



University of
Nottingham
Energy Institute

The Gas Network in Decarbonised UK

GasNetNew

21 Nov 2025

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WP2. Non-potable water in
the gas network
Latent Heat Pump

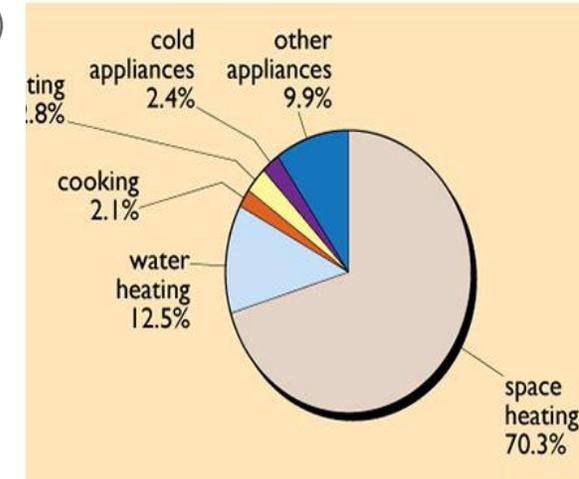
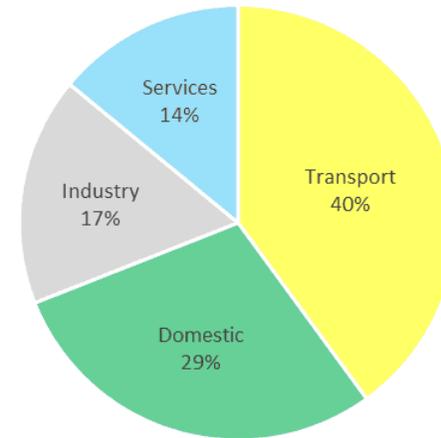


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The Importance of Phasing Out Natural Gas for Heating

- Reduction of **greenhouse gas emissions and CO2 production** is a top global and UK priority.
- Set goals for **zero greenhouse gas emissions by 2030 and 2050**, prompting a re-evaluation of fuel choices.
- Current Challenges in the UK for Heating:
 - Heating and hot water account for around 80% of household energy use, with over 24 million UK homes relying on natural gas boilers, contributing to approximately 30% of the nation's carbon emissions.
 - Significant emission reductions in this area are essential to achieving national climate goals.
 - While comprehensive policies exist for carbon neutrality in transportation, similar success is lacking for energy consumption in industries and homes.

UK Energy Consumption (2015-2016)



Household Energy Consumption



*Source: United Kingdom housing energy fact file 2012

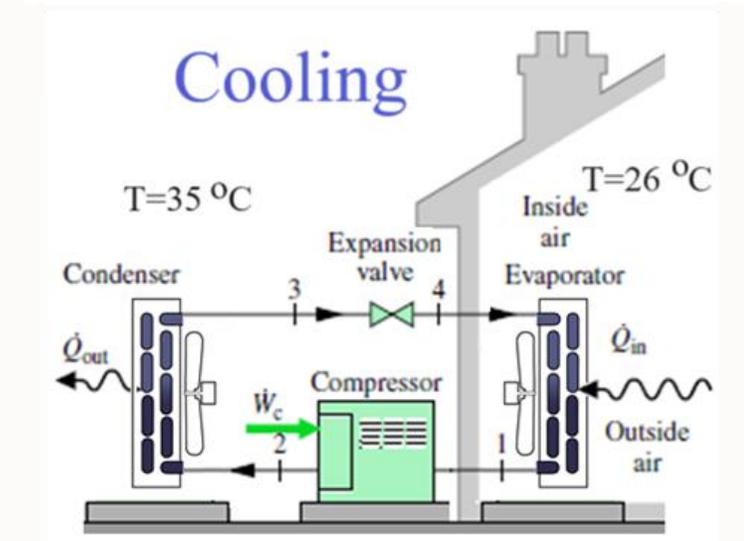
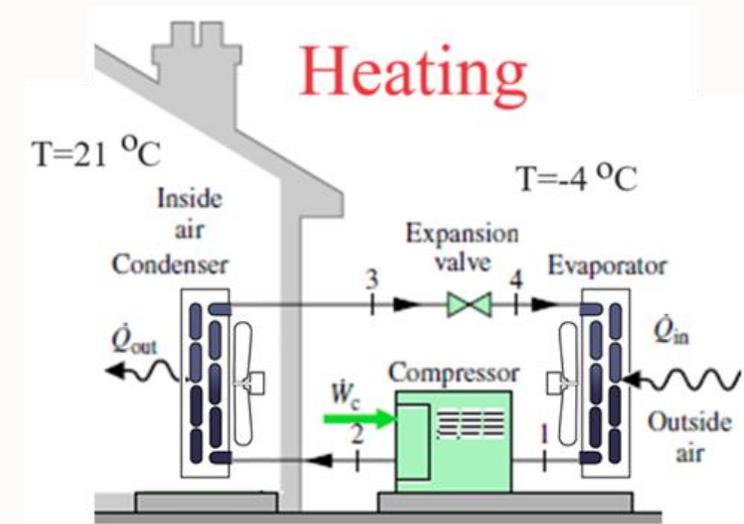
Heat Pump Solutions

- Heat pumps are efficient systems that transfer heat from natural sources such as air, water, or the ground into buildings.
- Heat pumps can derive a significant portion of their heating energy from low-temperature thermal sources, reducing the reliance on electrical energy.

Heat pumps can utilize a variety of heat sources:

- Air
- Water(Lakes, Rivers, Rainwater, Black water (wastewater))
- Ground-source heat pumps(extracting heat from the earth)

It is the most important clean energy solution for heating.



Air Source Heat Pumps

Advantages

Relatively low installation costs

Easy to install and retrofit into existing buildings

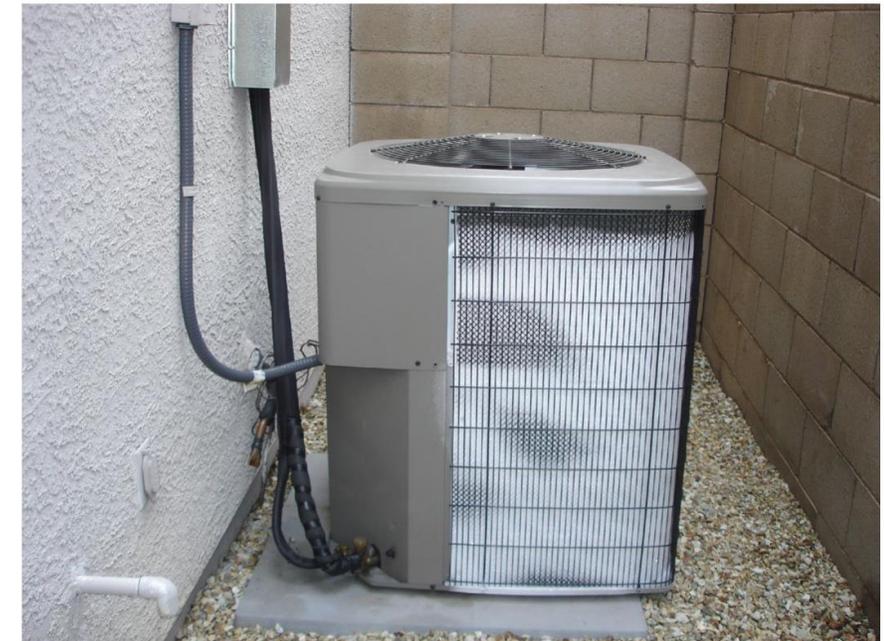
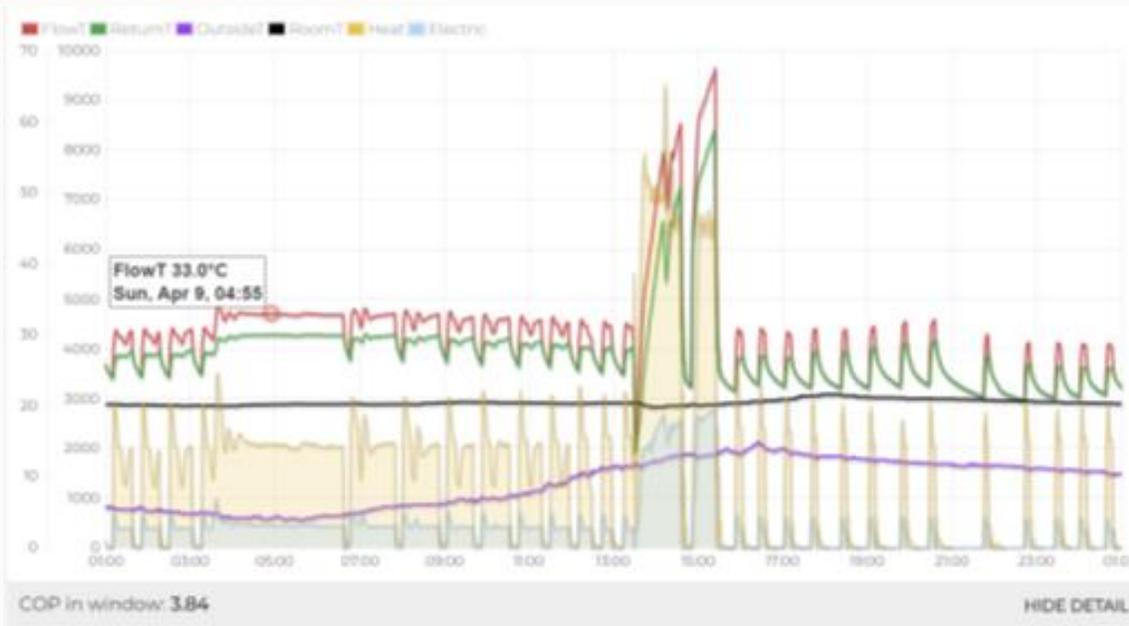
Can provide cooling in addition to heating

Disadvantages

Reduced efficiency in cold temperatures

Performance can drop significantly during peak cold periods

Requires backup heating in extremely cold climates



Water Source Heat Pumps



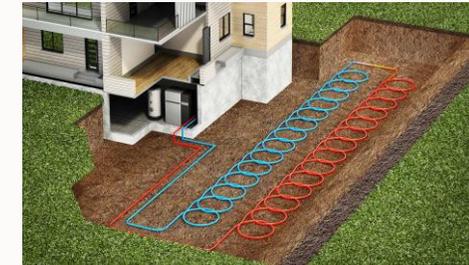
Advantages

- **High efficiency** due to stable water temperatures
- Ability to draw heat from multiple sources (lakes, rivers, etc.)
- Generally requires less energy compared to air-source systems

Disadvantages

- **High water consumption and potential ecological impact**
- Dependence on proximity to water sources
- May require permits and regulations related to water usage

Ground Source Heat Pumps (Geothermal)



Advantages

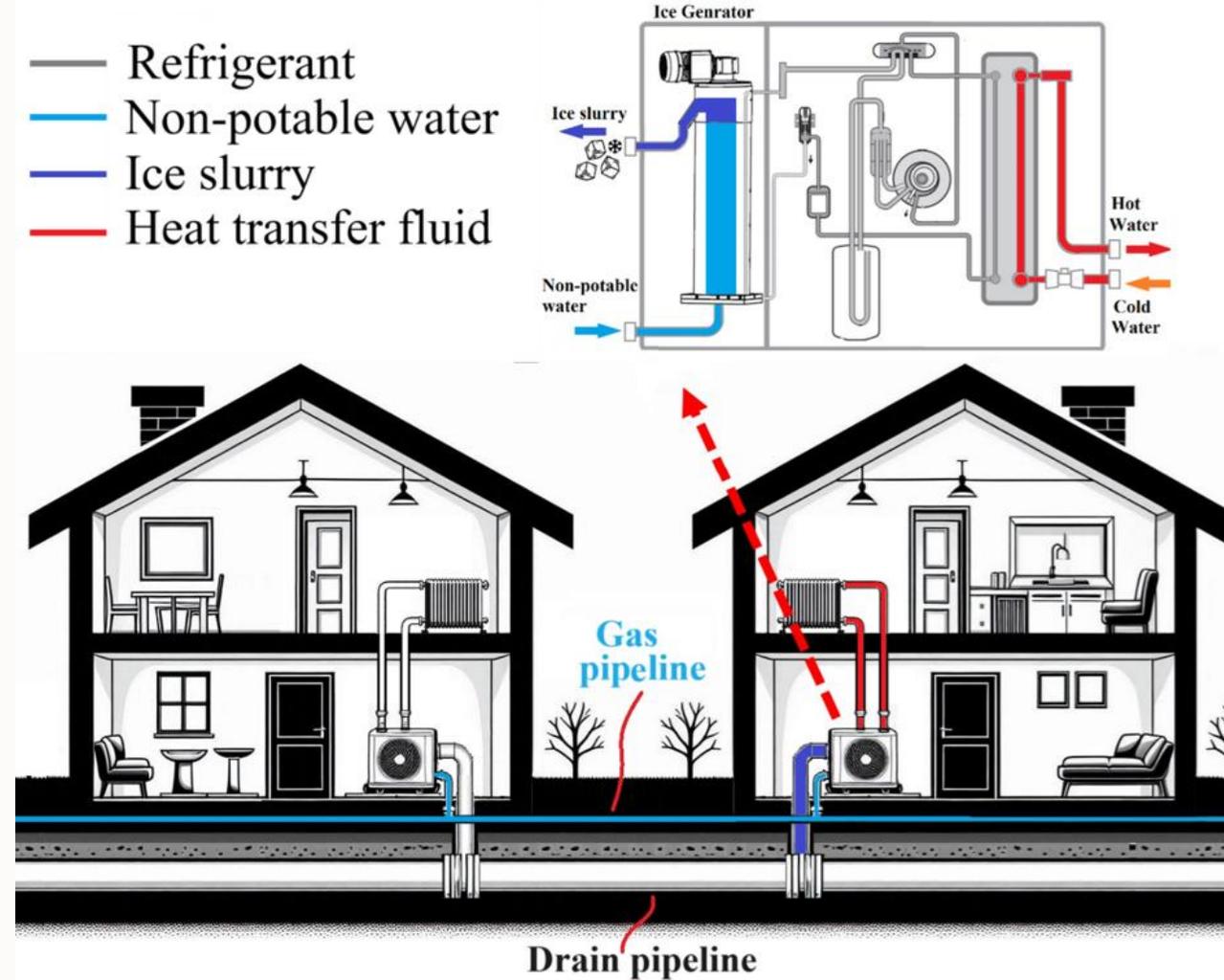
- Consistent performance year-round due to stable underground temperatures
- **Very low operating costs** once installed
- Environmentally friendly with minimal emissions

