ETH Zurich Department of Architecture
ARCHITECTURE OF TERRITORY
Chair of Architecture
and Territorial Planning
Professor Milica Topalović

The Production of Cloud
Fall 2025

Atlas

Heating and Cooling

Serena Peier, Rebecca Grobotek, Matteo Bianchi, and Linus Ham

Data centres are the invisible pillars of the cloud and are increasingly shaping the physical landscape. They produce enormous amounts of waste heat, the potential of which usually remains untapped. This dual role of places of intensive cooling that are also sources of energy, is examined in this research. Using the example of the data centres in Zurich Glattbrugg, it shows how technical systems, energy flows, and urban networks intertwine.

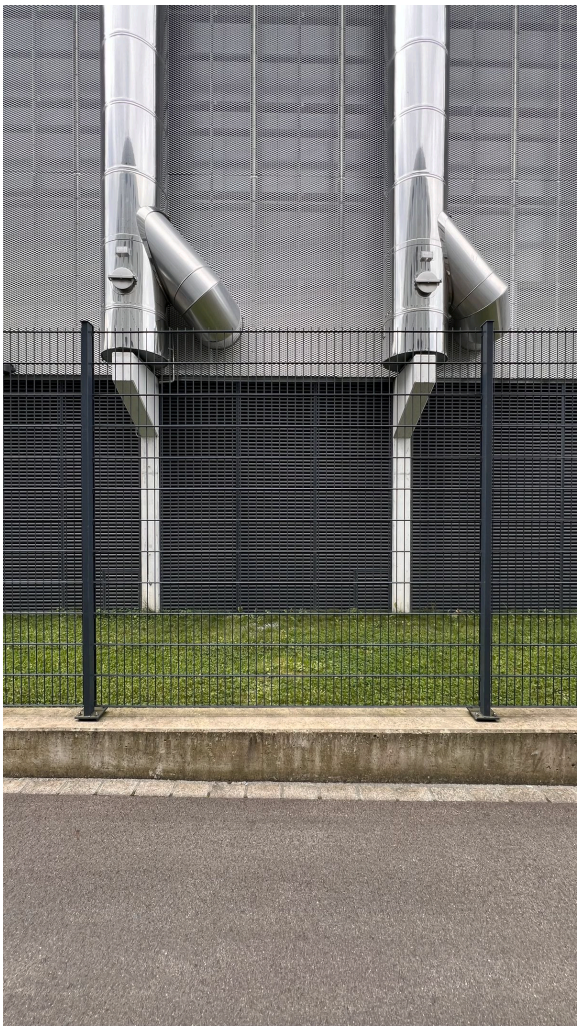
The work interrogates how data centers can evolve from isolated “fortresses” to open *forums,* becoming ecologically and socially integrated infrastructures where heat becomes visible and usable as a shared resource.

Hot to Spot a Data Centre



DATA CENTER ZUR 2&3, DIGITAL REALTY GLATTBRUGG. Photograph: AOT, 2025.

You can (almost) always tell when you’re standing in front of a data centre. No windows, no openness, no trace of life: a box wrapped in perfectly brushed aluminium, gleaming like an oversized USB stick dropped in the middle of nowhere. Walk around it and you’ll begin to notice the signs: fences, cameras, and yellow border lines warning you off. Long silver pipes reach skyward: lifelines powered by diesel, ready to keep servers alive when the grid falters.



Fences



Cameras



Pipes

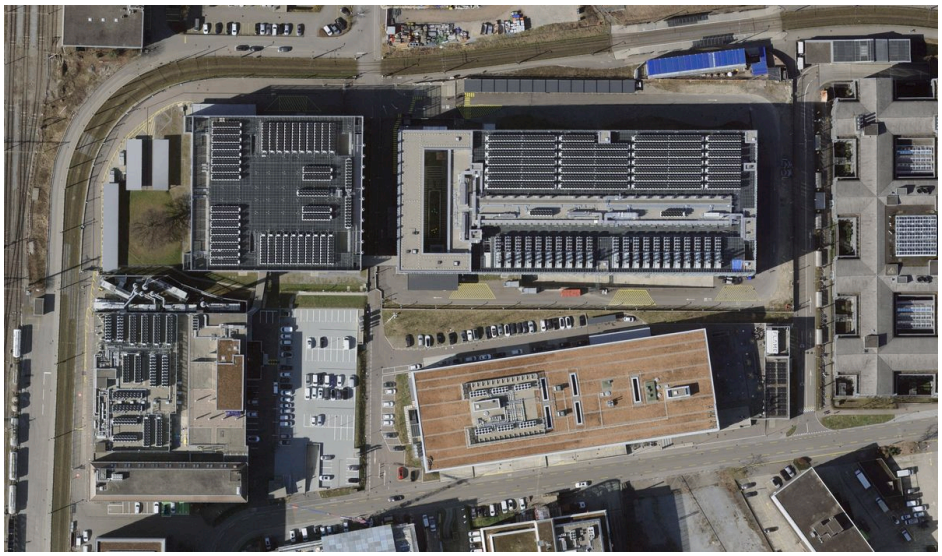


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Cooling Infrastructure on the roof of the data center ZUR3, DigitalRealty Glattbrugg. Photograhp: AOT, 2025.

Above, the rooftops pulse with an industrial rhythm; coolers, fans, and pipes forming a dense mechanical landscape that the aluminium facade below works so hard to disguise. From the sky, though, the truth becomes visible. Here, the most distinctive feature of a data centre stands out: the coolers.

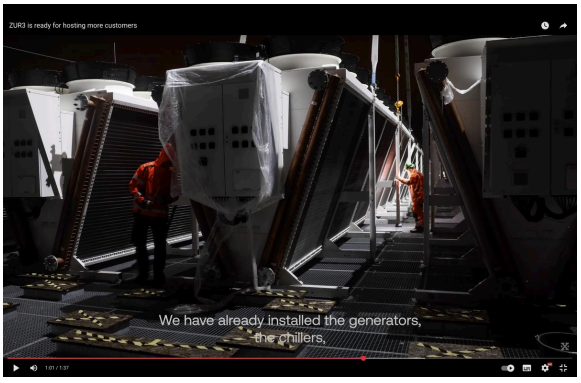


Aerial view of DigitalRealty Campus in
Glattbrugg. Photograph: map.geo.admin.ch, 2025.

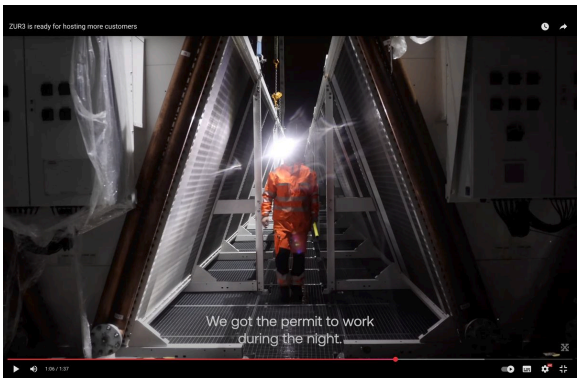
In Glattbrugg, airplanes flying overhead have a perfect view of these rooftop chillers that mark the buildings unmistakably as data centres. Installing this equipment often happens at night, away from sight. More than 850 tons of machinery lifted under darkness, the work continuing while the city sleeps. At night, lit only by work lamps, the site resembles a tunnel, as if all the infrastructure was underground. Even test runs for the chimneys are done in the dark, when diesel engines exhale their dark smoke, quietly out of view. Seen this way, data centers are not really buildings in the conventional sense, they are infrastructure.



Transport of the chillers
for installation on the roof.
Screenshot from YouTube video by DigitalRealty
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Installation of the chillers at night.
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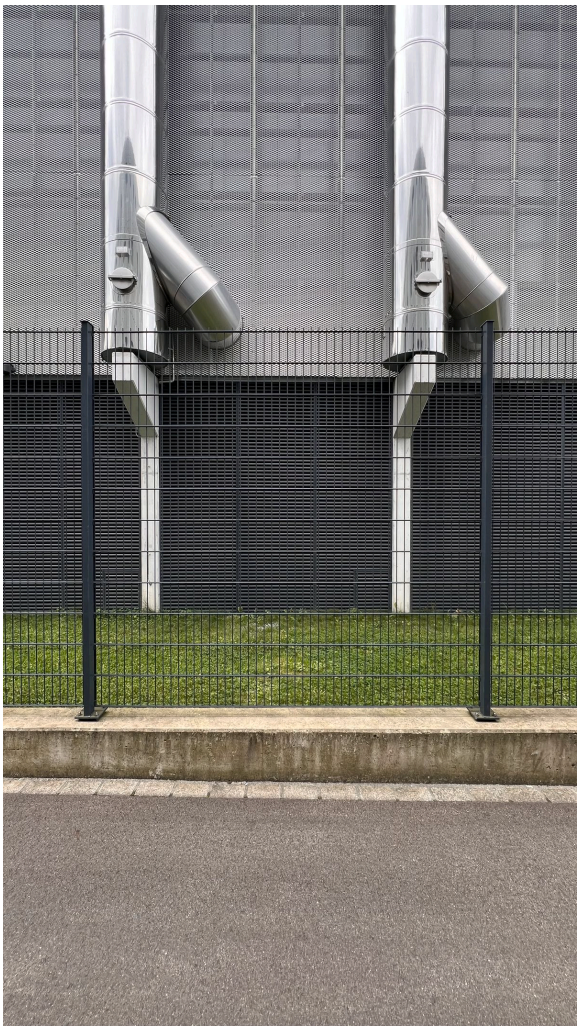


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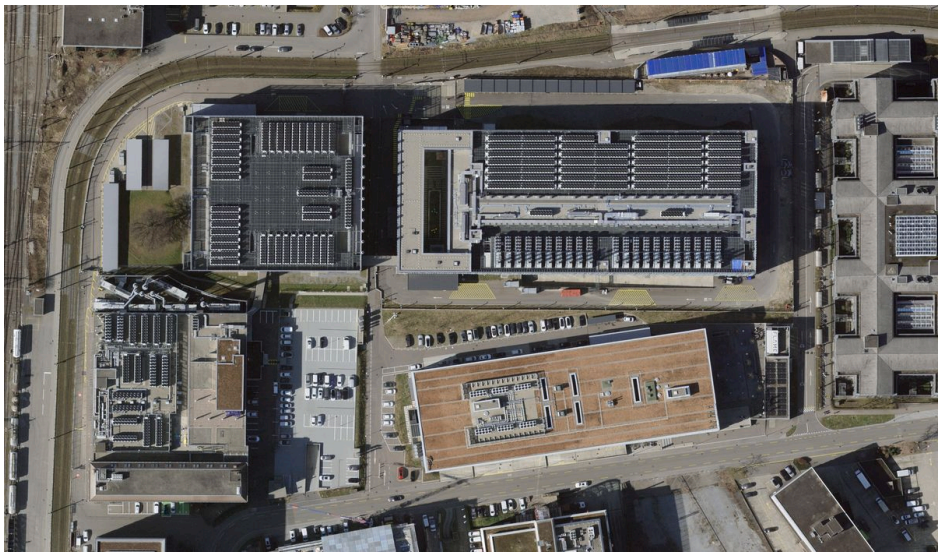


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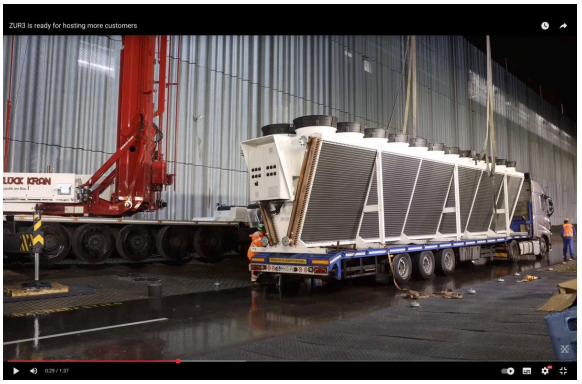
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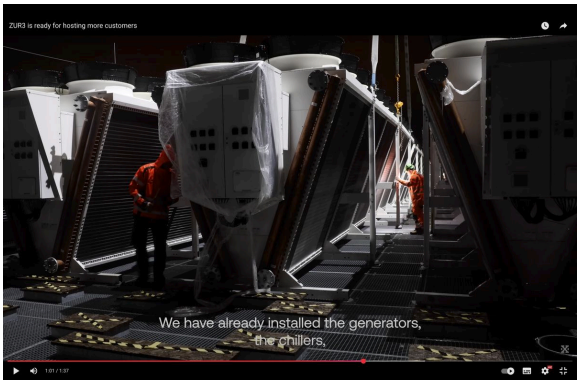


