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Building a climate-neutral future together

Sino-Swiss Cooperation on Zero Emissions Building

Technical Report

Anergy Networks

Shaping a Low-Carbon Energy System

ENGLISH VERSION

JULY 2024

中华人民共和国
住房和城乡建设部

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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This report has been produced within the framework Sino-Swiss Zero Emissions Building Project; an international collaboration funded by the Swiss Agency for Development and Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development.

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The Sino-Swiss Zero Emissions Building Project is an international collaboration funded by the Swiss Agency for Development Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development. The project aims to reduce greenhouse gas emissions and enable carbon neural development of the building sector in China by sharing Swiss know-how on sustainable and zero emission building.

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Cover image: Residential building at the Frielager district, Zurich.

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Image: Anergy network system at the Frielager district, Zurich.

1. PROJECT BACKGROUND

About Sino-Swiss ZEB Project

In order to jointly address global climate change and to strengthen cooperation between China and Switzerland in the field of emission reduction in the construction industry, the Ministry of Housing and Urban-Rural Development of the People's Republic of China and the Swiss Federal Ministry of Foreign Affairs signed a Memorandum of Understanding (MoU) on 24 November 2020. The Memorandum is about the development of cooperation in the field of building energy efficiency. Within the framework of this MoU, the Swiss Agency for Development Cooperation (SDC) initiated and funded the Sino-Swiss Zero Emission Building Project. The project aims to support China in formulating the technical standard of zero carbon buildings and long-term roadmaps for reducing carbon emissions in the construction industry. Switzerland contributes by sharing know-how and use cases of zero emission building demonstration projects in different climate zones, while carrying out various forms of capacity building activities, so as to ultimately promote the carbon-neutral development of China's construction industry.

Project purpose

- Upgrading existing building energy efficiency standards to Zero Carbon technical Standards
- Implementing demo projects in 4 typical climate zones for testing the new ZEB standards and finding optimization potentials
- ZEB capacity building and knowledge dissemination

Project duration

- Phase I: 15. Mar. 2021 – 28. Feb. 2025

Project impact on climate protection

- Reduce CO2 Emission in building sector

Introduction of Anex and its contribution to ZEB Project

Anex offers comprehensive building technology solutions that are functional, resource-saving, and cost-efficient. Their broad range of services includes HVAC planning, client consulting and quality assurance, overall management, spatial and technical coordination, building and energy simulation, building physics and acoustics, photovoltaics, and drinking water hygiene.

Anex collaborates closely with the ZEB team, advising Chinese planning teams on several demo projects to explore the potential of implementing an anergy grid. However, due to limited project space, geothermal resource issues, and other factors, the solution has not been considered so far.

This booklet illustrates the advantages and potential of the anergy grid network. With case studies from Switzerland, it aims to provide a deeper understanding and, hopefully, pave the way for implementation in suitable projects in China in the future.

2. ANERGY NETWORKS

2.1. About anergy networks

In thermodynamics, energy is a closed system consisting of exergy and anergy, which are subdivided using the ambient temperature (Figure 2). Anergy is the part of energy that cannot be converted into work.

Anergy network is the heating and/or cooling network that transports thermal energy close to the ambient temperature between suppliers and consumers. Operating at a lower level than traditional heating systems, the anergy network' s relatively low temperature requires the integration of water-to-water heat pumps to elevate the heat to a level suitable for heating buildings. This distinct characteristic of anergy networks not only enables heating but also facilitates cooling energy due to the low network temperature.

As a key component of broader district heating and cooling networks, the anergy network system focuses on optimizing energy use and minimizing carbon emissions through effective thermal energy distribution. The system is particularly efficient for transferring energy over short distances and is often used in combination with renewable energy sources and heat pumps.

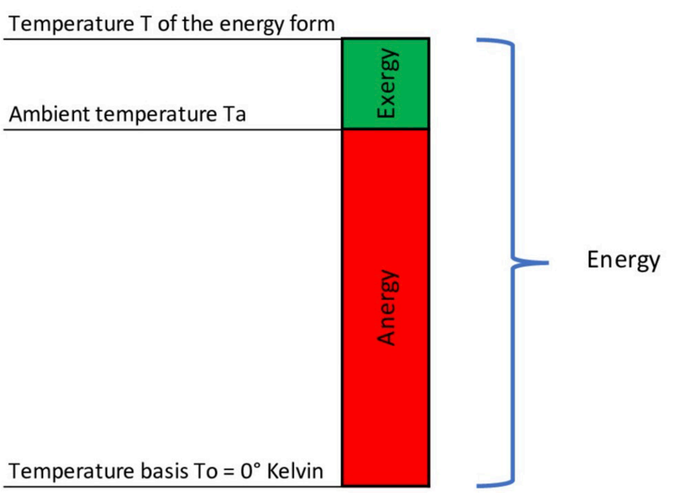

Figure 1: Distinction between exergy and anergy as forms of energy. Source: Useful work as monetary base for a global currency

2.2. Function and operating principle of anergy network

The underlying principle of the anergy network is to harness otherwise wasted low-temperature energy sources, such as ground heat or industrial process waste heat. This approach makes it a sustainable and environmentally friendly option for heating and cooling in urban areas, particularly in energy-efficient buildings, thereby promoting more sustainable urban development.

For instance, when using groundwater as the energy source (Figure 2), an anergy network functions as a piping system through which water circulates. The temperature is regulated by the local network operator, maintained within a defined range of typically 8°C to 26°C. This allows customers to produce their own heat supply (for space heating and hot water) using their heat pumps connected to the anergy network. If necessary, the anergy network can also provide cooling or re-cooling services.