Disadvantages

- **High installation costs and complexity**
- **Requires significant land area for horizontal systems**
- Longer payback period compared to other heat pump types

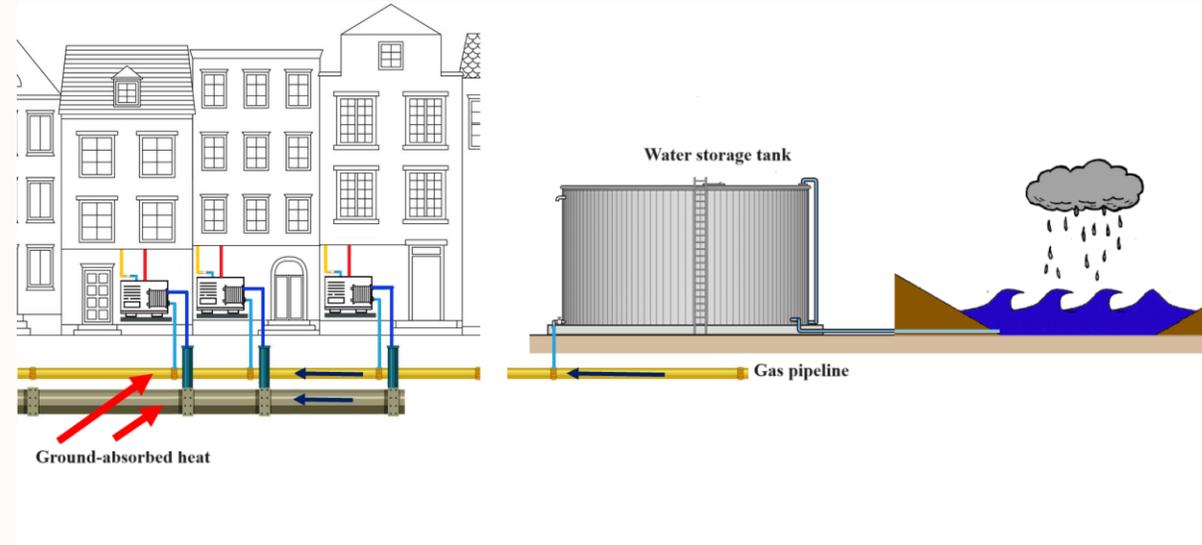
Ice-Source Heat Pumps

- The operating principle of this heat pump is similar to that of an air-source heat pump.
- However, its evaporator is similar to that of a geothermal or water-source heat pump, where it is in contact with water.
- The sensible energy and latent heat of fusion in the water are absorbed, and ultimately, an ice slurry is discharged from the heat pump.



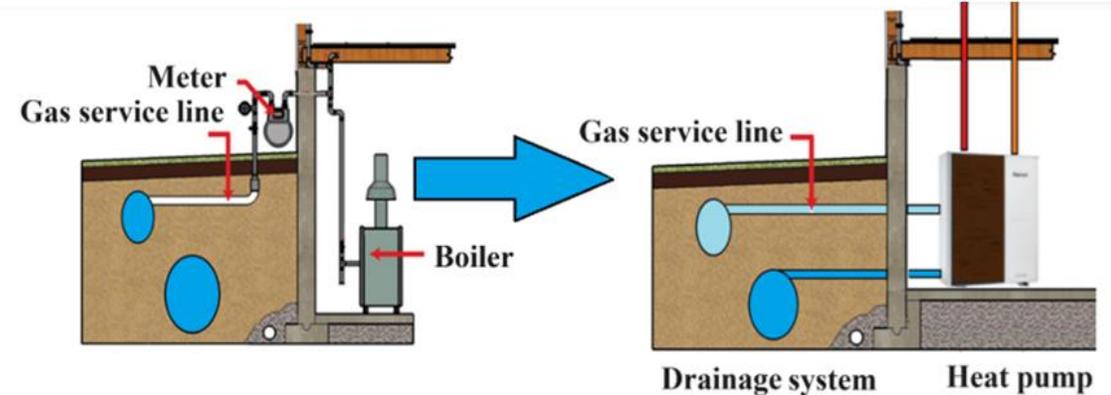
Implementation of the Central Ice Heat Pump Non-potable water in the gas network

- In the proposed system, an ice-source heat pump is used as the heating system, and gas pipes are utilized to supply and transfer water for this system. The heat pump extracts the energy from the water to heat the residential unit, converting the water into ice, which is then discharged into the drainage system.



Infrastructure Benefits:

- This approach integrates with **existing pipelines**, requires no additional piping, and offers a centralized, compact solution.
- Furthermore, the system's use of stable ground temperatures aligns with the principles of **geothermal heat pumps**.

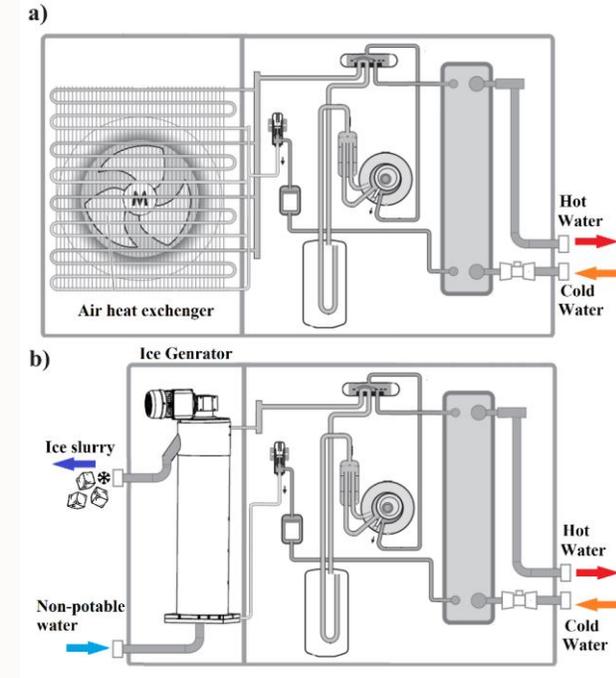


Installation of the heat pump into the gas and wastewater pipeline system.

The performance drop in air-source heat pumps occurs due to the following reasons:

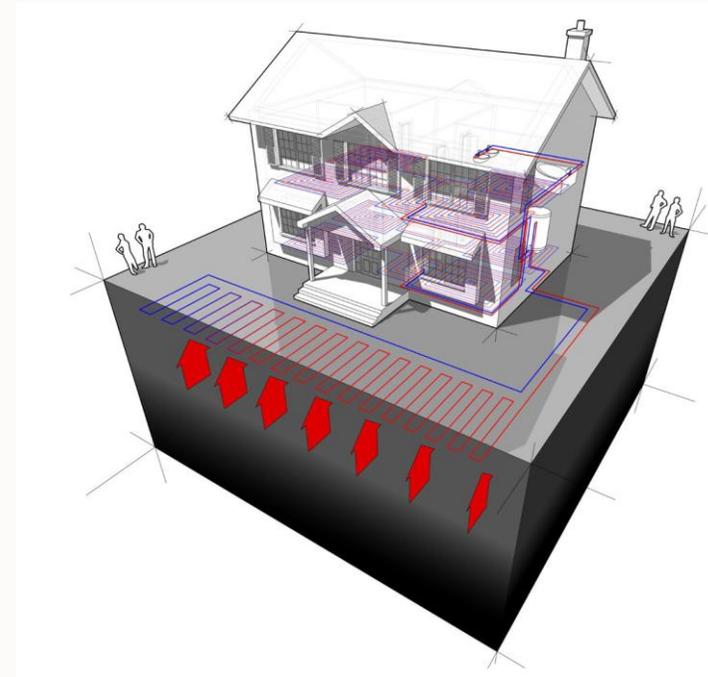
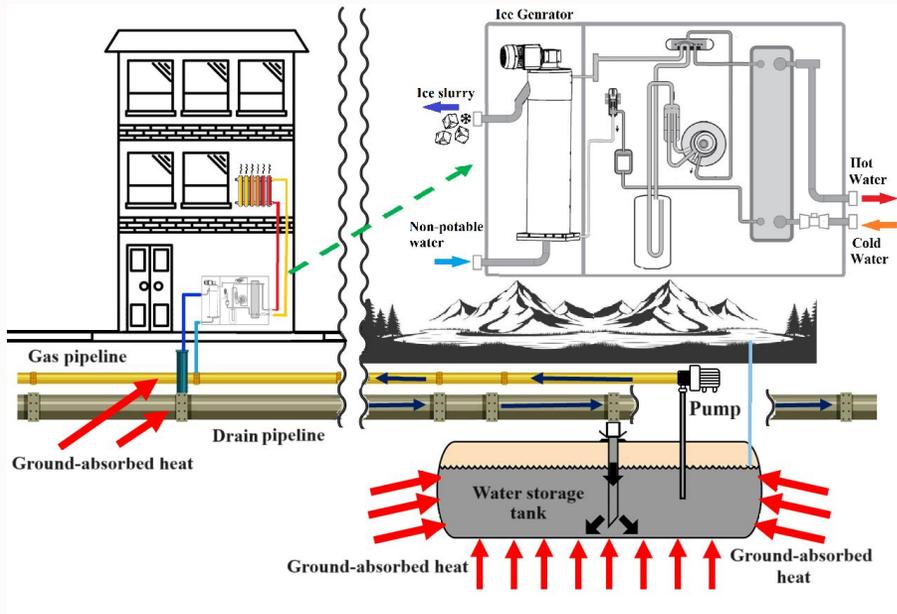
- Losses in the control system
- Losses in the defrost system
- Inappropriate dimensions of the evaporator for heat transfer at low temperatures

In contrast, the **ice-source heat pump** benefits from a **simpler control** system, operates at a **constant temperature**, has a smaller heat pump size, lacks a fan, and utilizes a higher operating temperature of the heat source, resulting in better performance conditions.



Comparison of Ice-Source Heat Pump with Water-Source or Geothermal Heat Pump

- Reduced water consumption or circulation
- Higher temperature of the heat source.

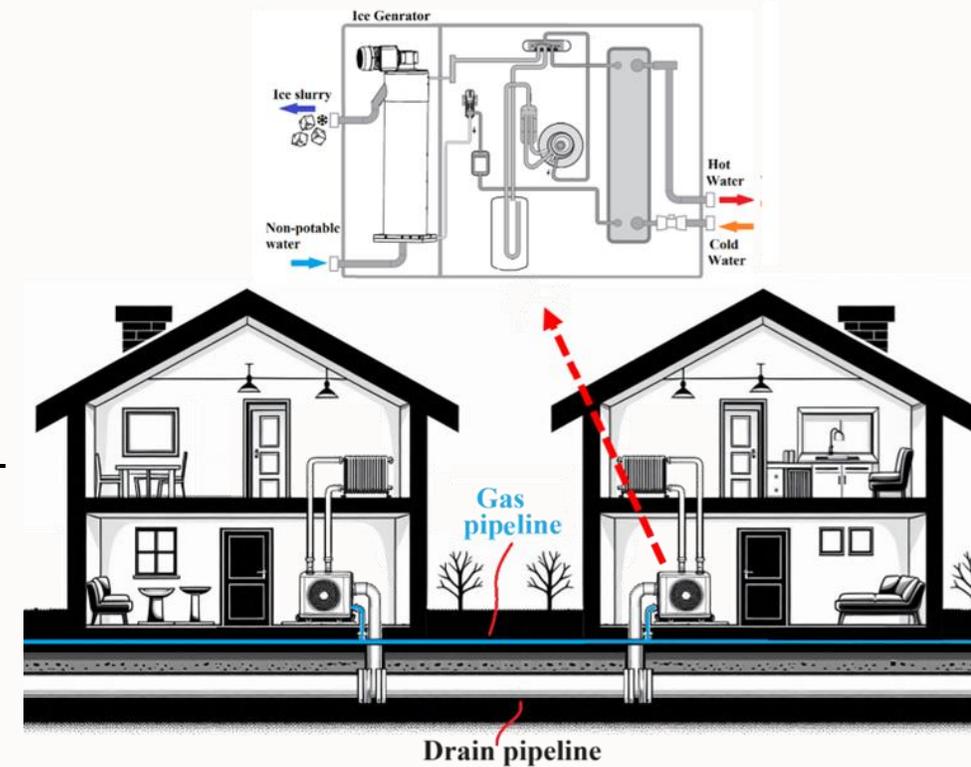


Highlighted Data:

The dimensionless energy ratio, comparing the energy required to freeze one kilogram of water (334 kJ) with the energy needed to raise the temperature of the same amount of water by 1 degree Celsius (4.18 kJ), is approximately **80**.

