FORESIGHT

BC NET ZERO INNOVATION NETWORK

ZEIC ZERO EMISSIONS INNOVATION CENTRE

Scan of Waste Heat Recovery and Thermal Storage Technologies

Prepared For:
Zero Emissions Innovation Centre
Foresight Canada

Prepared By:
Inform Energy Solutions

Sept 2025

Executive Summary

Every year, hundreds of terawatts of energy globally are lost as unharnessed heat from industrial processes, buildings, transportation networks and other urban infrastructure. This valuable energy, or "waste heat," can be captured and reused, greatly reducing reliance on other primary fuel sources, therefore reducing carbon emissions and providing substantial cost savings. When combined with District Energy Systems (DESs), energy produced from sources of waste heat can be distributed to buildings, improving efficiencies and increasing energy security by utilizing local, low-cost sources. A study by McKinsey highlights that the annual global savings by harnessing waste heat could reach up to €140 billion. [1]

While few heat recovery and Thermal Energy Storage (TES) technologies are designed, manufactured, and/or assembled in Canada, some notable examples directly support the recovery of local waste heat sources, including:

- **SHARC Energy:** Provides raw sewage heat recovery systems
- **Vitalis:** Builds CO_2 high-temperature heat pumps
- **Combustion & Energy Systems:** Manufactures flue gas economizers
- **CIMCO:** Produces a variety of industrial heat pump solutions

A number of Canadian DESs have implemented—or are in the process of implementing—heat recovery and TES to leverage cheap or free waste energy, increase resource efficiency, maintain alignment with shifting regulations, and decrease operational costs all while reducing system GHG emissions. Currently, the most prominent DES technology adoption trend is heat recovery from raw sewage, cooling systems, and combustion flue gas.

Key recommendations following this study include:

- Further investigate and demonstrate the use of local waste heat sources in Metro Vancouver to support heating and cooling demands in medium to high-density areas.
- Prepare GIS-based thermal mapping to identify and match thermal energy supply to demand, and to substantiate local energy planning and heat zoning initiatives.
- Conduct studies in coordination with BC Hydro to explore how DES with TES systems can successfully alleviate local grid constraints.

The technologies and project examples highlighted in this study should inspire further innovation, catalyze greater efforts to harness waste heat resources in Metro Vancouver, and promote low-carbon DESs as a crucial strategy to deliver sustainable building heating and cooling.

[1] Mckinsey & Co:
https://www.mckinsey.com/capabilities/sustainability/our-insights/waste-not-unlocking-the-potential-of-waste-heat-recovery

Project Partners

The Zero Emission Innovation Centre (ZEIC) is a purpose-built charitable organization dedicated to market transformation and enabling zero carbon communities and economies across the region and province. ZEIC is part of the Low Carbon Cities Canada (LC3) Network established by the Government of Canada and the Federation of Canadian Municipalities.

Inform Energy Solutions is a boutique engineering consulting and advisory firm based in Vancouver, Canada, specializing in practical energy and decarbonization solutions for buildings sector thermal systems and district energy systems.

Foresight Canada helps the world do more with less, sustainably. As Canada's largest cleantech innovation and adoption accelerator, we connect public and private sectors to the world's best clean technologies. We de-risk and simplify adoption of solutions that improve productivity, profitability, and economic competitiveness, all while addressing urgent climate challenges.

ZEIC ZERO EMISSIONS INNOVATION CENTRE

inform ENERGY SOLUTIONS

FORESIGHT

Land Acknowledgement

With gratitude and respect, the project partners acknowledge that the lands on which we operate are the traditional, ancestral, and unceded territories of the First Nations, Inuit, and Métis peoples.

Acknowledgements

Recognizing the efforts of experts and participants is crucial to appreciating the importance of this research. Their expertise was key to this study. We sincerely thank the following individuals and organizations:

- **Foresight Canada:** Nina Bader, Alyssa Kelly, Aislinn Crawford, Heather Kingdon
- **Zero Emissions Innovation Centre:** Peter Sun, George Benson
- **City of Vancouver – Neighbourhood Energy Utility:** Alex Charpentier
- **Federation of Canadian Municipalities:** Terry Sidhu
- **Building Decarbonization Alliance:** Aurélie Vérin, Mathieu Lévesque, Brett Kerrigan
- **SHARC Energy:** Brock Trimble, Robbie Forrester
- **Natural Resource Canada CanmetENERGY**: Raymound Boulter
- **Eden Energy Equipment:** Michael Ridler
- **CIMCO:** Rob Martin, Bashar Naser
- **Kaaj Energy:** Reza Lotfalian
- **Noventa:** Ed Rubinstein
- **ThermaStor Solutions:** James Bereton, Evan Ericson
- **Cadillac Fairview:** Yichao Chen
- **First Light Energy Solutions:** Moises de Alba
- **Thermofin:** Alexandre Beuque
- **Combustion & Energy Systems:** Cam Veitch, Sean Burrowes
- **Creative Energy:** Keith Bate
- **Enwave:** Cameron Leitch
- **AIC Heat Exchangers:** Saji Mathews
- **Halifax Regional Water Commission:** Jeff Knapp

Table of Contents

Introduction

Background

In Canada, the buildings sector is the third largest emitting sector, responsible for 18% of the country's total greenhouse gas (GHG) emissions. [2] Modern district energy systems have re-emerged as an effective and adaptable strategy for reducing emissions within the sector. In leveraging available and accessible waste heat resources, these systems achieve substantial energy use reductions and play a vital role in advancing decarbonization goals by reducing reliance on fossil fuels. When integrated with thermal storage technologies, they further capitalize on waste heat opportunities while easing the growing pressure on local electrical grids, delivering environmental and operational benefits, as well as capital cost avoidance.

A 2023 McKinsey study estimated that there is over 600 terawatt-hours of feasibly extractable waste heat from sources across the Americas—the equivalent of over 100 Site C Dams—that is currently untapped. When harnessed, the annual global cost savings could reach up to €140 billion. This is comparable to the worth of all natural gas imported by the European Union. [3] Tangible financial benefits can be achieved for a variety of parties as the use of waste heat offers a free or low-cost alternative to primary fuels, a potential new revenue stream for waste heat producers, and reduced capital costs for developers and municipalities.

Metro Vancouver is a leading market in North America in this regard, with significant uptake for some of these approaches. Notably, the SHARC Energy Solutions heat exchange system is now used in the City of Vancouver's Neighbourhood Energy Utility and will be utilized at the Squamish Nation's Seńák̲w housing development.

[2] Canada Green Building Council: https://www.cagbc.org/why-green-building/building-climate-solutions/

[3] Mckinsey & Co:
https://www.mckinsey.com/capabilities/sustainability/our-insights/waste-not-unlocking-the-potential-of-waste-heat-recovery

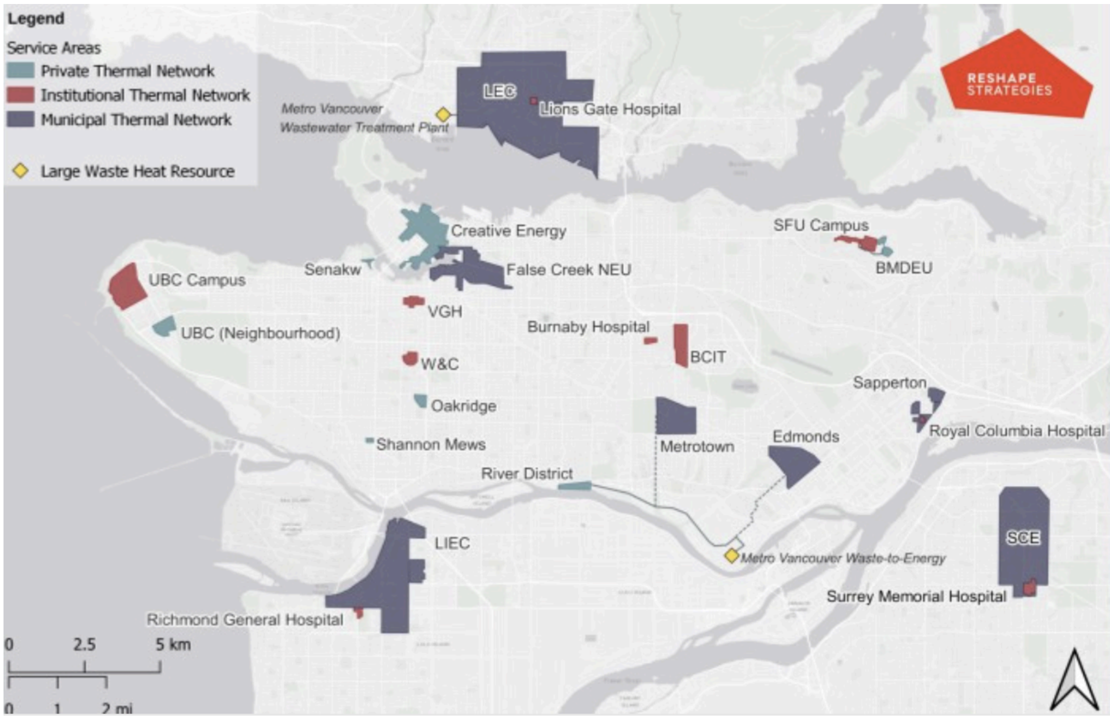


Figure 1: Map of thermal energy networks in Greater Vancouver produced by Reshape Strategies.
Source: Reshape Strategies

