District heating and cooling. District heating and cooling systems are those in which a central heating and/or cooling plant is connected by a network of pipes to multiple buildings, rather than each building having its own heating and cooling system. District systems provide energy much more efficiently than small in-building systems, because they produce heat and cooling at a larger scale. Copenhagen has the most impressive district heating system in the world, which meets 98% of the city's heating demand via district heating fueled by waste heat from coal plants and waste-to-energy plants.[1] The U.S. historically had many urban district heating systems, but many fell into disuse as they aged. Manhattan's Con Edison Steam Operations is the largest system in operation today, but Seattle, Milwaukee, New Orleans, Boston, Cambridge, Chicago, Houston, Las Vegas, Portland, and Los Angeles also have district heating systems.[2] So do a number of universities: for example, the University of New Hampshire has district heating produced by a cogeneration plant that runs on landfill gas.[3]

District heating and cooling provide efficiency gains regardless of the type or source of energy produced. When powered by conventional fossil fuel-based energy, district energy can reduce GHG emissions by burning less fuel. However, district energy can also be powered by a variety of other, even more environmentally friendly sources such as geothermal, anaerobic digestion, and decentralized renewable energy. Furthermore, it can be coupled with other efficiency measures such as heat pumps, combined heat and power, thermal storage, and use of "waste" heat from industrial processes.[4]

District heating is best suited to areas with high heat load density (# of buildings requiring heat per unit area), which minimizes the ratio of piping to heat needed, and a total heat requirement that is high enough make the system economically viable. Thus, cities in cool climates represent the biggest potential beneficiaries.[5] Many U.S. drinking water and sewage systems have aging infrastructure, and coordinating the replacement of water and sewage pipes with installation of steam pipes for district heating could advance this energy efficient technology while achieving significant cost savings.[6] In new buildings, the costs of installing district heating connections can be cut in half by utilizing radiant heating to distribute heat inside buildings.[7]

- Fishery friendliness: District heating and cooling have no direct impact on fisheries or fishery ecosystems. Furthermore, by reducing the amount of energy needed for heating and cooling, district heating and cooling can reduce the amount of energy production

[1] Project Drawdown. "District heating." https://drawdown.org/solutions/district-heating
[2] Wikipedia. "District heating." https://en.wikipedia.org/wiki/District_heating
[3] Wikipedia. "District heating." https://en.wikipedia.org/wiki/District_heating
[4] C40 Cities and United Nations Environment Programme. *Good practice guide: District energy*. https://www.districtenergy.org/viewdocument/good-practice-guide-district-energy
[5] Wikipedia. "District heating." https://en.wikipedia.org/wiki/District_heating
[6] Wikipedia. "District heating." https://en.wikipedia.org/wiki/District_heating
[7] Wikipedia. "District heating." https://en.wikipedia.org/wiki/District_heating

needed to maintain current standards of living, including energy that is produced in fishery-unfriendly ways. Co-benefits: District heating and cooling can help building owners and tenants save money on heating and cooling bills.

- Environmental externalities: There do not appear to be any significant environmental externalities associated with district heating and cooling. The total environmental impact of these systems will depend on the source of energy used, which can be fossil fuel, biomass, or renewable; however, regardless of source, district heating and cooling provides greater efficiency in energy use than the use of single-building heating and cooling systems.
- Policy catalysts: To facilitate adoption of district heating and cooling systems, governments can set long-term targets for low-carbon energy and GHG emissions reduction, build public awareness and support, conduct energy mapping to identify appropriate opportunities for district heating and cooling, identify appropriate ownership models for implementing district energy systems, develop supportive policies and enabling tools, and convert legacy district energy systems from fossil fuels to low-carbon sources.[8] Governments can also play a key role by providing debt provision and bond financing, loan guarantees and underwriting, grants, loans, revolving funds, city-level subsidies and development-based land-value capture strategies.[9]
- More information:
  - Drawdown: District heating
  - Wikipedia: District heating
  - IEA: District heating
  - International District Energy Association: District Heating
  - United Nations Environment Program (UNEP): District energy in cities
  - C40 Cities and United Nations Environment Programme. *Good practice guide: District energy.*

