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Aligning Heat Demand with Sources Based on Heat Intensity: A Heat Roadmap for China

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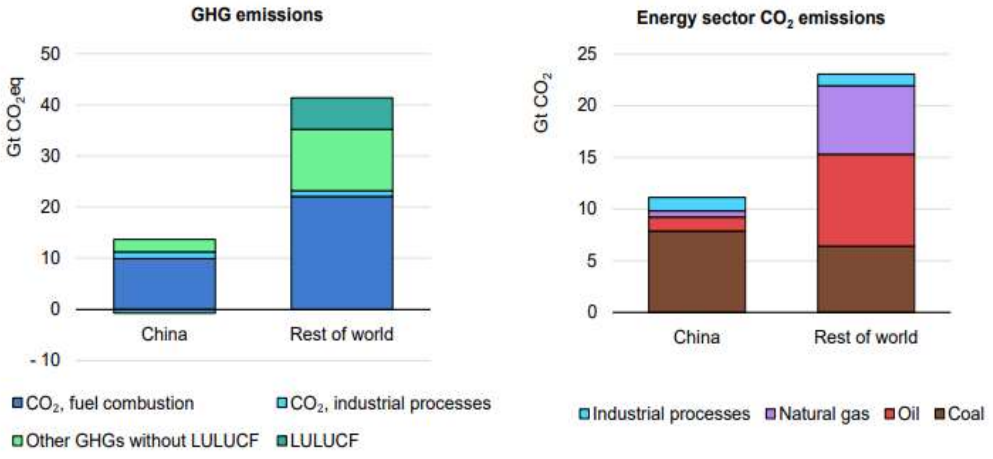
Background： The Absence of a Heat Roadmap China

- China has set targets for carbon reduction: CO2 emissions peak before 2030 and achieve carbon neutrality before 2060
  - Numerous roadmaps have been developed for China's energy system, power system, and various end-use sectors (buildings, transport, industry)
  - Heat, as an important cross-sectoral energy system, does not have a targeted roadmap for zero-carbon development
  - The heat-related elements encapsulated in zero-carbon development policies developed at the national, provincial and city levels are also ambiguous



Greenhouse gas emissions in China and the rest of the world in 2020 [1].

[1] IEA (2021), An energy sector roadmap to carbon neutrality in China, IEA, Paris

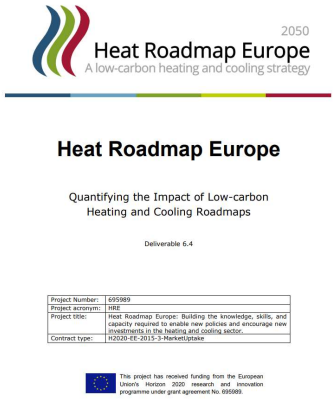
Background: Heat Roadmap Europe to learn from

Heat Roadmap Europe Pre-Study 1

Stratego/Heat Roadmap Europe 3

Heat Roadmap Europe Pre-study 2

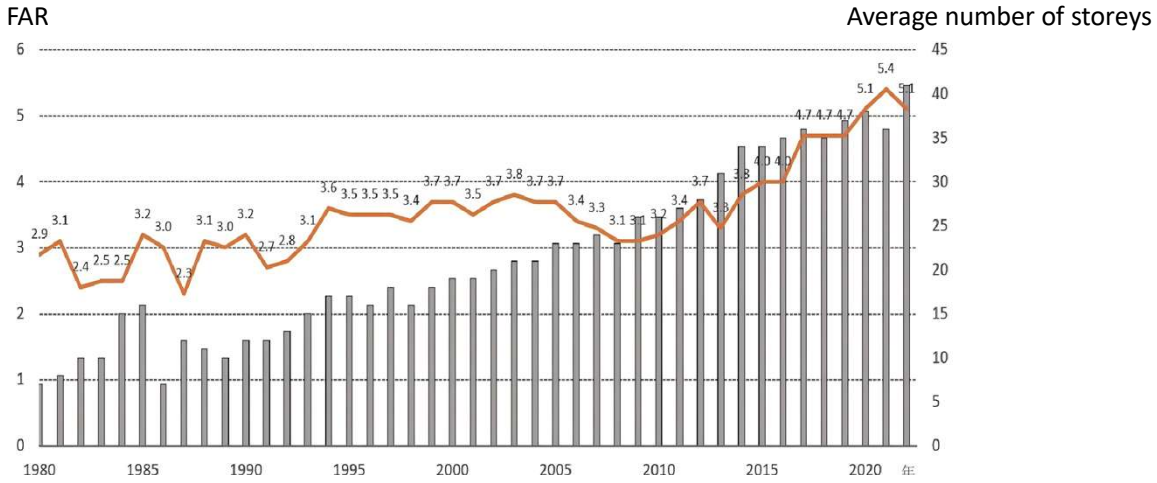
Heat roadmap Europe 4



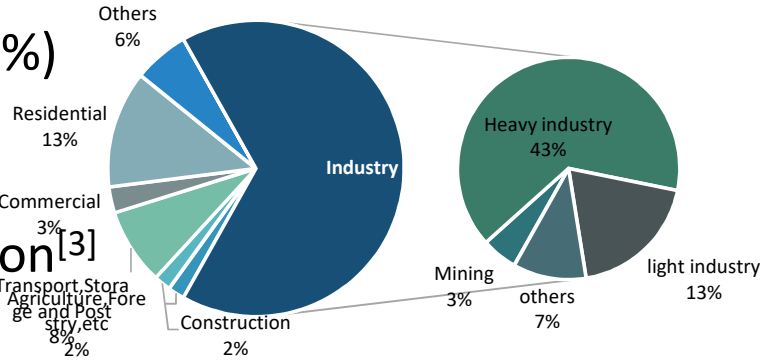
- Heat Roadmap Europe
  - Heat demand
  - Low carbon heat source
    - Waste heat map
  - Multi-objective optimization:
    - Energy consumption
    - pollutant emissions
    - economic efficiency