Beyond the energy savings potential, other environmental benefits can be realized through the water-energy nexus. Addressing the climate crisis in urban areas requires a deep understanding of the relationship between water and energy. Our efforts to decarbonize and transition to a clean economy are directly linked to how we manage our water resources. Energy production is water-intensive, from thermal power plants that require large amounts of cooling water to hydroelectric power plants that rely on water flow. At the same time, we consume significant amounts of energy to treat, convey, and transport water for various uses.

Discussions about our energy systems and water resources are inextricably linked. Integrating water and energy planning is an environmental necessity and a critical strategy for building resilient, sustainable, and equitable communities across Canada. The recovery and reuse of waste heat and the implementation of thermal storage systems are one way to reduce our energy consumption in buildings. Recognizing the crucial role that these technologies play, this study has been developed to begin cataloging Canadian market-ready solutions.

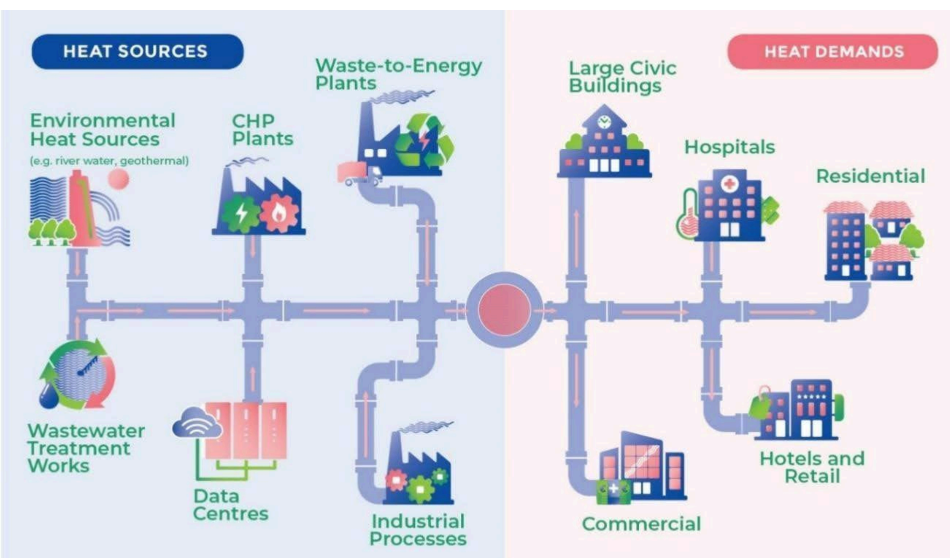
Purpose and Scope

The primary purpose of this project is to promote the uptake of low-carbon district energy systems in Metro Vancouver by identifying existing and emerging waste heat recovery and thermal storage technologies. The scope includes a detailed scan of Canadian market-ready solutions, analysis of adoption trends influenced by technological, market, regulatory, and economic drivers, and recommendations aimed at accelerating the deployment of these technologies.

Key objectives of this study were as follows:

- **Technology Identification:** Pinpoint Canadian technologies and solutions for waste heat recovery and thermal storage that are ready for market deployment.
- **Adoption Trend and Opportunities Analysis:** Investigate factors shaping the deployment of these technologies in British Columbia and beyond.
- **Recommendations for Advancement:** Provide guidance for demonstrations, research initiatives, and policy considerations that support the adoption and integration of waste heat recovery and thermal storage technologies.

This study aims to empower asset owners, policymakers, and industry leaders with the technology information needed to catalyze energy efficiency and emissions reductions via the deployment of modern low-carbon district energy systems.



Examples of District Energy Heat Sources and Demands [4]

[4] Interreg HeatNet NWE: https://guidetodistrictheating.eu/about/what-is-district-heating/

Methodology

The project methodology focused on identifying and analyzing market-ready Canadian waste heat recovery and thermal storage technologies to promote low-carbon district energy systems.

The approach involved the following key steps:

1. **Technology Scan and Data Collection:** Conducted a broad scan of Canadian technologies by engaging with industry leaders, accelerators, utilities, and equipment providers to gather technical information on solutions and project examples.
2. **Technology Identification and Categorization:** Organized the identified technologies based on similarities in characteristics or concepts.
3. **Technology Analysis and Explanation:** Evaluated the applicability and use cases for DESs.

Overview of District Energy Systems (DES)

DESs are localized energy infrastructure that supply heating, cooling, and/or domestic hot water to multiple buildings, generally from a centralized, shared energy plant or multiple interconnected energy plants for larger or more complex systems. Unlike conventional heating and cooling, where each building has its own boiler or chiller system, a DES decouples thermal energy production from individual buildings and consolidates it into a more efficient, scalable, and flexible infrastructure.

District Energy vs. Thermal Energy Networks

DES is sometimes used interchangeably with the concept of Thermal Energy Networks (TENs). TENs and DESs are, in essence, the same: they are centralized systems for distributing heating and cooling to a cluster of buildings. However, the concept of a TEN is now often used to specifically refer to a DES that is highly decentralized and "opportunistically to draw from the thermal resources at the location, which may include energy-intensive buildings that shed waste heat, sewer systems, and the subsurface ground temperature" and specifically or commonly use significant geothermal heat resources.[5]

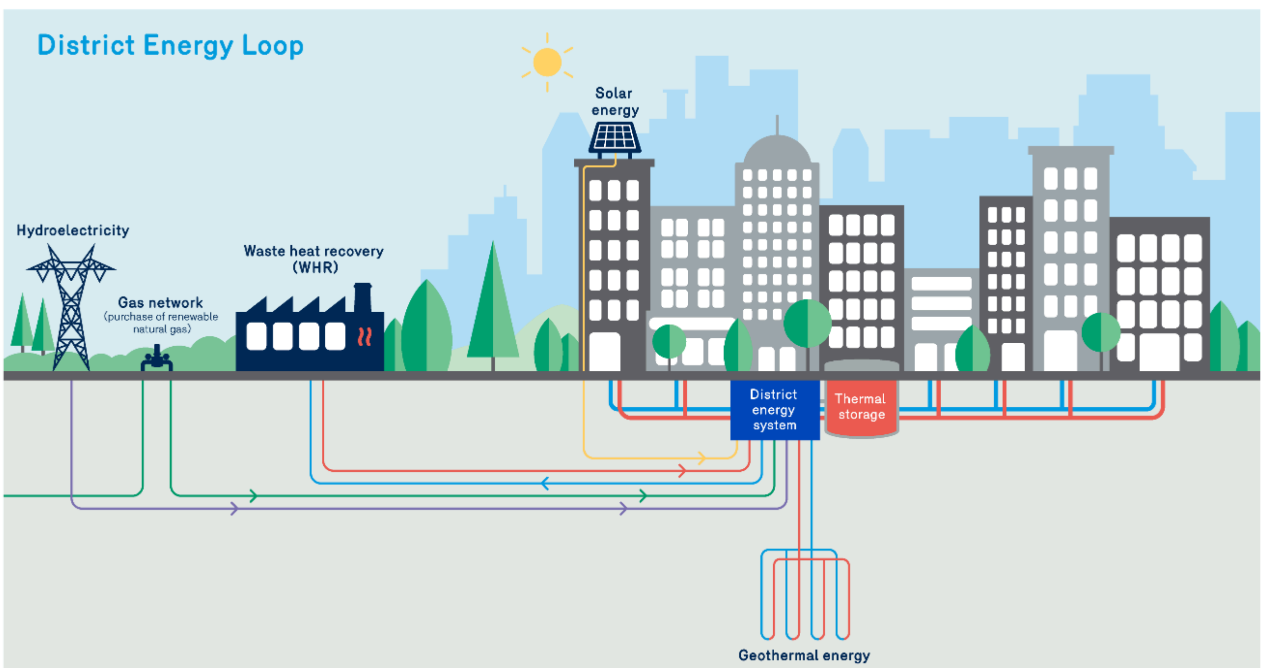
This paper will use district energy as the overarching term, but TENs—specifically geothermal TENs—are a significant and growing typology to consider within this field.