Advantages of Ice-Source Heat Pump :

- **Space Efficiency:** Suitable for densely populated areas by using existing gas pipelines, avoiding new installations.
- **Compact and Quiet Design:** Smaller, quieter heat pump without air components, suitable for enclosed spaces.
- **Indoor Installation:** Fully installable inside a residential unit.
- **Cost-Effective Centralization:** Lower costs through centralized heating/cooling for multiple units using existing infrastructure.
- **Reduced Electricity Use:** Consumes less electricity compared to air-source heat pumps.
- **Water Supply for Additional Use:** Provides non-potable water for gardening and sanitary purposes.



Articles on the ISHP Concept

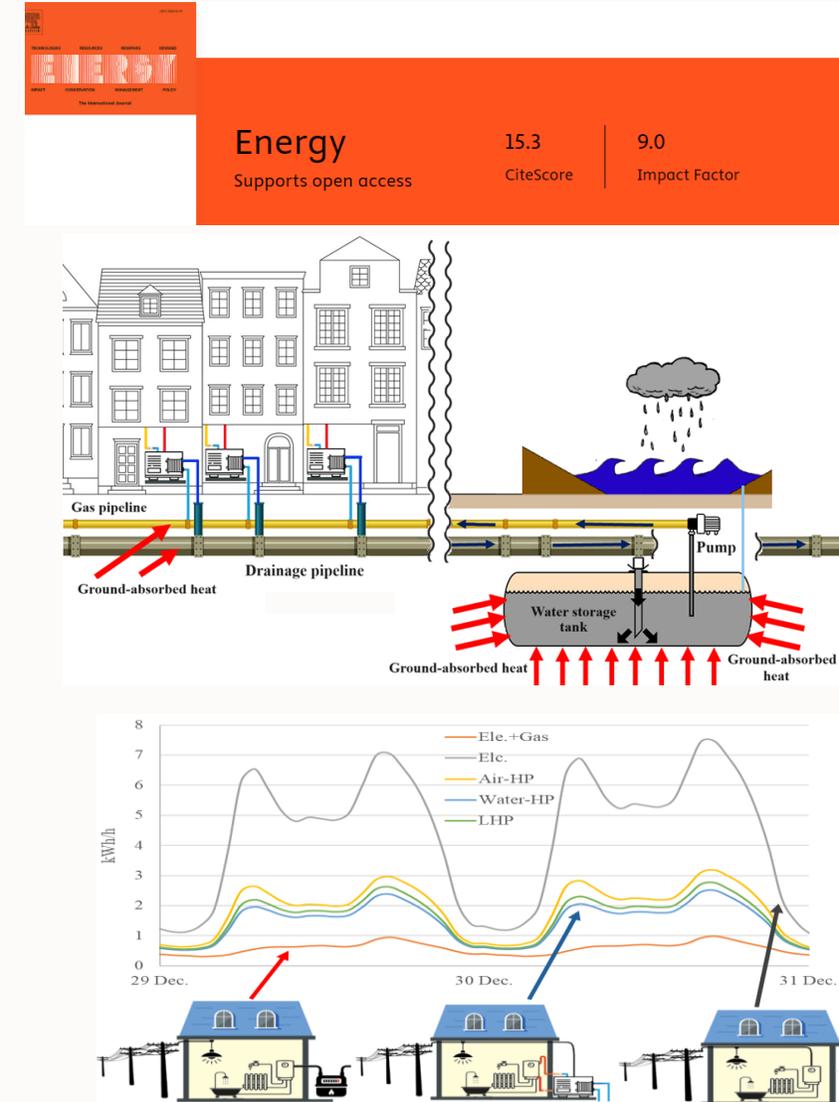
- [1] Mehdipour, R., Garvey, S., Baniamerian, Z., & Cardenas, B. (2024a). Ice source heat pump system for energy supply via gas pipelines – Part1: Performance analysis in residential units. *Energy*, 132974. <https://doi.org/10.1016/j.energy.2024.132974>
- [2] Mehdipour, R., Garvey, S., Baniamerian, Z., & Cardenas, B. (2024c). A Comparative study on the performance of Ice-Source heat pumps versus other heat source heat pumps: a case study in the UK. *Renewable Energy*, 121867. <https://doi.org/10.1016/j.renene.2024.121867>
- [3] Mehdipour, R., Garvey, S., Baniamerian, Z., & Cardenas, B. (2025b). Ice-Source heat pumps: Sustainable heating solutions for urban areas utilizing water and gas networks. *Energy and Buildings*, 343, 115916. <https://doi.org/10.1016/j.enbuild.2025.115916>
- [4] Mehdipour, R., Garvey, S., Cardenas, B., Baniamerian, Z., & Wood, C. J. (2025). Ice-Source Heat Pump for residential heating: A case study on energy storage and pipeline repurposing in the UK. *Case Studies in Thermal Engineering*, 106579. <https://doi.org/10.1016/j.csite.2025.106579>
- [5] Mehdipour, R., Baniamerian, Z., Hasan Asgari, Garvey, S., Cardenas, B., Sajad Sadr, Davood Shafiei, & Wood, C. J. Integration of Ice-Source Heat Pumps and Seasonal Ice Storage Systems for Sustainable Management of Water and Energy Resources(Under review)

Ice Source Heat Pump System for Energy Supply via Gas Pipelines – Part1: Performance Analysis in Residential Units

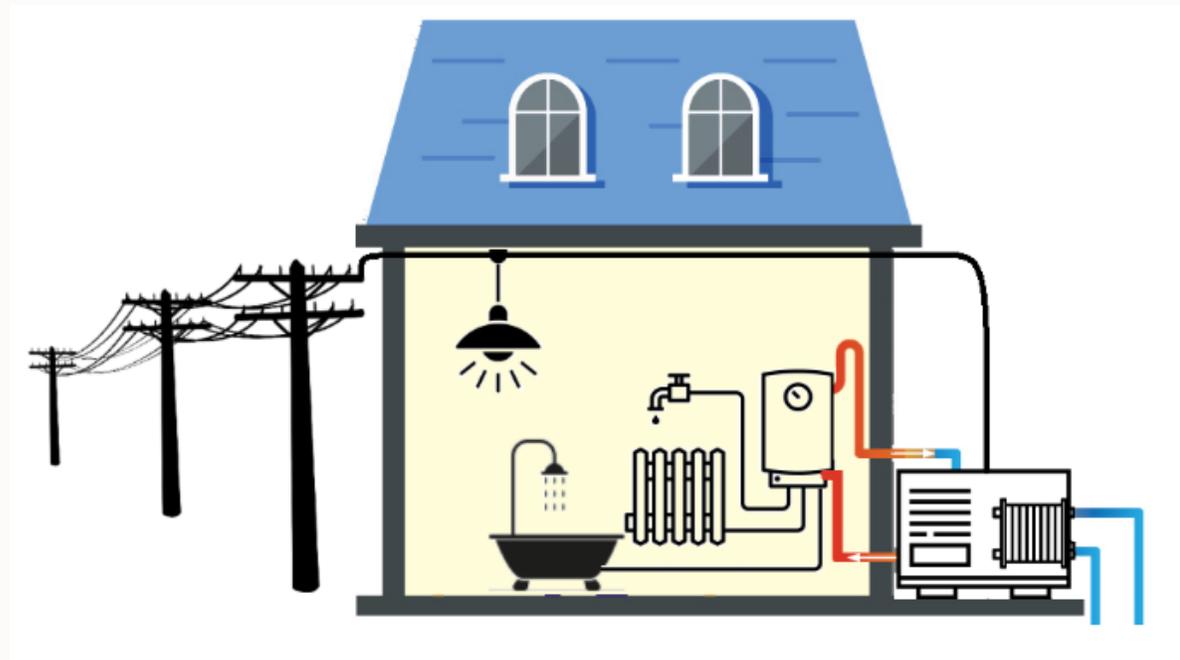
Published

- **Ice-Source Heat Pump System:** The study examines heat pumps using water or ice as a heat source via repurposed gas pipes, with a focus on the ice-source heat pump.
- **Urban Energy Benefits:** The proposed system offers key advantages for urban energy networks, particularly in densely populated areas.
- **Efficiency and Implementation:** The article compares the thermal efficiency of this system with other heat pumps and evaluates its implementation and water needs through gas pipelines.
- **Impact on Peak Electricity Demand:** Modeling in Nottingham shows that switching to heat pumps significantly increases peak electricity demand.
- **Post-Gas Demand Management:** The findings emphasize the system's role in managing peak electricity demand and boosting capacity after eliminating natural gas.

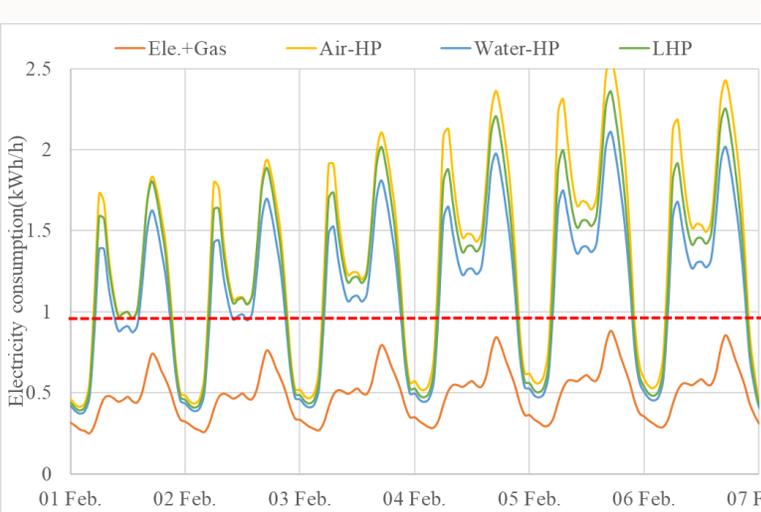
The superior performance of this type of heat pump compared to other heat pumps has been investigated.



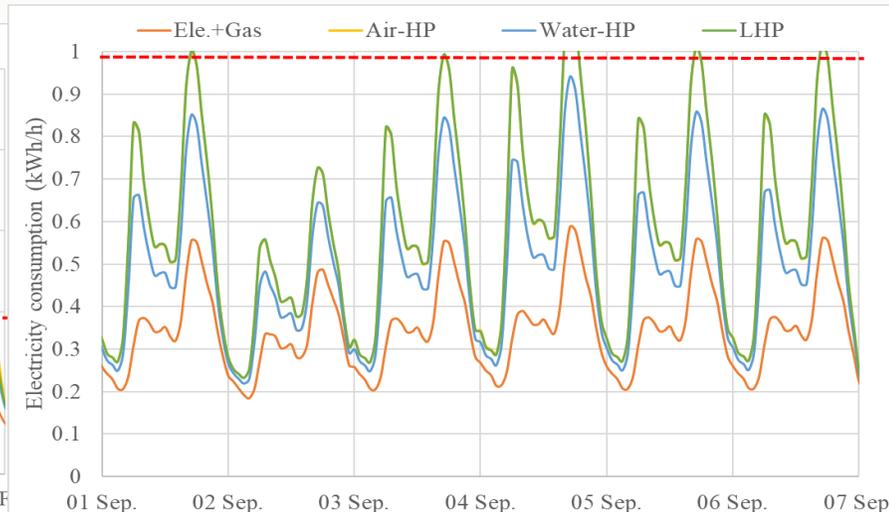
The performance of the ice-source heat pump in cold weather has been better than that of the air-source heat pump.



