2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016

Using heat pump to recover waste heat from thermal power plants for district heating

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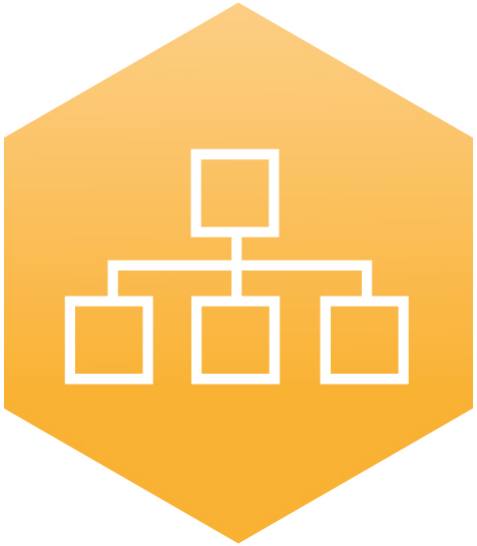

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4DH
4th Generation District Heating
Technologies and Systems

Current situation of district heating (DH) in China

- DH demand in north China accounts for about 40% of the total building energy consumption.
- The DH demand in China is growing rapidly. At the end of year 2012, the total DH production of China was over 2×10^7 TJ, and the production increment per year is about 2×10^6 TJ.
- DH production share:

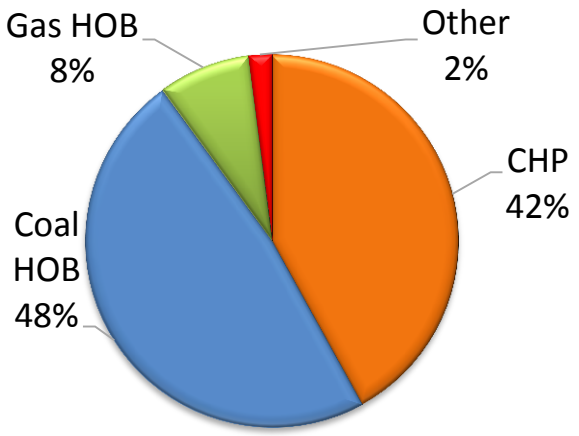
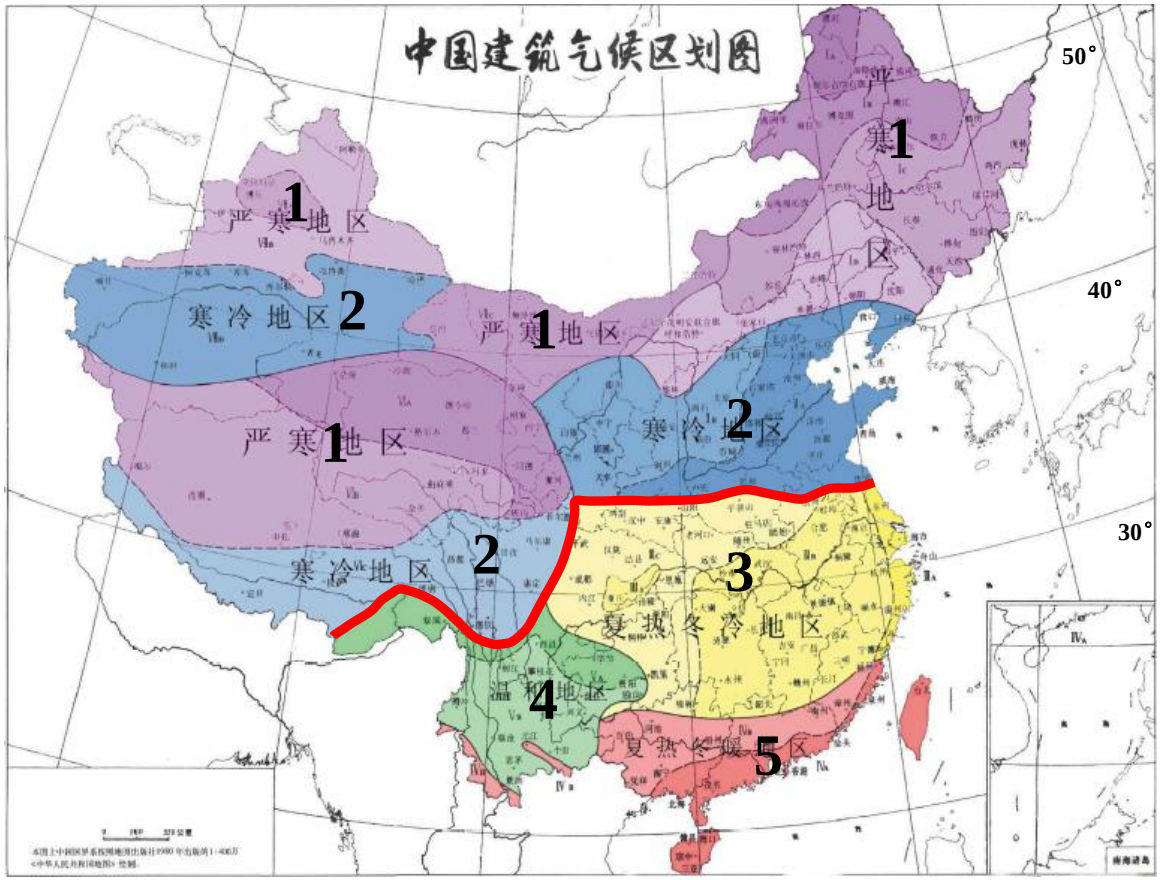