Furthermore, customers of the anergy network can mutually benefit from each other. For example, one customer can release waste heat from their cooling process into the network, which other customers can then utilize for heating with their heat pumps. By optimizing the operation of the anergy network within the specified temperature range, customers require significantly less electrical energy to operate their heat pumps compared to individual systems. This results in a more efficient energy supply. Consequently, the anergy network effectively taps into low-grade energy sources and contributes to the efficient utilization of groundwater resources.

Core operational principle of anergy network includes:

- Dual Functionality: an anergy network comprises a closed circulatory system with double pipelines for flow and return, as well as inlet and outlet lines connected to heat pumps in buildings (Figure 3). Consequently, anergy networks can simultaneously provide both heating and cooling services for a designated area. This feature proves especially beneficial in settings like hospital complexes, where there is a consistent demand for both heating and cooling throughout the year.
- Integration of renewable energy sources: the incorporation of water and wastewater in building temperature regulation through anergy networks represents a promising approach to

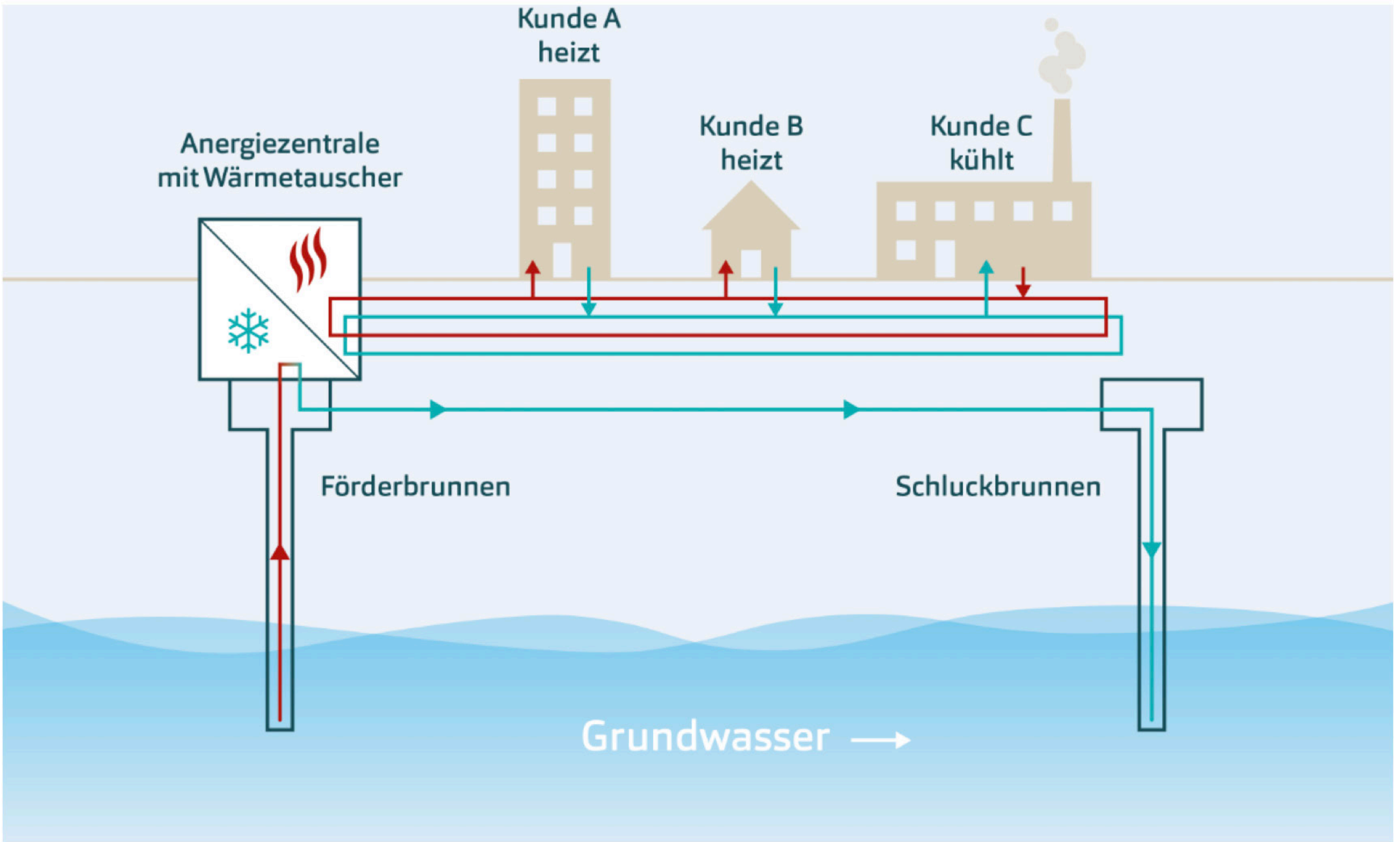

Figure 2: Anergy network function example - using ground water. Source: Kommunale Planung für Anergienetze; Festlegung des Tarifrahmens für die Nutzung von Grundwasser zu Wärmezwecken