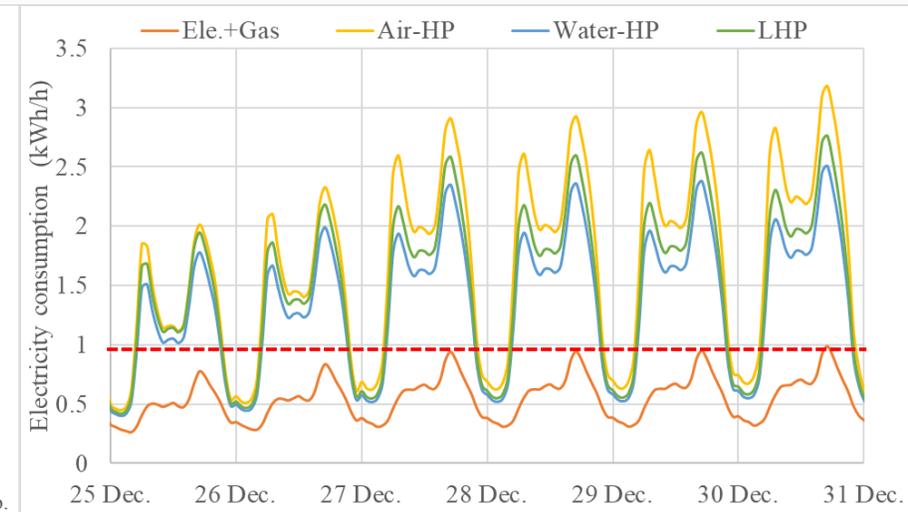
February



September



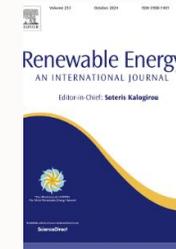
December



A Comparative study on the performance of Ice-Source heat pumps versus other heat source heat pumps: a case study in the UK. Renewable Energy

Published

- **Comparing Heat Pump Performance:** The article focuses on comparing the thermal performance of ice-source heat pumps with other types, highlighting their advantages.
- **Optimizing Heat Pumps for UK Climate:** The study explores optimizing heat pump efficiency using various low-grade heat sources, specifically for the UK's climate.
- **Significant Water Savings:** The proposed system can reduce the water volume needed for residential heating by up to 95%, requiring far less water than traditional systems.



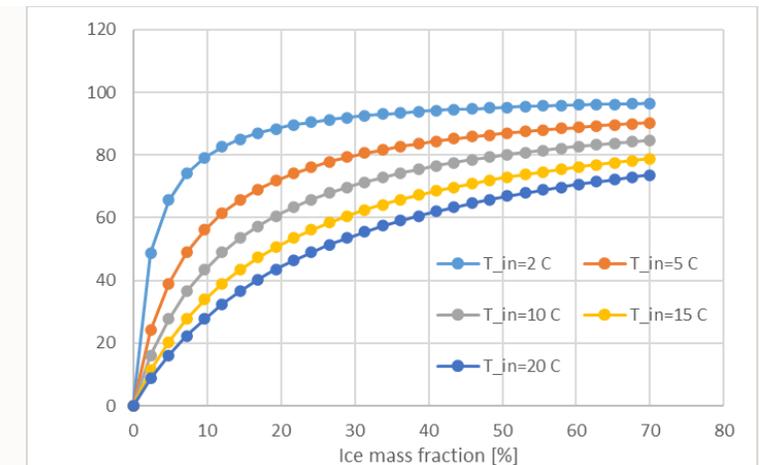
Renewable Energy
Supports open access

18.4
CiteScore

9.0
Impact Factor

The coefficient of performance of heat pumps with different heat sources.

	COP(min)	COP(max)	SPF2
Heating by air	4.32	5.85	5.42
Heating by lake and river water	4.77	6.24	---
Heating by Ground	4.77	6.24	---
Heating by pipe water (winter)	4.77	6.24	---
Heating by pipe water (autum)	4.77	7.21	---
Heating by waste water (grey water)	4.77	9.37	---

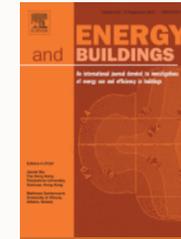


The application of the ice-source heat pump and its comparison with other heat pumps have been examined.

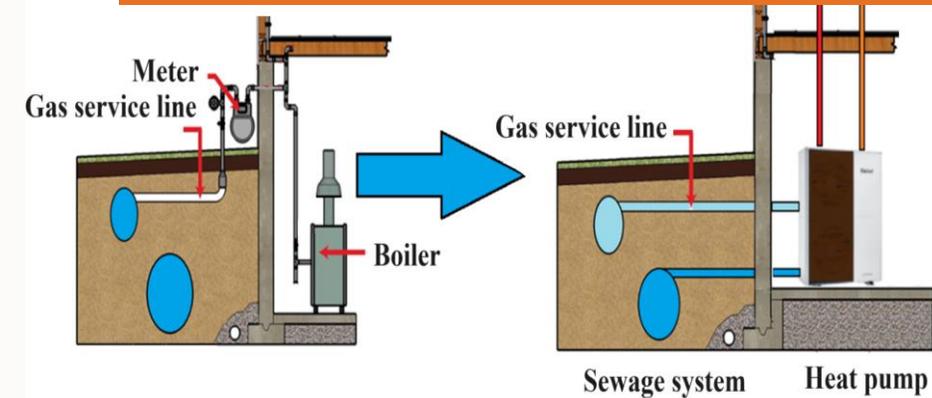
Ice-Source heat pumps: Sustainable heating solutions for urban areas utilizing water and gas networks.

Published

- **Comparison of Heat Pumps:** The first section compares the performance of ice and water-based heat pumps with other systems, highlighting their advantages during peak consumption periods.
- **Water Transfer Using Gas Pipelines:** The second section focuses on water transport via gas pipelines, noting that the current pipeline capacities are exceeded, especially in winter, making ice-source heat pumps essential.
- **Energy Transfer and Efficiency:** The system demonstrates a transfer capacity equivalent to 39.66% of natural gas energy during peak times. Ice-source heat pumps use 37.56 times less water than water-source pumps, with slightly lower thermal performance.

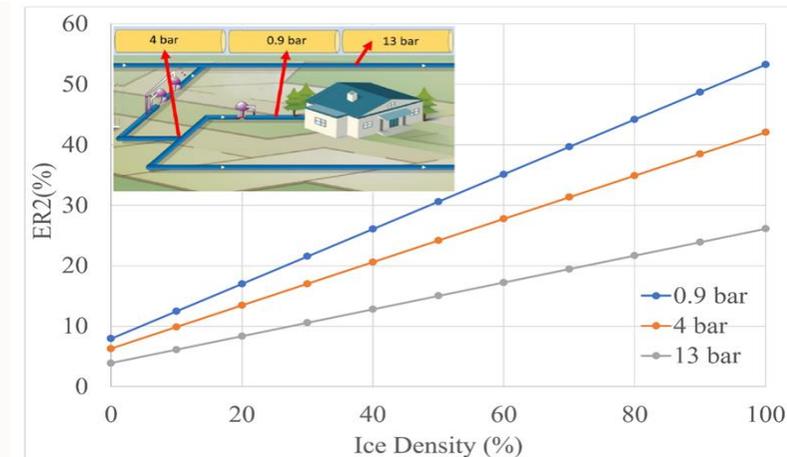


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The implementation of the ice-source heat pump and the repurposing of gas pipelines for water transmission have been studied.

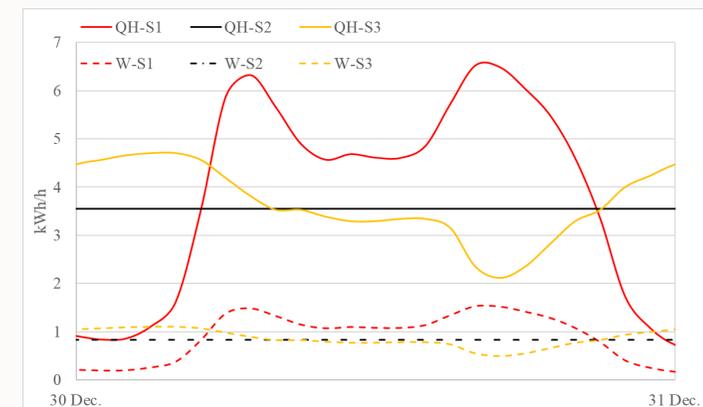
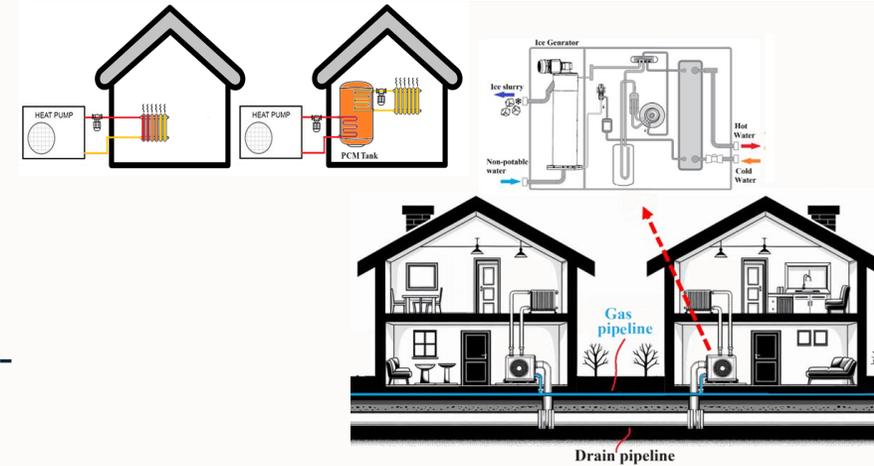
It was shown that the gas network, with this repurposing, can provide energy services at the same scale.



Ice-Source Heat Pump for residential heating: A case study on energy storage and pipeline repurposing in the UK

Published

- **Transition to Cleaner Heating Methods:** The study emphasizes the need to transition from natural gas to cleaner heating methods, highlighting the role of heat pumps.
- **Peak Electricity Demand Challenges:** Heat pumps cause two peaks in electricity consumption, unlike gas heating, with air, ice, and water source heat pumps increasing peaks by 2.84, 2.70, and 2.56 times, respectively.
- **Advantages and Barriers of Heat Pumps:** While water and ice source heat pumps are more efficient during peak conditions than air source heat pumps, their high cost and implementation difficulty in dense areas are challenges.
- **Proposed Ice-Source Heat Pump System:** The study suggests a new heating system using ice source heat pumps that circulate water through existing gas pipes, offering a cost-effective and practical solution.
- **Impact of PCM Energy Storage:** The study explores phase change material (PCM) energy storage to reduce peak electricity demand, achieving reductions of 40.65% for air-source, 40.75% for ice-source, and 40.64% for water-source heat pumps.



The interaction between energy storage and the ice-source heat pump in enhancing energy network efficiency has been analyzed.

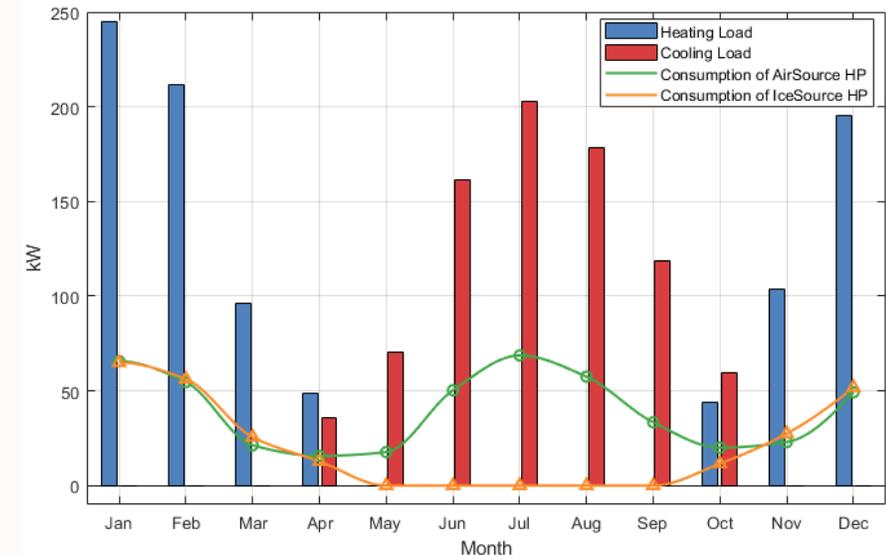
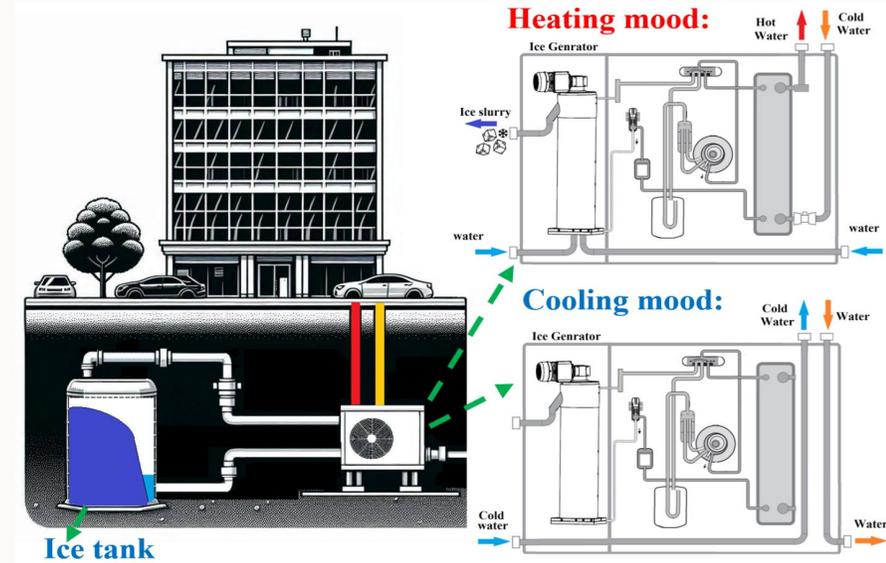
Integration of Ice-Source Heat Pumps and Seasonal Ice Storage Systems for Sustainable Management of Water and Energy Resources

Under review

The system performs three functions: winter heating, summer cooling, and water storage

- Approximately 60% reduction in gas consumption throughout the year
- In some areas, a complete reduction in energy consumption for cooling
- Reduced heating energy consumption compared to gas boilers in winter
- Water storage and reduced water loss (similar to natural glaciers)

It has been shown that this system is a valuable and efficient option even for dry and water-scarce regions.