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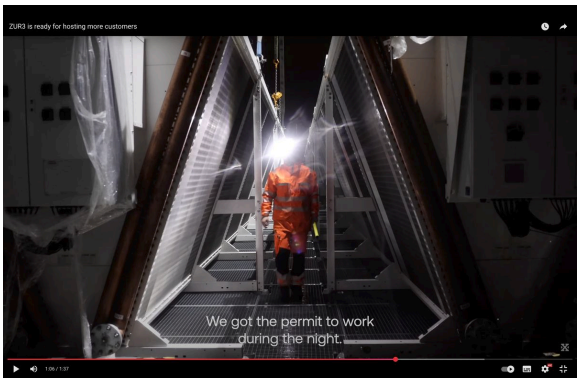
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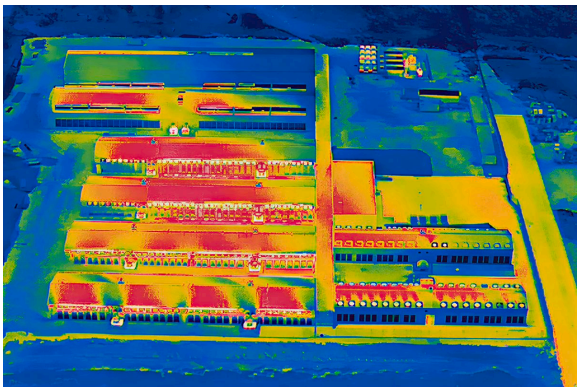
Cooling Infrastructure: Keeping the Cloud Alive

At first glance, the data center Blönduos in Iceland is barely distinguishable from any ordinary industrial facility. Its architectural camouflage is enhanced by a deliberate integration of the cooling infrastructure, which is largely concealed from exterior view. For the casual observer, the absence of visible cooling hardware suggests minimal thermal output.

Yet, when subjected to thermal imaging, the building's true nature is revealed. Even small data centres, such as this example, emit substantial quantities of waste heat, invisible to the eye but clearly mapped in infrared.



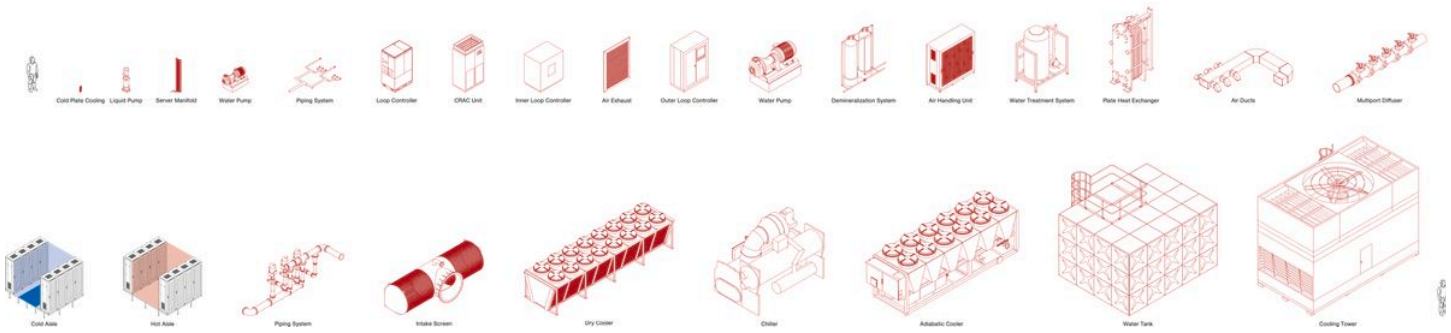
INCONSPICUOUS DATACENTER
IN BLÖNDUOS, ICELAND
Source: Invest in Iceland, 2023.



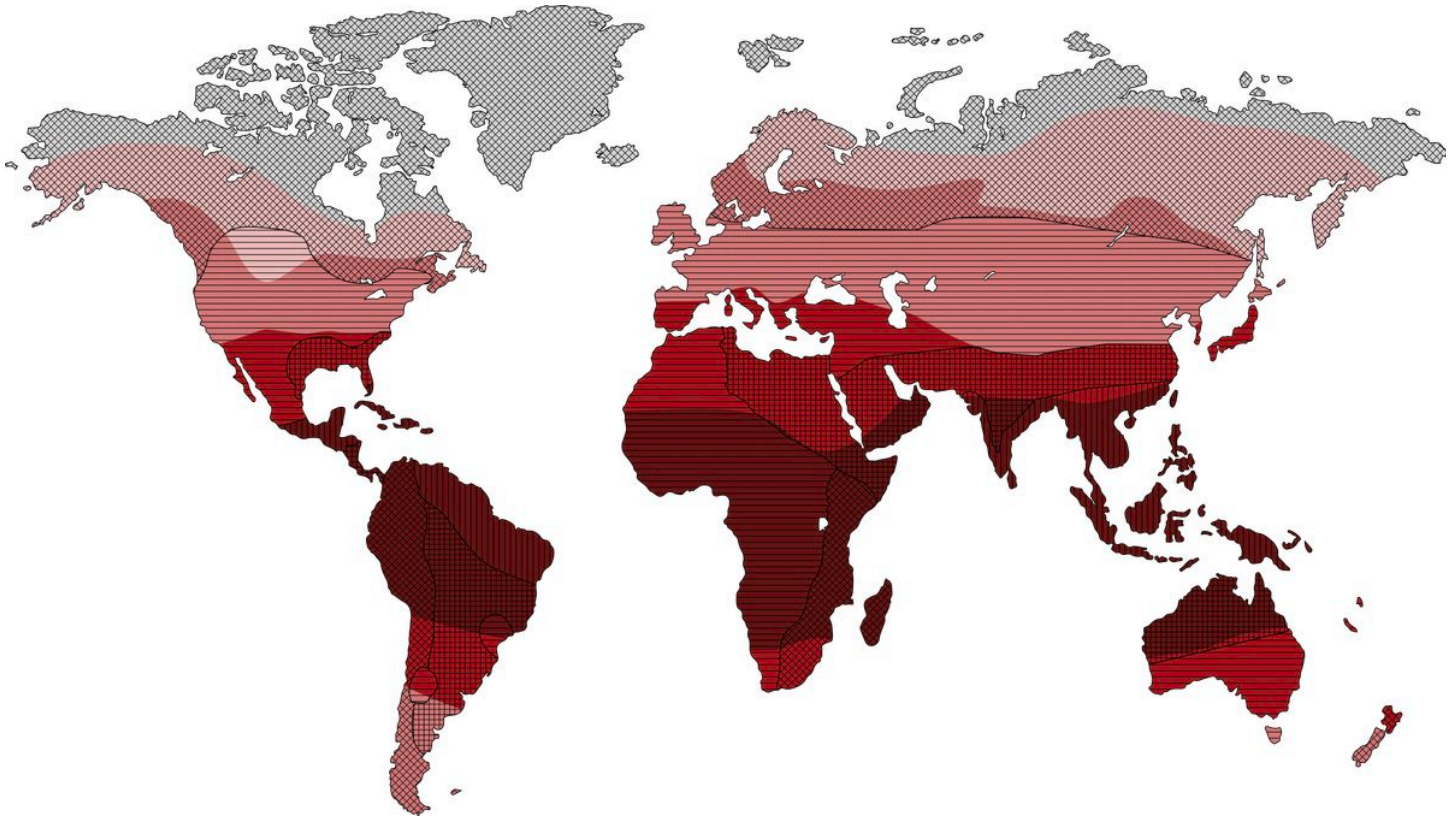
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The majority of this excess heat is dissipated through arrays of rooftop chillers: modular units that have become nearly emblematic of contemporary data centre design. Even for data centres of modest size, the arrangement and scale of chillers and piping illustrate the complexity required for reliable thermal regulation. Data centres commonly feature only two main archetypes of server racks, each with its advantages and disadvantages. Despite the apparent simplicity of rack layouts, the spectrum of cooling solutions adopted is extraordinarily varied, often scaling up to monumental proportions.





The choice of cooling system is intrinsically linked to climate. Mapping global climate zones alongside the most prevalent regional cooling methods illustrates a strong correlation between climatic conditions and cooling system selection, especially in Asia and Oceania.

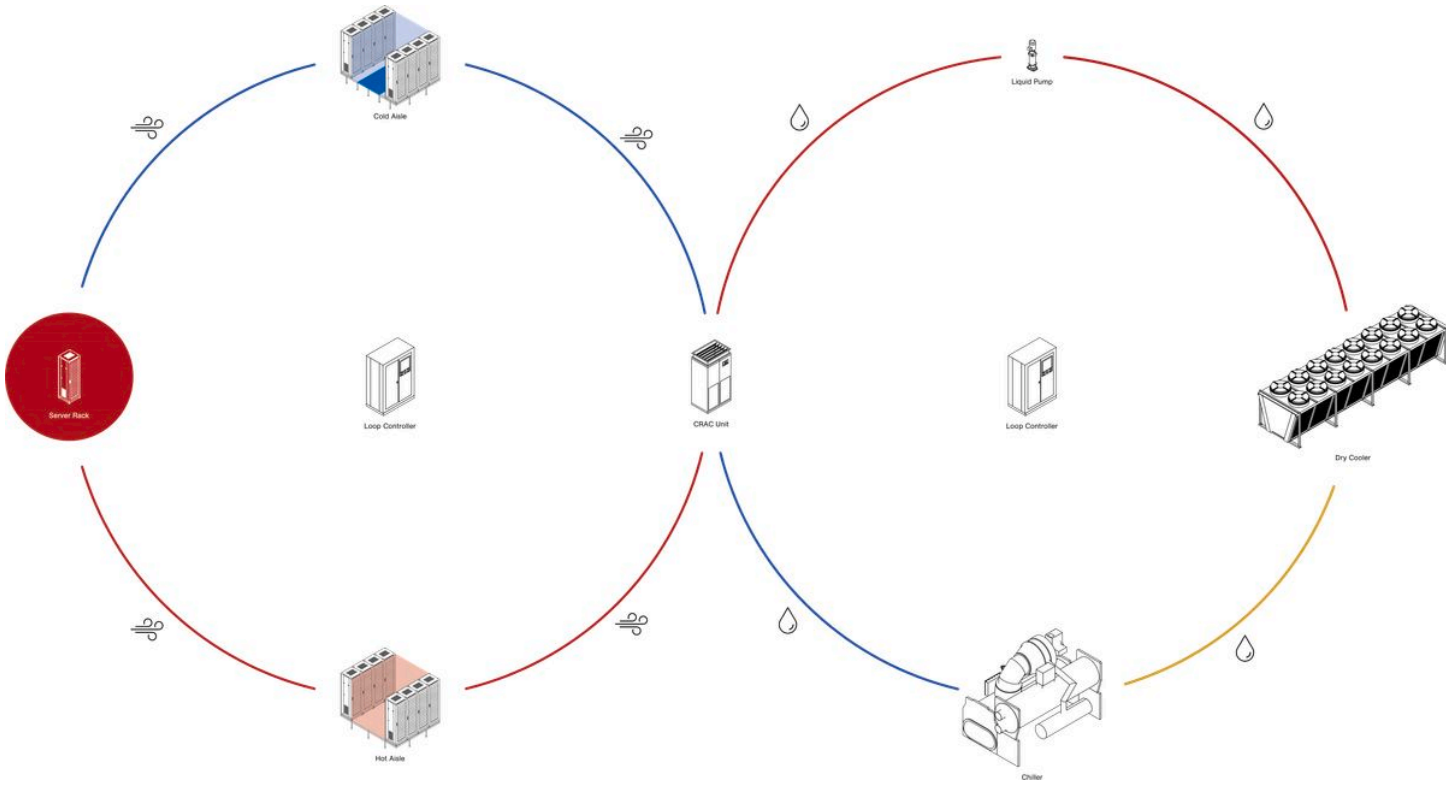


PREDOMINANT COOLING STRATEGY BY REGION
Source: Microsoft, 2023.

