# **Decarbonize Coal-based Space Heating in China**

Jan, 2023



# **Outline**

- Space heating overview: mainstream solutions, coal consumption, and carbon emissions
- Removing coal in space heating: alternatives, potential and opportunities
- EFC activities and potential impact

# Varied climate zones and heating solutions in China



# Urban heating energy use and emissions in northern China

Urban heating covers **15.2 billion m**<sup>2</sup> buildings in north China, consumed **213 million tce** energy. Urban heating generated **550million tons CO**<sub>2</sub> in 2020



- Coal-fired heating accounted for a large rate
- Energy efficiency of coal-fired boilers was low: lower as 72% on average
- The average of energy efficiency of coal-fired CHPs was low, too. There are still many small CHP plants and the waste heat of large ones was not recovered.

Data Source: Low Carbon Heating Development Study for northern China, Tsinghua University; China Building Energy Conservation Annual Research Report, 2020, Tsinghua University

## **Rural heating overview**

**6.5 billion m<sup>2</sup>** rural buildings in northern China consumed **105 million tce** energy for space heating, and generated **167 million tons CO<sub>2</sub>** in 2020



- On-site coal consumption accounts for 42%, with very low efficiency and negative impact to health and air quality
- 80% of existing rural buildings are not energy efficient
- Most rural buildings don't link to the district heat network and burn scattered coal, bio-mass, etc. in small furnaces, ovens on-site for heating

Data Source: Low Carbon Heating Development Study for northern China, Tsinghua University; China Building Energy Conservation Annual Research Report, 2020, Tsinghua University

# **Removing heating coal: alternatives, potential and opportunities**

#### Urban district heating

Alternatives	Potential of coal reduction	Opportunities
<ul> <li>Replace heat source/fuel</li> <li>switch to gas, RE or nuclear</li> <li>use industry waste heat</li> <li>use coal power plant waste heat</li> </ul>	40%-100%	<ul> <li>Sufficient waste heat (industry, nuclear)</li> <li>Large amount of bio-mass</li> <li>Young power plant</li> </ul>
<ul> <li>Switch to distributed heating</li> <li>gas boiler</li> <li>electrical heater</li> <li>heat pumps</li> </ul>	30%-100%	<ul> <li>Rapid building EE progress</li> <li>Rapid technology advancement</li> <li>Growing alert on gas</li> </ul>
<ul> <li>Network and demand management</li> <li>Building EE</li> <li>household level DM</li> <li>smart control</li> </ul>	10%-30%	<ul> <li>Building energy retrofit</li> <li>Big data and technology advancement</li> </ul>

# The waste heat resources can cover heating demand in most provinces of north China, and this makes heating carbon neutrality achievable and affordable.



Jilin

Waste heat

















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# Waste heat meets district heating demand in intense urban areas and makes heating carbon neutrality achievable and affordable.



**Waste Heat >> Heating Demand**. 3 provinces, Shanxi, Inner Mongolia and Ningxia, have sufficient waste heat heating, even if more coal-fired power plants are phased out.

**Waste heat >= Heating demand**, 6 provinces, Shandong, Henan, Shanxi, Gansu, Qinghai, and Xinjiang, waste heat within the province meets its heat demand.

**Regional waste heat>= Heating Demand**, JJJ (Hebei-Tianjin-Beijing), Hebei, waste heat can provide to Beijing and Tianjin.

**Waste heat< heating Demand**, 3 provinces in severe cold zones, Heilongjiang, Jilin, and Liaoning, need more bio-mass thermal plants, and high efficiency to recover waste heat.

### **Removing heating coal: alternatives, potential and opportunities**

• Rural heating and regions with emerging heating demand

Alternatives	Potential of coal reduction	Opportunities
<ul> <li>Rural heating in northern China</li> <li>building EE</li> <li>heat pumps</li> <li>other electrified solutions</li> <li>solar thermal</li> </ul>	30%-100%	<ul> <li>Aboundant renewables</li> <li>Rapid technological advancement: PEDF, electricity/heat storage, various radiation products</li> <li>National Rural Revitalization</li> </ul>
<ul> <li>Regions with emerging heating demand</li> <li>heat pumps, including reversible AC</li> <li>electrical heaters</li> <li>waste heat for urban district</li> </ul>	/	<ul> <li>Rapid technology advancement</li> <li>Rich waste heat sources</li> </ul>

1	2	3	4
Replace coal/gas burners and low efficiency CHPs by waste heat based urban district heating	Replace scattered coal for burners and low efficiency rural household heating by PEDF new building energy	Reduce heating load through more stringent building energy efficiency code	Promote heat pumps

system

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# Scale up waste heat based urban district heating