Differences between China and Europe

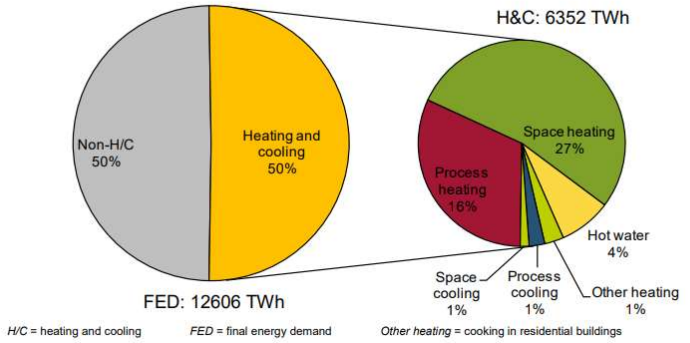
- China's energy consumption is dominated by industry(70%)
- For building sector : High floor area ratio of residential buildings in China, high district heating ratio(88%)
- For industry : Only light industry has real heat consumption[3]



Average FAR and number of storeys of newly-built blocks in Shenzhen[1]



Structure of energy consumption in China



Structure of energy consumption in Europe[2]

[1]崔光灿,张子蒂悦,等.高密度街区式住区布局形态生成机制及方法研究——以深圳为例[J].世界建筑导报,2024,39(03):27-30.DOI:10.14080/j.aw.2024.03.009.
[2] HRE: Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps
[3]Refers to the consumption of heat outside of the production process as a raw material or fuel.

Aim: A roadmap for decarbonizing heat in urban China

Heat Demand


Heating in Northern urban China


Heating in HSCW


Domestic hot water


Light industry

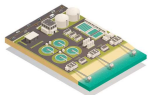
- Heat demand
  - Current status and future development trend
- Heat Intensity
  - Heat consumption per unit of land area

Waste Heat


Heavy industry


Nuclear power plants


Thermal Power Plants

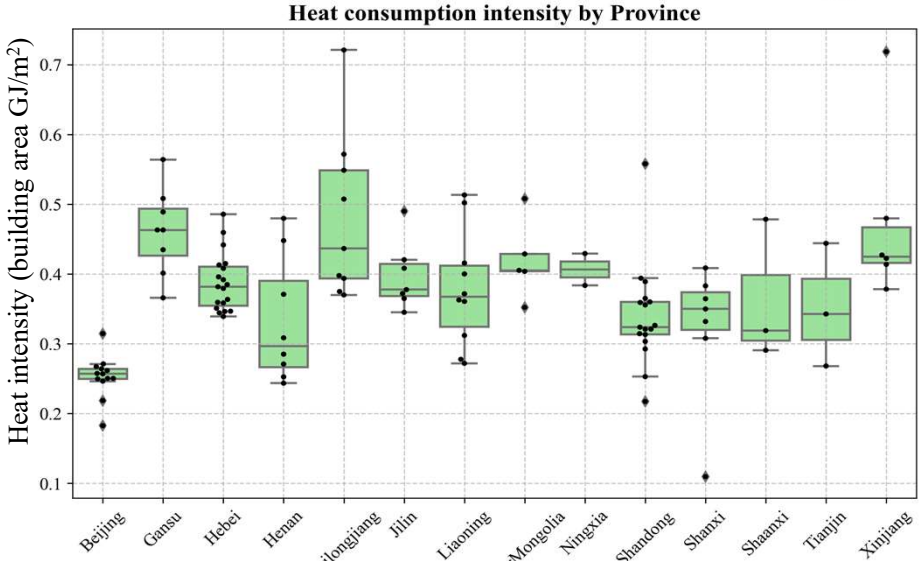

Water Treatment Plants

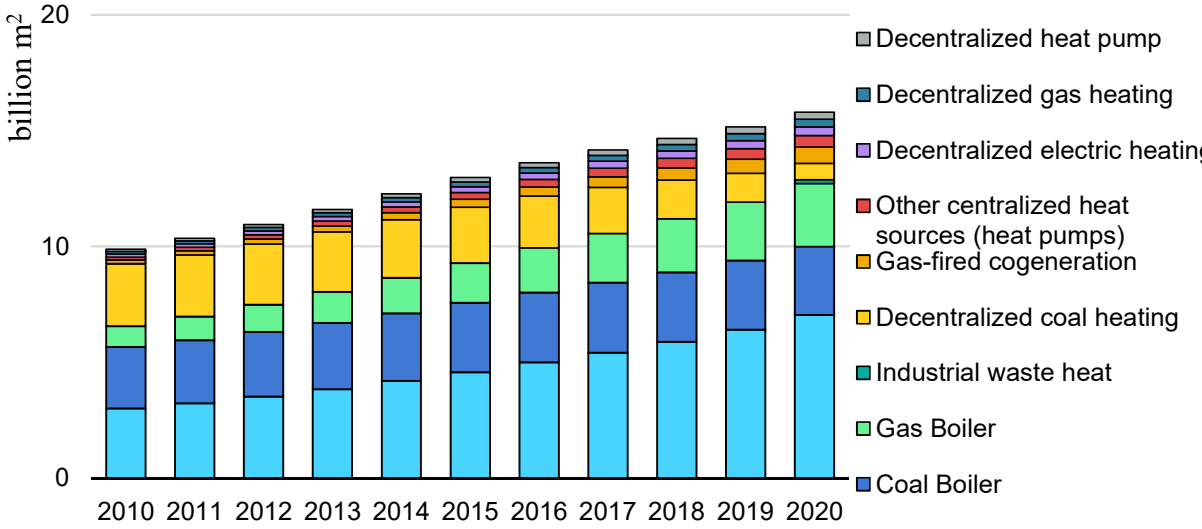

Data Center

- Waste heat potential
  - Current status and future trends of waste heat recovery potential
- Waste heat distribution
  - Waste heat mapping