Polar zone
Subpolar Zone
Temperate Zone
Subtropical Zone
Tropical Zone
Free Air Cooling
Adiabatic Cooling
Mechanical Cooling
High-efficiency Mechanical Cooling

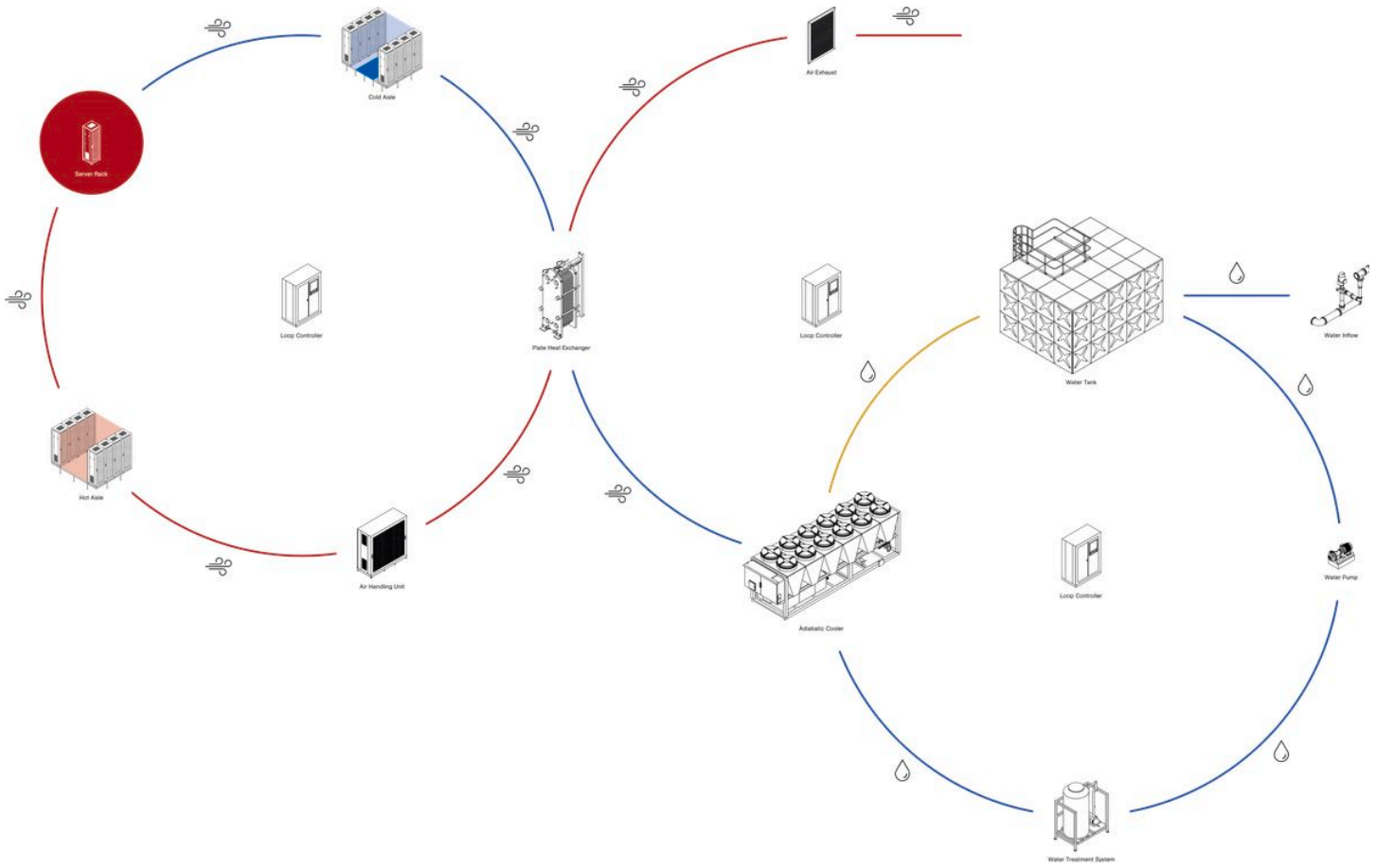
In subpolar climates, free air cooling is widely implemented and strongly promoted as highly sustainable, operationally efficient, and effective in reducing both energy and water consumption. The system leverages cold ambient air, particularly during extended seasons of low outdoor temperatures. This technique is frequently blended with adiabatic cooling in temperate regions to optimise efficiency during periods of fluctuating environmental conditions. Also the DigitalRealty data center in Glattbrugg, Switzerland, uses for much of the year free air cooling suffices, with ambient air itself serving as the primary medium for heat exchange. The inner cooling circuit and outer circuits remain isolated, preserving efficiency and operational safety.

In almost all setups, plate heat exchangers act as mediators between circuits, enabling heat transfer without direct mixing of fluids. Their repeated appearance in schematics and technical photographs is a testament to their ubiquity within advanced data centre engineering. The potential for sustainable energy redistribution is exemplified by the role of plate heat exchangers in waste heat recovery. These devices facilitate the transfer of thermal energy from data centre cooling loops to external consumers such as local housing cooperatives or district heating networks. Such repurposing of byproduct heat represents a promising avenue for urban energy synergies and reduced overall carbon footprint.



FREE AIR COOLING SYSTEM
Hot server air is cooled in CRAC units and recirculated to the servers. The Warm coolant is sent to dry coolers for outside air cooling; if external temperatures are high, it is additionally cooled by a chiller before returning to the CRAC.

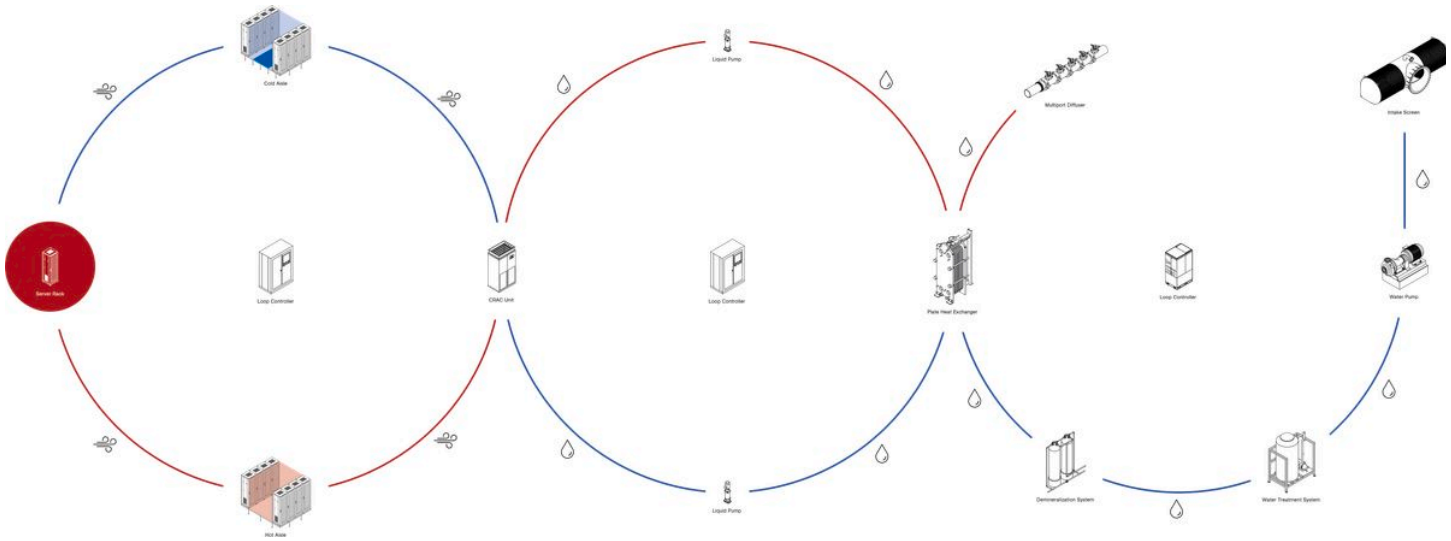
hot
warm
cold
liquid
air



ADIABATIC COOLING SYSTEM

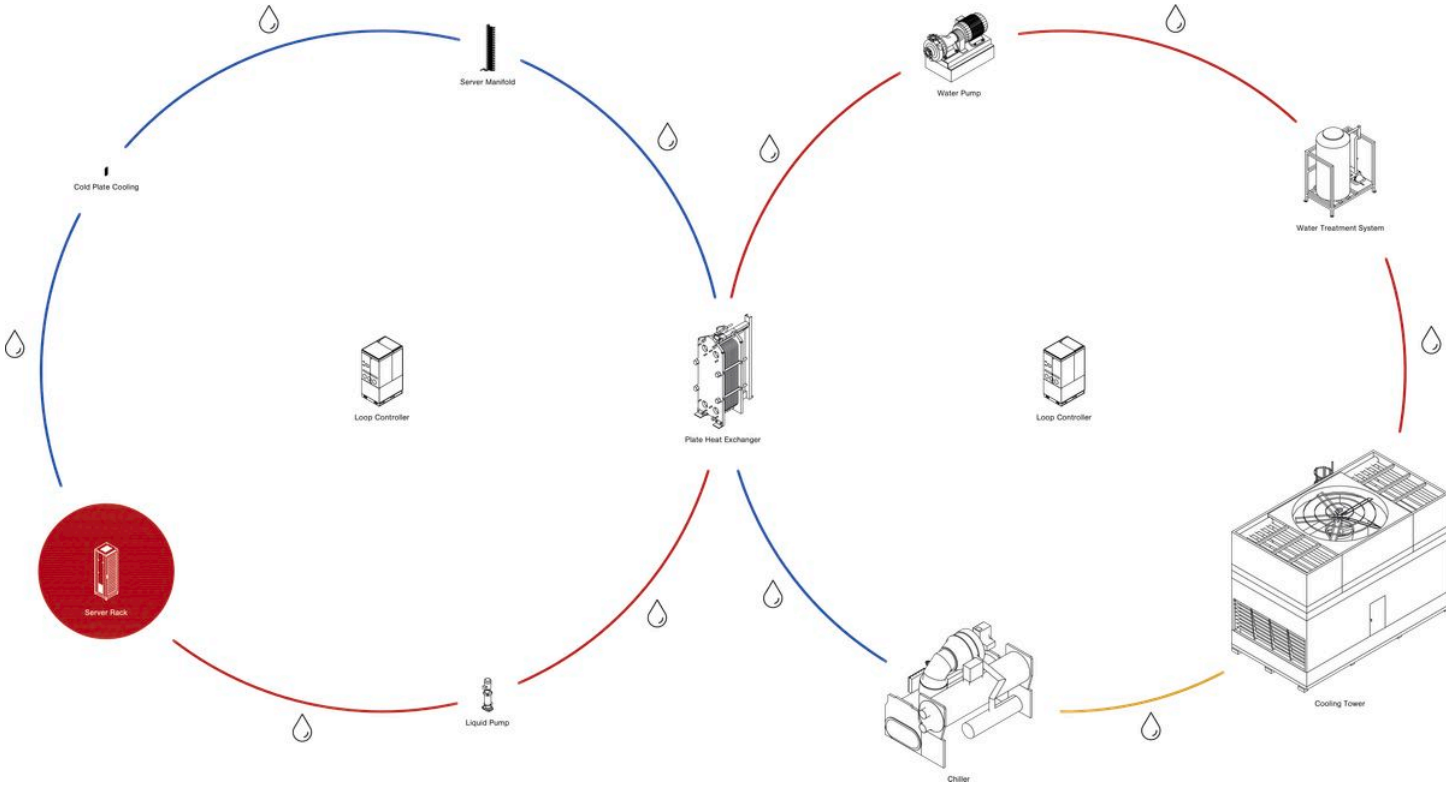
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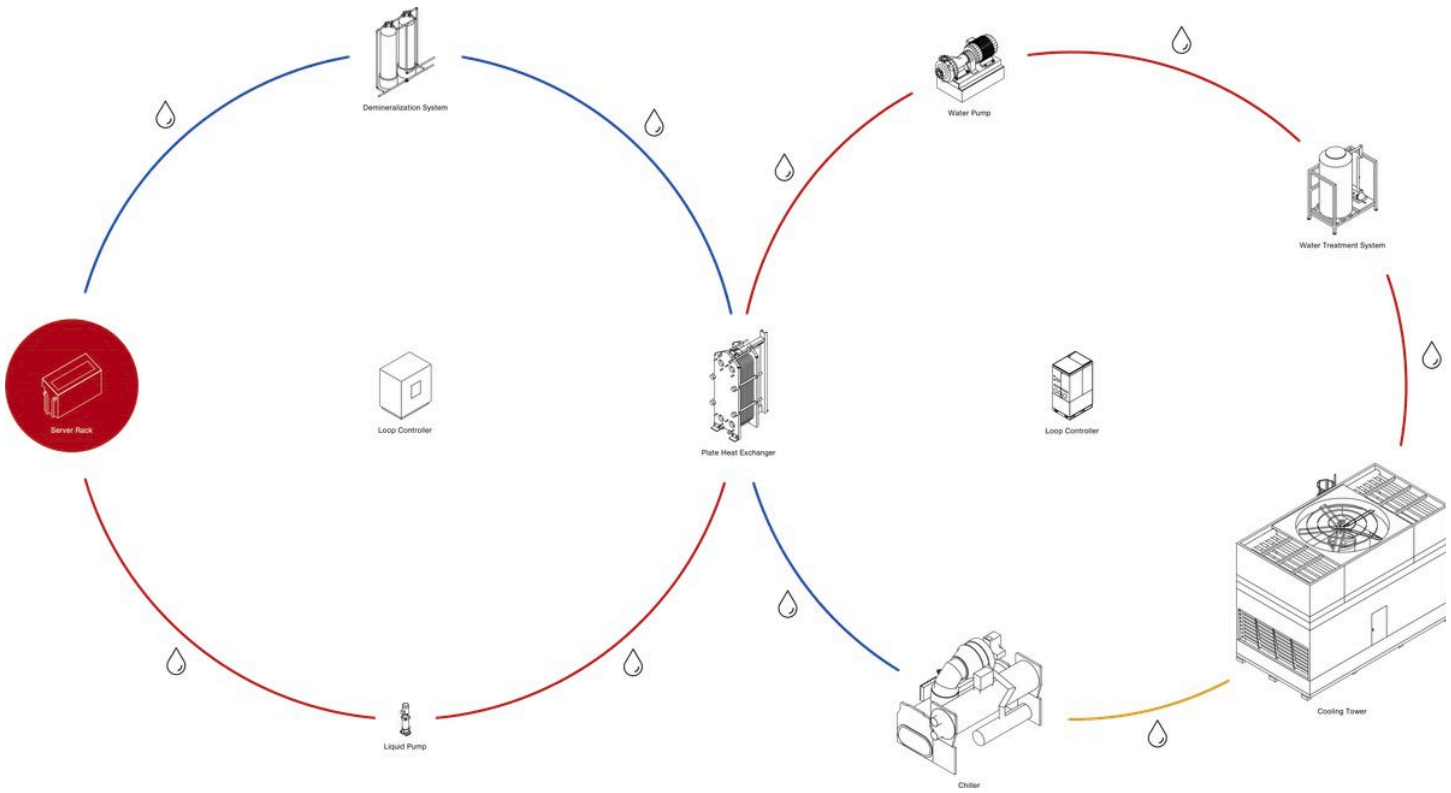
RIVER-/LAKEWATER COOLING SYSTEM
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LIQUID COOLING SYSTEM
Servers are cooled directly by liquid. Hot liquid from the servers flows into a liquid-to-liquid plate heat exchanger, where it is cooled and then recirculated back to the servers. The cold liquid for the plate heat exchanger is chilled by circulating through cooling towers and chillers.