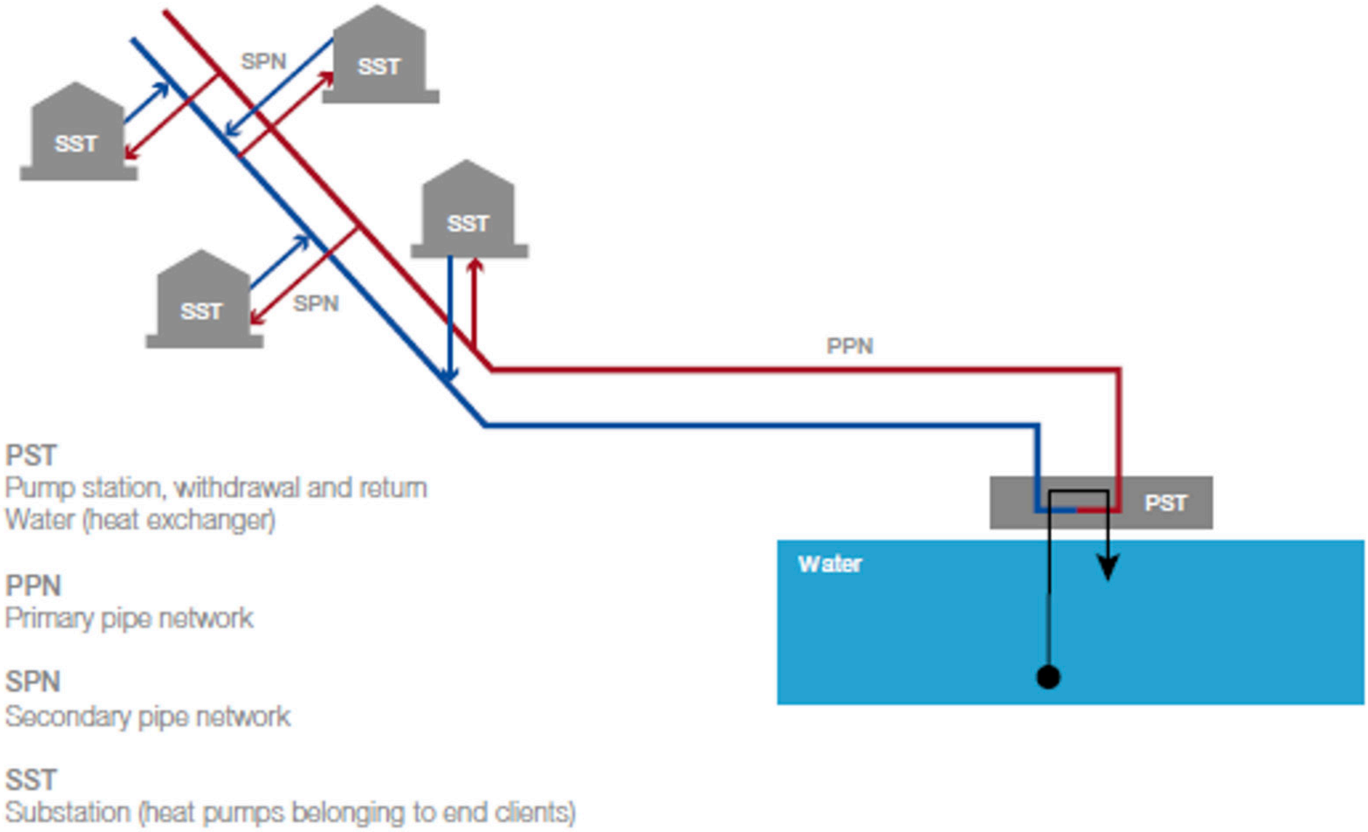

Figure 3: Dual functionality of the anergy network diagram . Source: ANERGY NETWORKS: THERMAL USE OF WATER AND WASTEWATER

integrating renewable energy. In Switzerland, this concept benefits from geographical advantages, as major lakes like Lake Constance, Lake Zurich, Lake Lucerne, and Lake Geneva border significant urban areas. Harnessing the potential heating energy from these extensive bodies of water is an enticing prospect, given their proximity to large towns and cities. Moreover, the thermal properties of wastewater, which tends to be warmer in winter and cooler in summer compared to ambient air, make it a viable option for building temperature control. To maximize this energy source' s effectiveness, it is crucial for buildings, especially those with high energy demands such as administrative centers, educational institutions, hospitals, and residential complexes, to be situated near substantial sewer systems or wastewater treatment plants. This proximity is essential for cost-effective utilization of water/wastewater energy.

- Sink: the sinks represent the opposite of the source, i.e. energy is withdrawn from the grid. In this sense, the heating energy consumption, or all losses of the "heating network" system is a sink [1].
- Storage/Seasonal geothermal storage: energy storage systems play a pivotal role in maintaining an energy balance between sources and sinks over a specified period. As depicted in Figure 4, in anergy networks with a diverse array of sources and sinks, geothermal energy storage (or low-temperature storage in general) assumes a special role. During warmer months, surplus heat can be stored in underground storage fields and subsequently utilized for heating during colder periods. The use of ground temperature levels minimizes energy losses in the