Fig. 1. DH production technologies in China.

Tsinghua University building energy research center, 2014.

Building climate zones in China



1 – extremely cold area; 2 – cold area; 3 – hot summer and cold winter area;
4 – mild area; 5 – hot summer and warm winter area.
Fig. 2. Building climate zones in China.

Power plants in China, 2012

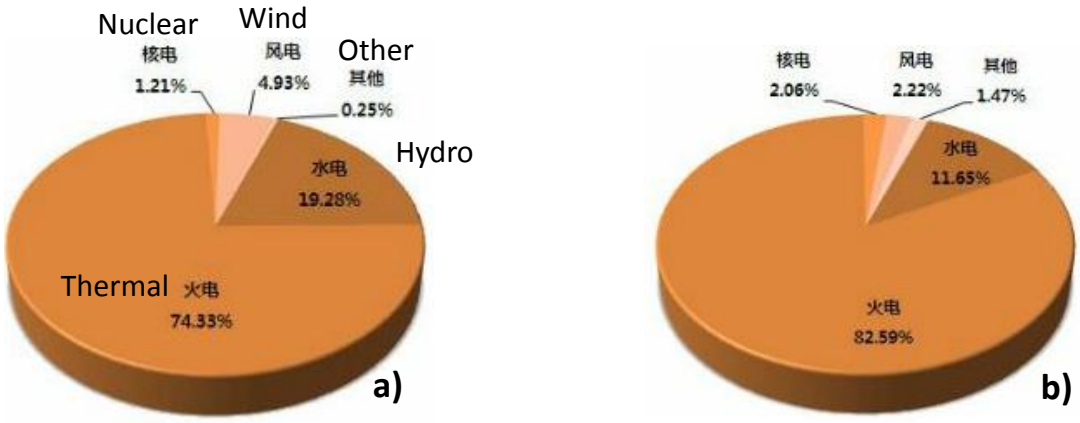


Fig. 3. Power plant technologies in China, a) Capacity equipped and b) power production, in 2012.

- Thermal power plant efficiency, typically around 40%.
- Main reason: Condensing loss! + Flue gas
- In 2005, about 3.4×10^8 t standard coal (equivalent) was completely wasted as condensing loss. This amount of coal can account for15% of total energy consumption or 36% of the building energy consumption in China in 2005!