Heat demand in buildings

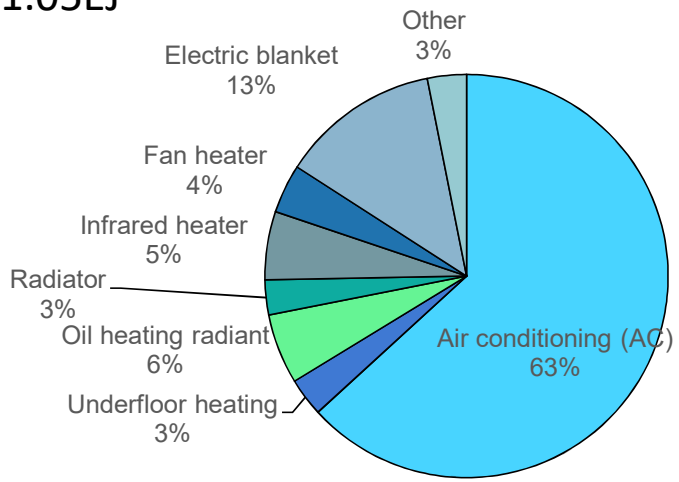
- Space heating in northern urban China
  - Statistics in 2021, covering 120 heat companies and 3.14 billion m^2
  - Heat intensity(building area): 0.364GJ/m^2 building area: 16.2 billion m^2 Heat demand: 5.86EJ
  - Room temperature : above 18/20℃
  - Future trends： increasing building, energy saving

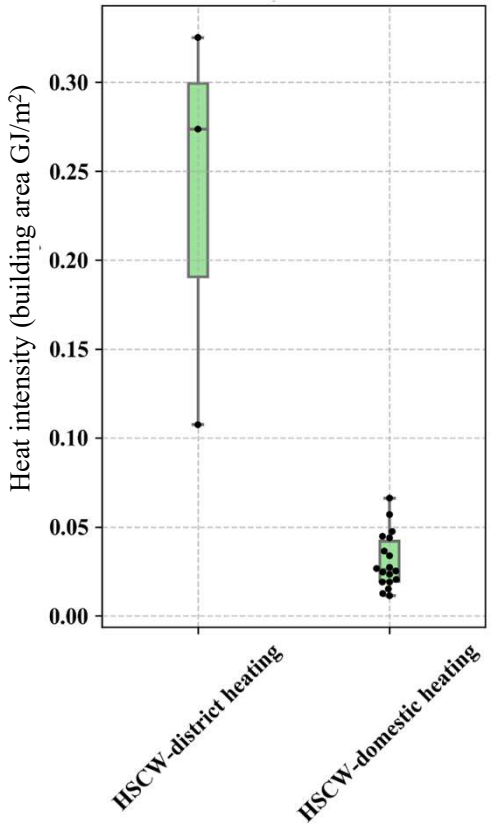




Heat demand in buildings

- Heating in hot summer cold winter area(HSCW)
  - At the end of 2021, the heating area of HSCW is about 33.9 billion $m^{2,}$
  - The district heating area is 80 to 100 million m^2, accounting for less than 1%; separated air conditioning accounts for 60%
  - Heat intensity(building area): District heating 0.235GJ/m^2; decentralized heating 0.031 GJ/m^2, total heat demand: 1.05EJ
  - Room temperatures: For decentralized heating, 11-18℃ ;
  - Future trends: part-time, part-space model; energy saving, improving indoor environments

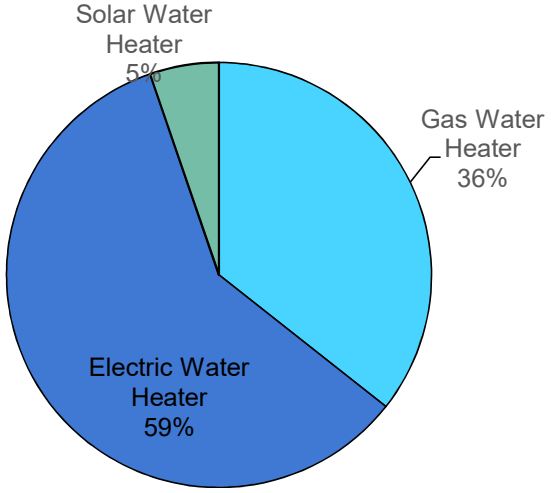


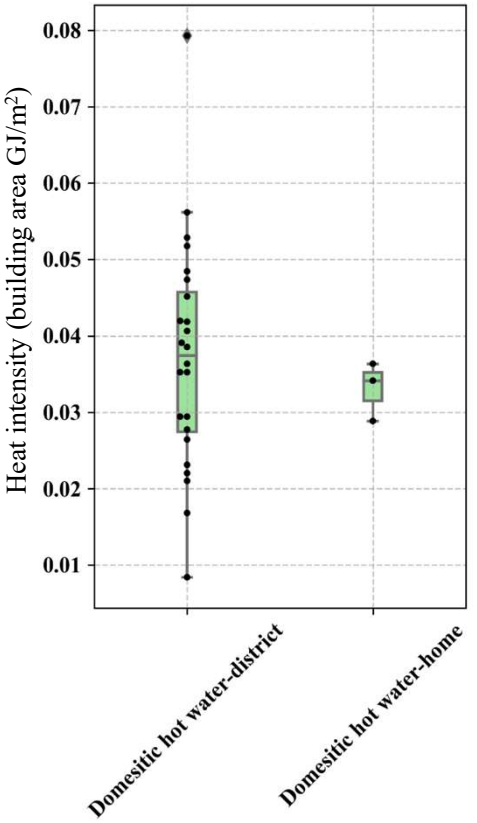


Heat demand in buildings

- Domestic hot water
  - At the end of 2021, China's total residential building area is 54.2 billion m^2,
  - Domestic hot water supply is mainly decentralized: 100.7 water heaters per 100 urban households nationwide in 2020.
  - Heat intensity(building area): District : 0.017-0.056GJ/m^2,34L/cap·d;