1 Source: Grundlagen-/Thesen Kalte Fernwärme (Anergienetze)

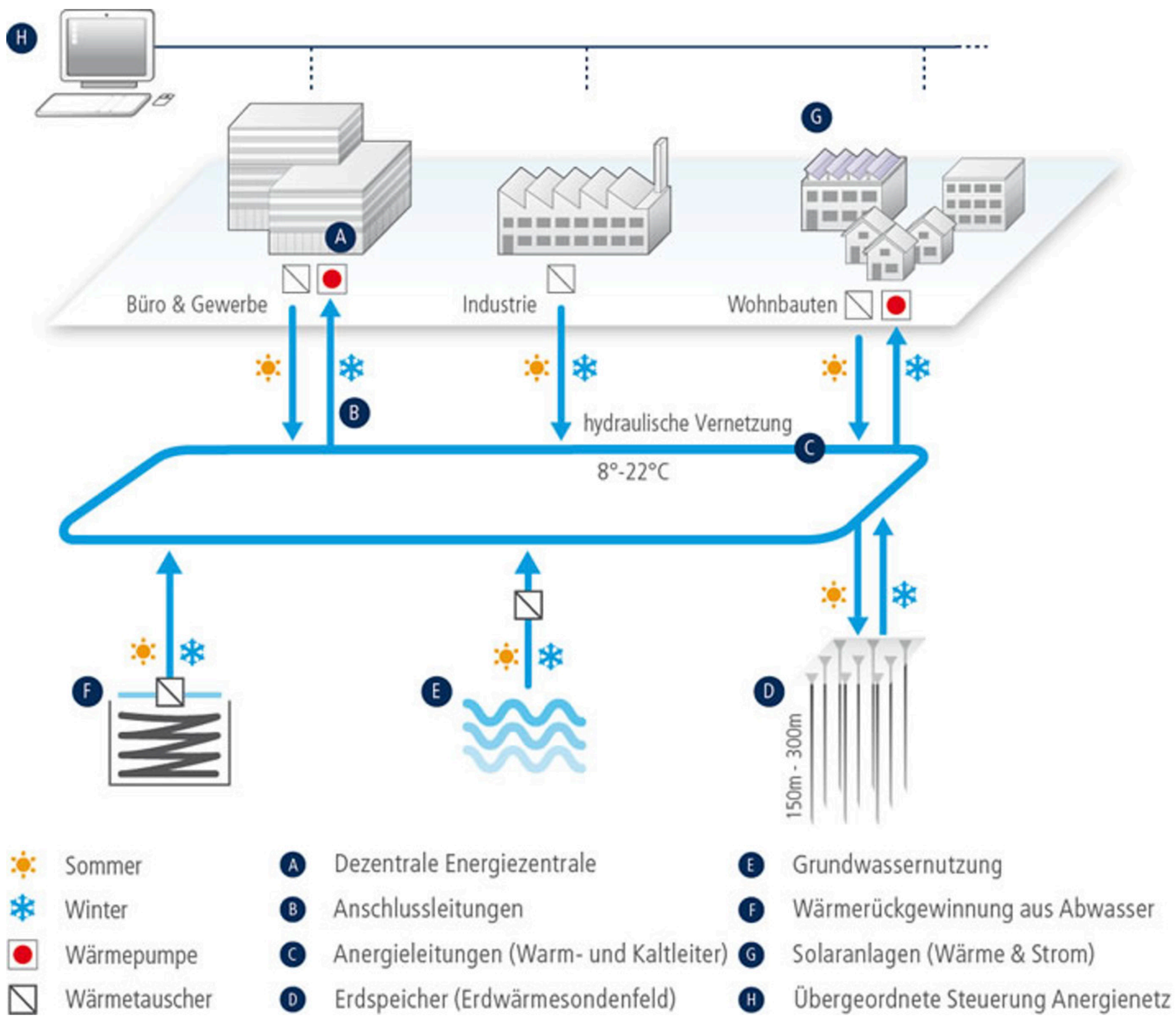

Figure 4: Illustration of an anergy network, with heat and cold exchange between geothermal probe fields and buildings, groundwater, or waste heat as energy source. Source: Energienetz-gsg

soil, and this system is engineered to operate with minimal additional energy input, thereby reducing operational costs. A prerequisite for the successful implementation of thermal area networking is achieving a consistent heat balance over the year, ensuring that the annual heat withdrawal (sink) from the anergy network equals the annual heat feed-in (source) .[2]

- Centralized control with decentralized operation: an anergy network may incorporate a central control system responsible for maintaining the energy distribution balance. However, it also allows for decentralized operation, enabling individual consumers to function as either energy sources or sinks based on their immediate requirements. In contrast to conventional district heating networks primarily designed for large-scale energy distribution, decentralized anergy networks offer efficiency and adaptability. They are particularly well-suited for integrating renewable energy sources and minimizing transmission losses due to their localized nature and lower operating temperatures. Decentralized anergy networks for heating and cooling typically feature multiple small-scale heat sources and cooling users, including data centers, service buildings, and light industries. These networks exhibit a diverse user structure, handle relatively low-energy loads, operate with lower distribution temperatures, and often employ heat pumps for efficient heat management.