Ice Source Heat Pump Test Rig

The implication of these results is that the use of an **ice-source heat pump** is essential for the heating solution.

- Hybrid Heat Pump
 - Air Source Heat Pump
 - Water & Ice Source Heat Pump
- 7 kW Heat Pump
- R290 Refrigerant
- Production of ice slurry with a concentration up to 90%.



Ice Production Unit

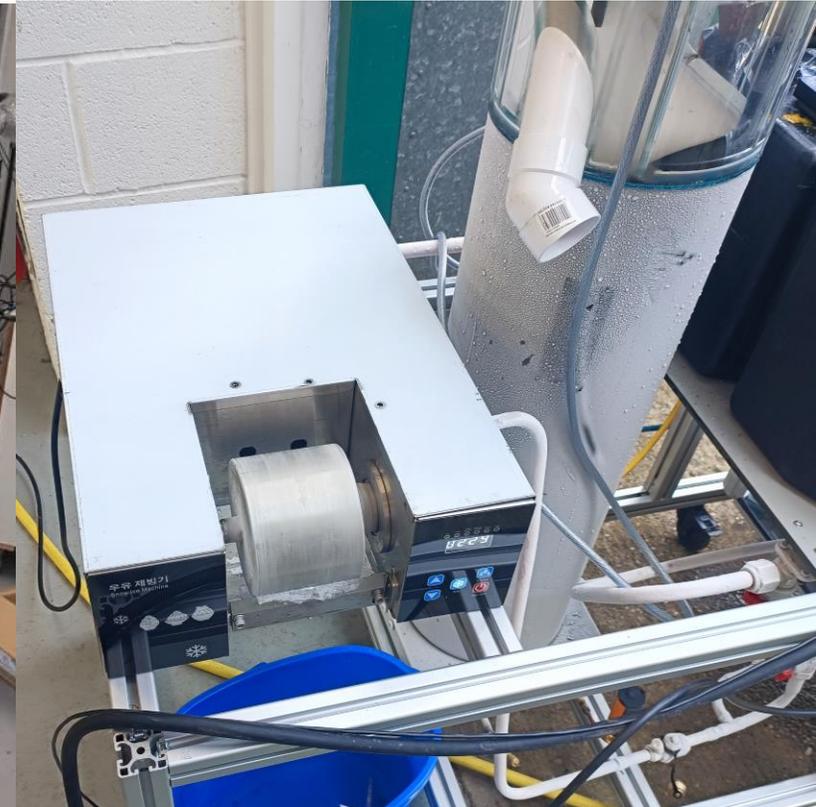
Plate Freezing



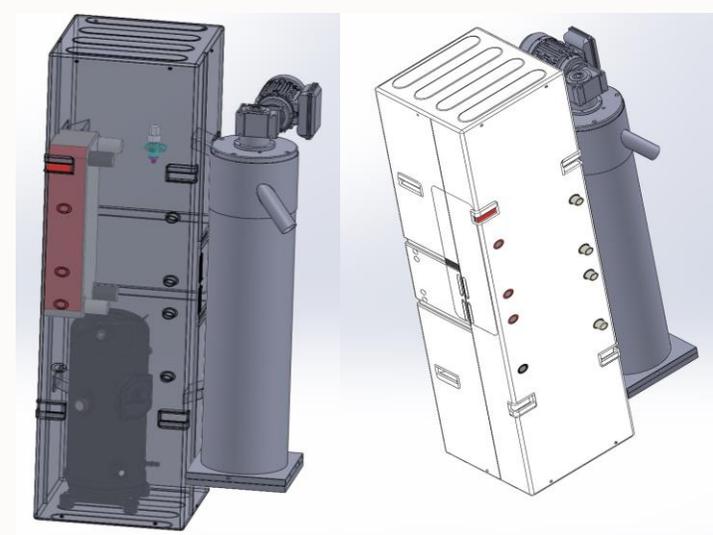
Scraped Surface Generators



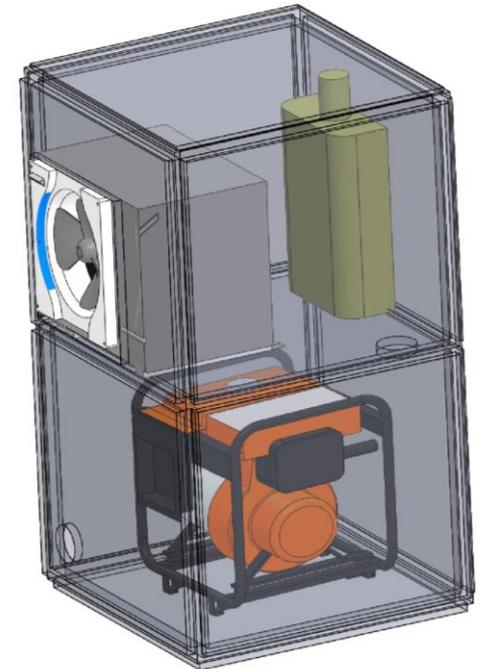
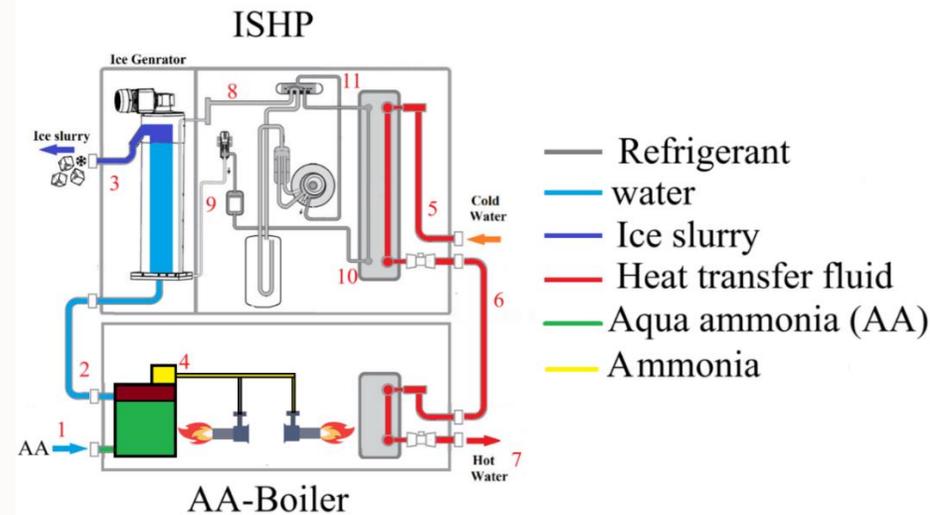
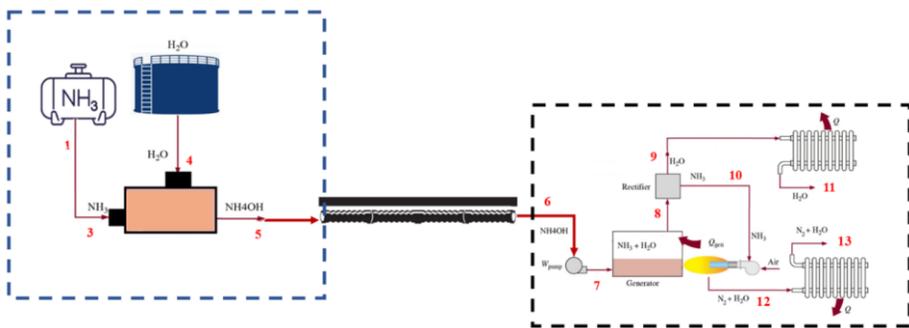
Ice Shaving



Projects Under Development

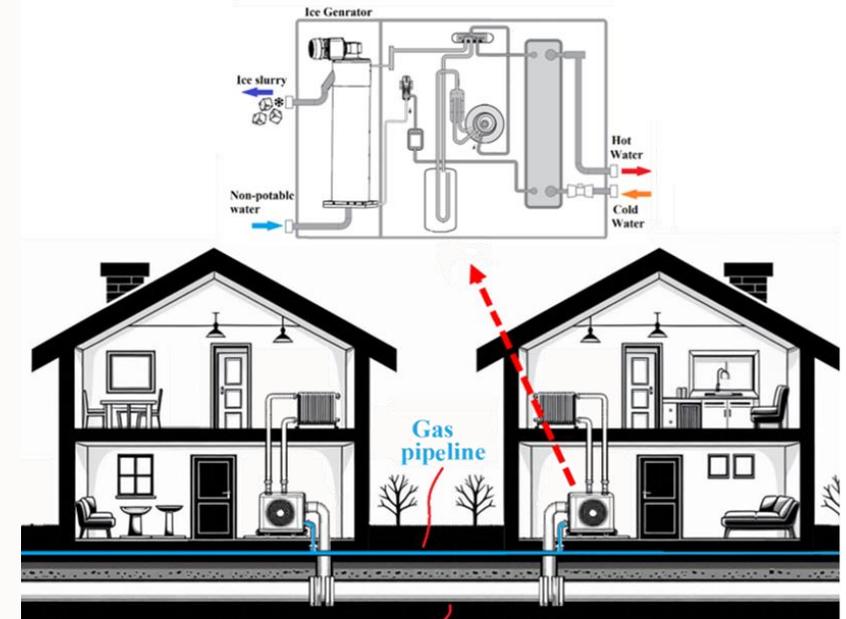


- ISHP Commercial Model Design
- Ultrasonic Ice Maker
- Gas and Hydrogen Engine Driven Heat Pump (GEHP, HP3)
- Fuel Transportation with Water (Aqua ammonia)



Conclusion

- Ice-source heat pump concept presented.
- Implementation method introduced.
- Performance of the system evaluated.
- Gas companies should consider practical solutions, especially ice-source heat pumps, for repurposing pipelines.
- Ice-source heat pump offers excellent heating and is attractive for heating/cooling industries, including food processing.
- Nottingham team is developing the technology for commercialization; industry collaboration is welcomed.





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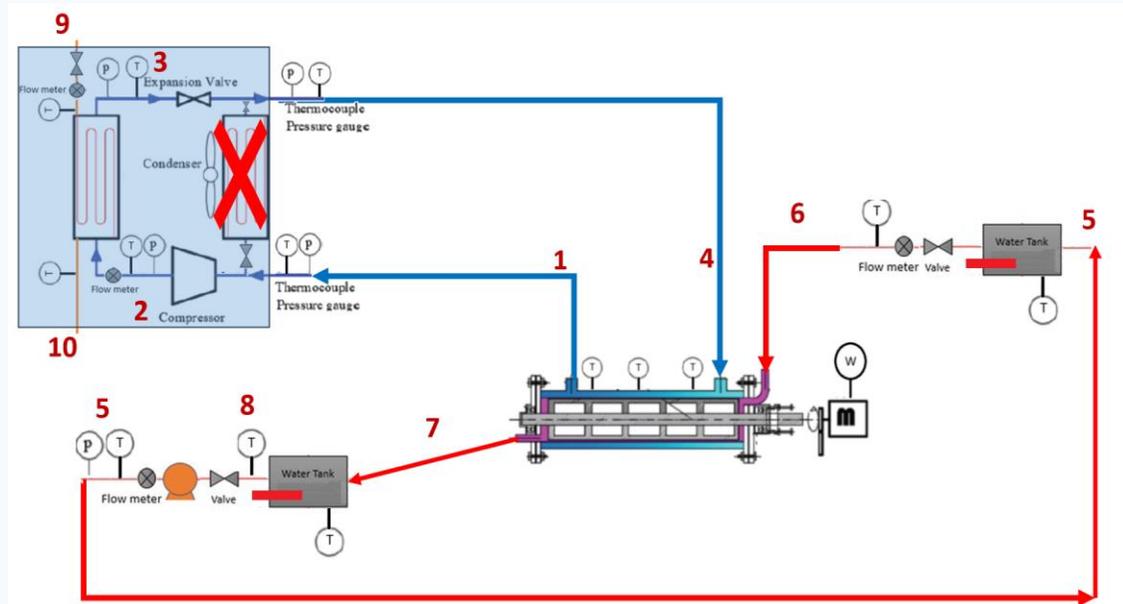
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Experimental Test Section

- Performance test
- Comparison ice source heat pump with air-source heat pump,
- Performance improvement for commercialization.