DESs can be supplied by a variety of energy sources—including electricity, fossil gas, biomethane, waste heat sources, and biomass. They are especially well-suited for dense urban environments, campuses, and mixed-use developments. Modern DESs leverage its economies of scale to enable cost-effective integration of waste heat sources and renewable energy to increase low-carbon thermal energy production.

[5] Camargo *et al.* "The Future of Heat: Thermal Energy Networks as an Evolutionary Path for Gas Utilities Toward a Safe, Equitable, Just Energy Transition." *ACEEE Summer Study on Energy Efficiency in Buildings.* (2024).

Key benefits of a DES include:

- **Energy Efficiency:** High system-level efficiency through load diversity, optimized plant operation, and waste heat recovery.
- **GHG Emissions:** Lower emissions via centralized control, renewable integration, and decarbonization pathways.
- **Operational Flexibility:** Can integrate multiple energy sources and storage; easier to upgrade or transition over time.
- **Resilience:** Centralized backup and redundancy and professional utility operations improve reliability during outages.
- **Space Savings:** Eliminates need for large mechanical rooms and mechanical rooftop space at each building.
- **Lifecycle Cost:** Typically lower total cost of ownership due to economies of scale and reduced maintenance.
- **Urban Integration:** Enables low-carbon planning, supports smart city infrastructure, and aligns with climate goals.
- **Sector-coupling and Optimization:** Smart integration across energy sectors and helps to mitigate electric grid constraints in an increasingly electrified economy.



***District Energy System Diagram Showing Use of Multiple Energy Sources* [6]**

[6] Énergir: https://energir.com/en/about/our-energies/thermal-energy-networks/thermal-energy-networks

District Energy System Components and Generational Evolution

The major components of a typical DES can be broken down into the following:

- **Energy Generation Plant(s):** Produces thermal energy using boilers, chillers, heat pumps, combined heat and power (CHP) systems, etc.

- **Distribution Network**: A network of pipes (typically buried underground) that transport thermal energy to and from buildings. Hydronic distribution networks typically use supply and return piping to form a closed-loop network.

- **Energy Transfer Stations:** Interface units in each building that transfer heat from the network to the building's internal energy systems.

- **Control Systems:** Monitor and optimize system performance, load balancing, and fault detection.

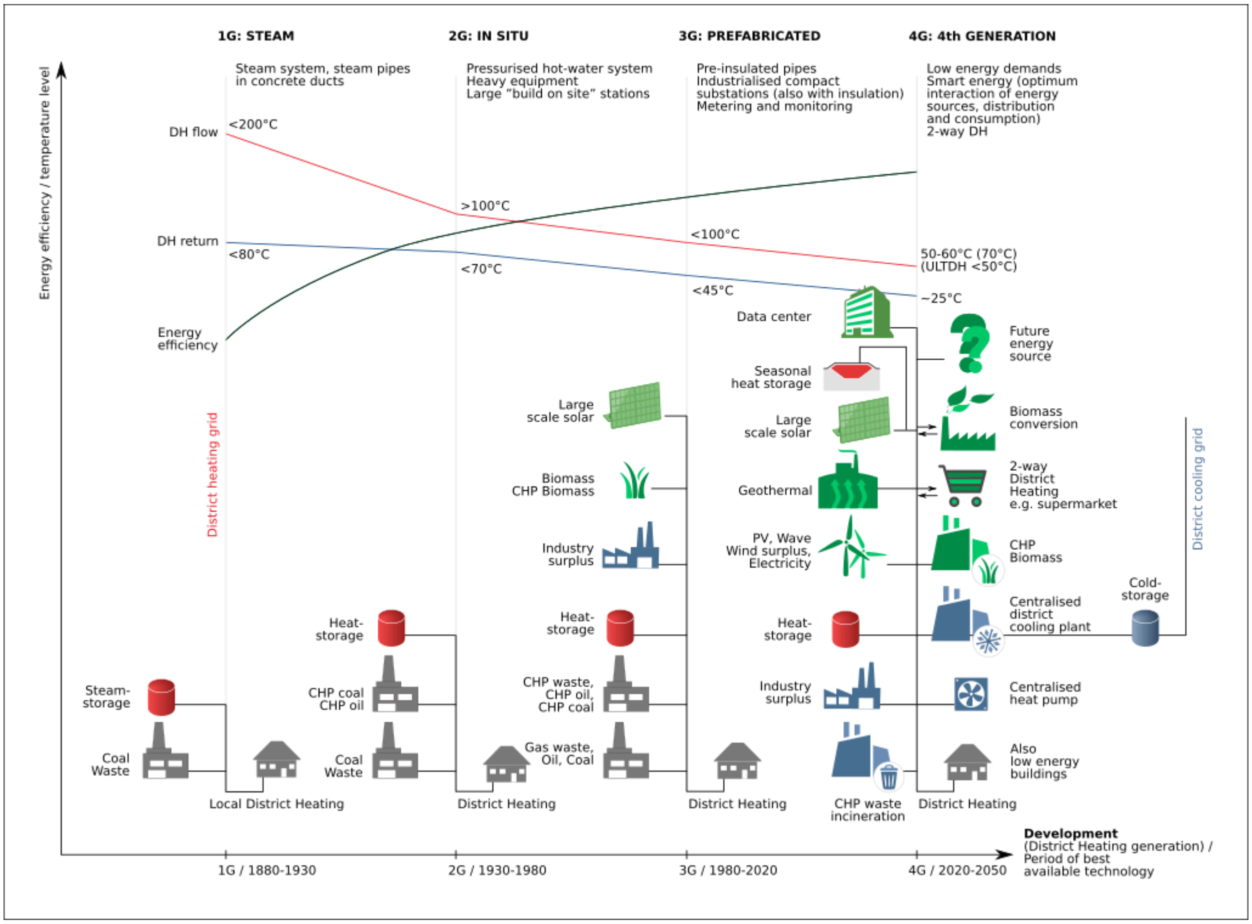
- **Thermal Energy Storage (TES) (optional):** Stores excess thermal energy for later use, enhancing flexibility and peak shaving.

DESs can be classified based on their 'generation,' which is broadly associated with their system temperature level. The evolutionary advancement of district heating systems follows a trend of decreasing system temperatures and increasing energy efficiency as well as integration of waste heat and renewable energy sources.

The International Energy Agency Technology Collaboration Programme on District Heating and Cooling (IEA DHC) has broadly defined [7] the district heating generations based on the following district heating network descriptions:

- 1st generation networks use steam.
- 2nd generation networks use water above 100°C.
- 3rd generation networks use water between 100°C and 70°C.
- 4th generation networks use water below 70°C.