2 Source: Grundlagen-/Thesen Kalte Fernwärme (Anergienetze)

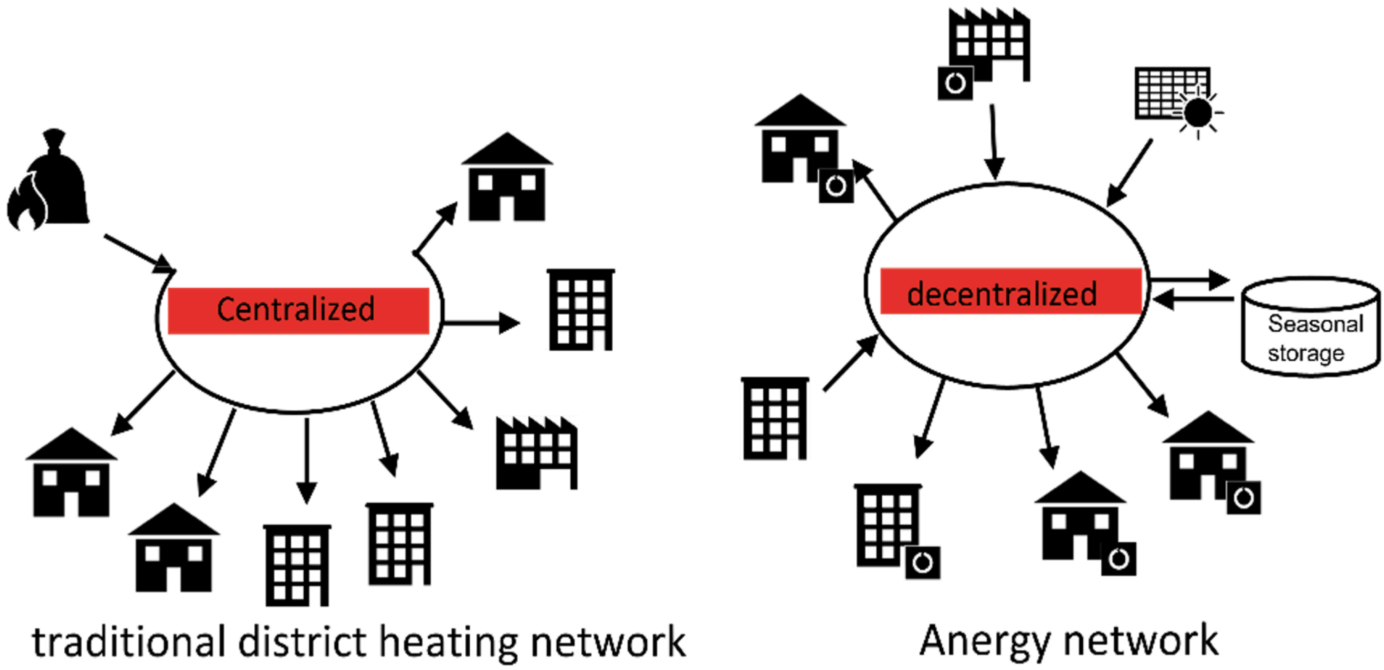

Figure 5: Decentralized networks compared to centralized traditional district heating network . Source: ZEB talk: In-depth course on thermal area networking

3. SHAPING A LOW-CARBON FUTURE: THE ROLE OF ANERGY NETWORK IN TRANSFORMING BUILDING SECTOR

3.1. Challenges & opportunities in the emission balance of the building sector

The building sector currently accounts for 39% of global energy-related carbon emissions, with 28% stemming from operational emissions, which result from the energy required to heat, cool, and power buildings. The remaining 11% of emissions originate from materials and construction processes. Looking ahead to the middle of the century, when the world' s population is expected to approach 10 billion, it is anticipated that the global building stock will double in size.

Addressing carbon emissions in the building sector is imperative, presenting both a substantial challenge and promising opportunities. The building sector finds itself at a pivotal juncture, necessitating the adoption of decisive and innovative methods to meet the demands of a growing population and combat the increasing threats of climate change. This transformation involves a comprehensive shift in practices, encompassing technologies, policies, and a critical emphasis on energy efficiency. Energy efficiency plays a vital role in reducing energy demand, lowering emissions, and propelling the transition to clean energy.

From a global energy perspective, a pivotal element of this energy transition involves tapping into the potential of local energy sources. This includes harnessing resources such as waste heat, lake water, wastewater treatment plants, groundwater, and geothermal energy. The consistent utilization of these locally available sources reduces reliance on fossil fuels, minimizes energy transmission losses, and contributes to a more sustainable energy ecosystem. Another noteworthy facet of the energy transition is the ongoing electrification of various sectors. This shift toward electric power aims to reduce carbon emissions and enhance overall energy consumption efficiency. Electrifying transportation, heating, and industrial processes can significantly mitigate environmental impacts. Nevertheless, this transition presents its own set of challenges, including the need for grid upgrades, energy storage solutions, and the expansion of renewable energy capacity.

3.2. Anergy network: bridging the energy efficiency gap & integrating renewable energy

Incorporating anergy networks into the building sector presents a substantial opportunity to enhance energy efficiency and reduce greenhouse gas emissions. The key benefits of anergy networks include:

- Improved Energy Efficiency: anergy networks operate at temperatures closer to ambient levels, resulting in reduced energy consumption for heating and cooling, thereby lowering greenhouse gas emissions. Additionally, these networks can effectively tap into local waste heat sources, such as waste heat from large data centers and exhaust heat from flue gas condensation processes. This utilization of waste heat contributes to a more efficient energy utilization process.
- Integration with local renewable energy sources: anergy networks can seamlessly integrate with local renewable energy sources, such as geothermal energy. This integration not only reduces reliance on fossil fuels but also facilitates a sustainable energy supply for buildings, further reducing environmental impact.
- Urban Planning Contribution: anergy networks play a significant role in urban planning by accommodating diverse user profiles, including residential, office spaces, data centers, and light industries. These networks offer flexible and expandable connections, enabling them to adapt to various urban forms and meet the specific energy requirements of different building types. Their integration into urban energy systems can optimize energy performance across both vertical and horizontal urban expansions. By aligning with the growth and development patterns of cities, anergy networks enhance the overall efficiency and sustainability of urban energy systems. They support a cohesive approach to urban planning that prioritizes energy efficiency and carbon reduction.

In summary, anergy networks, with their flexible and efficient design, are pivotal for the sustainable transformation of the building sector, especially in urban settings. Their integration with urban planning can lead to optimized energy use and reduced emissions, contributing significantly to a more sustainable and environmentally friendly urban landscape.