• Large scale application of three key technologies in CHP



# Scale up waste heat based urban district heating

#### **Taiguli Pilot in Shanxi Province**



Long-distance heat transmission, large water temperature difference



 Significant energy reduction with less cost than coal burner





# Scale up waste heat based urban district heating

- The technology of the Taiguli program are applying to 53 power plant and 52 heating networks in northern China
- Covering cities in 14 provinces (Taiyuan, Shijiazhuang, Jinan, Huhhot, Xian, Zhengzhou, Yinchuan, etc.)
- Meeting 728million m<sup>2</sup> building space heating demand
- Reducing 6.41 million tons of coal consumption, 17.8 million tons of  $CO_2$ , 6089 tons of air pollutants, annually
- It has a scale-up potential of covering 10 billion m<sup>2</sup> space heating demand in northern China, which could
- Reduce 90 million tce of coal use, 250 million tons of CO2 emission, and 84k tons of air pollutants
- Trigger 1 trillion RMB investment
- EFC has been working on creating additional pilots, building consensus and policy environment for the scaling up





# Replace scattered coal for rural household heating by PEDF new building energy system

- Average **20kW** roof-top PV installation capacity, for each rural household.
- Potentially, China rural area can install roof-top PV up to 2 TW, generating electricity 2500TWh, which is 3-4 times of electricity demand when villages are all-electrified, removing all scatted coal burned in villages
- EFC has a flagship project to support PEDF development

### PEDF New Building Energy System Piloted in Villages of Ruicheng, Shanxi Province













# **Reduce heating load through more stringent building energy** <u>efficiency code</u>

- Building energy efficiency has significant impact on heating load and heating options<sup>1</sup>
- There is a big potential for existing buildings to reduce its heating load through energy efficiency retrofit given 52.5% of the buildings are far below the EE code requirements
- However, in the past 15 years, only 3% of existing building stocks were retrofitted<sup>2</sup>, which is only 1.77billion sqm
- The amount of ultra low, near-zero, zero buildings are small, 12million vs. 10billion sqm built in the past five years
- EFC has been funding the drafting and revision of almost all national BEE codes and local BEE codes in key climate zones



#### The Path of China Building Energy Efficiency Codes

1. The Carbon Peaking Implementation Plan for Urban Rural Construction Area requires to "guide ultra-low energy buildings to give up district heating systems in cold winter climate zone" 2. China Building Energy Conservation Annual Research Report, 2019, Tsinghua University



### **Promote heat pumps**



#### Carbon Intensity (kg CO2/GJ)

Carbon Intensity of Different Heating Technologies

### Heating up the global heat pump market

Heat pumps are widely recognized as a key clean energy technology in the energy transition. While the global heat pump market has expanded significantly, more than doubling in some countries in a single year, expanded policy support will be needed to build confidence in the technology and meet climate goals.

#### Jan Rosenow, Duncan Gibb, Thomas Nowak and Richard Lowes

eat pumps are a low-carbon heating technology with the potential to deliver large-scale reductions in carbon emissions from building heat. They use electricity to move heat from ambient outside air, water or ground to a building's interior and to heat water. This process is highly efficient, with heat pumps delivering three to five units of heat for each unit of electricity needed to run them1. In addition to being highly efficient, heat pumps also use predominantly renewable thermal heat rather than relying on combusting fossil fuels. As much of the useful heat from a heat pump comes from inexhaustible environmental sources, 70-80% of energy provided by an average heat pump is renewable. Even with today's electricity mix, which tends to include fossil fuels such as coal, heat pumps can reduce emissions in most of the world's regions, which together made up 96% of global heating energy demand in 2015 (ref. 2) When the electricity used to drive the electric compressor is produced from low-carbon



**Fig. 1** | **Global historic heat pump sales and IEA net zero 2050 pathway.** Global stock of heat pumps through to 2020 (blue line) and growth to 2030 under a continuation of past trends (orange line), versus the number of units installed under the IEA's net-zero pathway (grey line). Credit: Blue line from<sup>16</sup>, orange line projection based on market growth rates in<sup>16</sup> and grey line from<sup>5</sup>.

Source: nature energy, 7, p901–904 (2022), https://www.nature.com/articles/s41560-022-01104-8

# Promote heat pumps

- Heat pumps could help reduce 20-40Mt/a CO2 on space heating only in 2060 compared to BAU in China
- Current penetration is low (5%-10%), the potential could reach 30%-70%
- Highly effective in reducing rural scatterred coal
- EFC is funding research on developing roadmaps, policies and capacity to scale up heat pumps in China



Source: China Academy of Building Research, EFC funded research





- Space heating is a significant coal consumption sector in China, the third biggest consumer after power and industry sectors
- Current mainstream space heating solutions are carbon/coal intensive
- Many low/zero carbon alternatives are emerging but need great efforts to scale up
- Philanthropic world can play catalytical roles in removing coal in China's space heating sector



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# **THANK YOU**