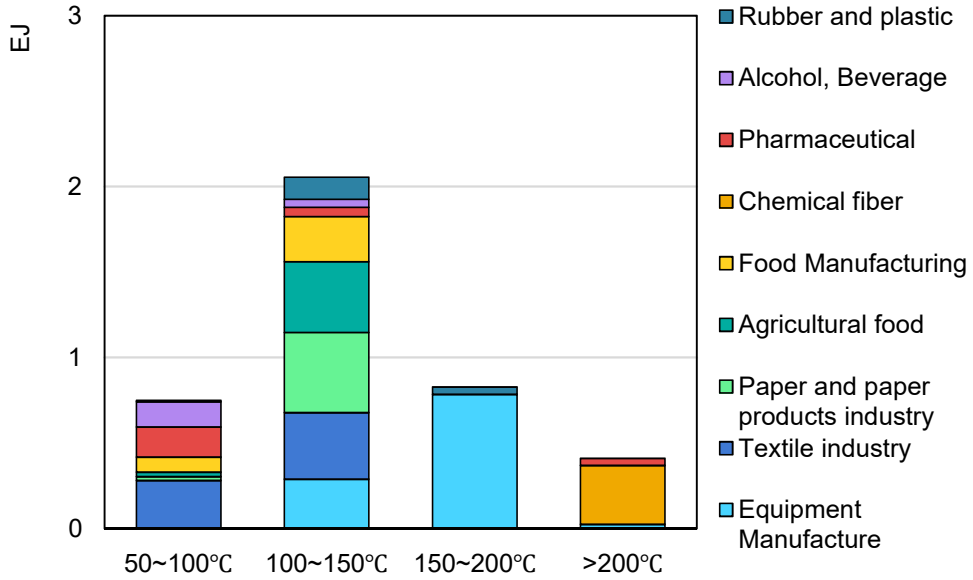
    Decentralized 0.029-0.036 GJ/m^2,32L/cap·d
  - total heat demand: 1.8EJ
  - Temperatures:
    - According to standards: ＞55 ℃
    - actual status quo： ＞ 45 ℃
  - Future trends: decentralized heating and Increasing urban population

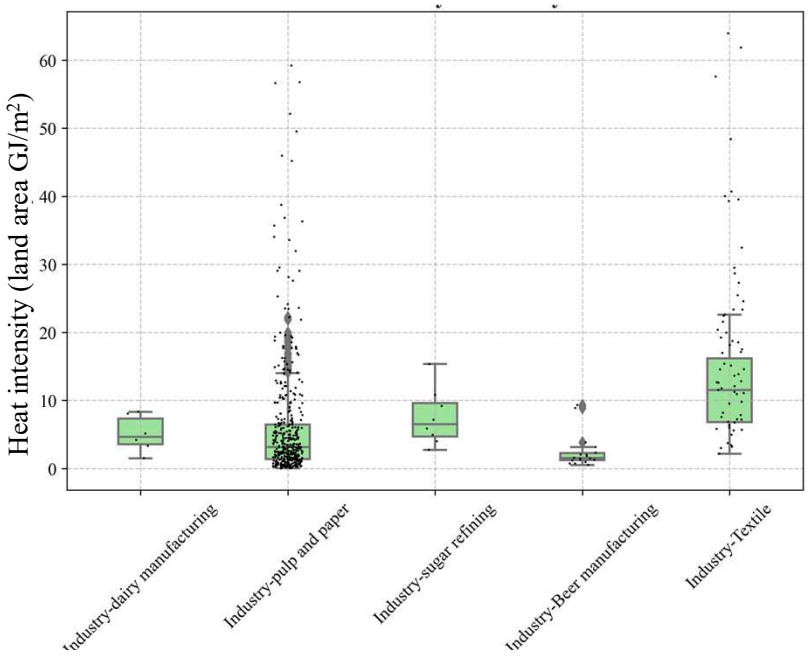




Heat demand in industry

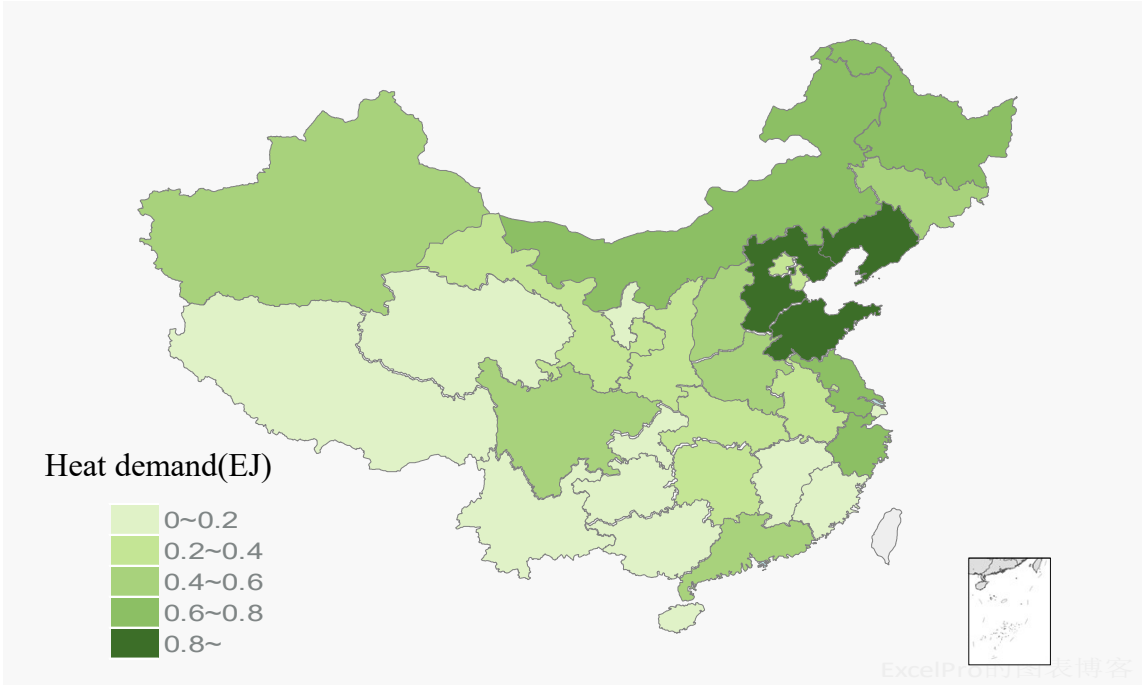
- In 2021, light industry consumed about 4.4 EJ , 70% of heat demand is under 150℃
- High heat intensity: generally higher than 1GJ/m^2(Land area) .