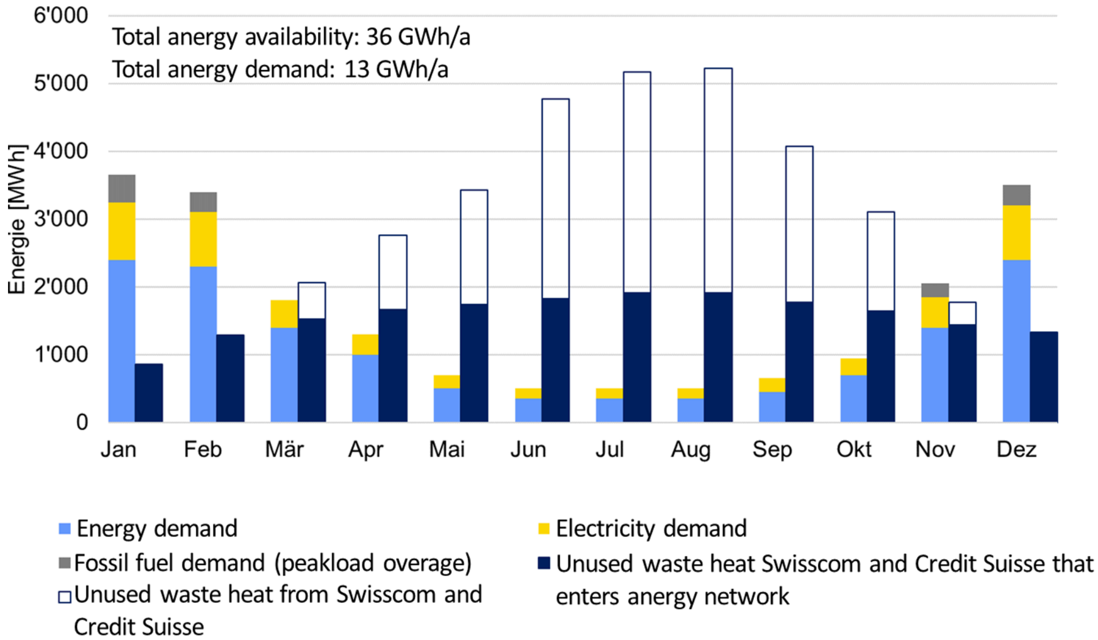

Figure 6: Energy demand of Friesenberg neighborhood compared to waste heat supply from data centers of Swisscom and Credit Suisse . Source: Forum Energie Zürich 2020: Anergienetz Friesenberg der Familienheim-Genossenschaft Zürich

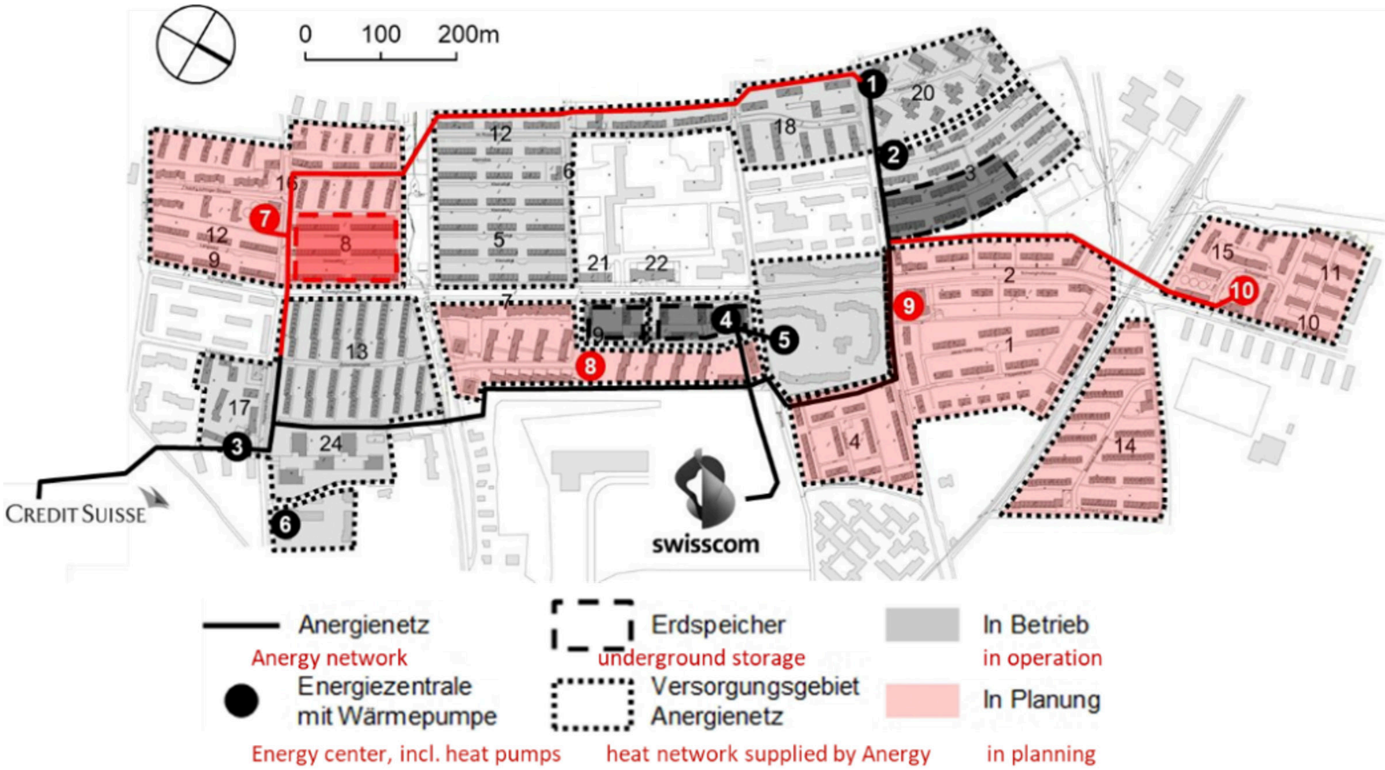

Figure 7: Plan of the Friesenberg neighborhood with the anergy network and the decentralized heat pumps energy center. Source: ZEB talk: In-depth course on thermal area networking

4. ANERGY NETWORK APPLICATIONS IN SWITZERLAND

4.1. Case 1: Friesenberg neighborhood - waste heat utilization

Since 2010, the Zurich family corporation (Familienheim-Genossenschaft Zürich, FGZ) has been actively planning and implementing an anergy network in the Friesenberg neighborhood, progressively replacing oil and gas burners with heat pumps. FGZ, being the largest contiguous housing cooperative in Zurich, is the primary investor in this project, allocating 42.5 million CHF for its realization. The Friesenberg neighborhood exclusively consists of residential buildings, with a total heated floor area of approximately 185,000 m2. The original heat demand for space heating and domestic hot water amounted to about 35 GWh/a.

