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Heat Pumps and China's Whole County PV Program
中国整县光伏计划带给热泵应用发展的新机遇

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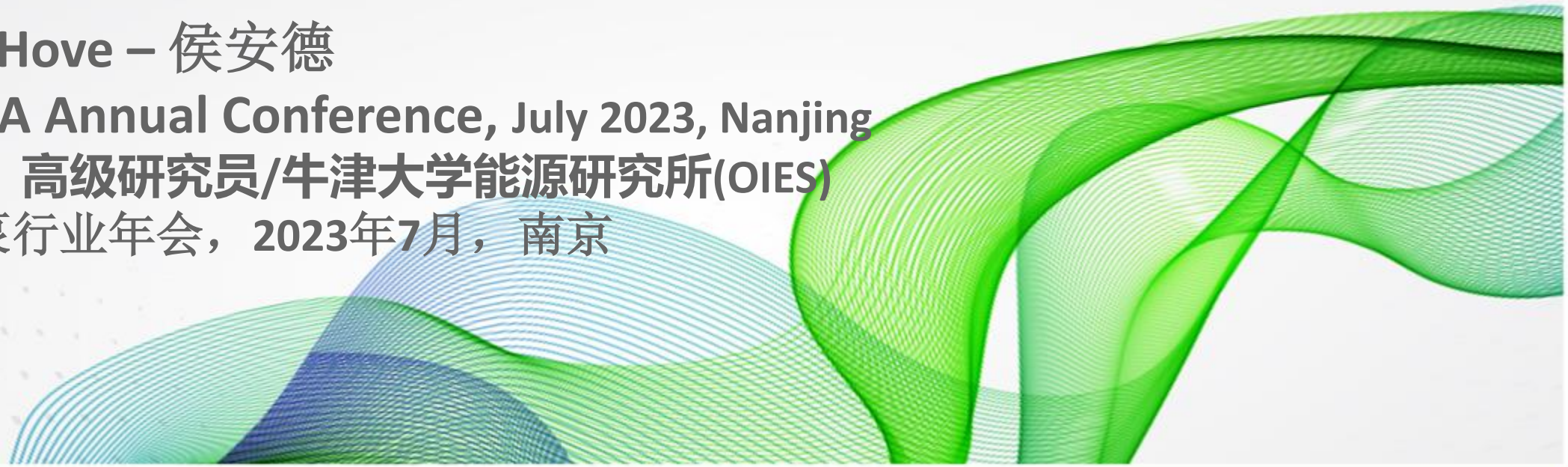
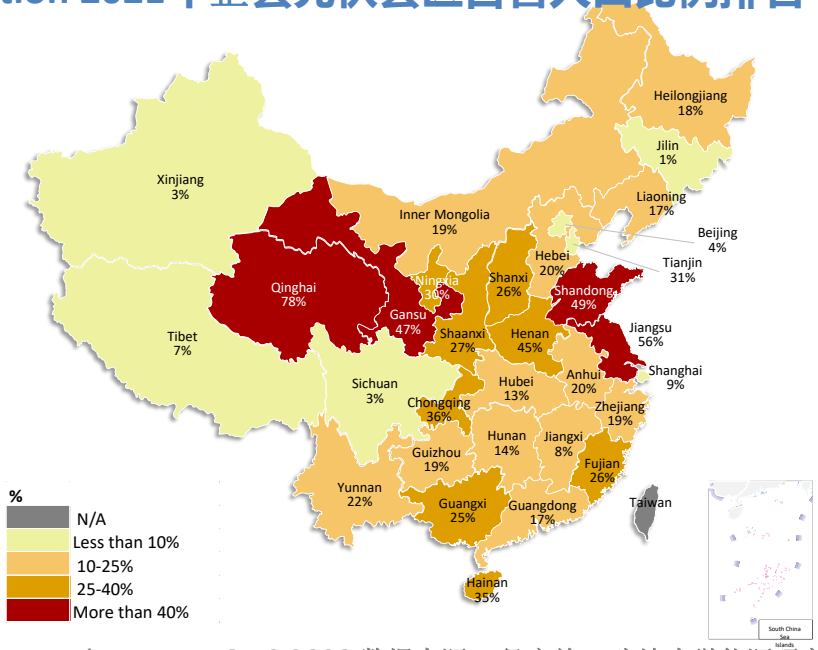