[7] IEA DHC District Heating Network Generation Definitions: https://www.iea-dhc.org/fileadmin/public_documents/2402_IEA_DHC_DH_generations_definitions.pdf



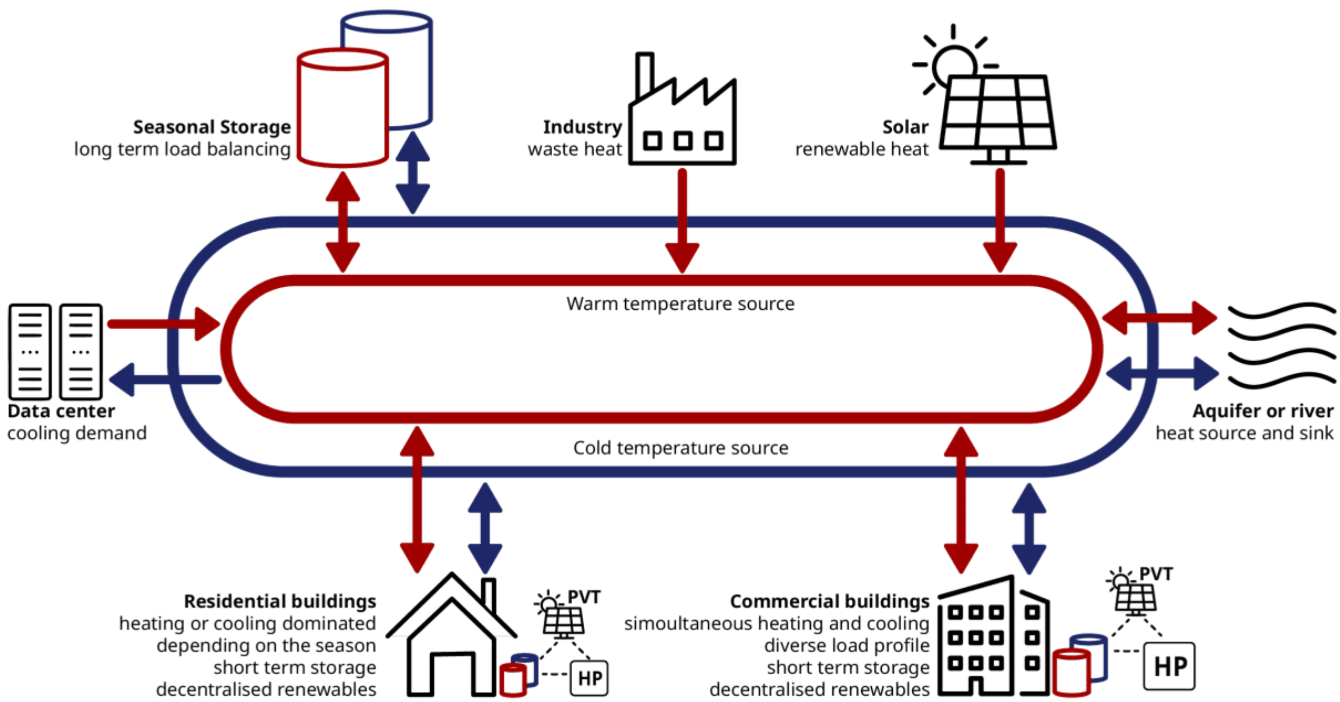
Generations of District Heating Systems [8]

The relatively new 5th generation DES, also known as ultra-low temperature or ambient systems, operates at network temperatures of about 10 to 25°C. This temperature range is so similar to the ground temperature that these systems often don't require pipe insulation. Ambient temperature systems are best suited for district energy networks that can provide simultaneous heating and cooling, where decentralized water-source heat pumps in each connected building use the distribution piping network as both an energy source and an energy sink to produce heating or cooling energy for the building. They are typically well-matched to integrate low-grade sources of urban waste heat.

[8] Henrik Lund et al: *4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems*. Energy 68, 2014, 1-11, doi:10.1016/j.energy.2014.02.089

One key benefit of ambient style networks is the ability to share thermal energy between buildings. For example, one building may be in cooling mode where its heat is rejected into the distribution network, while adjacent buildings may be in heating mode and can make use of that rejected heat from the loop.

Per the IEA DHC's definitions, 5th generation systems should be considered a sub-class of 4th generation systems and should not be considered a separate generation of DESs that are superior to 4th generation systems, particularly for heating-only systems.



5th Generation District Heating/Cooling System Example Diagram [9]

[9] Are district energy systems finally ready for prime time in Australia? (Dec 2022)

Integration of Waste Heat and Thermal Energy Storage

Modern DES increasingly integrate low-carbon and renewable energy sources, especially waste heat and TES, to improve environmental sustainability, energy system resilience, and system economics:

1. **Environmental Sustainability**
    - Reduces primary energy demand by capturing and reusing waste heat instead of relying solely on conventional energy sources (e.g., electricity, fossil gas, fuel oil).
    - Decreases GHG emissions by minimizing the combustion of fossil fuels for heating purposes.
2. **Energy System Resiliency**
    - Enhances local energy resilience by utilizing waste heat from diverse local sources, reducing dependency on conventional energy supplies.
    - Increases the flexibility and reliability of the energy system by decoupling energy production from demand through TES.
    - Provides a buffer during peak demand periods, ensuring a consistent energy supply and avoiding equipment or grid overloads.
3. **System Economics**
    - Lowers operational costs by reducing the need for conventional energy utility supply and maximizing the use of available waste heat, which is often free or very low cost.
    - Offers potential savings on energy bills for end users through optimized use of renewable energy, waste heat, and TES systems.
    - Encourages investment in local energy infrastructure, boosting economic activity and job creation in the renewable energy sector
    .

Waste Heat Recovery

Modern district energy systems offer a highly flexible infrastructure platform to capture and reuse waste heat from a variety of high- and low-grade sources, including:

- **Raw Sewage or Wastewater:** Using sewage heat recovery heat exchangers and heat pumps to extract low-grade heat from wastewater.
- **Cooling Systems:** Capturing rejected heat from building HVAC systems or industrial cooling processes.
- **Data Centres:** Recovering heat rejected from server cooling systems using warmed return air ducting systems or liquid cooling loops in modern, high-power-density server racks.
- **Industrial processes:** Utilizing excess heat from manufacturing or other industries.

These sources are often locally available, predictable, and underutilized, making them ideal for integration into DES. Most urban waste heat sources are typically characterized as low-grade or low-quality thermal sources. In thermodynamics and energy systems, heat quality broadly refers to the temperature and/or usability of thermal energy for performing useful work or meeting heating loads. Space heating and domestic hot water heating systems typically operate in the range of 40 to 70°C. In this context, high-grade waste heat sources are those where the recovered heat is hot enough (above approximately 60°C) to be used directly for heating buildings and water without supplemental energy input. Urban examples of this are somewhat uncommon but may include combustion exhausts, incineration flue gas, and industrial processes. Conversely, low-grade heat sources can be characterized as those below 60°C, which often require supplemental equipment and associated input energy (e.g., electric heat pumps) to produce useful heating. These sources are more commonly found in urban areas and may include wastewater, refrigeration systems, and data centre heat rejection.

Thermal Energy Storage (TES)

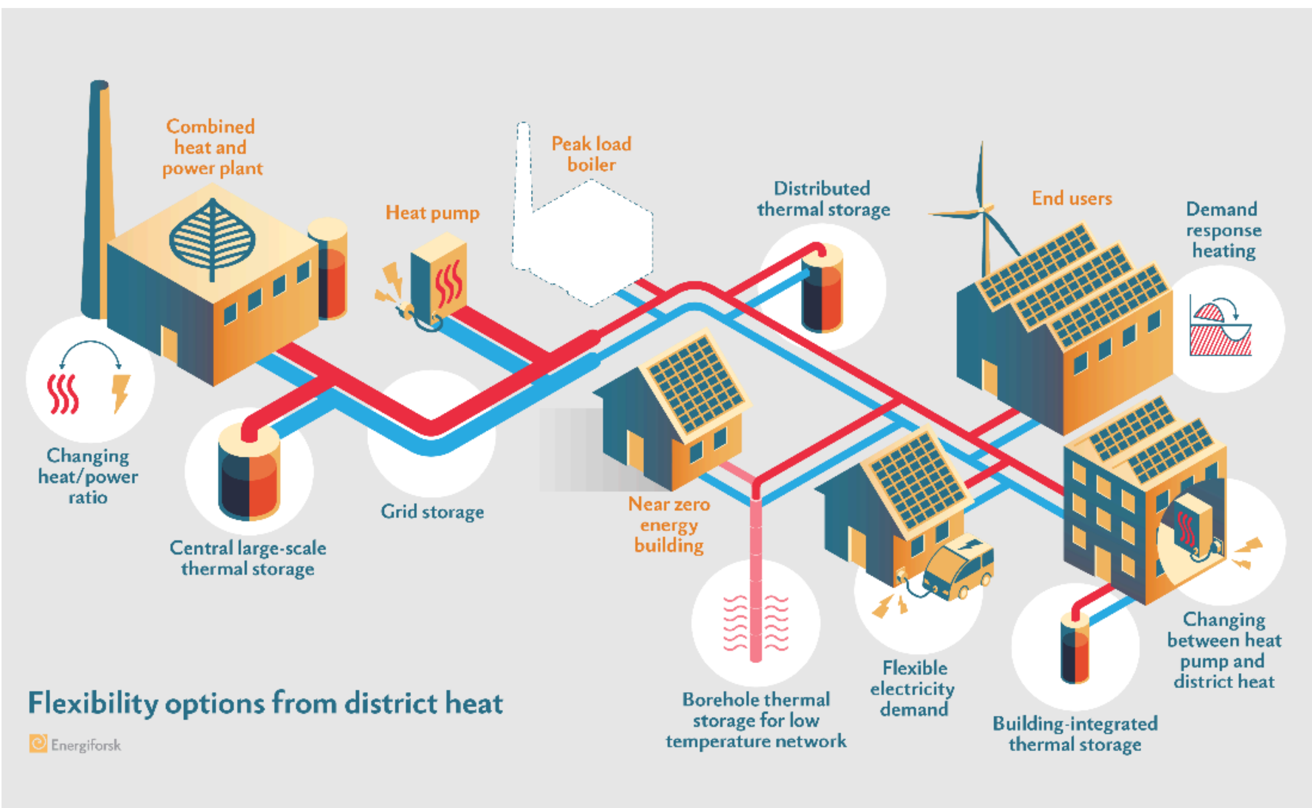
TES systems decouple energy production from demand, enabling:

- **Load Shifting:** Store heat or cold during off-peak hours and use it during peak demand.
- **Grid Balancing:** Support electricity grid stability and capacity during peak electricity demand periods.
- **Resilience:** Provide backup thermal capacity during outages or supply disruptions.

TES technologies can span a wide spectrum, but the most common types for DES include:

- Hot water tanks (sensible heat storage)
- Phase Change Materials (PCMs) (latent heat storage)
- Borehole Thermal Energy Storage (BTES), Pit Thermal Energy Storage (PTES), and Aquifer Thermal Energy Storage (ATES) for daily or seasonal energy storage

TES systems are particularly adept at capturing and preserving excess waste heat during periods of low thermal demand. By storing this surplus energy, TES enables the efficient use of waste heat resources that would otherwise be squandered. This stored thermal energy can then be deployed strategically during higher demand periods, effectively bridging the gap between supply and consumption, as well as helping to reduce energy and demand charges associated with conventional electricity and fossil gas supply.



District Energy System Diagram Integrating Various Heat Inputs and Thermal Storages [10]

[10] Energiforsk: https://energiforsk.se/program/termiska-energilager/illustrerande-systembilder/

Enabling Conditions for Waste Heat Integration

To leverage any significant urban waste heat resources, either an existing DES must be available or a new DES needs to be developed.

Technical and Spatial Considerations

To effectively harness waste heat sources within a DES, a number of technical conditions may need to be met. These ensure that the waste heat opportunities are usable, reliable, and can be efficiently distributed across the network.

The key technical conditions are summarized in the following:

1. **Temperature Compatibility**
   Waste heat must be at a temperature suitable for the DES supply or be upgradable—for example, via heat pumps. Low-grade sources (e.g., sewage, ambient air, cooling heat rejection systems) often require temperature lift to be viable for heating networks.

2. **Proximity and Accessibility**
   Waste heat sources should be geographically close to the DES network to minimize transmission losses and infrastructure costs. Urban planning and zoning can support the co-location of heat sources (e.g., data centres, industrial facilities) with DES infrastructure.

3. **Interconnection Standards**
   Standardized technical interfaces and protocols are needed to connect third-party waste heat sources to the DES safely and reliably. At minimum, this includes engineered heat exchangers, flow control devices, and metering infrastructure.

Anchor Loads and Progressive Business Models

Market conditions and partner alignment are equally important in enabling waste heat integration. The presence of large anchor loads provides a stable and predictable thermal demand that strengthens the business case for DES. These large users can serve as early adopters or anchor customers, helping to de-risk the system for other participants.

Innovative business models, such as energy-as-a-service or energy performance contracts, allow third-party investors to finance and operate waste heat recovery (and TES) infrastructure in exchange for long-term returns. This reduces the financial burden and technical risks on municipalities or individual building owners.

Waste Heat-Friendly Policy Environment

Policy frameworks play a foundational role in enabling the integration of waste heat and TES into DES. A highly impactful step is the formal recognition of waste heat as a renewable or low-carbon energy source, making it a priority to investigate and pursue. This allows it to qualify for incentives, carbon credits, and regulatory support, placing it on par with more traditional renewables like solar and wind. Additionally, mandatory connection policies—where new developments or large energy users are required to connect to existing DES infrastructure—can ensure a stable demand base, which is critical for justifying the capital investment in waste heat recovery systems.

Streamlined permitting processes and supportive urban planning policies also reduce the administrative and financial burden of deploying DES and TES infrastructure, such as borehole fields or underground tanks. Finally, public sector leadership—through procurement mandates, pilot funding, and feasibility studies—can de-risk early projects and catalyze broader market adoption.

Utility Economics Focused on Capital Cost Avoidance

From an economic standpoint, the integration of waste heat and TES into district energy systems is increasingly attractive due to both cost savings and new revenue opportunities. Capital incentives, such as grants or low-interest loans, can offset the high upfront costs of new infrastructure deployment and expansions. Once operational, waste heat offers a low-cost or often free energy source, significantly reducing fuel expenses and improving the long-term financial performance of the system.

Moreover, TES enables potential further financial benefits by providing multiple uses beyond simple heat storage. These include peak shaving, demand response, and optimized functionality with the electricity grid—especially relevant in electrified DES using large-scale heat pumps or electric boilers. Integrating waste heat and TES can also help avoid or defer costly infrastructure upgrades, such as new boilers, chillers, or electrical substations, particularly in dense urban environments where space and capital are increasingly constrained.

Case Study: SHARC Energy

The Vancouver Neighbourhood Energy Utility (NEU)'s integration of SHARC Energy technology is a prominent example of a successful DES harnessing waste heat from wastewater. The system captures thermal energy from raw sewage and uses heat pumps to transfer and distribute the heat to nearby buildings. The system supplies low carbon heat to 47 buildings across 670,000 square meters (7.2 million square feet) of floor area. This represents approximately 10,000 residents as well as a community centre, university campus, and a number of offices and businesses. The project is planning further expansions, with the total build-out expected to reach approximately 2,000,000 square metres based on current forecasts.

Technology Analysis

The technology scan identified a wide range and scale of waste heat recovery and thermal storage technologies that are applicable to various sectors and use cases. While a strong number of waste heat recovery and TES technology innovations are working towards commercialization, this study focused on larger-scale technologies suitable for district energy applications. The technologies selected have a Technology Readiness Level (TRL) of 8 or higher, which emphasizes their readiness for market deployment and integration into new or existing systems. A full table of identified technologies and their providers is included in the Appendix to assist partners in identifying potential collaborations and investigations. Project examples utilizing such technologies are also included in the Appendix.

Organization Type

To assist in surveying different segments of the DES supply chain, waste heat recovery and TES technology and project examples listed in the Appendix were categorized by **Organization Type:** Manufacturer, Solutions provider, and/or Asset owner. Some of the listed organizations may fall into more than one of these categories.

- **Manufacturer:** an organization or company which designs, fabricates, assembles, or otherwise produces and sells technology and equipment used for heat recovery and thermal storage.

- **Solutions provider:** a service-based organization which procures, integrates, and/or implements manufactured technologies for a project site to enable heat recovery or store thermal energy. They may act as an energy-as-a-service (EaaS) company.

- **Asset owner:** an organization which owns and operates heat recovery technologies and/or TES as part of its energy systems assets.

Waste Heat Recovery Technologies

Waste heat recovery technologies are designed to capture and repurpose thermal energy from a variety of sources, including but not limited to raw sewage, industrial processes, data centres, and other cooling and refrigeration systems—many of which are found in close proximity to dense urban environments.