The project relies on harnessing waste heat from adjacent data centers, namely Swisscom and Credit Suisse, to replace the current use of fossil fuels. As depicted in Figure 6, the waste heat supplied by these data centers surpasses the heat demand of the Friesenberg neighborhood. As there are more waste heat from summer months, it is temporarily stored in geothermal storage plants and subsequently utilized during winter. This approach results in a substantial reduction in greenhouse gas emissions and primary energy demand.

The implementation of the anergy network will be carried out in several stages:

- The energy requirement of the FGZ will be annually reduced from 35 GWh to 13 GWh by 2050, due to retrofit measures of the envelope.
- 90 % of the remaining 13 GWh will be covered by heat pumps using waste heat and about 10 % by fossil fuels for peak loads. (see Figure 7)
- The reduction of energy demand and the massive reduction of oil and gas consumption will reduce primary. Energy demand by approx. 65% and greenhouse gas emissions by approx. 90%.

The first part of the anergy network of Friesenberg neighborhood has been put into operation since 2014 and is continuously expanded. The temperature of the hot conductor varies in season between 8 °C and 28 °C, while the required power can be provided at any time. After overall completion (by 2050), the Friesenberg anergy network (plan shown in Figure 7 will consist of the following sub-objects:

- An anergy network with a main line of approximately 3 kilometers (warm and cold supply pipe)
- Three geothermal storage plants with a total of 450 probes at 250 m depth
- Integration of two large data centers with a total heat capacity of approximately 4.5 MW
- Central energy center with a total heat capacity of approximately 10 MW

4.2. Case 2: Freilager Zurich– waste heat utilization

Freilager Zurich, situated in the Zurich-Albisrieden neighborhood, served as a bonded warehouse from 1923 until the 1990s. Today, it has been transformed into a vibrant residential and office quarter, featuring 13 buildings with a combined area of approximately 70,500 m2. Within this district, there are 850 rental apartments and nearly 200 student accommodation rooms, making it home to approximately 2,500 residents and workers. The site was meticulously designed to align with the goals of the 2000-Watt Society and received certification in 2018 (certificates for '2000-Watt Sites' are awarded to housing developments that use resources sustainably in the construction, operation, and renovation of their buildings, and in the traffic they generate).

As shown in Figure 8, the anergy network plays a pivotal role in providing heating, hot water, and cooling services for sites A to D within the Freilager Zurich complex. This network was ingeniously designed, incorporating geothermal probes that utilize excess heat sourced from the nearby Union Bank of Switzerland's (UBS) computer center. In total, there are 205 geothermal probes, each extending to a depth of 220 meters and spaced 5 meters apart. These probes are strategically located in site A, near the central energy hub. Even during winter, the excess heat generated by the data center ensures relatively high source temperatures (>15°C) for the central heat pumps, contributing to the efficient operation of the anergy network.

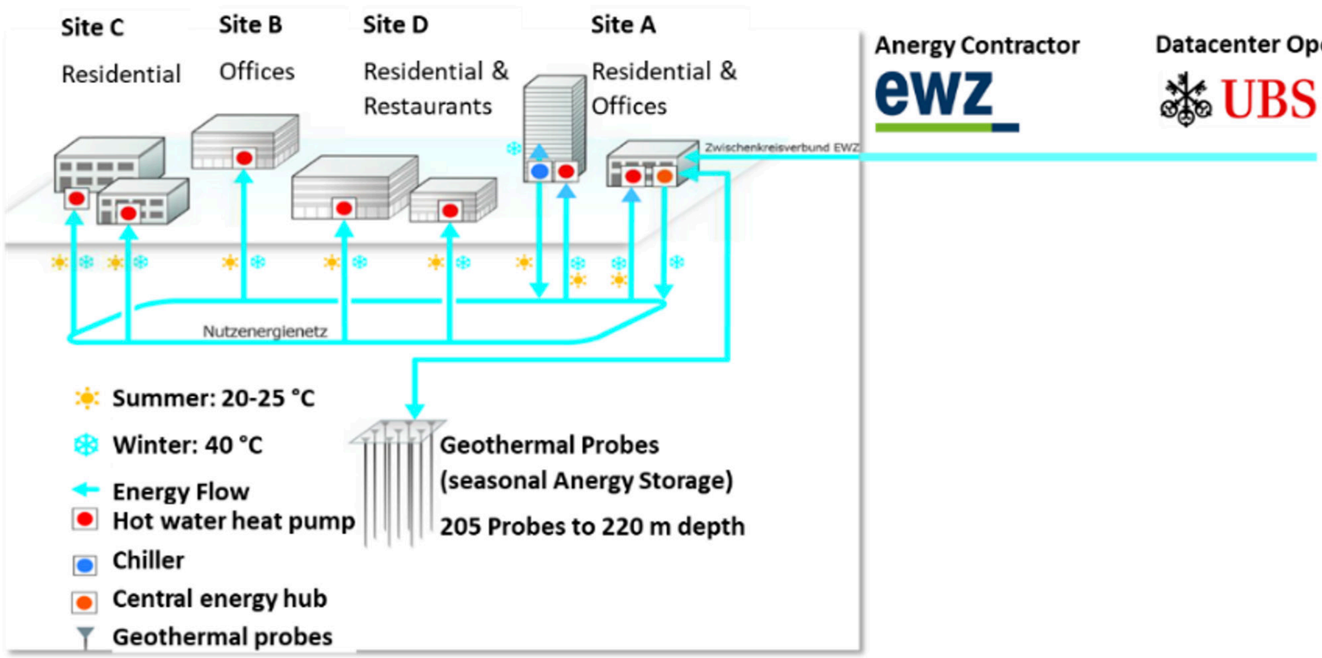

Figure 9: Freilager Zurich anergy network, source and components overview . Source: Züricher Freilager AG

4.3. Case 3: SBB Werkstadt Zurich - groundwater utilization

The Werkstadt site in Zurich is situated within the railway track area, positioned between Zurich' s main station and Altstetten. Swiss Federal Railways (SBB) has embarked on a transformation of the Werkstadt site with the aim of creating a vibrant urban space by the year 2035. This transformation will preserve the historical building fabric, which will harmoniously coexist with new structures and extensions.