Introduction（简介）

- My background我的背景
- Purpose of this study研究目的
- Main findings主要发现
  - 1. Pairing heat pumps with distributed PV makes sense in much of the Huabei and Huadong regions of China, especially compared to gas or electric heating
  - 在中国华北和华东地区，将热泵与分布式光伏系统相结合是合理的，尤其是与燃气或电采暖相比
  - 2. Heat pump adoption helps increase self-consumption of residential PV output
  - 采用热泵有助于增加住宅光伏发电的自消耗
  - 3. Energy storage helps further increase self-consumption of PV but likely not economical
  - 能源储存有助于进一步提高光伏自消耗，但可能不具备经济性

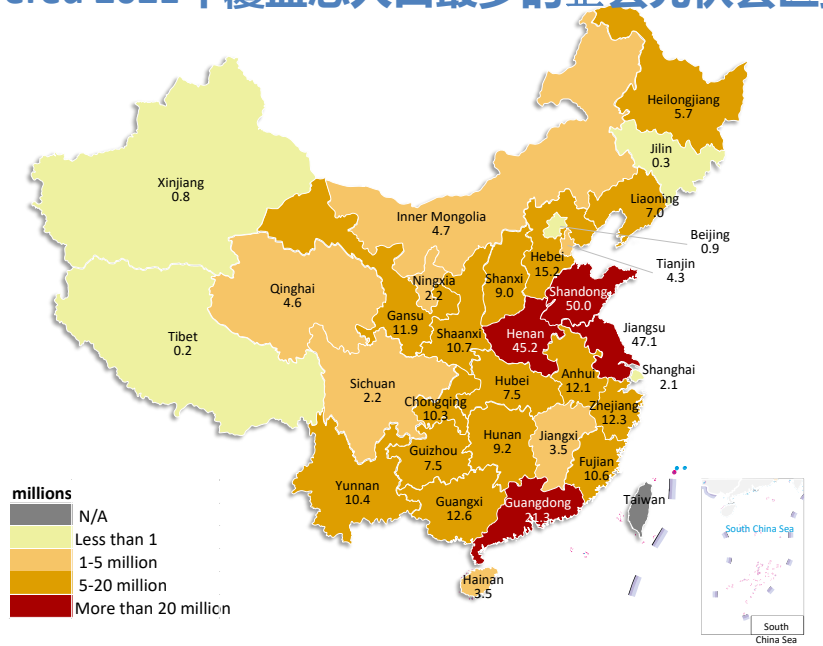
Whole County PV program initiated in 2021中国整县光伏计划