How to increase power plant efficiency when connecting to DH

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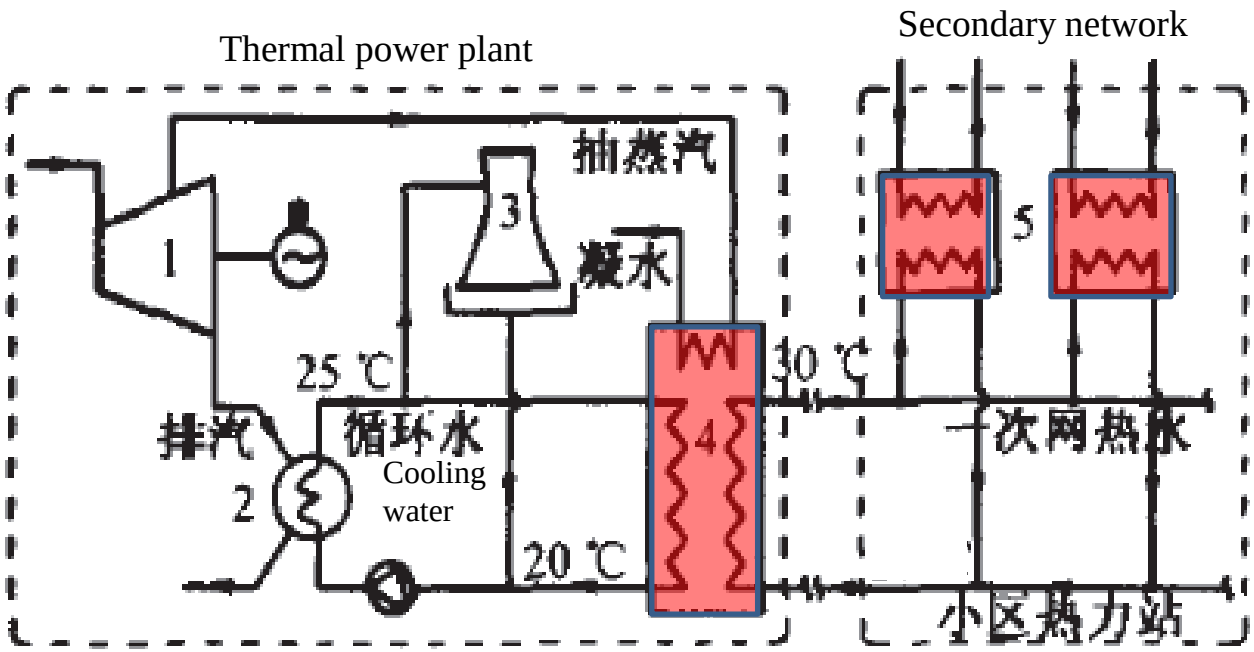
1. Change the operation conditions of steam turbines in power plants
   - Reduce the vacuum extent (increase the absolute pressure) in exhaust hood of a turbine and thus increase the temperature of exhausted steam for heating; this is called *low vacuum operation of steam turbine*.
2. **Use the heat pump to absorb the waste heat in cooling water (cooling water as the low grade heat source).**
   - **Absorption heat pump**
   - **Electrical heat pump**
   - Steam driven compressor heat pump
   - Mechanical heat pump

Using absorption heat pump to recover waste heat in cooling water -1



1 – Steam turbine
2 – Condenser
3 – Cooling tower
4 – Absorption heat pump
5 – Absorption heat exchanger

Primary network

Fig. 4 Schematic flow chat of DH system based on distributed absorption HP.