The energy concept for this redevelopment leverages solar energy and groundwater to provide 100% fossil-free heating, cooling, and electricity to the buildings. Groundwater serves as the source for heating and cooling, collected through four wells on the site. Subsequently, this groundwater is conveyed to energy centers located within the larger buildings, where heat pumps and chillers are employed to adjust it to the desired temperature. An anergy network interconnects all the buildings, facilitating the exchange of surplus energy between different groups of buildings. For instance, excess heat or cold available in one building can be utilized in another. This approach eliminates the need for individual groundwater drilling in every building. Smaller buildings are linked to the energy centers through a local heating network.

In the project' s final stage, the heating requirement amounts to 10,400 MWh per year, accompanied by a cooling requirement of 2,100 MWh per year. Both heating and cooling are generated 100% CO_2-free, as the residual electricity also originates from renewable sources. As illustrated in Figure 10, the adoption of a monovalent energy system will result in a CO_2 reduction exceeding 2,100 tons per year upon completion of the expansion .[3]

3 Information source: ewz, SBB Werkstadt

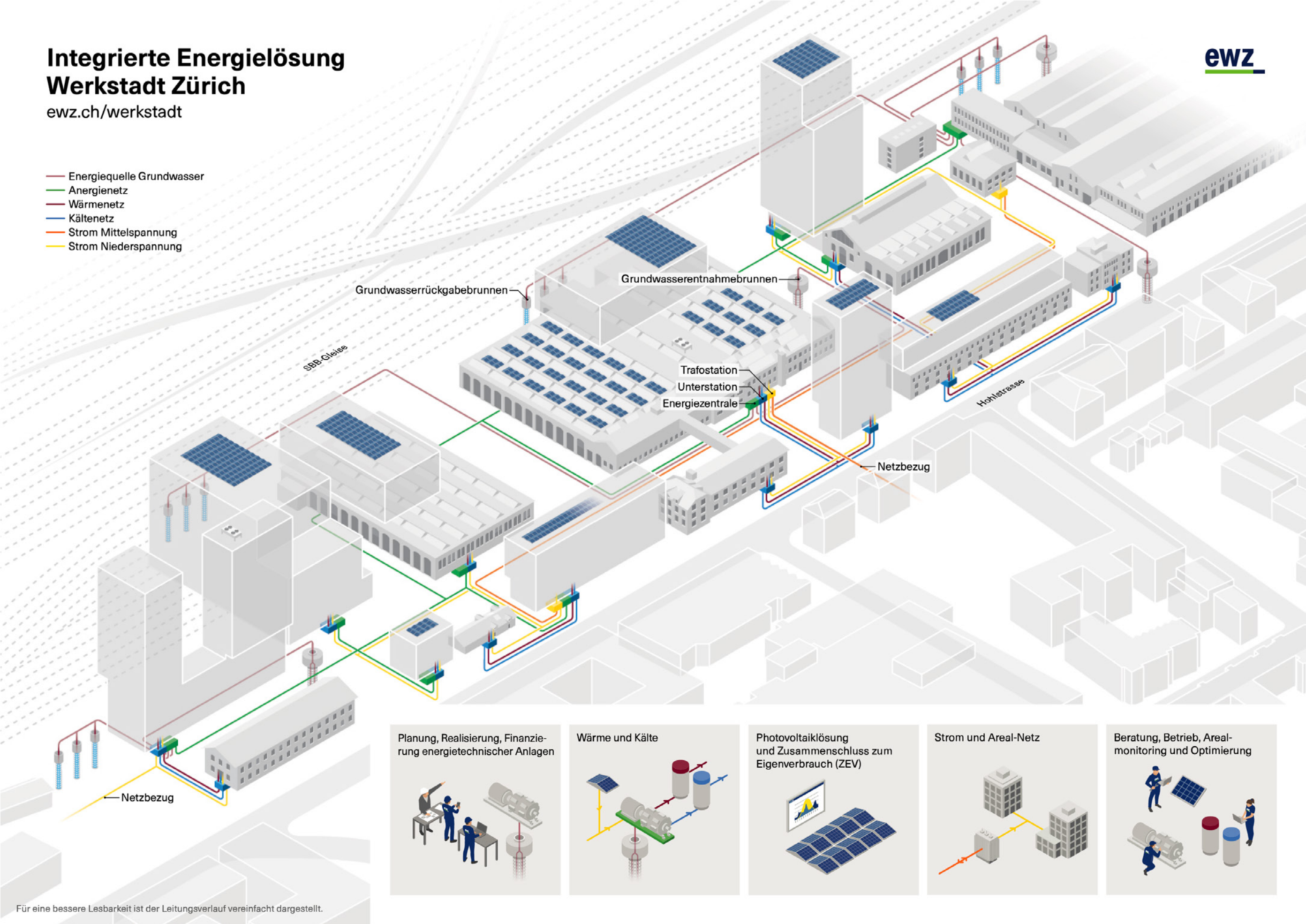

Figure 10: Werkstadt Zurich - integrated energy solution

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