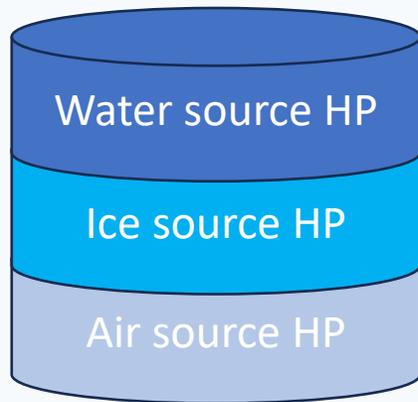


Performance Evaluation of the Heating System

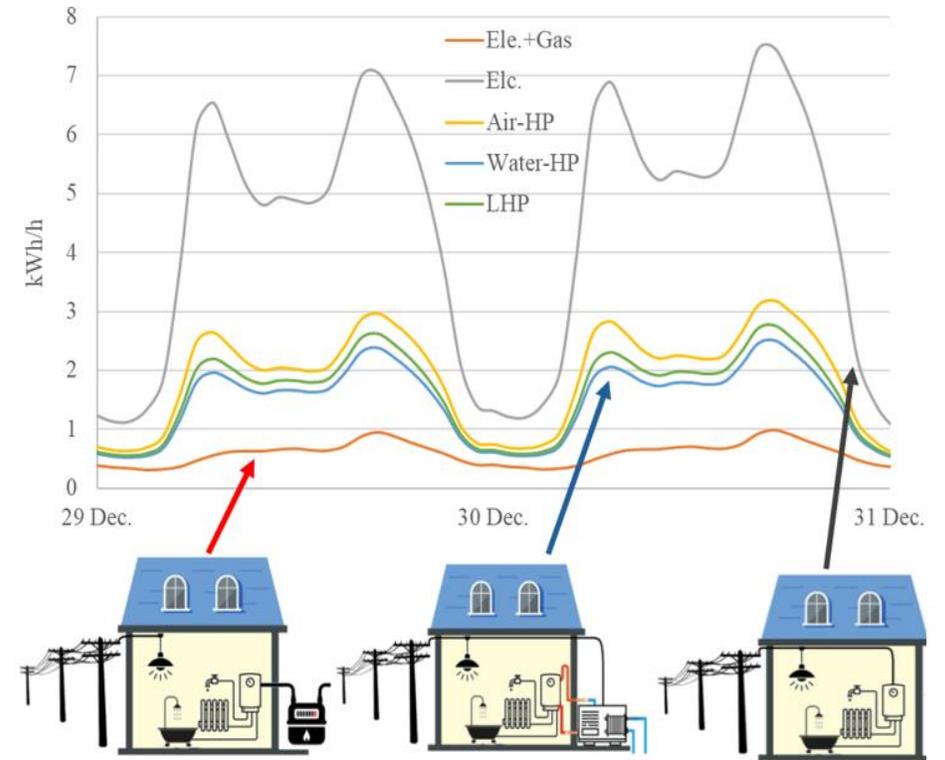
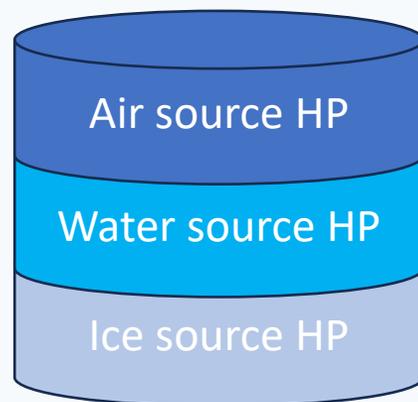
A residential unit was modelled with different heating system configurations (gas boiler, air source heat pump, water source heat pump, ground source heat pump, and ice source heat pump).

The peak electricity consumption has increased by **3.2** times for an air-source heat pump, **2.5** times for a water-source or ground-source heat pump, and **2.75** times for a Latent heat pump.

Cold peak



Autumn and Spring



electricity consumption per residential unit in three heating scenarios: gas heating, electric heating, and heat pump heating.

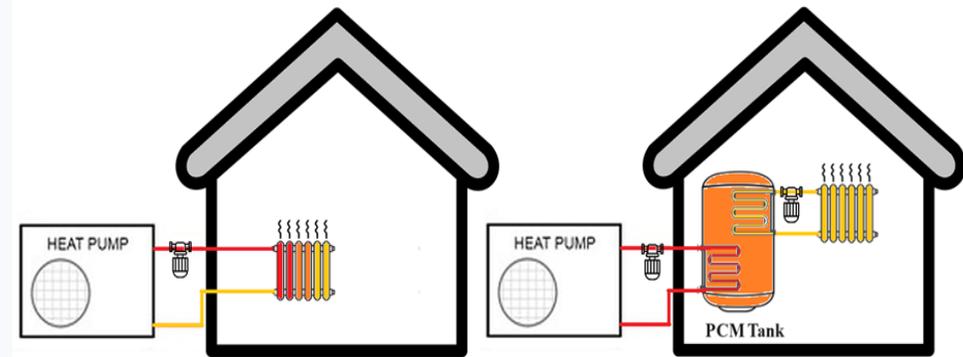
However, the performance of air source heat pumps declines significantly during peak cold periods, which may reduce their efficiency to that of a **simple heater**, leading to a sevenfold increase in peak electricity consumption.



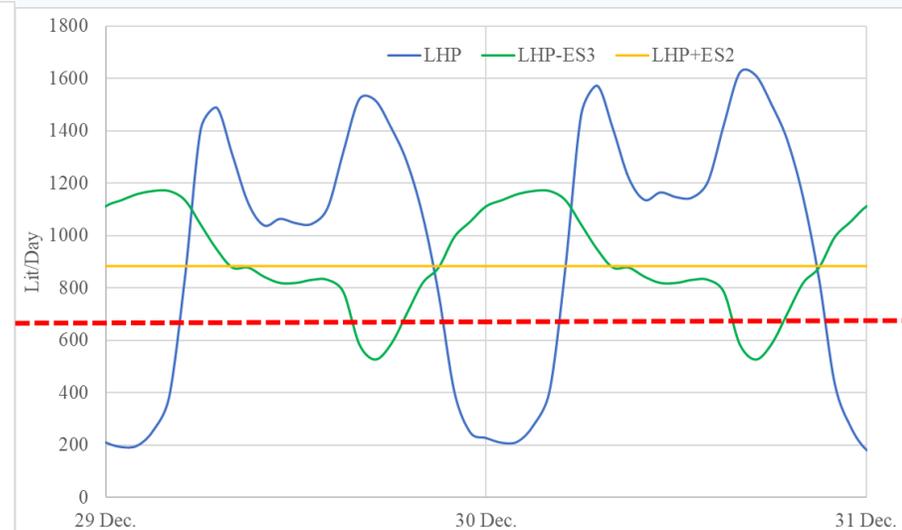
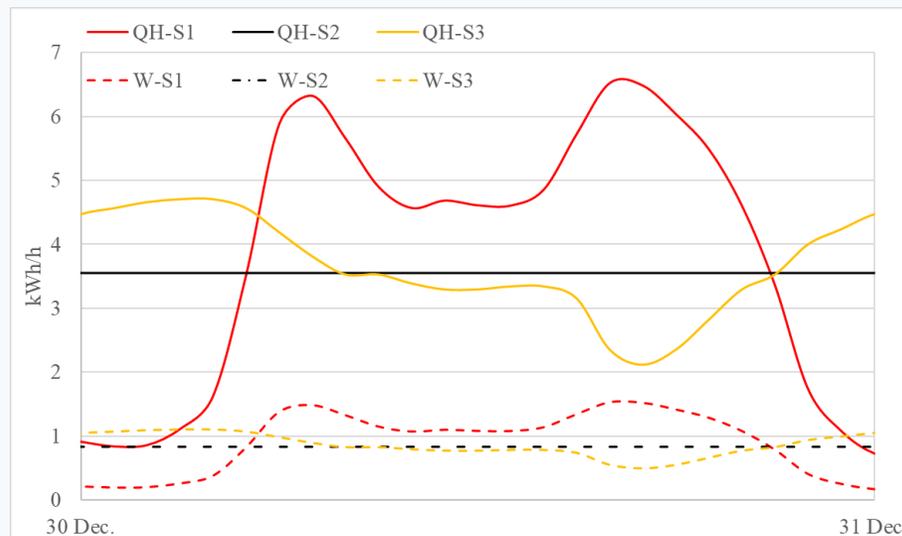
Thermal Energy Storage

The study explores the use of phase change material (PCM) energy storage to reduce peak electricity demand, achieving a reduction of 40.75% for ice-source systems. The peak electricity consumption increased by a factor of 2.75 to 1.63 times.

Providing heating to customers through the existing pipelines

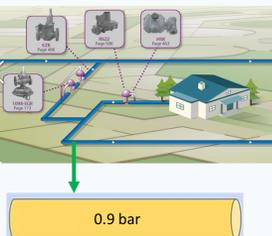


Peak electricity consumption



Energy (water) Transport Capability by Gas Pipe

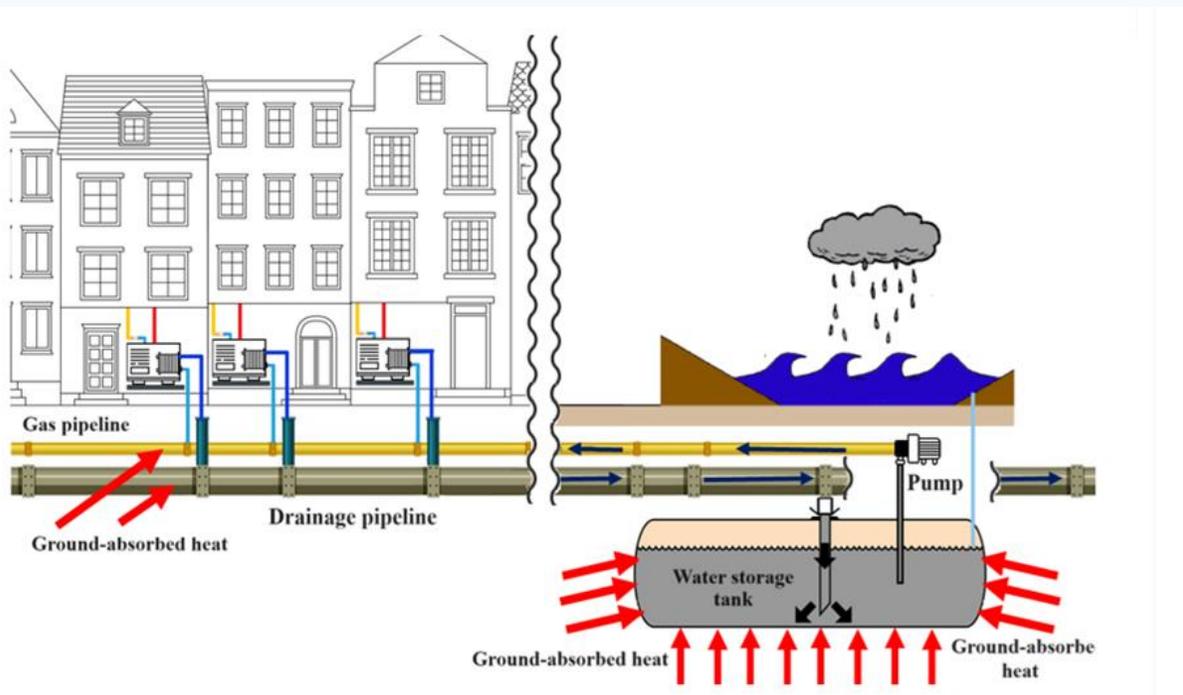
- $ER1 = \frac{\dot{E}_W}{\dot{E}_{NG}} = \frac{\dot{m}_w(c_w T_w + x h_f)}{\dot{m}_R(HV)} = \frac{\rho_w V_{max} W A_P (c_w T_w + x h_f)}{\rho_{NG} V_{max,NG} A_P (HV)}$
- $ER2 = \frac{\dot{E}_W \frac{COP}{COP-1}}{\dot{E}_{NG}} = \frac{COP}{COP-1} ER1$





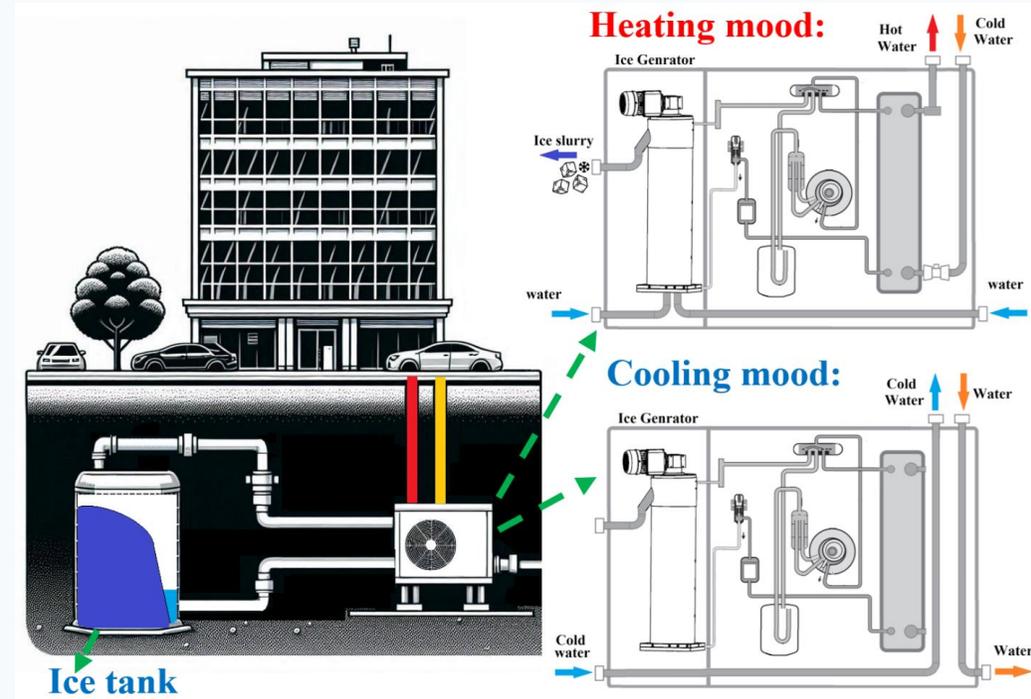
Is this system only suitable for high-rainfall areas?