Using absorption heat pump to recover waste heat in cooling water - 2

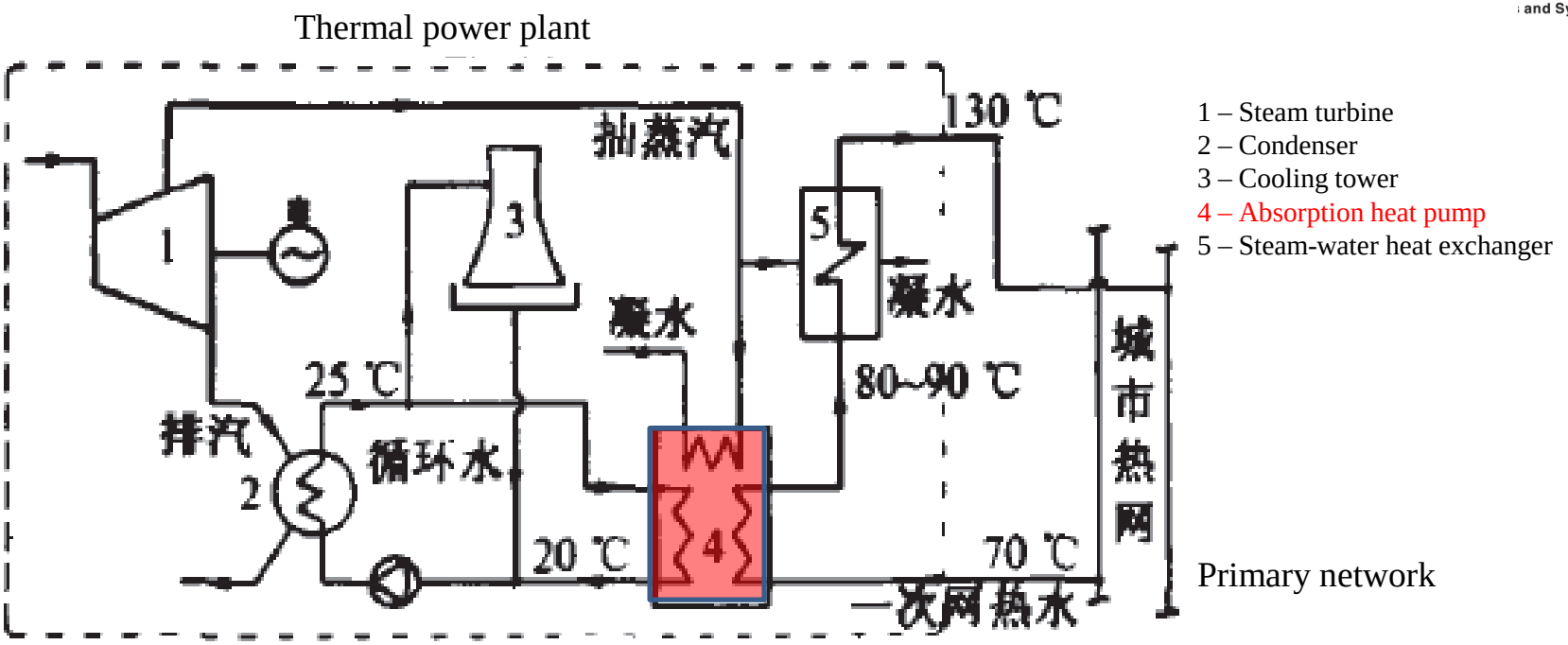


Fig. 5 DH system based on centralized absorption HP.

Using absorption heat pump to recover waste heat in cooling water - 3

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- Distributed absorption heat pump system
  - Reduce the DH return water temperature, and thus increase the useful temperature drop in the DH network;
  - Increase the heat delivery capacity of the DH network;
  - Increase the COP of the absorption heat pump in the power plant, because of the lower return DH water temperature.
  - More pipeline construction is required.
- Centralized
  - Cascade energy utilization;
  - COP is not high because of the high DH return water temperature;