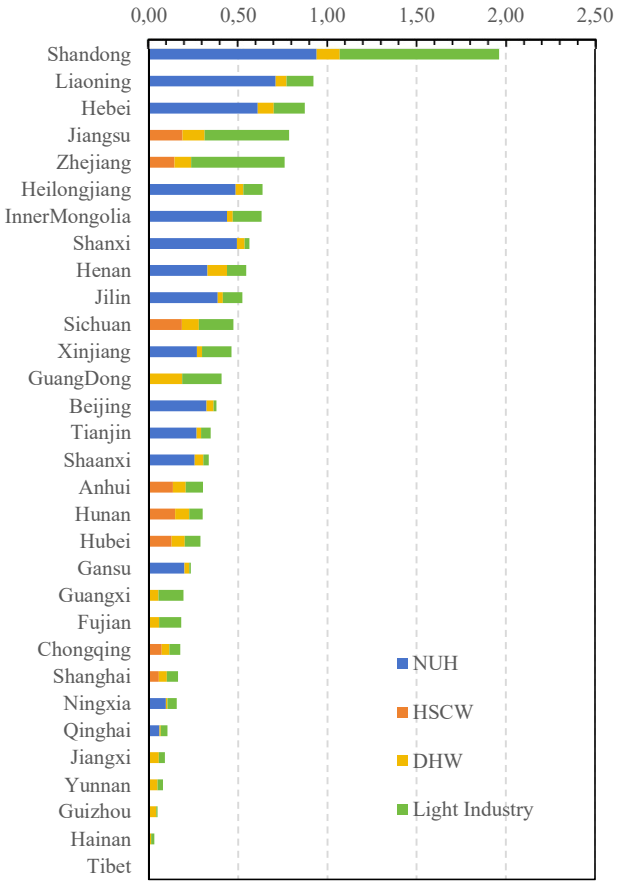




Heat demand distribution by province

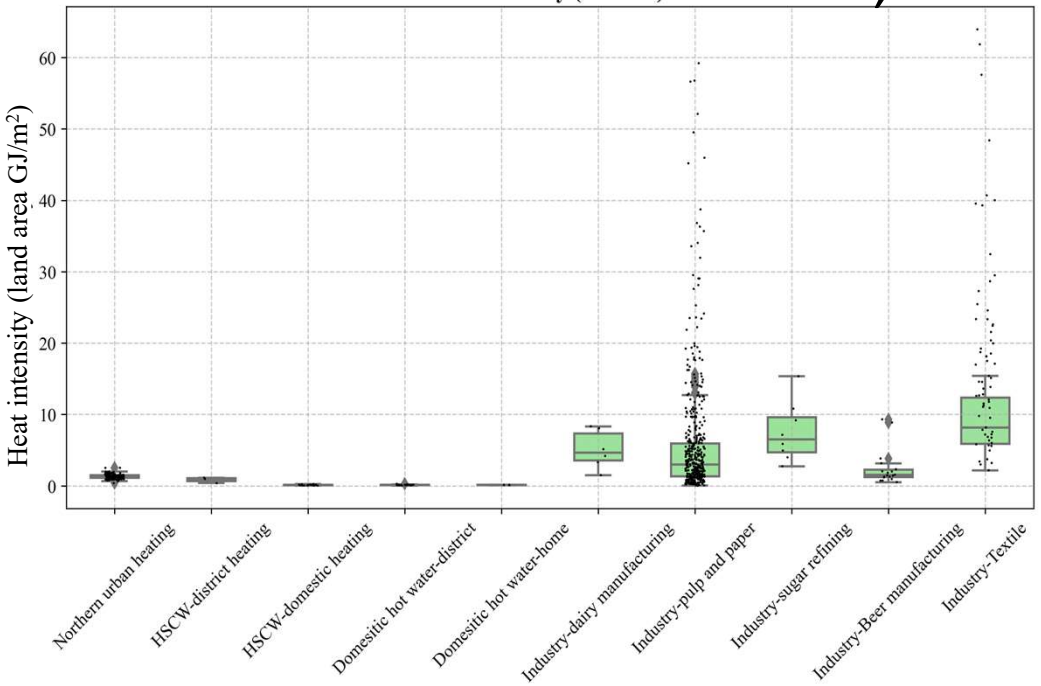
- Concentrated in the Bohai Sea region

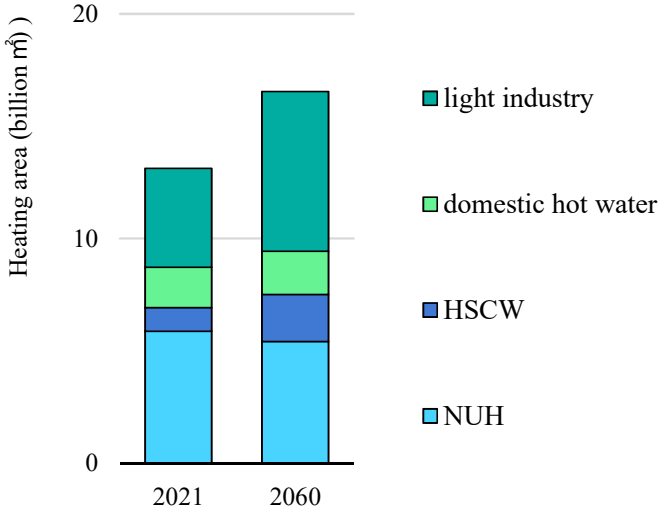




Summary: Heat demand intensity

- Heat intensity(land area): HSCW, domestic hot water <1 GJ/m^2, NUH, light industry >1 GJ/m^2
- Total heat demand : 13EJ in 2021, 16EJ in 2060





