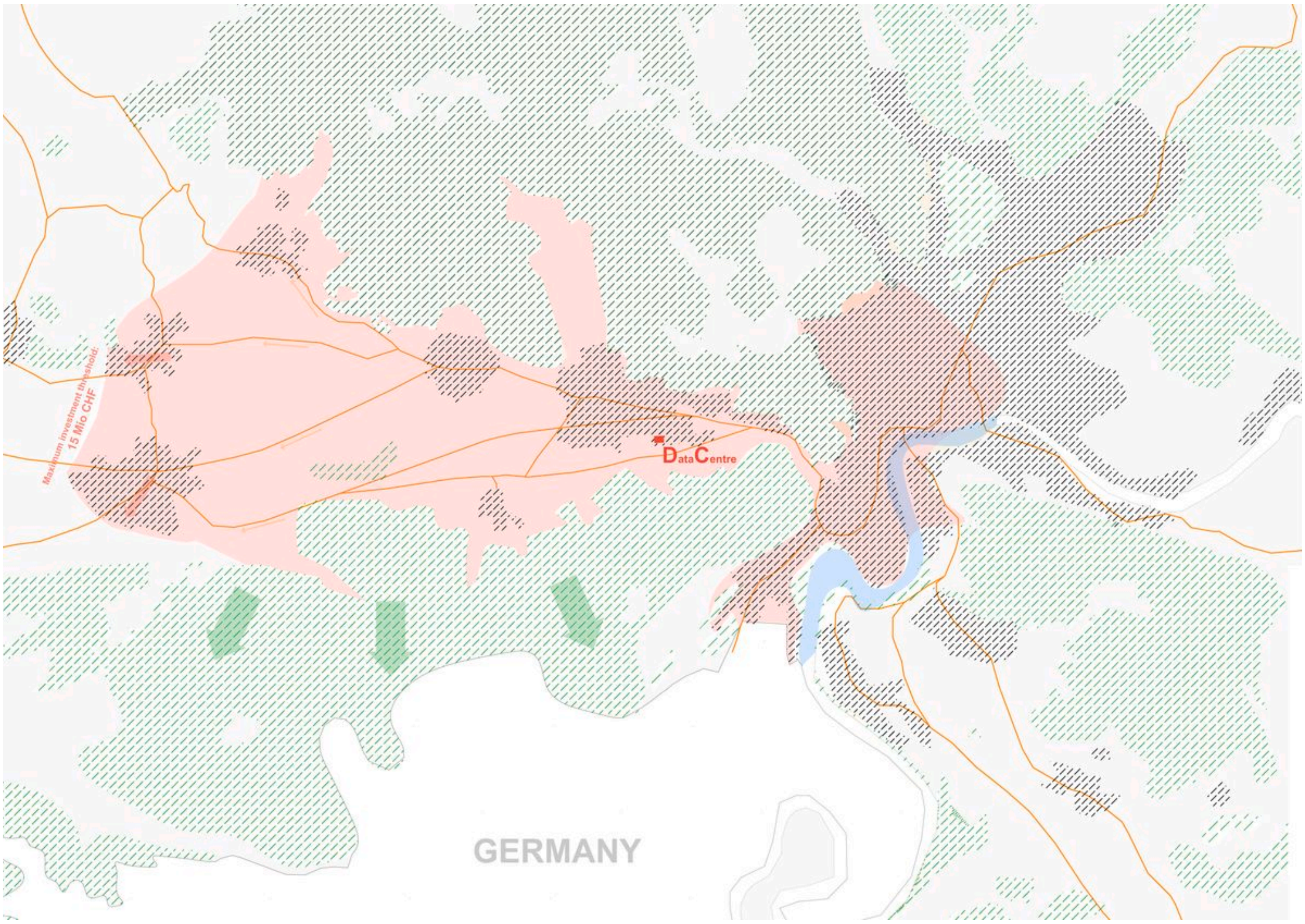


Potential waste heat networks in the Zurich region. Drawing: the authors, 2026.

The final part of the project expands the local proposals towards the scale of the Zurich metropolitan region. We identify potential clusters and thermal relationships between heat producers, heat consumers, and existing infrastructures.