2021 Whole County PV counties as share of provincial population 2021年整县光伏县区占省人口比例排名



Source: Anders Hove, OIES 2023 数据来源： 侯安德， 牛津大学能源研究所(OIES)， 2023

2021 Whole County PV counties by total population covered 2021年覆盖总人口最多的整县光伏县区排名

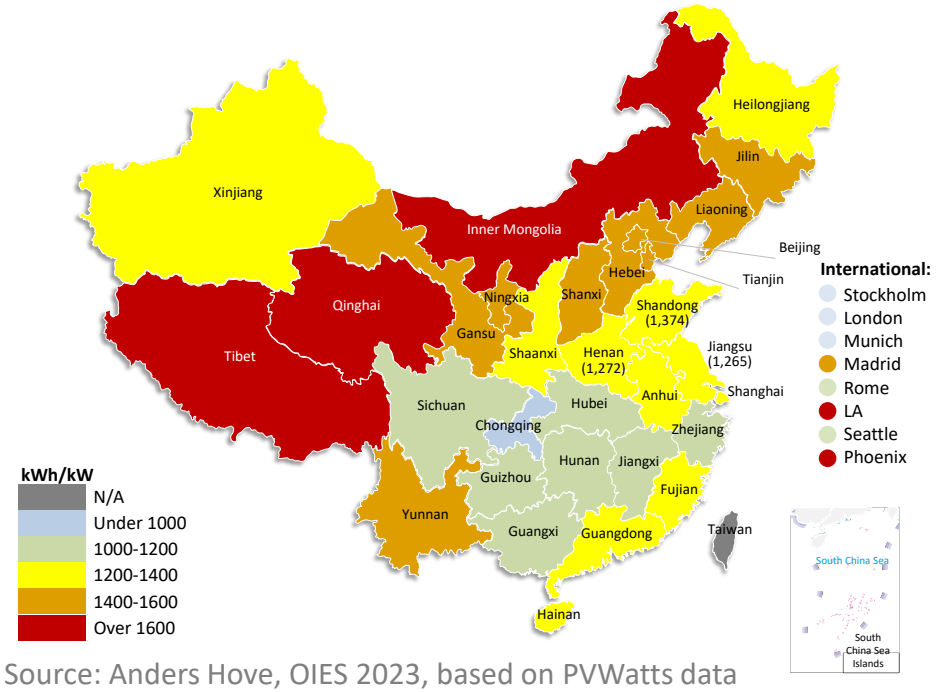


Source: Anders Hove, OIES 2023 数据来源： 侯安德， 牛津大学能源研究所(OIES)， 2023

- Whole County PV program launched in June 2021　　2021年6月启动的整县光伏计划
- By September 2021, over half of China's counties had joined, for a total of 676 counties
- 截至2021年9月，超过半数的中国县区已加入该计划，共有676个县区
- Although some are highly urban, most are mixed rural/urban in character
- 尽管其中一些是高度城市化的，但大多数县区具有农村和城市的混合特征
- Provinces with the most participating counties are in China's coastal region, especially Henan, Jiangsu, and Shandong
- 参与县区最多的省份位于中国的沿海地区，特别是河南、江苏和山东省

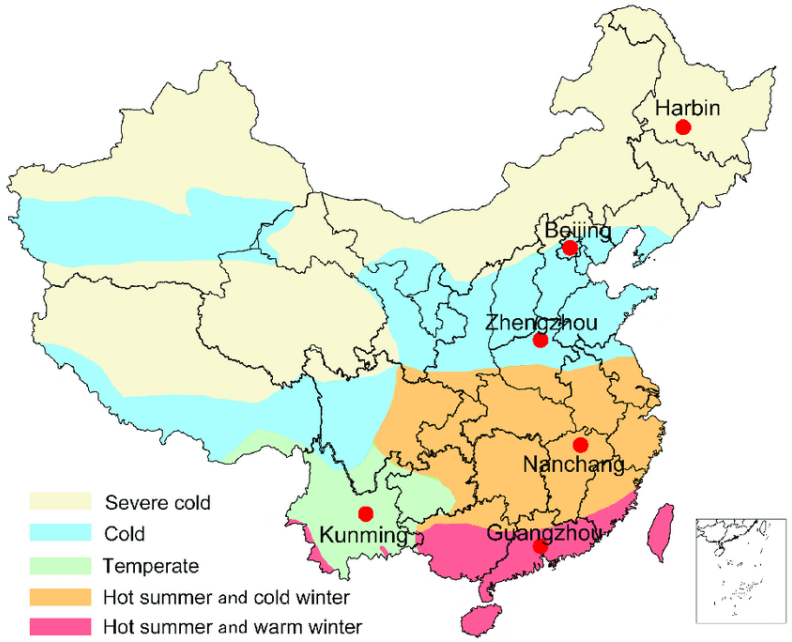
Is China's coastal region suited to PV?中国沿海地区适合光伏发电吗?

2021 Whole County PV counties in East-Central China have decent solar resources 2021年中国东部和中部地区的整县光伏县拥有良好的太阳能资源



Source: Anders Hove, OIES 2023, based on PVWatts data

Henan, Shandong, and Jiangsu straddle the *Cold* and *Hot Summer-Cold Winter* climate zones 河南、山东和江苏位于寒冷夏季-寒冷冬季气候带，这三个省份跨越了寒冷夏季和寒冷冬季的气候带。