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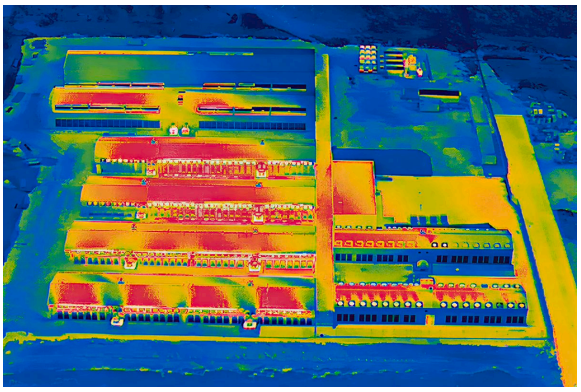
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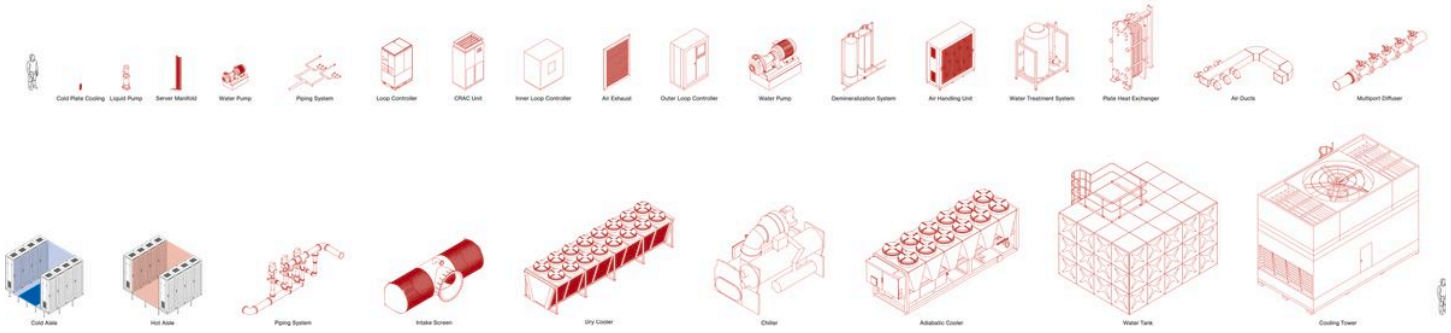
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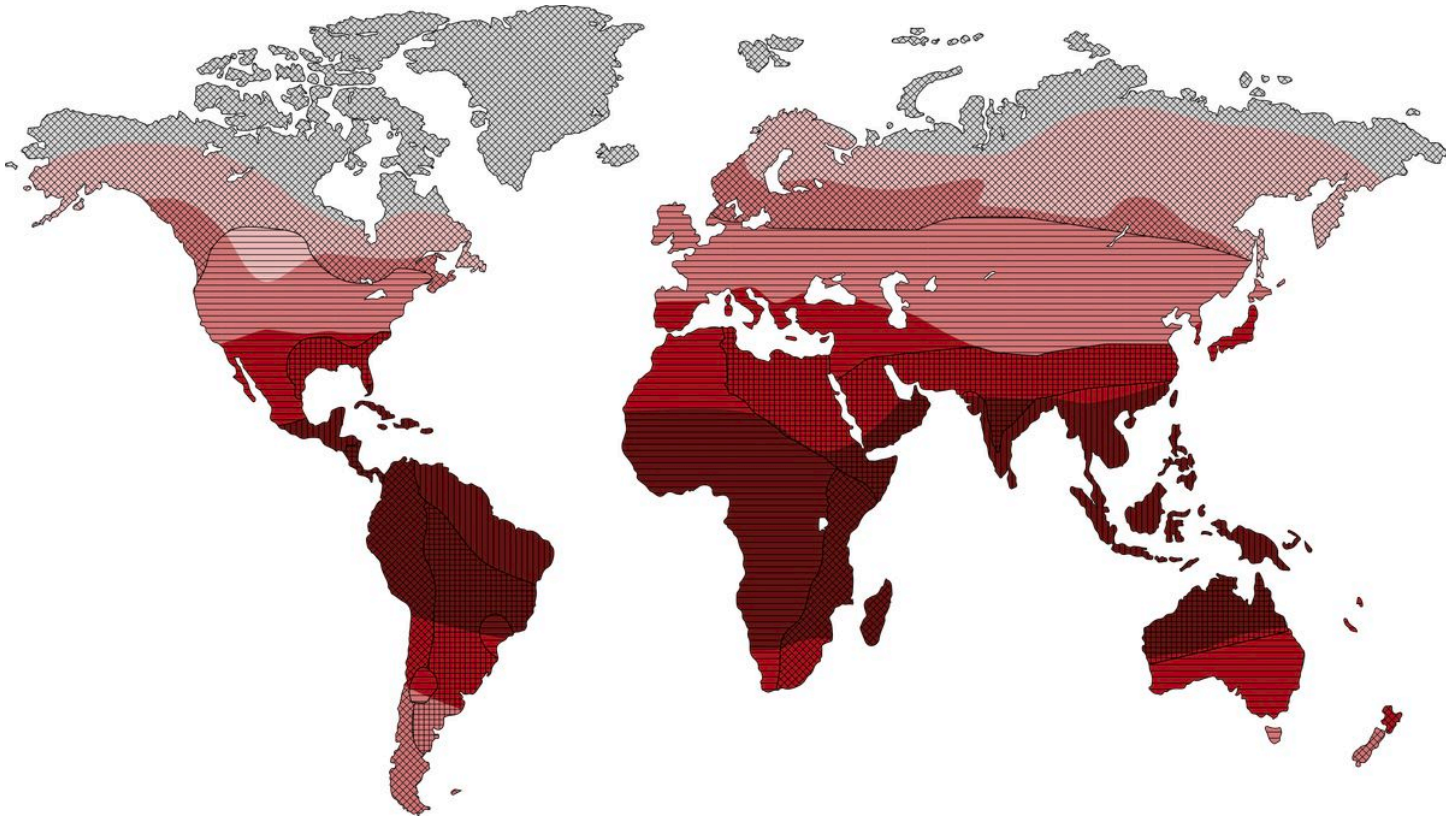
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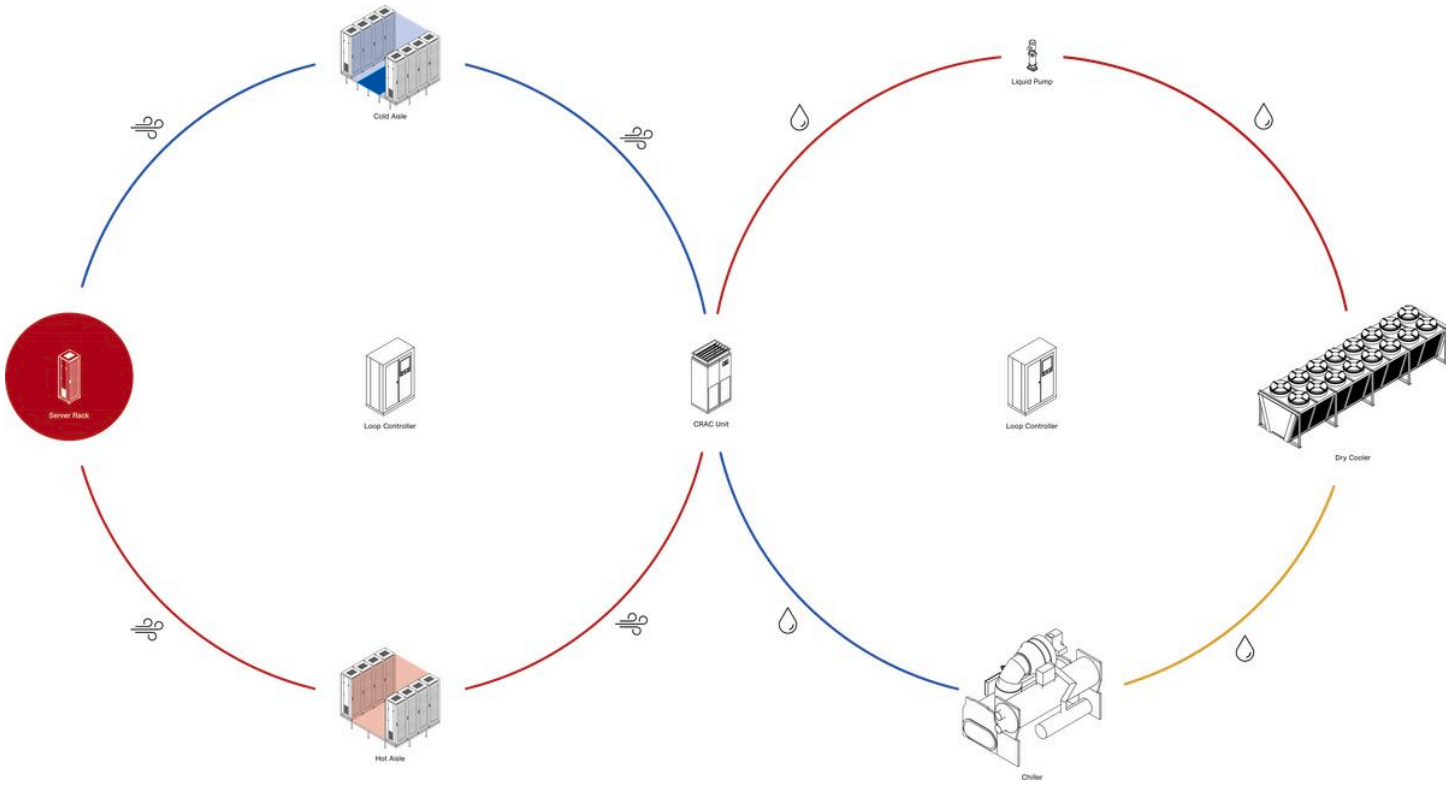