High efficiency heat pumps. Heat pumps transfer energy between a building's interior and the outside air, the ground (geothermal heat pumps), or a water reservoir (such as a pond or lake). They use refrigeration technology to transfer heat from a colder space to a warmer space or vice-versa. As a result, they can provide heating in winter, air conditioning in summer, and even hot water. Heat pumps are highly efficient. Moreover, because they represent electrical (as opposed to oil- or gas-based) heating systems, they can be paired with zero-emissions energy such as wind, solar, hydro, or nuclear to eliminate 100% of a building's heating and cooling energy emissions. They can easily be installed in existing homes and buildings without expensive structural changes.[10]

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[8] C40 Cities and United Nations Environment Programme. *Good practice guide: District energy*. https://www.districtenergy.org/viewdocument/good-practice-guide-district-energy

[9] United Nations Environment Program (UNEP). 2015. *District energy in cities.* https://www.enwave.com/pdf/UNEP_DES_District_Energy_Report_VØJNC122.pdf

[10] Project Drawdown. "High-efficiency heat pumps." https://drawdown.org/solutions/high-efficiency-heat-pumps

Geothermal heat pumps, also called ground source heat pumps, are a specific kind of pump that taps into heat beneath the Earth's surface to warm homes and buildings. Geothermal heat pumps can be used for a single residence or building, or to warm and cool many buildings simultaneously through district heating. According to the U.S. Environmental Protection Agency (EPA), geothermal heat pumps are the most energy-efficient, environmentally clean, and cost-effective systems for heating and cooling buildings.[11] This technology has a high capital cost and low operational costs compared to others, so assistance to overcome the initial investment through financing, rebates, and tax incentives can help facilitate broader adoption.

- Fishery friendliness: Heat pumps have no direct impact on fisheries or fishery ecosystems. Furthermore, by reducing the amount of energy needed for heating and cooling, heat pumps can reduce the amount of energy production needed to maintain current standards of living, including energy that is produced in fishery-unfriendly ways. However, when heat pumps replace oil- or gas-fueled heat, their installation represents the electrification of previously non-electrified energy systems, causing their fishery friendliness to depend in part on how friendliness of the electricity generation that powers them.
- Co-benefits: In the long run, heat pumps can help home/building owners and tenants save money on heating and cooling bills.
- Environmental externalities: There do not appear to be any significant environmental externalities associated with air-source heat pumps. However, ground-source heat pumps have raised concern about effects of groundwater temperature, quality, chemistry, and efficiency of neighboring installations.[12] These issues should be taken into consideration in the planning, permitting, and management of ground-source heat pump systems.
- Policy catalysts: Adoption of high-efficiency heat pumps can be enabled and incentivized through rebates, tax incentives, building codes, utility-based demand reduction programs, low-income energy efficiency programs, government procurement and lead-by-example policies, enabling of financing instruments (e.g., property assessed clean energy programs, energy savings performance contracting, green banks), certification incentives (e.g., LEED, Energy Star), and carbon pricing.
- More information:
    - Drawdown: High efficiency heat pumps
    - Department of Energy: Air-source heat pumps
    - Department of Energy: Geothermal heat pumps
    - U.S. Energy Information Administration (EIA): Geothermal explained

[11] U.S. Energy Information Administration. "Geothermal explained." https://www.eia.gov/energyexplained/geothermal/geothermal-heat-pumps.php

[12] Carosso, Alessandro and Rajandrea Sethi. 2019. Assessment and mitigation of potential environmental impacts of ground source heat pump (GHSP) systems. *Water* 11(1573). DOI: 10.3390/w11081573

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