Using electrical heat pump to recover waste heat in cooling water-1

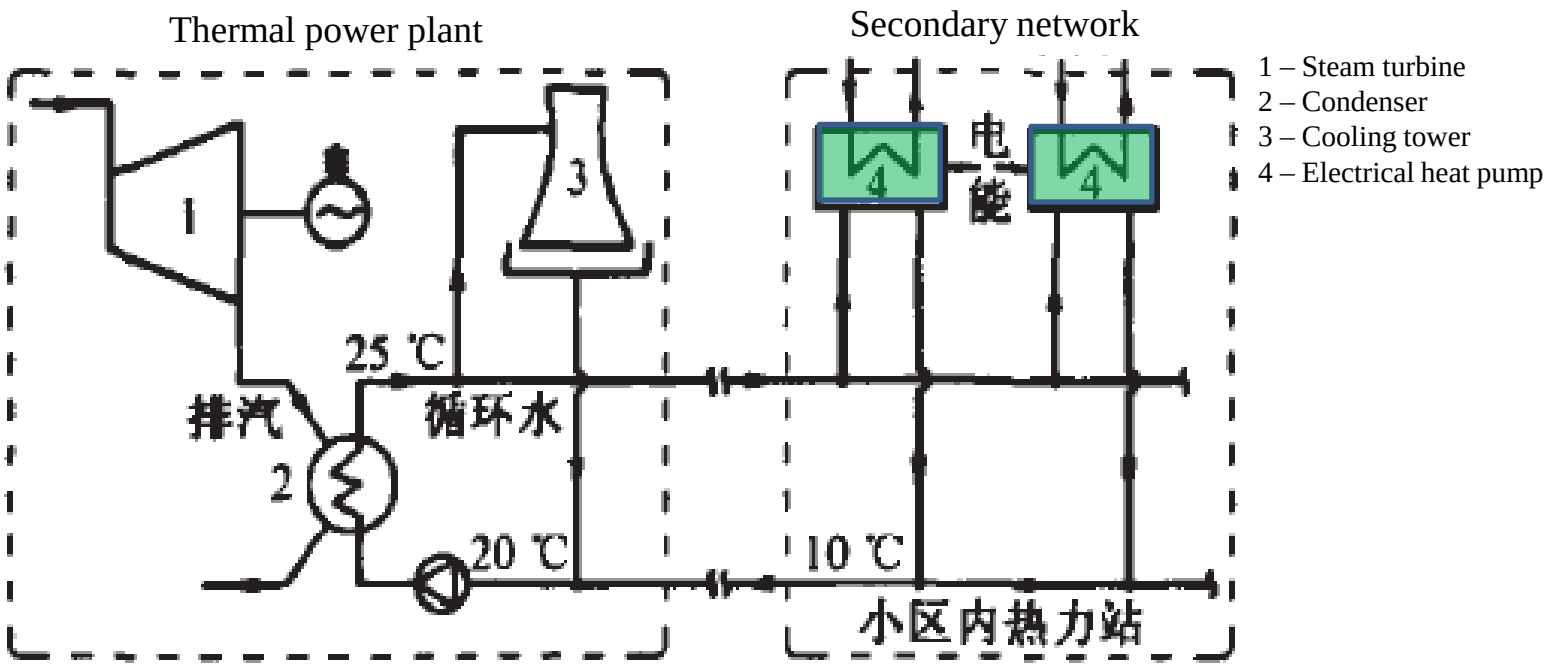
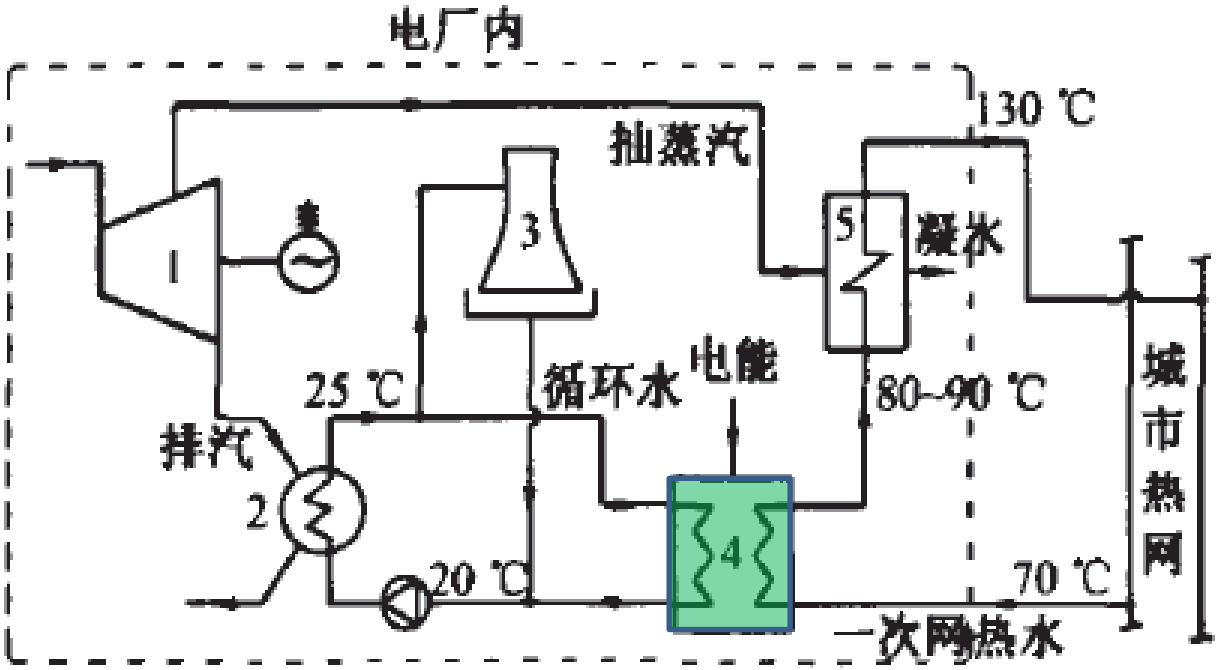


Fig. 6 The schematic flow chart of DH system based on decentralized electrical HP.

Using electrical heat pump to recover waste heat in cooling water-2



1 – Steam turbine
2 – Condenser
3 – Cooling tower
4 – Electrical heat pump
5 – Steam-water heat exchanger

Fig. 7 The schematic flow chart of DH system based on centralized electrical HP.

Using electrical heat pump to recover waste heat in cooling water-3

- Distributed electrical heat pump system
  - Cooling water flow to the substation directly, and it is cooled down in the electrical heat pump;
  - More construction of the pipeline network;
  - Due to the small available temperature drop, pump cost is high and heating radius is small;
- Centralized
  - Cascade energy utilization;
  - Less construction of pipeline network.

Discussion

- Distributed v.s. centralized?
- Possible Combination?
- Promising Combination
  - Electrical HP in CHP + Distributed absorption heat exchanger in secondary network
  - Why? Heat and power demands + heat production from the cooling water is affected by the power production (coupled though not CHP) + the use of heat storage in the power plants + peak shaving requirement (heat and power) + optimal operation of the plants…
- Detailed techno-economic analysis is needed.

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Thank you for your attention!

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