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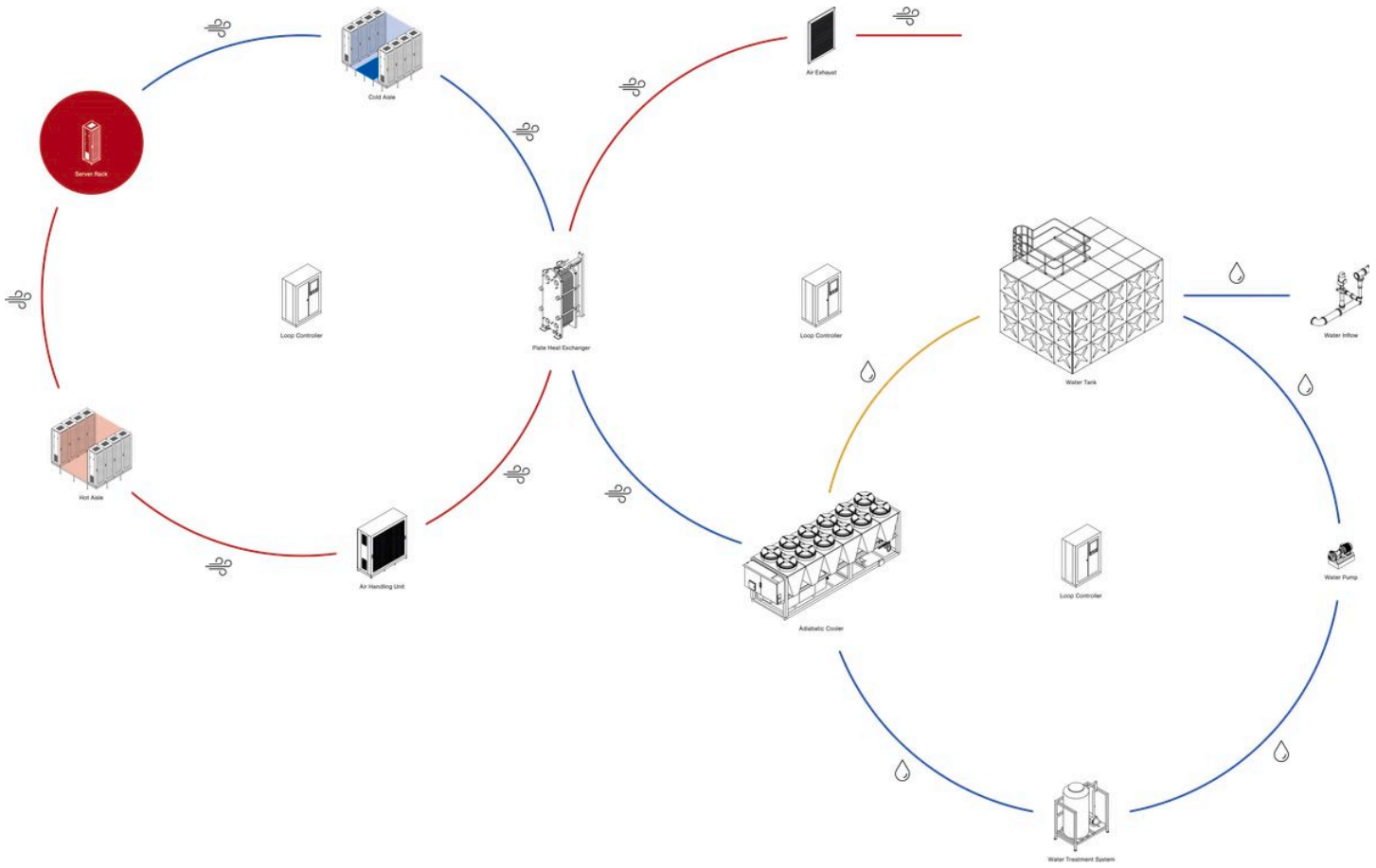
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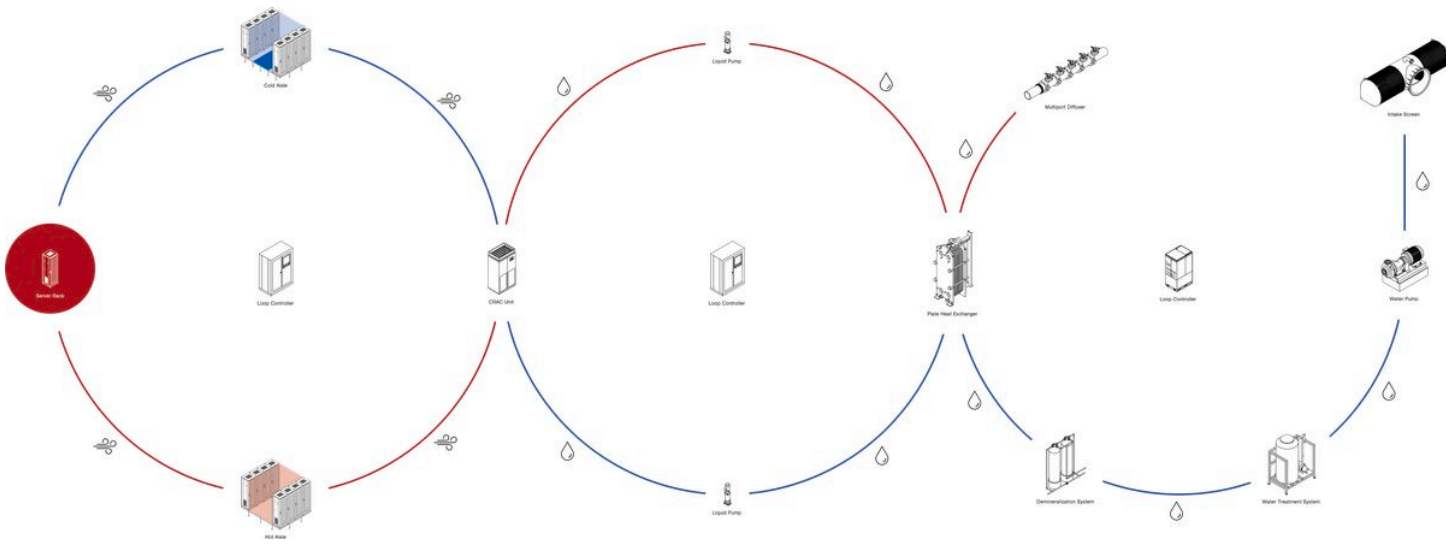
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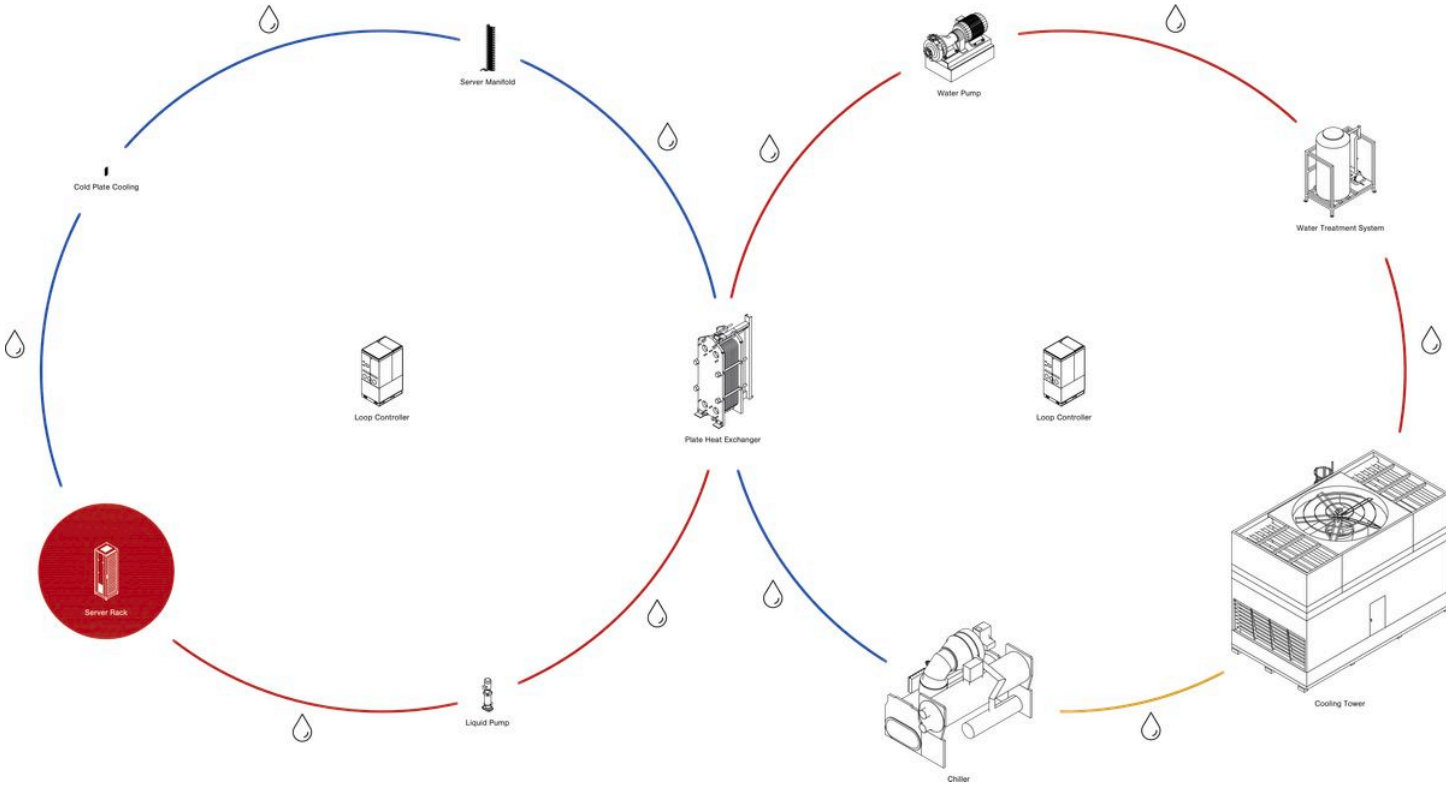
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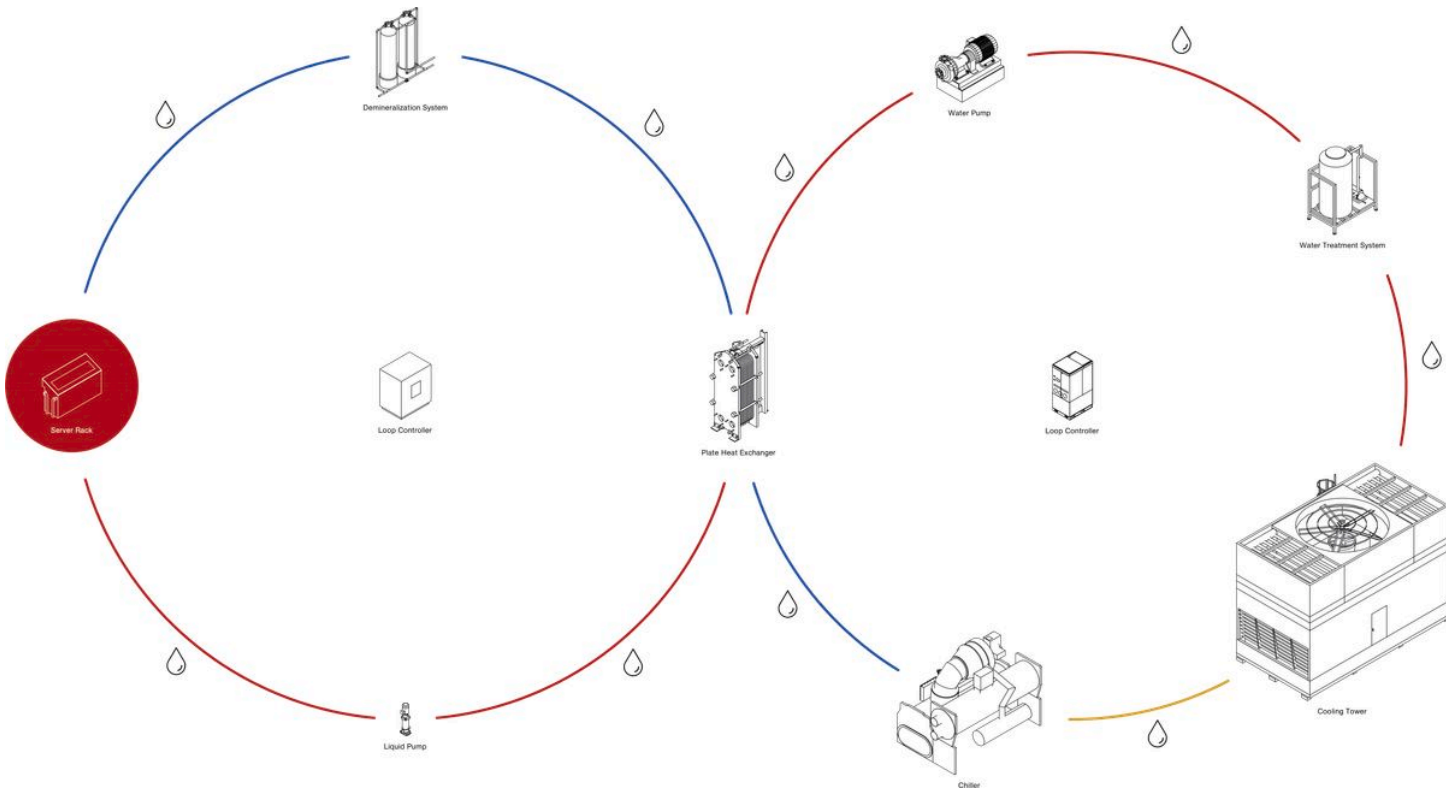
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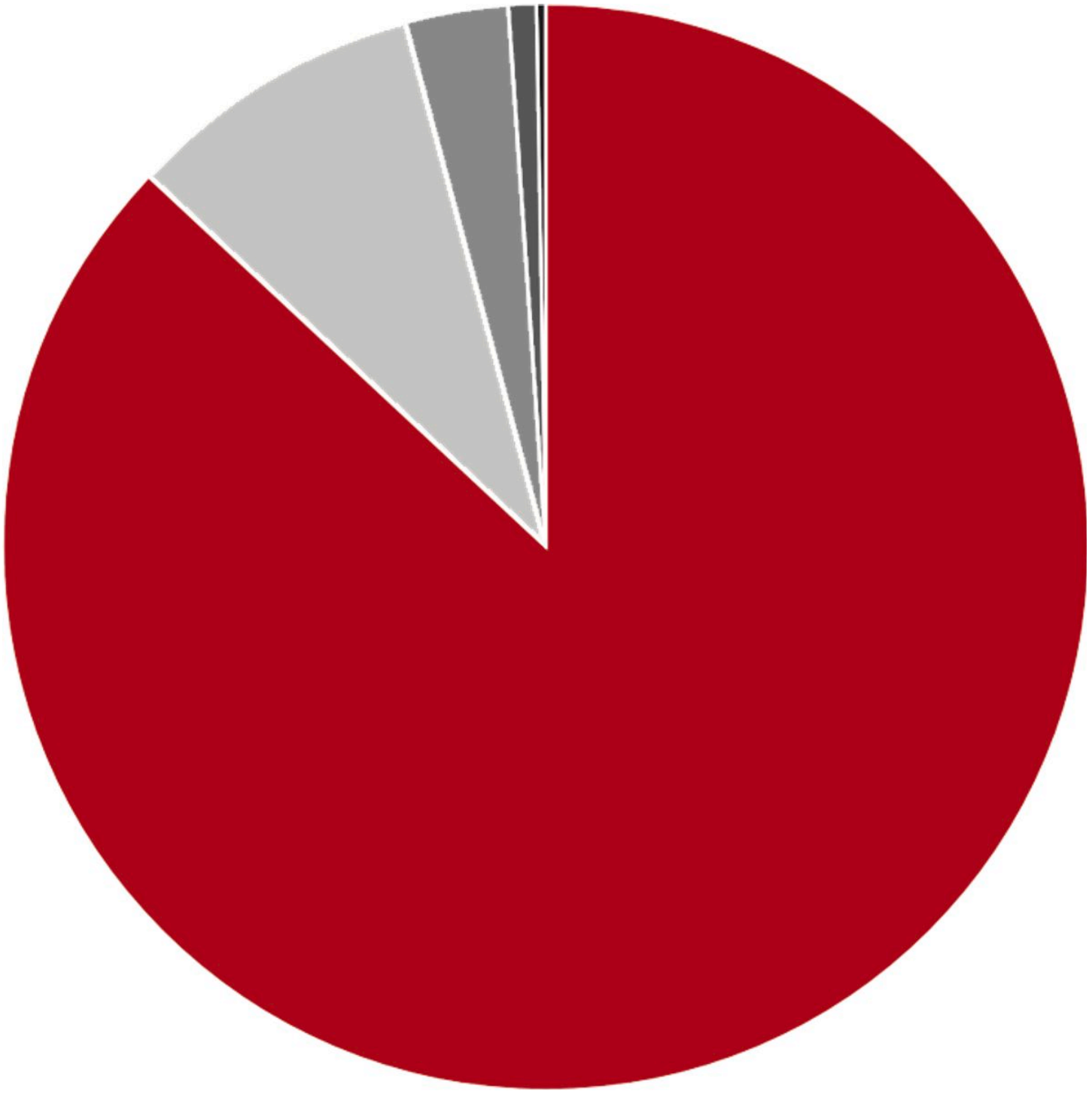
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Heat as a Resource