Suitable heat sources for different heat demands

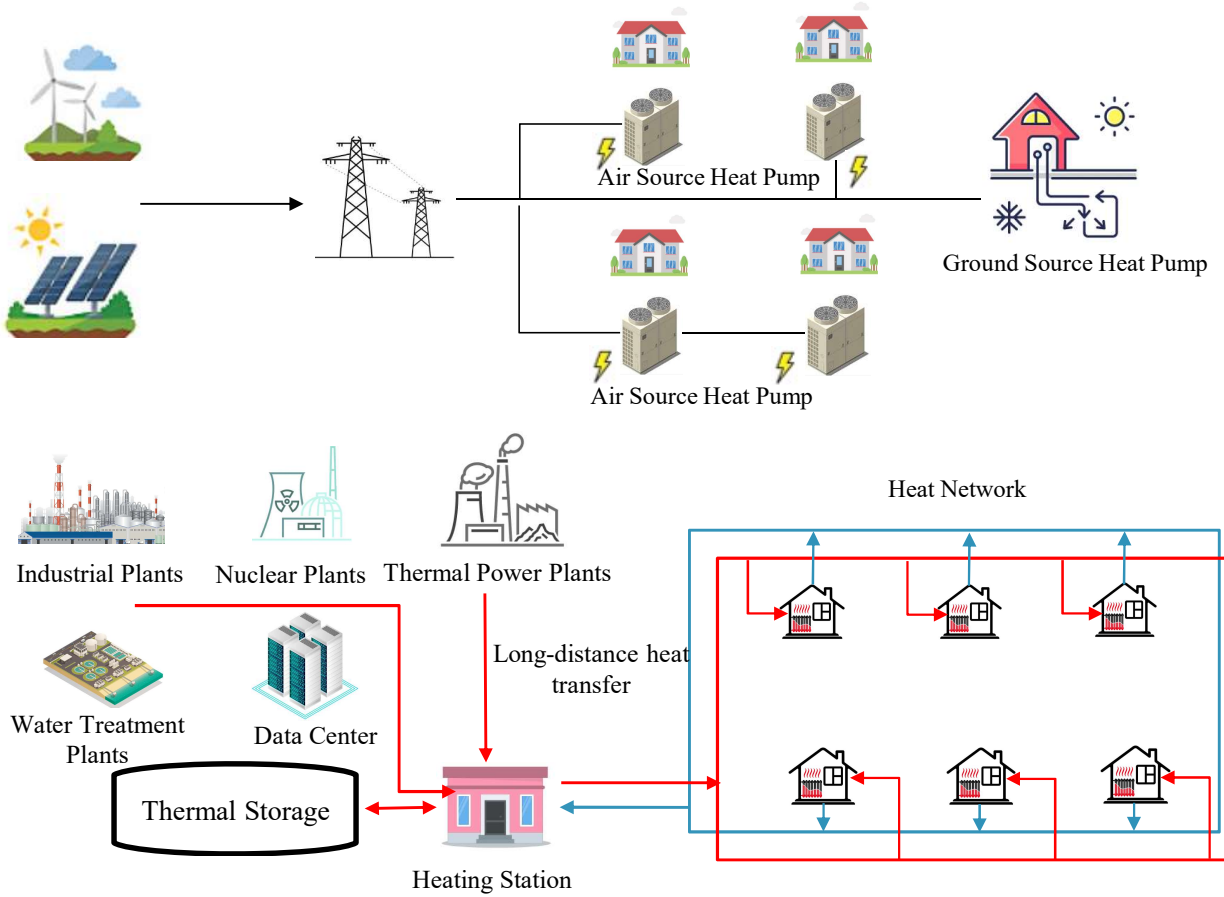
Electrification of heat supply

- Heat pump heating using natural heat source
- HSCW, domestic hot water

Low Carbon Heating Mode

Heating based on waste heat utilization

- Recovery of various types of artificial low-temperature waste heat
- NUH, light industry