Closed-loop cycle



Seasonal storage system

The primary advantage of this system, aside from its heating capabilities, is the ability to store and preserve water as ice during the cold season for use and transfer in the warm season.

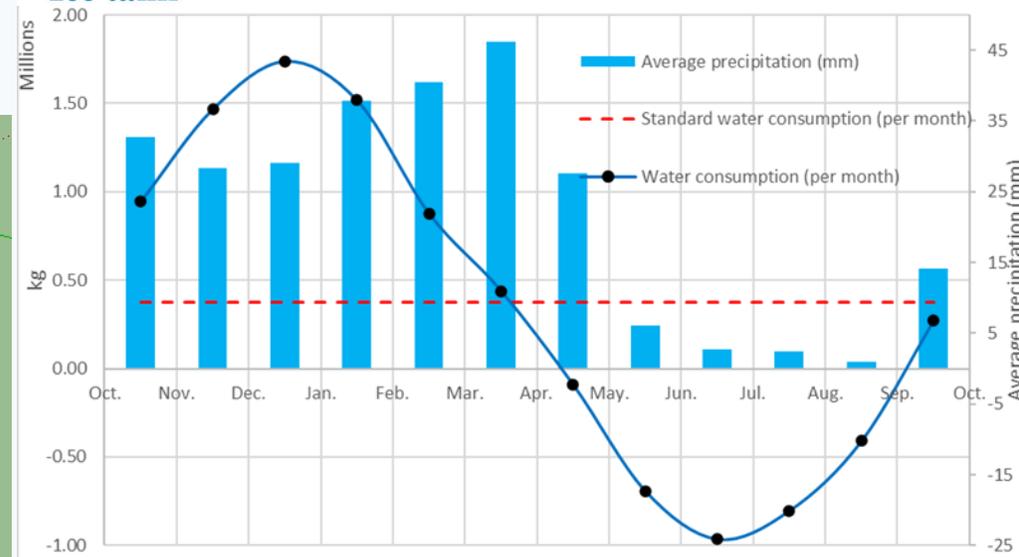
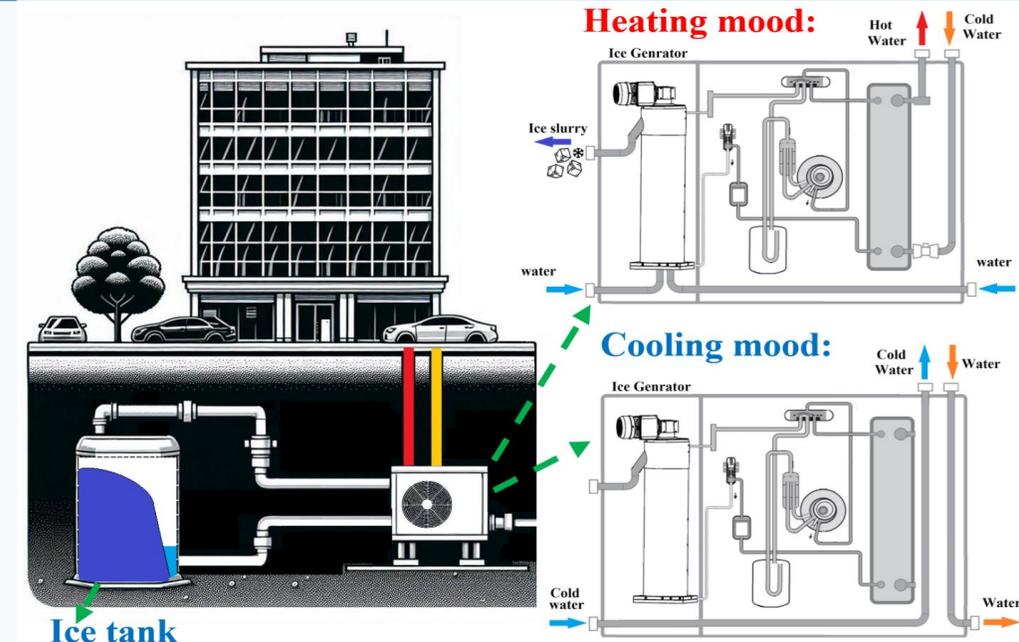
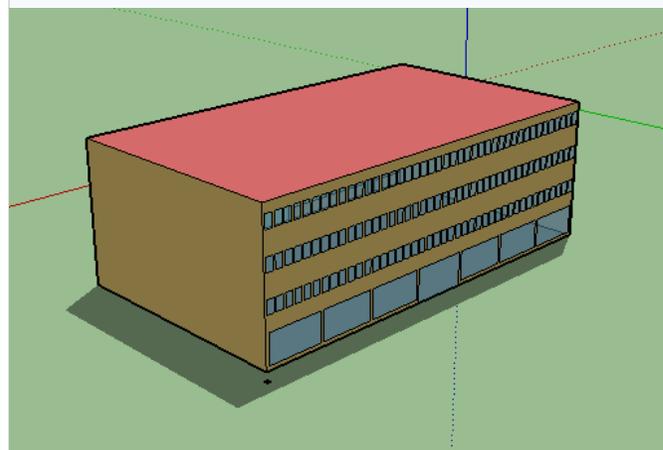
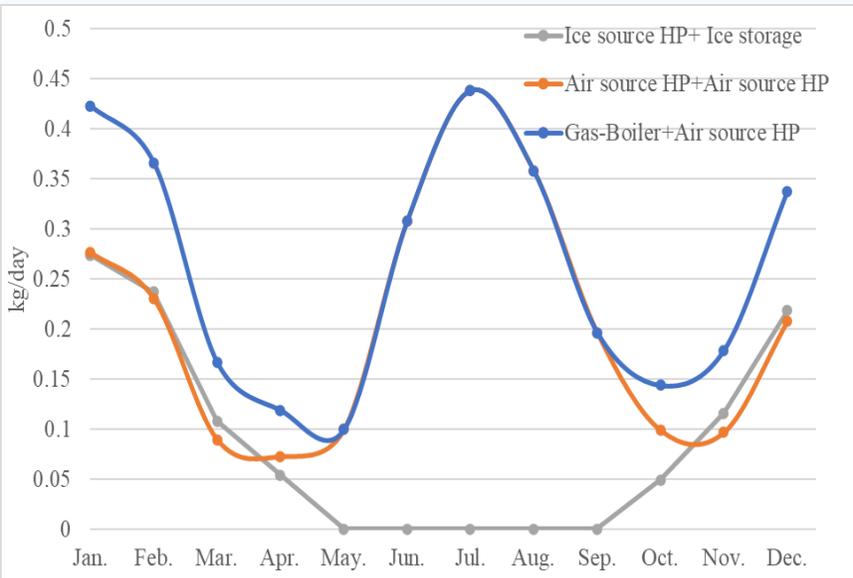




Ice-Source Heat Pump Seasonal storage system

The system performs three functions: winter heating, summer cooling, and water storage

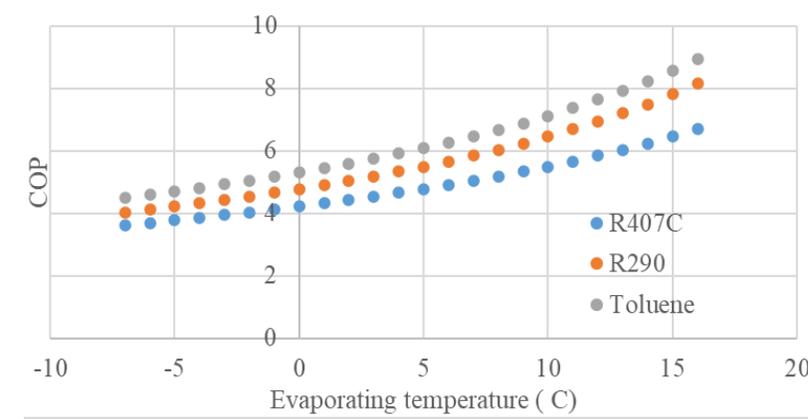
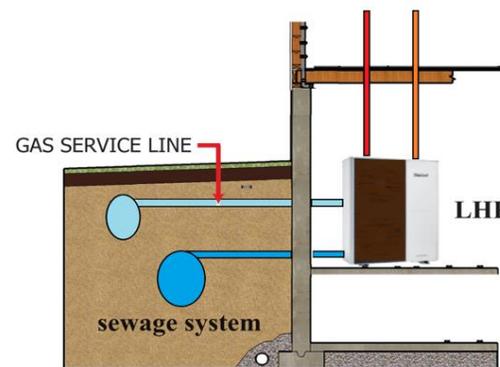
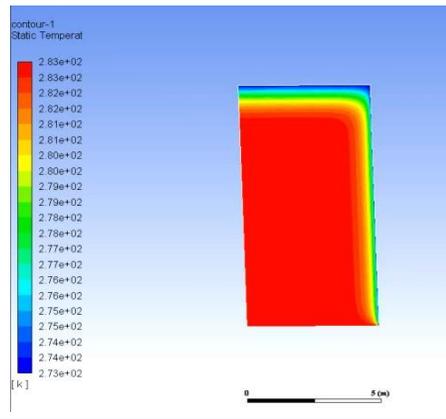
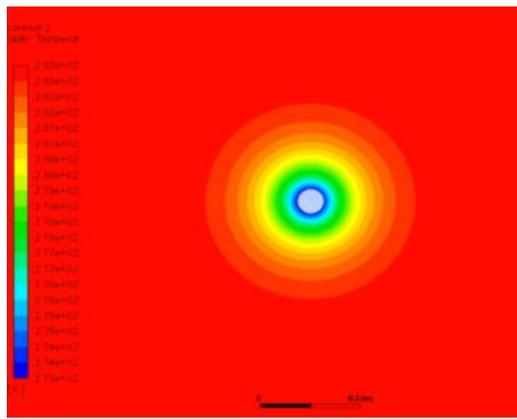
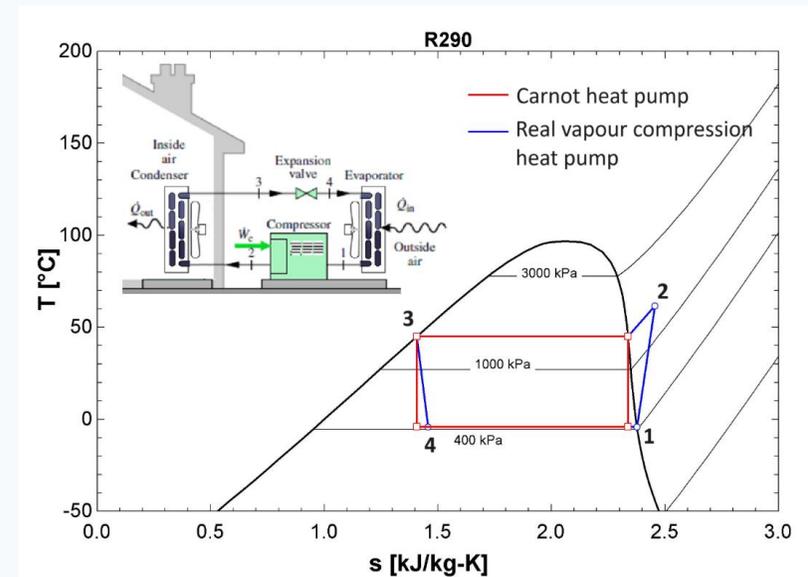
- Approximately 60% reduction in gas consumption throughout the year
- In some areas, a complete reduction in energy consumption for cooling
- Reduced heating energy consumption compared to gas boilers in winter
- Water storage and reduced water loss (similar to natural glaciers)





Modelling

- Modelling the performance of the heat pump
- Modelling the thermal performance of the heating system
- Modelling the energy requirements of a residential unit
- Modelling heat transfer from buried pipes in the soil
- Modelling the fluid or gas transfer capacity of the pipes
- Modelling the energy storage

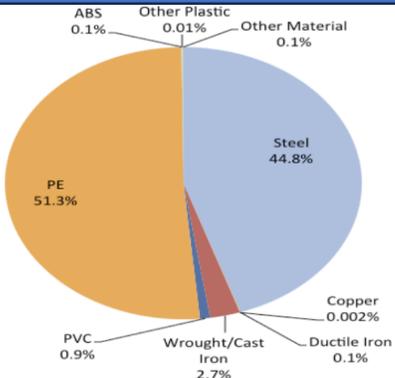


Water transfer through gas pipes

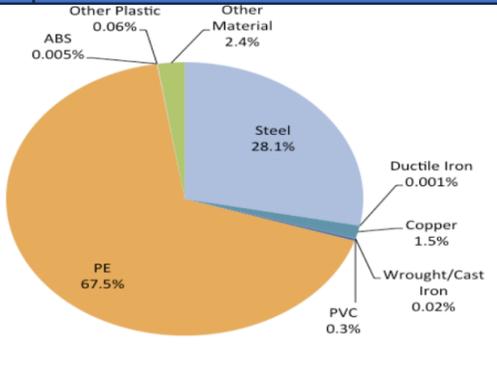
Materials used in piping

Gas Pipes:
Metal Piping, PVC Pipe,
 Fiberglass Pipe, PE Gas Pipe,
 Aluminium-Plastic, APCP,
 Hot Dip Galvanized Steel
 Pipes, HDPE.