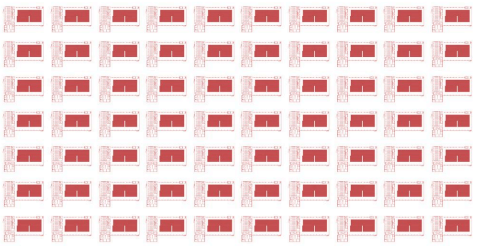
A 45 MW DATACENTER HAS A HEAT OUTPUT OF 51’694'500 WATT

0.01% people
1% lighting
2.9% power distribution
9% UPS with battery
87% IT-equipment

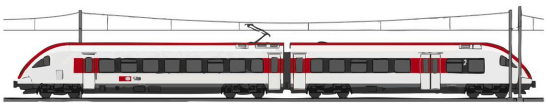
The magnitude of waste heat produced by a typical data centre is often underestimated. Consider a facility with a computational capacity of 45 megawatt (MW): the combined power of the three data centres of Digital Realty in Glattbrugg. Such a center generates approximately 51.5 MW of thermal energy as waste heat. If recovered with perfect efficiency, this output could supply the entire thermal energy demand (for residential and non-residential uses) in Zürich's Altstetten district. Alternatively, the same quantity of heat could operate 70 public swimming pools. Or if converted entirely to electrical energy, enable 18.8 InterCity train journeys from Zurich to Bern every hour. These comparisons illustrate not only the extraordinary energy density inherent in data centre operations, but also their potential for contributing positively to broader urban infrastructure.



WASTE HEAT COVERS THE THERMAL ENERGY DEMAND OF ALTSTETTEN (ZH)

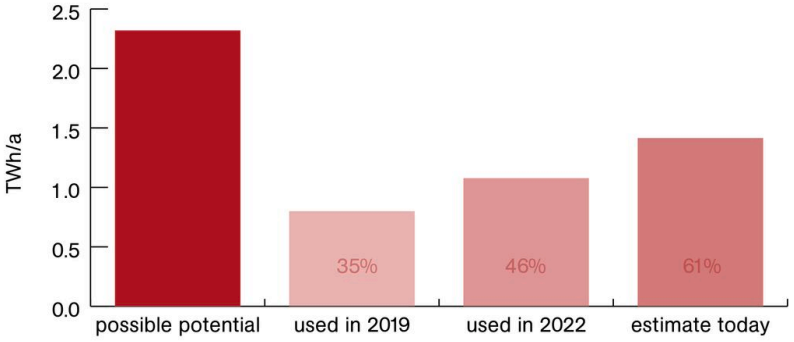


WASTE HEAT COVERS THE THERMAL ENERGY DEMAND OF 70 PUBLIC SWIMMING POOLS
Source: Energie Schweiz, 2024.



WASTE HEAT COVERS THE ENERGY FOR 18.8 INTERCITY TRIPS ZURICH - BERN PER HOUR

WASTE HEAT POTENTIAL



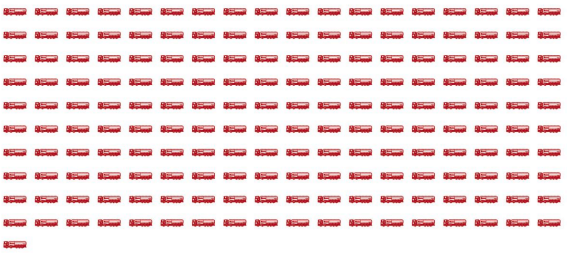
Waste heat potential of data centres in Switzerland. Source: EnergieSchweiz, 2023.

The realistic waste heat potential from data centers in Switzerland is between 2.02 and 2.62 terawatt hour per year (TWh/a) (median 2.32 TWh). In 2019, 35 % of data centres utilised this waste heat. By 2022, 46 % did, with another 15 % planning to do so. This gives a mid-term usage potential of 46–61 %. This waste heat could provide heating and hot water to 140,000–185,000 households (3.7–4.7 % of all Swiss homes), saving 420,000–555,000 tonnes of CO_2 per year by replacing fossil heating. Unlike other industries, data centres produce waste heat at a constant, reliable rate, year-round, 8,760 hours per year, making them secure sources for heating networks.

ENERGY NETWORK AIRPORT CITY



Map of the perimeter of the Airport City energy network. Source: EBL, 2022.



5.6 million liters of heating oil equal 181 large tank trucks with a capacity of approximately 31,000 liters each.

In projects like the Airport City Energy Network near Zurich Airport, operators aim to recycle the warmth produced by Digital Realty's facilities. Doing so could save 15,000 tons of CO_2 annually, the equivalent of 5.6 million liters of heating oil.

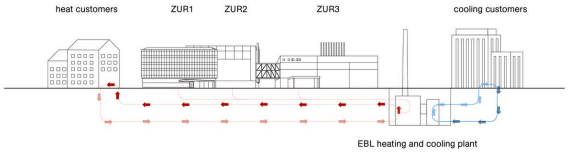
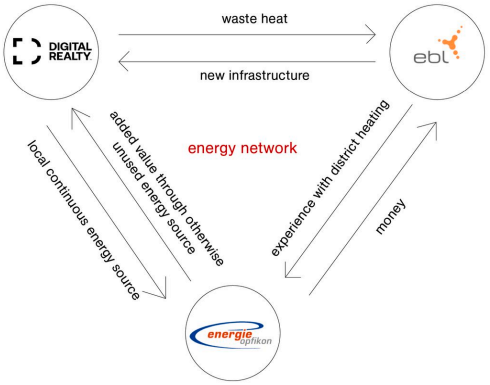


Diagram showing how the "Energieverbund" could work.