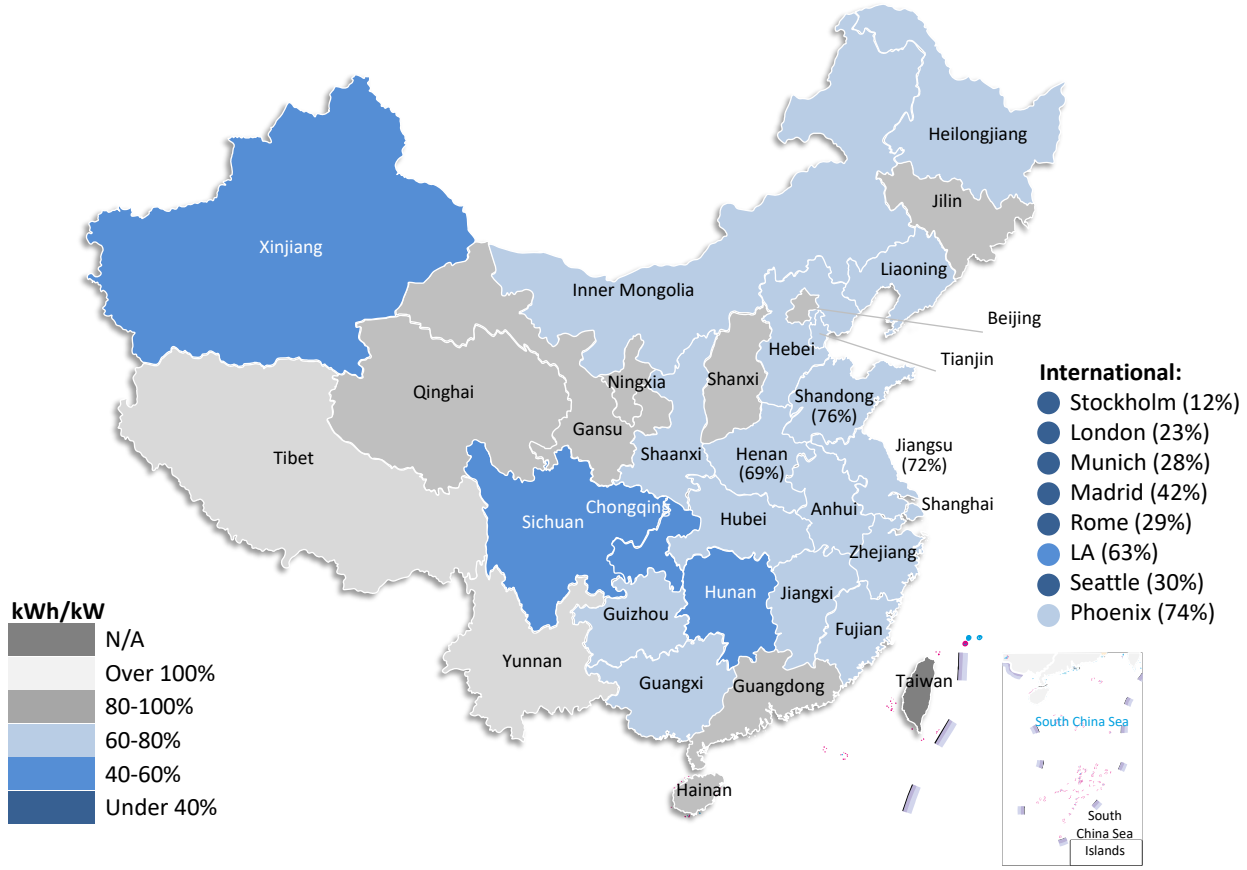


Fan Xinying et al., Energies, 2020 (CC)

- The top Whole County PV program provinces have solar resources around 1,300 hours per year, better than most of southern Europe
- 整县光伏计划的顶级省份每年的太阳能资源约为1,300小时，优于大多数欧洲南部地区。
- This region of China generally requires both heating and cooling, though heating energy demand far outpaces cooling demand
- 这个中国地区通常需要同时供暖和制冷，尽管供暖需求远远超过制冷需求。

Can PV support winter heating?光伏能源是否能支持冬季供暖?

Winter solar output in most China regions is relatively balanced with summer output在大多数中国地区，冬季太阳能输出与夏季输出相对平衡



- China's solar PV resources are far less seasonal than in most world regions, due to China's generally dry winter climate
- 由于中国冬季气候普遍干燥，中国的太阳能光伏资源的季节性要远低于大多数其他地区。
- Most of East-Central China has winter solar output up to 65-75% of summer output
- 东部中部地区的冬季太阳能输出可达到夏季输出的65-75%。
- That makes pairing PV with electric heating more viable than in other world regions
- 这使得将光伏与电加热相结合在中国比其他地区更具可行性。

Source: Anders Hove, OIES 2023, based on PVWatts data
数据来源： 侯安德， 牛津大学能源研究所(OIES)， 基于PVWatts数据

Can we quantify benefits of heat pumps for PV households?
我们可以量化热泵对光伏家庭的好处吗?