While heat recovery equipment comes in various sizes for a number of applications, several key parameters can be used to broadly categorize these technologies:

- **Technology Type:** passive or active heat recovery
- **Waste Heat Source:** wastewater, hydronic cooling loops, etc.
- **Heat Transfer Media:** process water, refrigerant
- **Application:** heating and/or cooling

Passive and active heat recovery systems offer distinct yet complementary approaches to capturing waste heat from either liquid or gaseous sources. These systems rely on heat exchangers to efficiently transfer thermal energy, and their design and selection plays a critical role in their effectiveness. The usefulness of recovered heat largely depends on the temperature of the available waste heat resource. If high temperature waste heat is available, then heat exchangers may be used to recover thermal energy where it can be directly used for heating purposes. More commonly, waste heat found in urban environments is from low-grade sources which requires active systems to extract and increase the temperature of the recovered energy to make it usable for space heating and domestic hot water heating.

Passive Heat Recovery Systems

Passive heat recovery systems operate on the principle of transferring thermal energy from a warmer medium to a cooler one without any additional energy input. For liquid sources like wastewater and cooling loops, heat exchangers facilitate efficient heat transfer between process water or refrigerant loops while maintaining separation between the fluids.

Two frequently used types of heat exchangers include:

- **Plate Heat Exchangers:** These consist of thin, corrugated metal plates stacked together, creating channels for the fluids to flow. Heat is transferred as the fluids pass on opposite sides of the plates, ensuring efficient thermal exchange. Plate heat exchangers are compact, highly efficient, and ideal for applications with limited space.
- **Shell and Tube Heat Exchangers:** These feature a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes while another circulates around them within the shell. This design is robust and well-suited for handling high pressures and temperatures, making it commonly used in industrial settings.

SHARC Energy is a key example of a passive heat recovery technology that recovers waste heat from sewage through a combination of sewage screening and heat exchanger equipment.

SHARC Energy Recovery Unit [11]

For gaseous sources such as combustion exhaust or warm ambient air, passive systems often utilize air-to-refrigerant heat exchangers or air-to-water heat exchangers ("economizers"), which are commonly found in large fossil-fuel boiler exhaust applications. Economizers recover sensible or latent heat from flue gases, which can be repurposed to heat water or air. These systems are highly effective in industrial settings where significant heat waste heat is available and can be effectively applied to district energy systems. An additional benefit that may be achievable through use of flue gas economizers is water reclaim, which results from the condensation of water vapour in the combustion exhaust. The reclaimed water can be repurposed and offset the consumption of fresh water in various processes. Combustion & Energy Systems designs and manufactures flue gas economizers.

[11] SHARC Energy: https://www.sharcenergy.com/

Active Heat Recovery Systems

Active heat recovery systems typically employ heat pumps to enhance the recovered heat through thermodynamic processes using external energy—usually electricity. For liquid sources like wastewater and cooling loops, heat pumps extract heat by cycling refrigerants through evaporators that absorb thermal energy from the liquid. The refrigerant is compressed to increase its temperature, and the heat is released via condensers for use in heating processes. The increased temperature of the output makes active systems particularly useful for applications requiring significant heating boosts. Various configurations of heat pumps are available and selecting the appropriate machinery depends on temperature and pressure ratings, alongside other technical specifications. Manufacturers who supply heat recovery heat pumps include Vitalis and Johnson Controls/York.

Heat Transfer Media

Heat recovery technologies predominantly utilize process water or refrigerant as their heat transfer media. These substances are key in facilitating the efficient exchange of thermal energy by acting as carriers between heat sources and sinks. The choice between process water and a refrigerant depends on various considerations to optimize thermal management and adaptability. This is true whether the system is passive (requiring no external energy) or active (using heat pumps for enhanced recovery).

York CYK High-Temperature Heat Pump [12]

[12] York CYK: https://www.york.com/commercial-equipment/chilled-water-systems/water-cooled-chillers/cyk_ch/cyk-water-to-water-compound-centrifugal-chiller-heat-pump

Thermal Energy Storage (TES) Technologies

TES systems are designed to store excess thermal energy for later use, allowing for efficient management of energy supply and demand. Many different configurations of TES exist, but not all are compatible with DESs in Canada. Three major types of TES with potential for use in Canadian DESs are available: water-based thermal storage tanks, phase change materials, and Underground Thermal Energy Storage (UTES)—including BTES and ATES. Each offers unique methods for capturing and releasing heat. International examples of these types of TES are shown in the Task Brochure – Use Cases by the International Energy Agency Energy Storage Technology Collaboration programme task on Large Thermal Energy Storages for District Heating. For detailed information, refer to Energy Storage Systems: A State-of-the-Art Study, a comprehensive report published in 2023 by the Savonia University of Applied Sciences in Finland.

Water-Based Thermal Storage Tanks

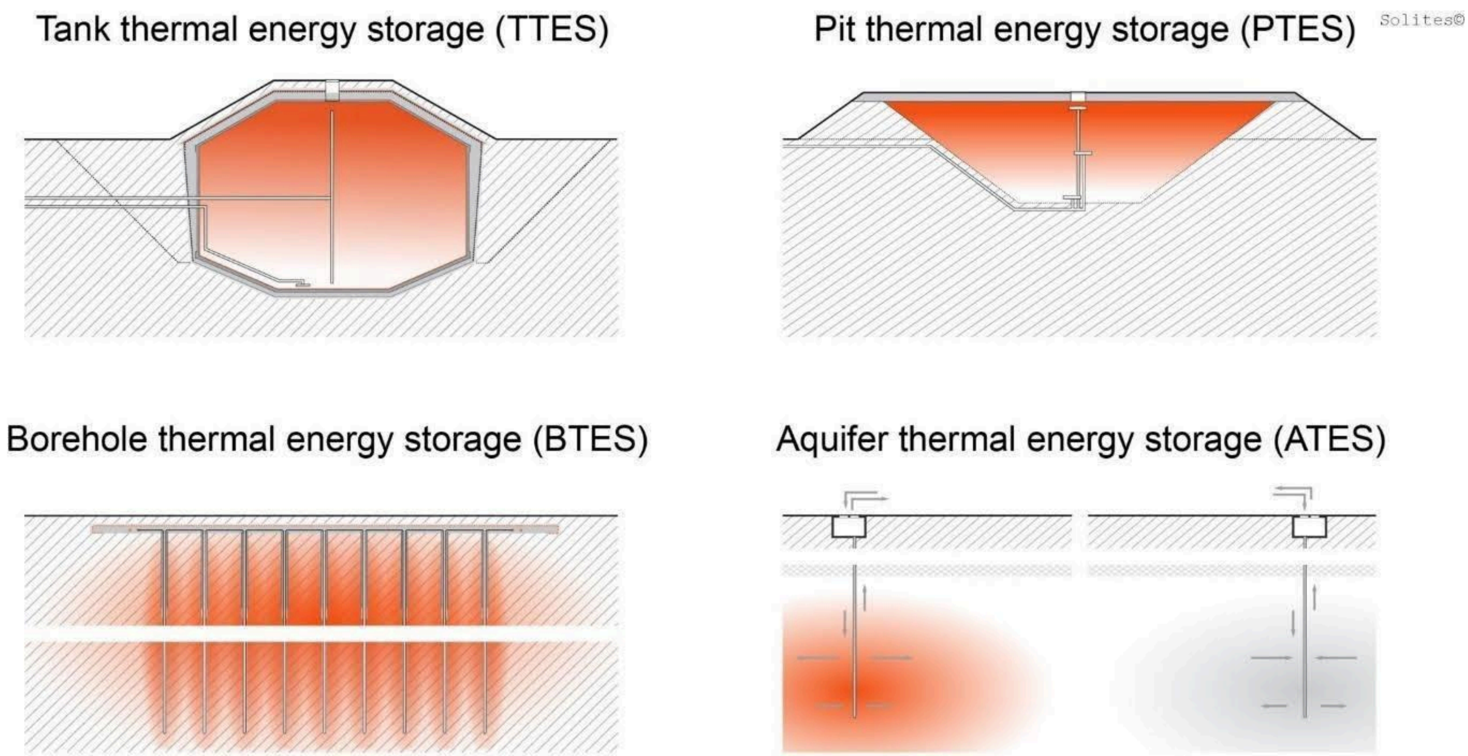
Water-based TES (also known as tank TES or TTES) relies on storing heated or cooled water in insulated tanks, which can range from small-scale installations to large-scale reservoirs. These systems work on the principle of sensible heat storage, where water absorbs heat during periods of excess energy supply and releases it when thermal energy demand rises. This method is cost-effective, relatively simple, and widely applicable to DES. By storing hot water, DES can provide consistent heating to residential and commercial buildings, ensuring reliability during peak demand periods. Large-scale hot water tanks are often fabricated as custom or semi-custom units. An example manufacturer for such hot water tanks is ATR Vessels.