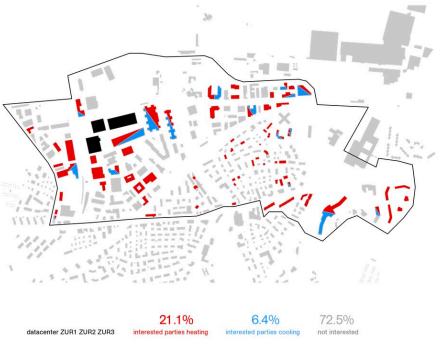
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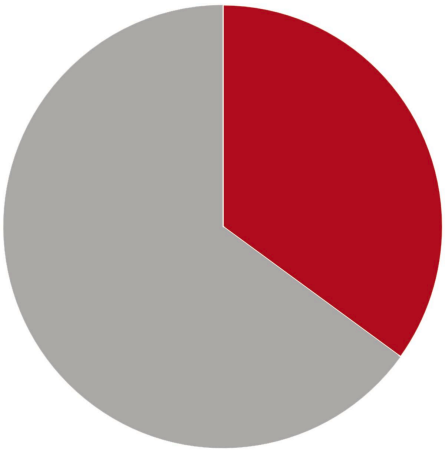
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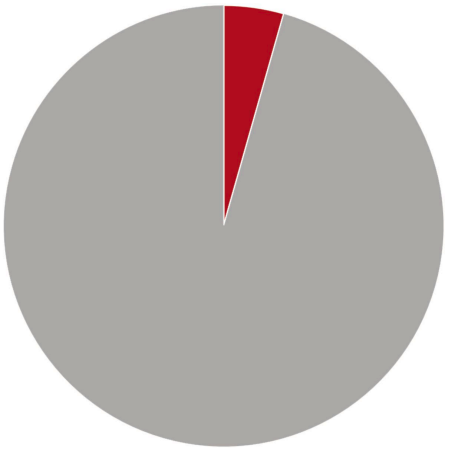
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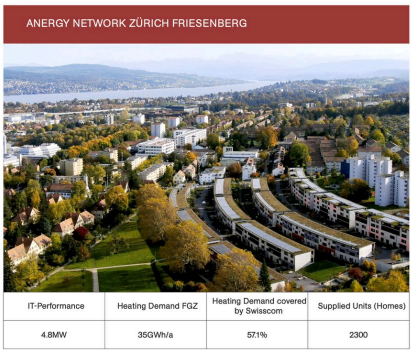
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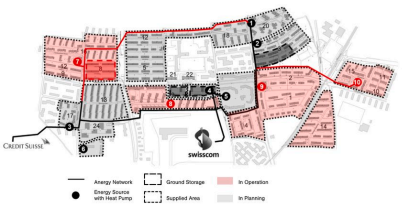


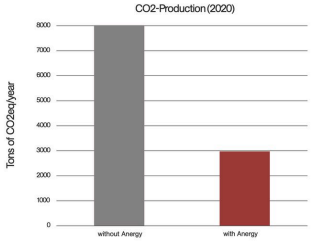
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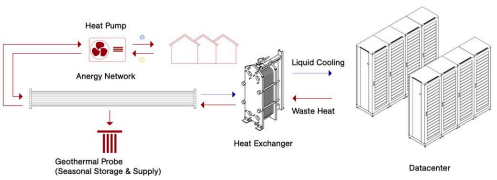
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WASTE HEAT UTILISATION: THREE CASE STUDIES





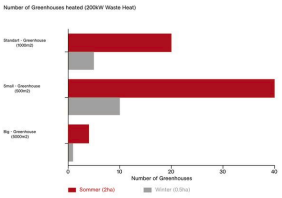


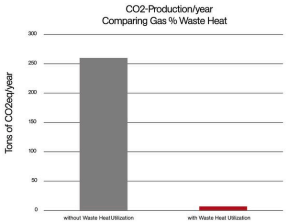


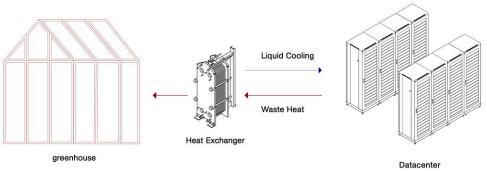
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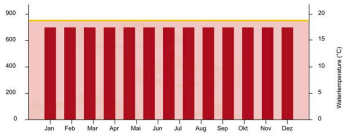


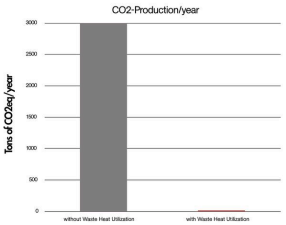


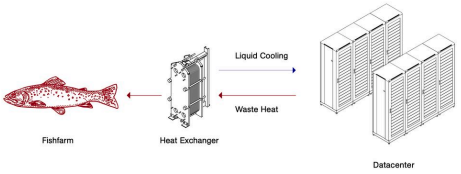
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IT-Performance	Heating Demand Fishfarm	Heating Volume	Fishproduction
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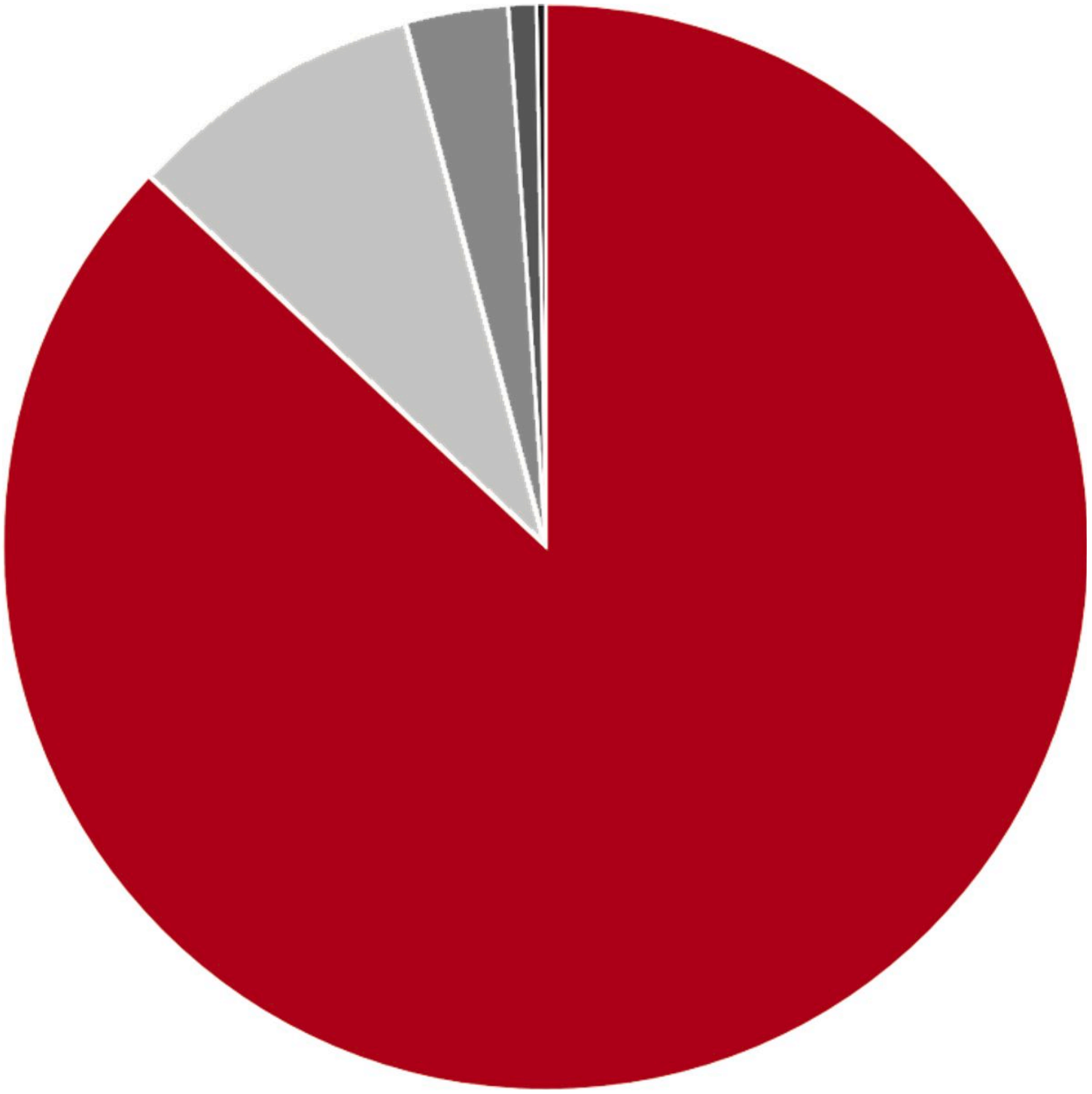






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These examples demonstrate the versatility of waste heat recovery. From residential heating to agricultural and aquaculture applications. Each project significantly reduces CO_2 emissions while turning previously wasted energy into a valuable resource.



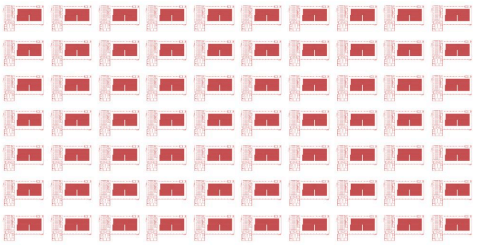
A 45 MW DATACENTER HAS A HEAT OUTPUT OF 51’694'500 WATT

0.01% people
1% lighting
2.9% power distribution
9% UPS with battery
87% IT-equipment

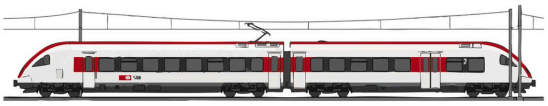
The magnitude of waste heat produced by a typical data centre is often underestimated. Consider a facility with a computational capacity of 45 megawatt (MW): the combined power of the three data centres of Digital Realty in Glattbrugg. Such a center generates approximately 51.5 MW of thermal energy as waste heat. If recovered with perfect efficiency, this output could supply the entire thermal energy demand (for residential and non-residential uses) in Zürich's Altstetten district. Alternatively, the same quantity of heat could operate 70 public swimming pools. Or if converted entirely to electrical energy, enable 18.8 InterCity train journeys from Zurich to Bern every hour. These comparisons illustrate not only the extraordinary energy density inherent in data centre operations, but also their potential for contributing positively to broader urban infrastructure.



WASTE HEAT COVERS THE THERMAL ENERGY DEMAND OF ALTSTETTEN (ZH)

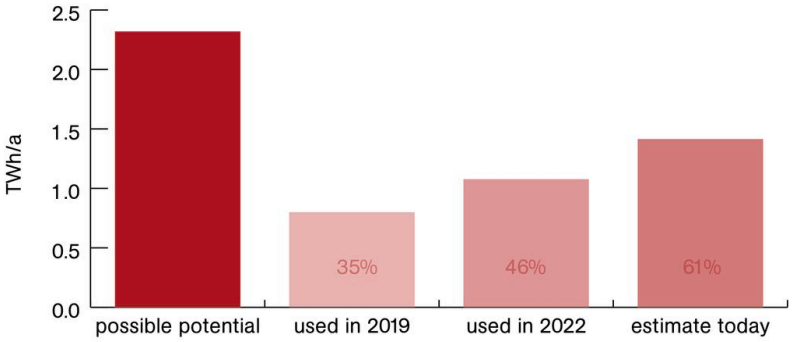


WASTE HEAT COVERS THE THERMAL ENERGY DEMAND OF 70 PUBLIC SWIMMING POOLS
Source: Energie Schweiz, 2024.



WASTE HEAT COVERS THE ENERGY FOR 18.8 INTERCITY TRIPS ZURICH - BERN PER HOUR

WASTE HEAT POTENTIAL



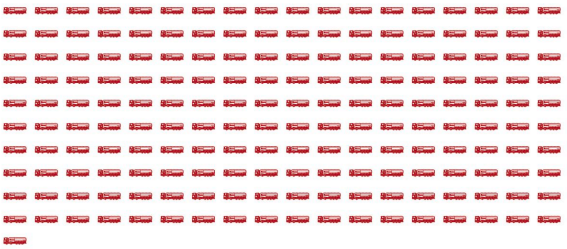
Waste heat potential of data centres in Switzerland. Source: EnergieSchweiz, 2023.