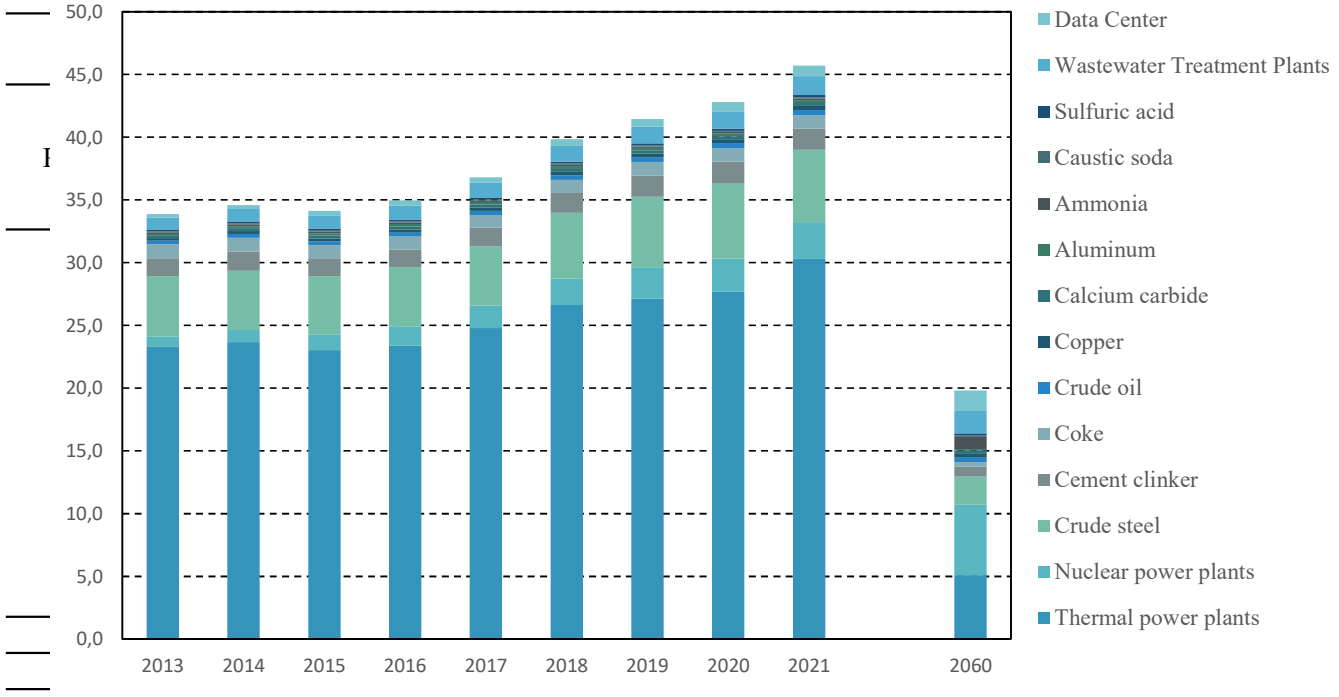
Abundant waste heat potential

- Method: based on product output and waste heat per unit of product

$$Q = P_{amount} * f_{waste,i}$$

P_{amount} : product output, $f_{waste,i}$: waste heat per unit of product for type I, according to the literature and the actual project

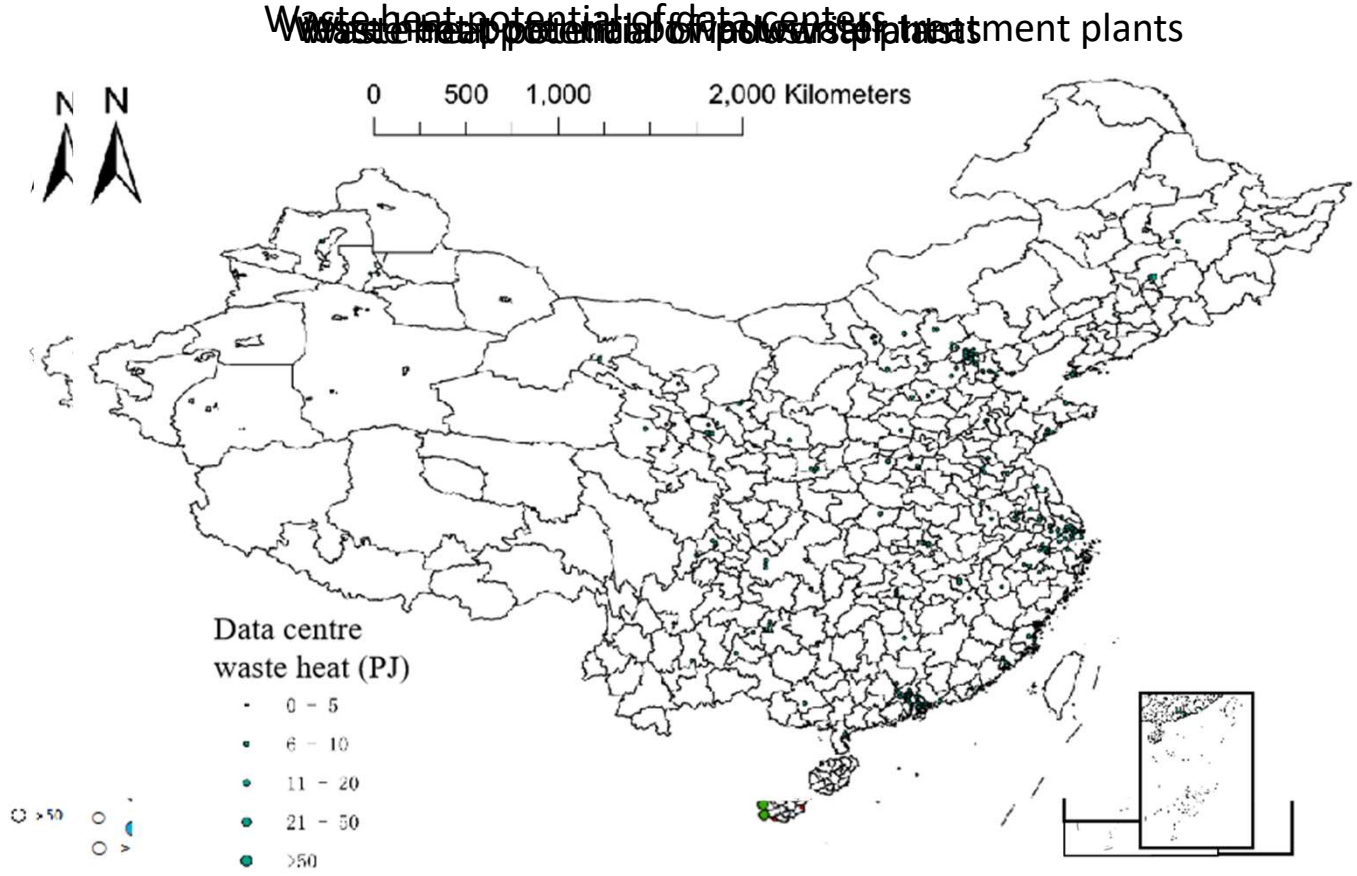
- Waste heat potential: 19EJ in 2060, covering 150% of the heat demand (34EJ)