Phase Change Materials (PCMs)

PCMs are advanced TES technologies that leverage the latent heat of fusion of a carefully selected material. These materials absorb or release significant amounts of thermal energy during phase transitions, such as melting or solidifying. PCMs are highly efficient, capable of storing more heat per unit volume than water-based systems. In DES applications, PCMs can be incorporated into systems requiring compact storage solutions, such as building-integrated designs. Their ability to maintain constant temperatures makes them ideal for applications like HVAC systems in urban environments. However, PCMs are currently uncommon in the building heating/cooling industry.

Underground Thermal Energy Storage (UTES)

UTES systems utilize subsurface resources, such as aquifers or borehole systems, to store heat energy. These systems use the earth as a thermal reservoir, storing excess heat during warmer months and retrieving it during colder months. These systems are particularly well-suited for large-scale DES projects due to their capacity for long-term storage (seasonal storage), but may require significant footprint to achieve an effective amount of stored energy. Urban areas with high energy demands can benefit from underground storage systems as part of district energy networks, particularly when coupled with excess waste heat. ThermaStor Solutions is an example of an engineering and service provider of UTES.



Large Water-based Thermal Energy Storage Types [13]

[13] International Energy Agency, Large Thermal Energy Storages for District Heating: https://iea-es.org/task-39/

District Energy System Use Cases and Trends

Waste heat recovery technologies are at the forefront of current trends in modern low-carbon district energy systems, offering innovative but proven solutions for significantly reducing energy consumption and emissions. The most notable application in the Metro Vancouver region involves the recovery of heat from raw sewage, where passive heat exchangers coupled with high-temperature heat pumps draw thermal energy from wastewater streams.

These systems are particularly advantageous in urban environments, where the steady flow of wastewater in large collector pipes provides a reliable and local heat source—which can also be used as a heat sink to assist cooling systems. Ultra-low temperature DES (ambient systems) can be paired with passive sewage heat exchangers to source and sink heat for a DES piping system, where connected buildings use localized heat pumps to produce heating and cooling. Treated wastewater (effluent) heat recovery systems are also possible for DES applications. However, since wastewater treatment plants are not typically located near urban centres, it is uncommon for an existing or new DES to leverage this opportunity.

Another emerging trend is the recovery of heat from cooling loops in HVAC systems, data centres, ice rinks, and other process cooling applications. Passive systems employ technologies like plate or shell-and-tube heat exchangers to transfer residual heat from these cooling loops into district heating circuits, while active systems such as heat pumps can be used to amplify the recovered heat to meet higher-temperature heating demands. Heat rejected from data centres or ice rink refrigeration units can be readily captured and redirected to serve the heating needs of nearby buildings, demonstrating the adaptability and efficiency of modern low-carbon district energy systems.

Case Study: Extract Energy

Extract Energy have developed an innovative solution that can be installed easily into any site that continuously generates low temperature waste heat (below 150°C/302°F). This includes industrial manufacturing, food processing facilities, energy generation stations, and data centres. The technology utilizes shape memory alloys (SMA), comprised of nickel titanium, and self-actuating valves to create a cyclical motion that is captured by the heat engine's generator and immediately converts it to usable energy.

Combustion exhaust from large process boilers using fossil fuels offers another significant opportunity for heat recovery. Residual heat captured by economizers from flue gases can be employed to supply heating energy to urban heating networks. Active heat recovery systems employing heat pumps further enhance this process by recovering latent heat from combustion exhaust, maximizing thermal efficiency and minimizing waste.

District energy systems not only excel in leveraging diverse waste heat sources—from wastewater streams to refrigeration loops and boiler exhausts—but also offer a powerful solution for alleviating electrical infrastructure constraints. By centralizing thermal energy recovery and distribution in a utility-scale system, these systems can be smartly integrated with conventional electrical and natural gas utilities, offering a significant opportunity to reduce the strain on local electrical grids. This is particularly beneficial in urban neighbourhoods where grid capacity may be limited or under pressure from increasing demand.

In addition to the waste heat sources mentioned above, the following potential urban waste heat sources have not been studied or explored extensively in Canada, and represent possible research and development opportunities:

- Supermarket refrigeration and commercial/industrial refrigeration
- Food production facilities, commercial bakeries, commissary kitchens
- Hospital and health facilities (boiler plant, incineration of medical wastes, medical imaging MRI/CT scan cooling, medical laundry)
- Industrial facilities (food/beverage processing, manufacturing, pulp/paper, chemical/fuel plant)
- Commercial laundry, hotel laundry
- District heating system return line
- Large drinking water supply lines
- Large electrical substations and transformers
- Seawater, lake, and river water
- Subway stations and tunnels
- Liquid-cooled high-power electric vehicle chargers (fleet charging, commercial truck charging, bus charging at distribution centres and depots)
- Wastewater treatment plant sludge digester heat and biogas flaming

Opportunities and Challenges in Technology Adoption

Technological and market considerations are crucial for the adoption of waste heat recovery and thermal storage solutions. Advances in heat pump technologies, TES systems, and heat exchanger designs have made these systems more efficient and adaptable to a variety of applications including DESs. However, the integration of these technologies into existing infrastructure requires careful planning and collaboration—compatibility with older systems can pose challenges. On the market side, increasing awareness of the benefits of energy efficiency and emissions reductions, coupled with rising energy costs, is fostering renewed interest and demand in low-carbon district energy systems. Yet, market adoption remains somewhat limited and is largely driven by government-led utilities. Smaller-scale developers often lack the resources or expertise to implement these systems effectively and default to conventional standalone building systems.

Economic factors, especially the cost-effectiveness of waste heat recovery technologies, can vary significantly depending on the scale of the project, installation complexity, and energy prices of established utility providers. Larger-scale or established DES may be able to demonstrate faster returns on investment for significant waste heat recovery opportunities due to economies of scale and higher energy capture efficiencies. However, new or smaller applications can struggle with upfront costs. This can deter potential adopters despite the long-term savings and environmental benefits these systems can provide. Financial incentives, such as grants, tax breaks, and low-interest loans, can significantly enhance the economic feasibility of these projects, but not all organizations are positioned to take advantage of such support.

TES adoption in British Columbia has been limited, partly due to historically low and flat electricity and gas rates. However, rising peak demand charges and system connection costs are starting to shift the economics. One of the most effective ways to improve the financial case for TES is through time-of-use (TOU) electricity rates, which offer lower prices during off-peak periods. TOU pricing enables TES systems to store thermal energy when production or recovery is cheap, and discharge it when electricity costs are highest. This approach reduces operating costs and peak demand charges. In jurisdictions with TOU rates, TES projects can achieve payback periods as short as 5–7 years—significantly better than what is possible under flat-rate structures. While BC Hydro has recently introduced optional TOU rates for residential customers, [14] extending these to commercial and institutional users would substantially improve TES feasibility and support broader energy system efficiency goals and the cost of thermal energy.

[14] BC Hydro: https://www.bchydro.com/news/press_centre/news_releases/2024/optional-time-of-day-rates.html

Policy and regulatory drivers are crucial in shaping the adoption landscape. In regions like British Columbia, increasingly stringent building performance regulations and rising energy prices have spurred increased interest in waste heat recovery and thermal storage systems. Local and provincial governments play a critical role by setting emissions reduction targets and offering subsidies or incentives that lower financial barriers for developers and facility owners. Public-private partnerships have also proven effective, as demonstrated by multiple successful implementations where financial and policy supports are aligned to accelerate deployment. However, inconsistent regulations and a lack of standardization across jurisdictions can slow adoption.

Several barriers continue to hinder the greater adoption of these technologies. In addition to technical challenges, such as system integration and the need for tailored solutions for specific buildings, a significant barrier is the limited awareness among asset owners and developers. Many are unaware of the potential true cost savings, energy efficiencies, and environmental benefits associated with these systems. Moreover, a general shortage of skilled labour in designing, installing, and maintaining advanced energy systems further complicates implementation. Educational initiatives, industry training programs, and collaborative efforts between governments, utilities, and the private sector are encouraged to address these barriers and unlock the potential of urban waste heat recovery and thermal storage systems in the transition to low-carbon energy solutions.