The realistic waste heat potential from data centers in Switzerland is between 2.02 and 2.62 terawatt hour per year (TWh/a) (median 2.32 TWh). In 2019, 35 % of data centres utilised this waste heat. By 2022, 46 % did, with another 15 % planning to do so. This gives a mid-term usage potential of 46–61 %. This waste heat could provide heating and hot water to 140,000–185,000 households (3.7–4.7 % of all Swiss homes), saving 420,000–555,000 tonnes of CO_2 per year by replacing fossil heating. Unlike other industries, data centres produce waste heat at a constant, reliable rate, year-round, 8,760 hours per year, making them secure sources for heating networks.

ENERGY NETWORK AIRPORT CITY



Map of the perimeter of the Airport City energy network. Source: EBL, 2022.



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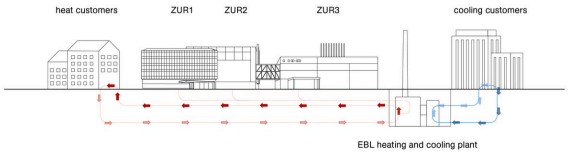
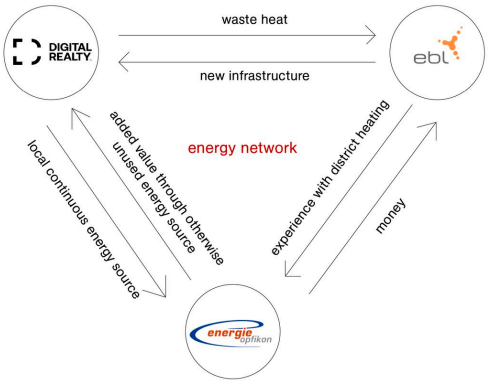


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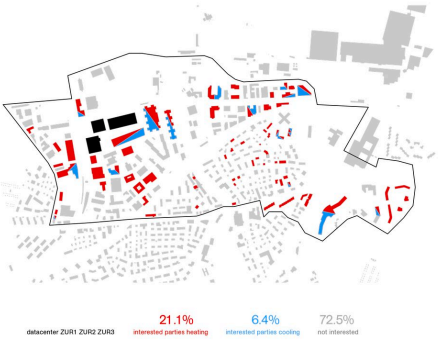
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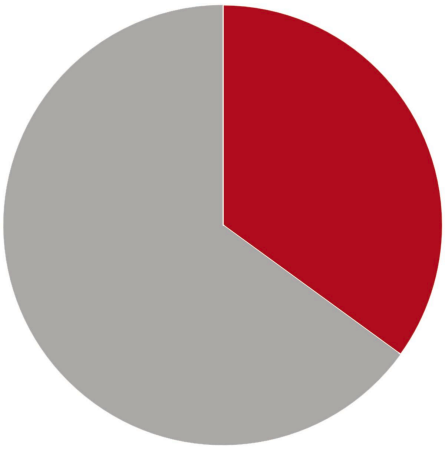
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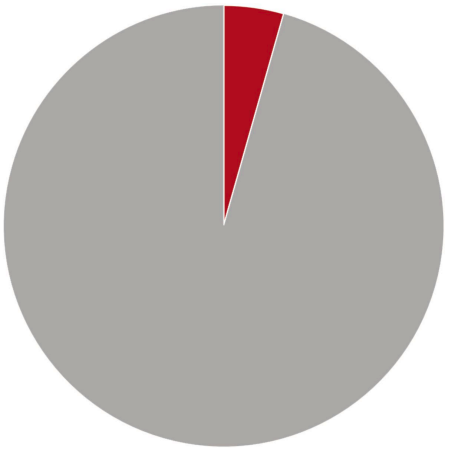
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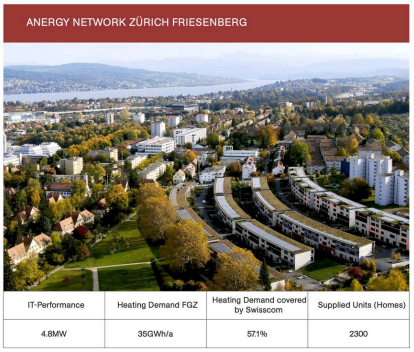
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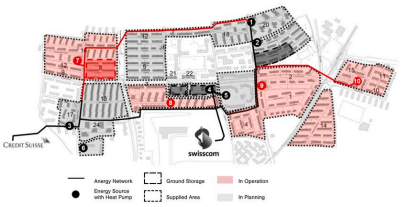


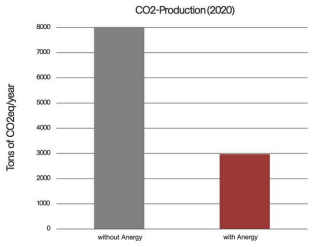
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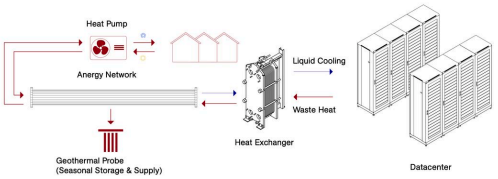
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WASTE HEAT UTILISATION: THREE CASE STUDIES





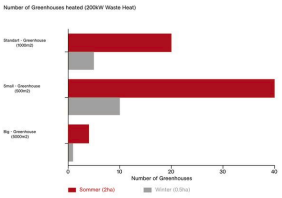


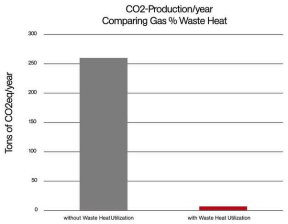


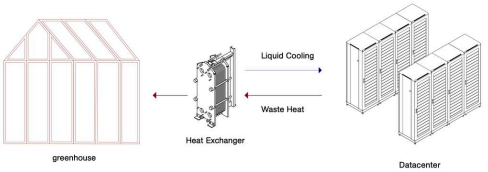
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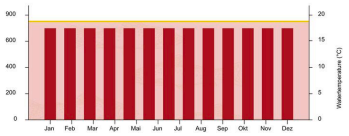


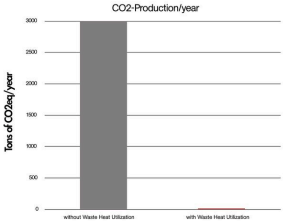


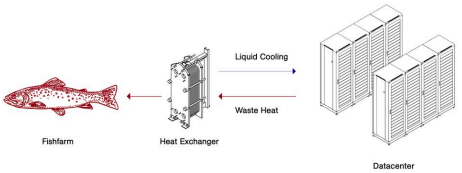
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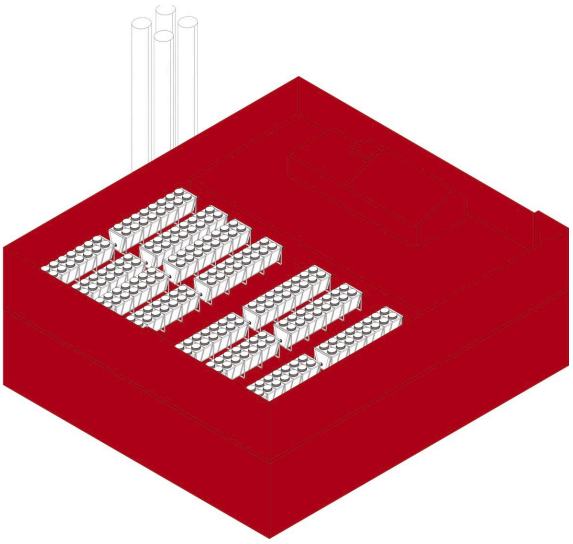




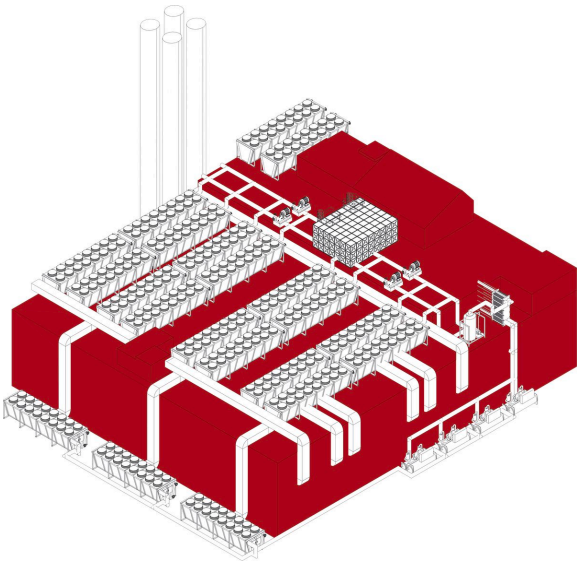
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From Fortress to Forum: Data Centres as Civic Infrastructure



AXONOMETRY OF A TYPICAL DATA CENTRE



AXONOMETRY OF A DATA CENTRE WITH VISIBLE INFRASTRUCTURE (INSIDE OUT)
Drawing: the authors, 2025.

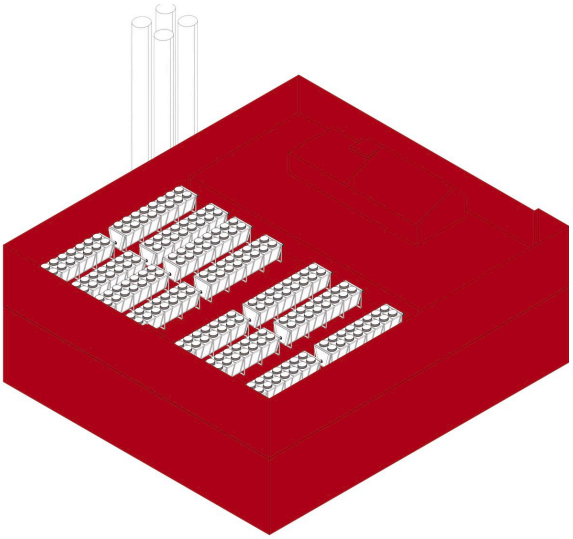
Waste heat could become part of the urban metabolism, tying digital infrastructure into physical cities. Can data centres evolve into living, adaptive, or hybrid ecological systems? If computation was a public good, what would its architecture look like? Can visibility and design reclaim these buildings from anonymity and make the cloud a civic utility, not just a corporate fortress?



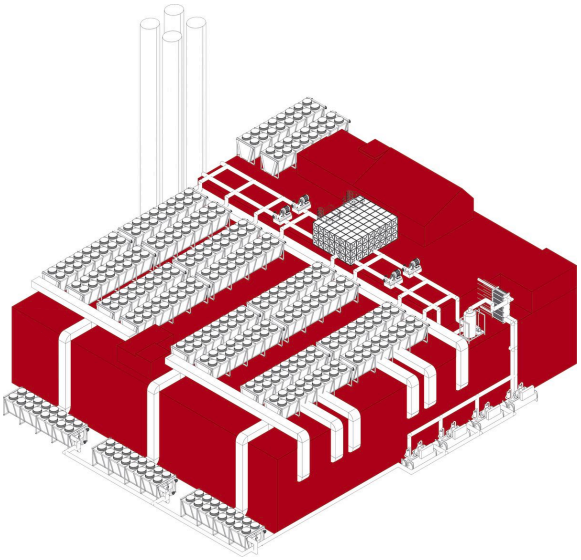


CONCLUSIONS

When waste heat is left unused, it remains a private byproduct of corporate infrastructure. Communities miss out on tangible energy and climate benefits. Every unrecaptured watt means more fuel burned elsewhere, more emissions, and an invisible cost to the climate. But when cooling infrastructure becomes visible, acknowledged as part of our cities, it can spark awareness, innovation, and social pressure to use energy more intelligently.



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Waste heat could become part of the urban metabolism, tying digital infrastructure into physical cities. Can data centres evolve into living, adaptive, or hybrid ecological systems? If computation was a public good, what would its architecture look like? Can visibility and design reclaim these buildings from anonymity and make the cloud a civic utility, not just a corporate fortress?





CONCLUSIONS

When waste heat is left unused, it remains a private byproduct of corporate infrastructure. Communities miss out on tangible energy and climate benefits. Every unrecaptured watt means more fuel burned elsewhere, more emissions, and an invisible cost to the climate. But when cooling infrastructure becomes visible, acknowledged as part of our cities, it can spark awareness, innovation, and social pressure to use energy more intelligently.

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