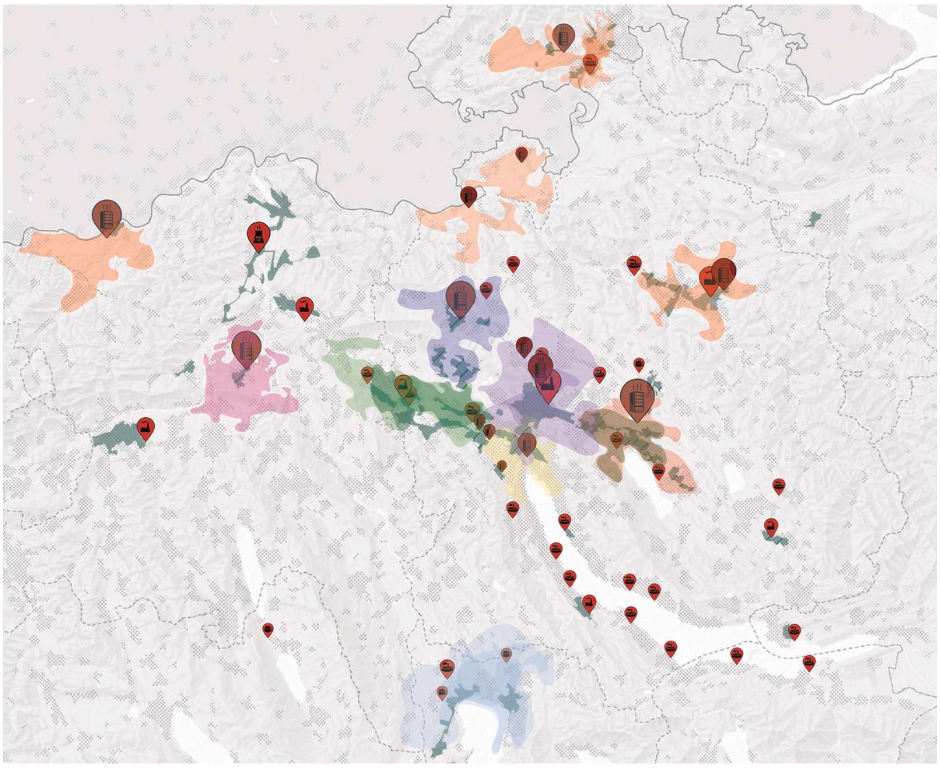
The clustering process is based on spatial and economic criteria including investment costs, transport distances, settlement structures, heat demand density, road corridors, topography, and natural barriers such as forests and rivers.

With the project, we propose a new understanding of waste heat as a shared spatial resource. Future thermal systems should no longer operate through isolated producer-consumer relationships, but argues for thermal systems that are interconnected, resilient, multi-scalar, adaptive and integrated into different territorial conditions while simultaneously generating public value across different scales.



Beringen: potential waste heat network according to criteria including investment costs, transport distances, settlement structures, heat demand density, road corridors, topography, and natural barriers such as forests and rivers. Drawing: the authors, 2026.

- Road corridor/3000 CHF/m
- Proximity/15 Mio max
- Settlement area/heat demand
- Forest/avoid elevation
- River/avoid
- Data centre



Visualising proximities: potential waste heat networks in the Zurich region. The interconnected heat networks link local, regional, and metropolitan conditions across the Zurich data centre cluster. Drawing: the authors, 2026.

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SOURCES

- Beringen. “Digitaler Knotenpunkt in Schaffhausen, Medienmitteilung zum geplanten Rechenzentrum in Beringen.” 2021.
- “Beringen gilt jetzt als IT-Gemeinde.” Interview with Roger Paillard about the data centre in Beringen. *Energieschweiz*. 2025.
- “E-Hub Beringen/Schaffhausen – Vorprojekt Abwärmenutzung Rechenzentrum Beringen.” Renercon Genossenschaft für Erneuerbare Energie. March 2025.
- Informationsveranstaltung “Kantonsratssaal” – Energie-Hub Beringen-Schaffhausen, Renercon/SwissSTES, March 16, 2026.
- “Machbarkeitsstudie Erweiterung Wärmeverbund Holzenergie Beringen.” Andy Wickart Haustechnik AG, on behalf of Holzenergie Beringen GmbH. March 30, 2023.
- “Machbarkeitsstudie zur Nutzung der Abwärme des Rechenzentrums Beringen – Schlussbericht.” Amstein + Walthert AG, on behalf of Baudepartements des Kantons Schaffhausen. December 13, 2022.
- Marinoni, Andrea et al. “The data heat island effect: quantifying the impact of AI data centers in a warming world.” *arXiv*. 2026.
- Nachhaltige Wärme für Beringen – Informationsanlass für die Gemeinde Beringen, Holzenergie Beringen GmbH, June 11, 2025.
- “Wärmeverbunde und Netze Winterthur – Ausarbeitung Masterplan Teil 2.” Denkgebäude AG/Stadtwerk Winterthur. Schlussbericht Version 1.1a. March 18, 2024.

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