Case Studies in Implementation

Notable projects in Canada that employ waste heat recovery and/or TES technologies are summarized below. The innovative technologies demonstrated in these projects showcase the potential of waste heat recovery and TES systems in advancing efficient, low-carbon energy solutions. These examples should serve as a source of encouragement and inspiration for further DES investigations and developments.

- **City of Vancouver Neighbourhood Energy Utility (NEU) (Vancouver, BC)** is a pioneering DES that utilizes the SHARC energy recovery system (five units, each with an inlet flow capacity of 75 L/s) for sewage heat recovery. It is paired with industrial high-temperature heat pumps by Trane and Johnson Controls (total heat pump capacity of 9.8 MW) to supply the baseload of its district heating system.

- **The Creative Energy Seńáḵw District Energy System (Vancouver, BC)** incorporates sewage heat recovery using SHARC Energy equipment and a high-temperature heat pump by Ark Heat (1.9 MW of heat extracted, 2.75 MW of sewage heat pump output). It also uses tank-type TES systems by ATR Vessels (115,000 litres providing 7.5 MWh of storage). The project efficiently supports low-carbon district heating and cooling of the Seńáḵw development. The heat recovery system accounts for more than 90% of the total heating system load and when combined with the thermal storage, results in a 55% reduction in peak electrical demand and a 30% reduction in energy use.

- **The Blatchford District Energy System (Edmonton, AB)** incorporates geo-exchange energy, heat pump systems, and seasonal TES to deliver efficient heating, cooling, and hot water to the community through a 5th generation district energy system. The system features an ammonia (R717) heat pump (1 MW capacity) for the first phase, and a second 1 MW heat pump for the second phase of buildout.

- **The University of British Columbia (Vancouver, BC)** utilizes a flue gas economizer by Combustion & Energy Systems to recover approximately 1 MW of waste heat from boiler exhaust which is used to supplement the campus' district heating system demand.

- **Lonsdale Energy (North Vancouver, BC)** leverages a CO_2 (R744) heat pump ice plant (316 kW) that serves the community outdoor skating rink during winter. The heat rejected (196kW at 80°C and 328kW at 32°C) from creating and maintaining the ice rink is fully recovered and distributed into Lonsdale Energy's district heating system.

- **The Zibi District Energy System (Ottawa, ON and Gatineau, QC)** is a low-carbon, ambient-temperature and low-temperature thermal network that supplies heating and cooling to the Zibi mixed-use waterfront community. A 5th generation system serves the Quebec side of the development whereas a 4th generation system serves the Ontario side. The system's most innovative feature is its integration of industrial waste heat recovery from the Kruger Products tissue plant, which discharges warm process effluent (average 22°C during winter) into the nearby Ottawa River. This recovered heat, combined with centralized water-to-water heat pumps, provides space heating and domestic hot water for connected buildings. Cooling is provided through reversible heat pumps and river-source cooling. The system is designed for a peak heating load of approximately 18 MW and a peak cooling load of about 16 MW.

- **The Sewage Heat Recovery System at Toronto Western Hospital by Noventa (Toronto, ON)** uses a HUBER ThermWin sewage heat recovery system to support an initial 10 MW heating and 9 MW cooling from sewage via heat pumps to serve the hospital campus.

- **The Well by Enwave (Toronto, ON)** features a 55 ft diameter, 150 ft deep, 7.6 million litre TES tank buried below The Well development. The tank stores thermally controlled water and is also served from Enwave's Deep Lake Water Cooling district system. The TES serves both heating hot water and chilled water systems for the 3 million sqft mixed-use development containing retail, office, and residential spaces.

- **Markham District Energy (Markham, ON)** captures waste heat resulting from continuous cooling service for data centres and hospitals with the use of a 4 MW ammonia heat pump by CIMCO. The recovered heat is elevated in temperature before feeding into the community heating loop.

BC as an Energy Recovery Innovator

British Columbia, with its existing array of DES and experience in building decarbonization, is uniquely positioned to lead in thermal energy innovation. Local governments and private utilities in Metro Vancouver are already embarking on unique projects every year—but more initiatives are needed to solidify a coherent, province-wide strategy.

Successfully deploying the necessary innovations to decarbonize beyond Metro Vancouver and across all of BC's heating systems will require greater effort and coordination. These innovations must not only maximize the use of existing thermal resources but also align with efforts to preserve and restore precious water resources.

What's Happening Now

- **Foresight Canada** is exploring the business models of effective integration of waste heat into district energy systems.
- **ZEIC** and the **Royal Danish Consulate** are hosting symposiums, workshops, and reciprocal delegations to bring together the Danish and BC energy sectors to share and learn on deploying next-generation district energy systems.
- The Canadian **Building Decarbonization Alliance**(BDA) is developing a whitepaper and nation-wide impact models to understand the decarbonization potential of widespread district energy system deployment.
- **ZEIC** is leveraging 2024 and 2025 visits from New York State to share and learn about workforce transition strategies that can be used to help transition workers from the gas sector into developing and operating district energy systems
- The **MaRS Social Discovery District** is working to understand the implications of data centres as potential sources of waste heat, building on their work in industrial heat recovery.
- **BC Hydro**, **Metro Vancouver**, and **ZEIC** are undertaking a two-year study to understand the region-wide greenhouse gas and economic development potential of deploying advanced district energy systems.
- **ZEIC** and **SFU** are exploring opportunities to enhance utility regulations to enhance uptake of TES and waste heat recovery.

Where We Need to Go

Activity in BC is increasing in momentum—there are more systems being developed and increasing attention is being paid to how advanced district energy systems with thermal storage and heat recovery can plan a role in neighbourhood level decarbonization and energy efficiency.

However, to continue this momentum several interventions are needed:

- A clear and progressive **energy plan for BC** that **focuses on local energy planning** and understands the importance of both district energy and distributed energy resources (DER) more broadly in achieving local and provincial energy goals.
- **Common datasets and potential frameworks around energy demand**, underpinned by models like the one to be developed by BC Hydro, Metro Vancouver, and ZEIC.
- **Progressive building codes** that harmonize energy and emissions regulations with district energy objectives. These could encourage or require connection readiness for new developments in designated areas through land use policy, development guidelines, or building permit conditions.
- **Defined pathways to favourable utility economics**, including time-of-use electricity rates for some commercial and industrial customers, standardized waste heat utility fees for different “producers,” and other interventions.
- **Industry coordination and capacity building**, bringing together local government staff, engineers, and developers with training programs, case studies, and other projects. The focus of this work should be on local energy planning, large-scale heat recovery and TES technologies, and long-term system optimization.

With a network of partners able to deliver on and advocate for these solutions, powerful contributions to BC’s energy sovereignty, water efficiency, and economic development objectives are possible.

Conclusion

The advancement of low-carbon DES, particularly through the integration of waste heat recovery technologies and TES, represents a significant opportunity for achieving sustainable urban energy and water solutions in Metro Vancouver. These systems can effectively access and leverage local waste heat opportunities, offering immense potential for cost-effectively reducing building sector carbon emissions, enhancing energy efficiency, and reducing the increasing burden on local electrical distribution infrastructure.

This study highlights waste heat recovery and TES technologies that are already available or in use in Canada and are compatible with DES. In particular, systems that recover heat from waste sources like raw sewage, cooling heat rejection, and large combustion exhausts should serve to inform and inspire further study and project development. These sources are found locally in Metro Vancouver and, in the coming years, will be fulsomely mapped as part of broader regional energy planning work.

The work of innovation leaders like Foresight, ZEIC, and others, will be instrumental in championing innovative methods to deploy these technologies throughout BC. Pilot projects, demonstrations, and other partnerships need to scale to demonstrate to the public and private sectors the full potential of addressing the water-energy nexus—an opportunity that can not only impact the region, but the entire world.

With a clear map of what heat—and technology—is available, Metro Vancouver is demonstrating that BC can lead in regional and continental decarbonization, energy, and water innovation, and drive a competitive advantage in the global clean energy transition The region is actively proving that a coordinated, multi-faceted approach can serve as a blueprint for the entire province.

Appendix: Waste Heat Recovery and Thermal Energy Storage Technology Providers and Projects

The table of technology providers and projects can be found here.