47EJ in 2060, covering 150% of the heat demand (34EJ)

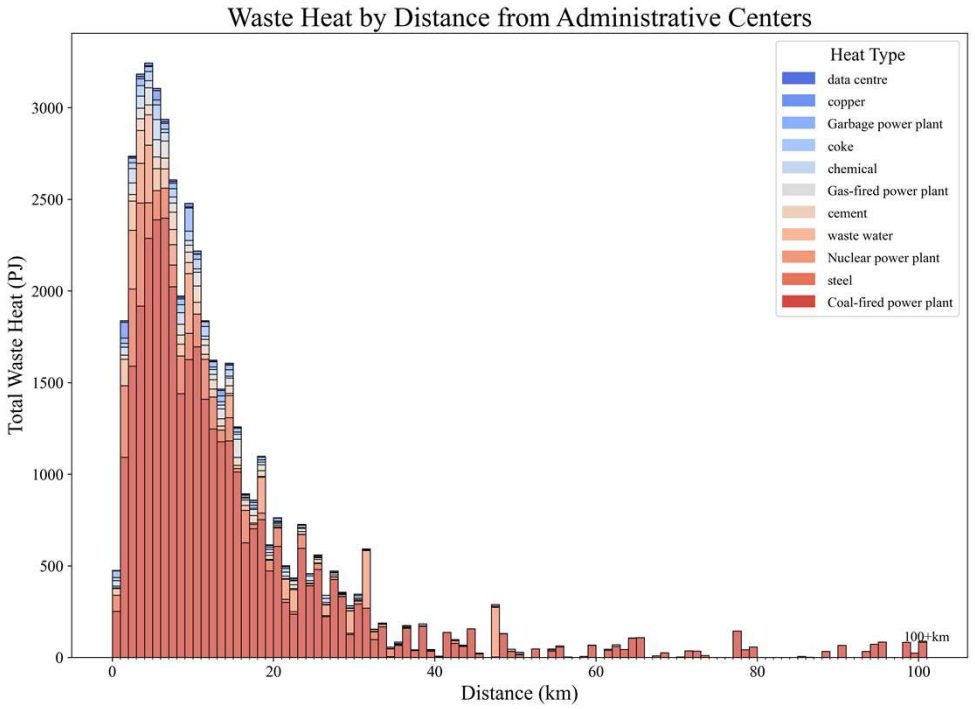
Heat map

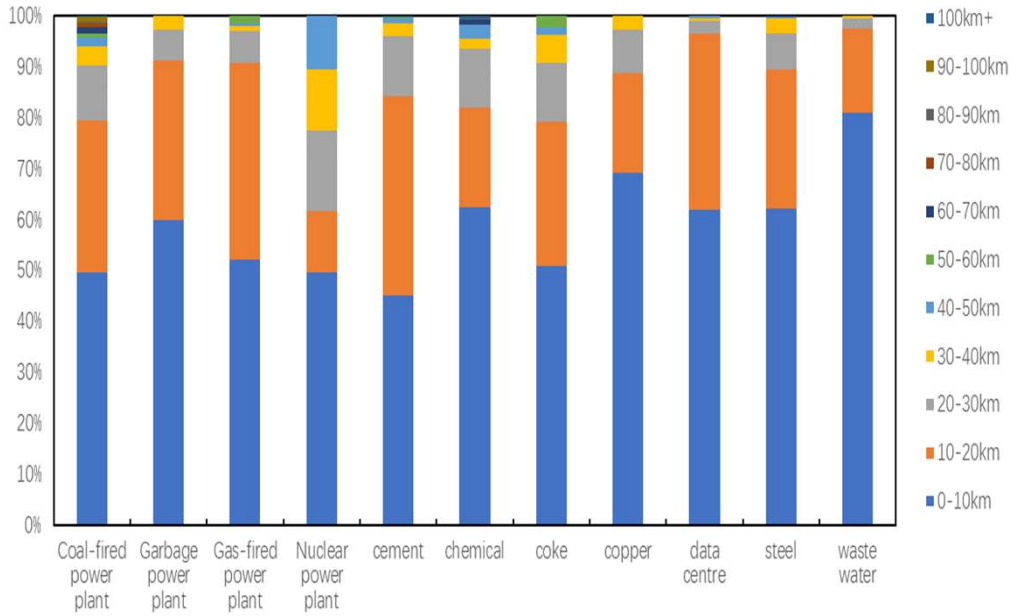
- Data source of the waste heat map :
  - Corporate GHG emissions management system
  - Open data of the production and process
  - Location : Baidu API
  - Over 10000 plants



Heat map

- Waste heat resources can be economically and efficiently transported to the nearest district or county towns.





Conclusion

- China’s heat demand is substantial and continues to grow.
- Heat intensity exhibits considerable variance across sectors, thereby constraining the viability of heat pump heat sources.
- Abundant waste heat resource, mostly within economically transportable range, have great potential as a heat source for high-intensity heat demand.

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