Water Pipes:
PVC Pipes
Steel Pipes
Copper Pipe



(c) Distribution mains



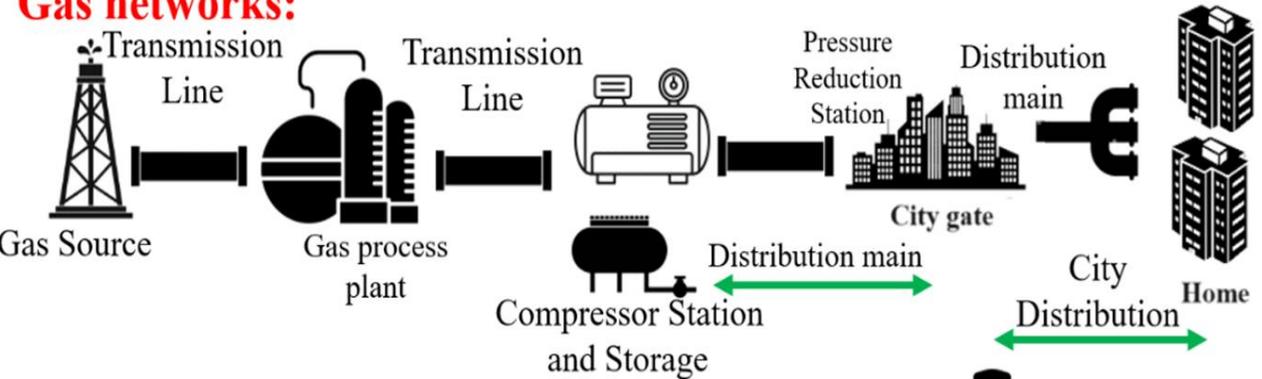
(d) Distribution service lines

Pressure in pipeline

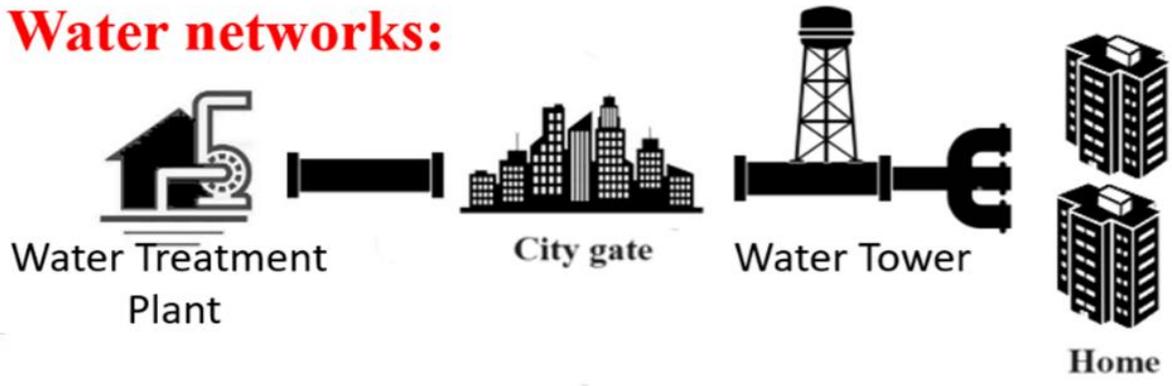
Gas Source:
6.895 to 103.42 bars.
Pressure Boosting Station:
13.79 to 103.42 bars.
Inter-City Transmission Lines:
6.895 to 68.95 bars.
Pressure Reduction Station:
0.6895 to 13.79 bars.
City Distribution Network:
0.2758 to 4.137 bars.
Regulators at Residences:
0.2758 to 0.8274 bars.

City Water Pressure: In municipal water distribution networks, water pressure typically falls within the range of **2.8 to 5.5 bar**. These values can vary in different areas and networks.
Domestic Water Pressure: In domestic plumbing systems inside buildings, water pressure commonly ranges from **1.4 to 4.1 bar**.

Gas networks:



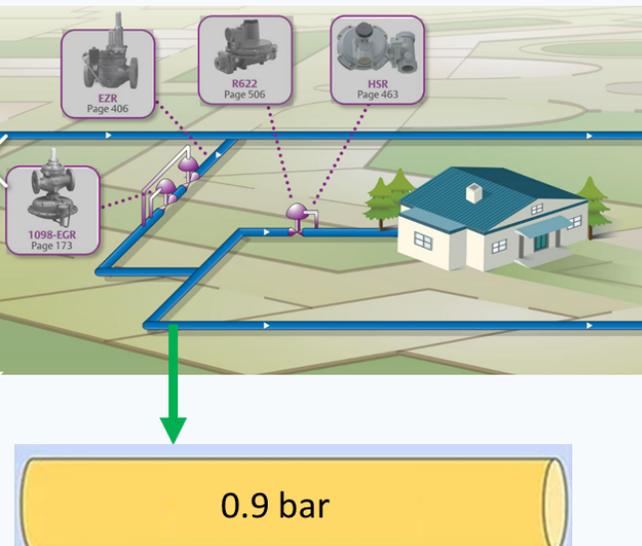
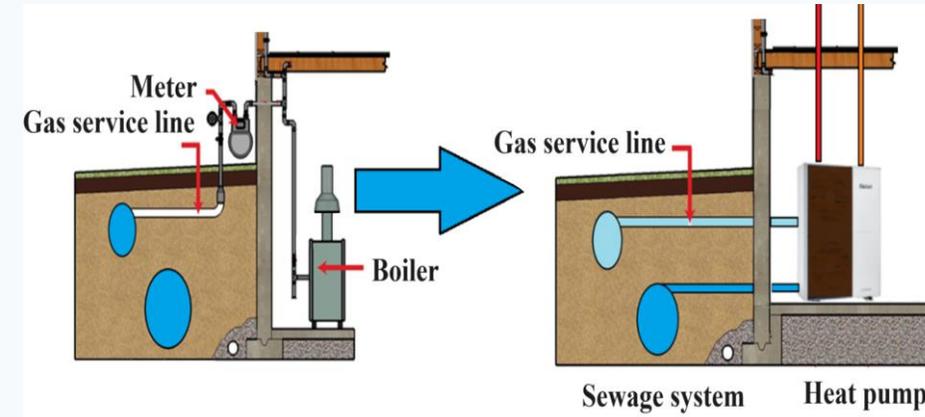
Water networks:





Evaluation of Energy Transfer Capability through Pipes

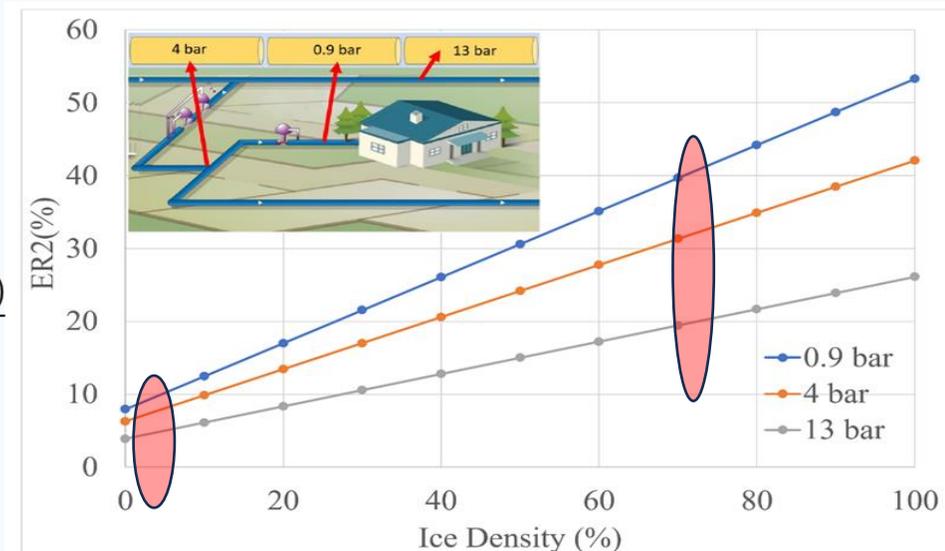
- If the existing gas pipes are repurposed for transporting water to supply heating in this system, they can provide approximately 39.66% of the previous heating capacity based on the heating value of natural gas.
- The modelling showed that the heating system's water consumption is 2.3 times the unit's drinking water usage, rising to 86.5 times with a water-source heat pump.

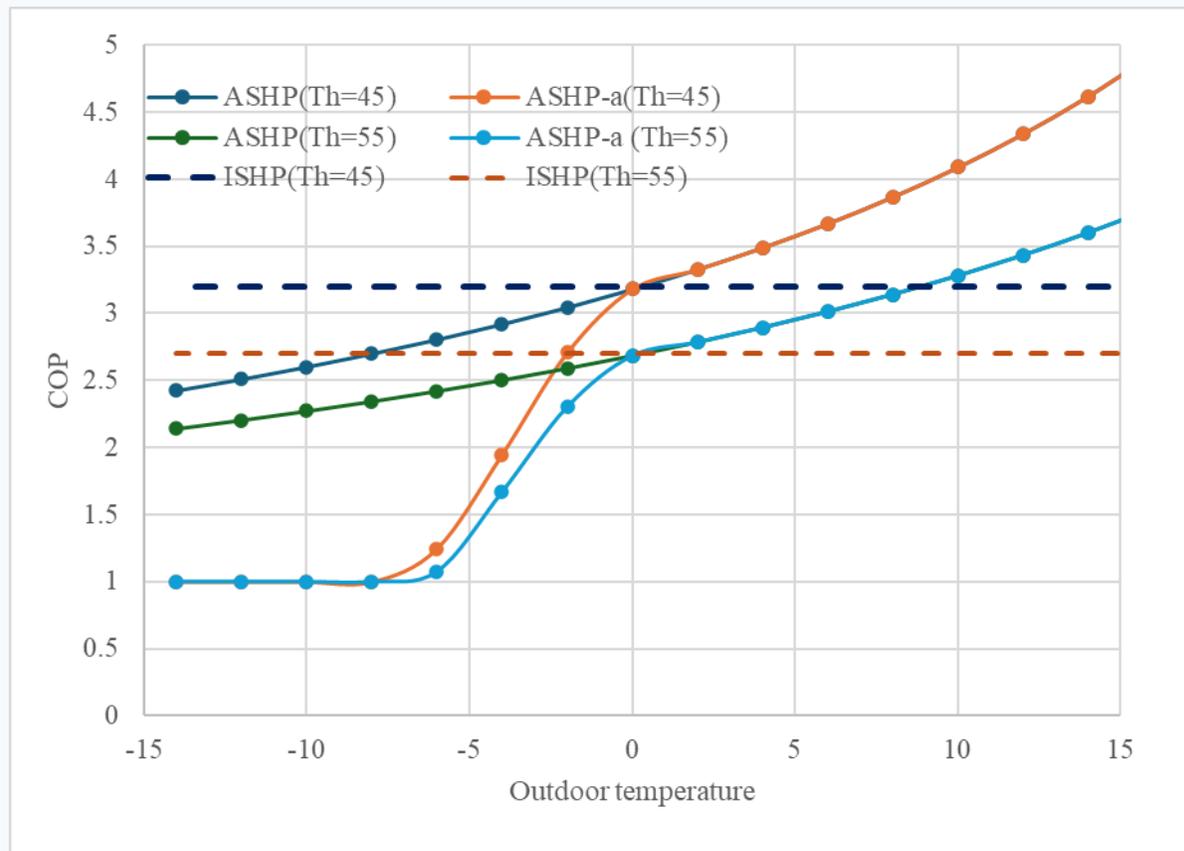


Energy (water) Transport Capability by Gas Pipe

$$\bullet \text{ ER1} = \frac{\dot{E}_W}{\dot{E}_{NG}} = \frac{\dot{m}_w(c_w T_w + x h_f)}{\dot{m}_h(HV)} = \frac{\rho_W V_{max,W} A_P (c_w T_w + x h_f)}{\rho_{NG} V_{max,NG} A_P (HV)}$$

$$\bullet \text{ ER2} = \frac{\dot{E}_W \frac{COP}{COP-1}}{\dot{E}_{NG}} = \frac{COP}{COP-1} \text{ ER1}$$





Integration of Ice-Source Heat Pumps and Seasonal Ice Storage Systems for Sustainable Management of Water and Energy Resources

Under review

The system performs three functions: winter heating, summer cooling, and water storage

- Approximately 60% reduction in gas consumption throughout the year
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