- Purpose of the analysis is to evaluate whether to pair heat pumps with the existing household PV program, therefore the analysis considers only households with PV already installed—meaning, the PV is free
- 本分析的目的是评估是否将热泵与现有的家庭光伏计划相结合，因此分析仅考虑已安装光伏的家庭，这意味着光伏是免费的

- The analysis evaluates 4 options for transitioning to clean heating, possibly paired with building energy retrofit:
- 分析评估了4种清洁供暖的选择，可能与建筑能源改造相结合：

  - gas, coal, or electric resistance heating with cooling from A/C in summer;
  - 燃气、煤炭或电阻加热并在夏季使用空调制冷；

  - or an air-source heat pump used for both heating and cooling
  - 或者使用空气源热泵进行供暖和制冷

Can we quantify benefits of heat pumps for PV households?
我们可以量化热泵对光伏家庭的好处吗?

Other assumptions:其他假设：

- 100 square meter home insulated to China national standard (even many new rural homes are not), outside the extreme cold areas of China
- 100平方米的住宅符合中国国家标准的绝热性能（尽管许多新农村住宅并未达到该标准），位于中国极寒地区之外

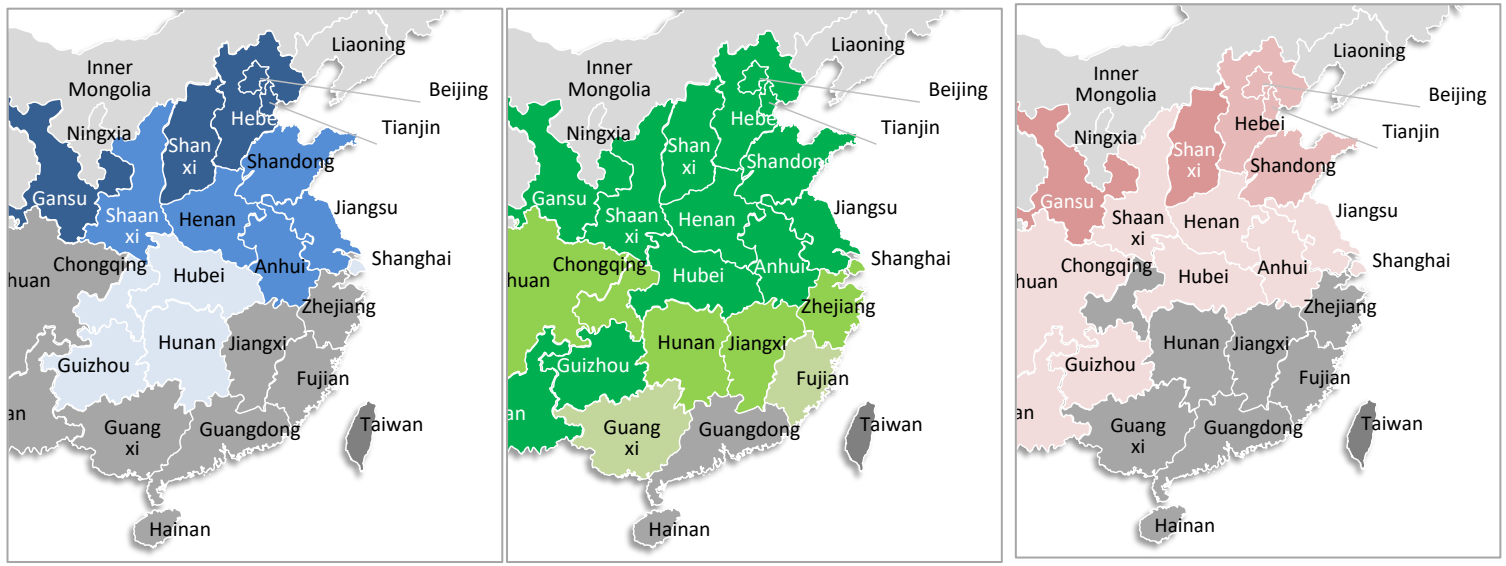
- Full-occupancy, activating heating and cooling whenever above or below set points (16 degrees for heating, 25 degrees for cooling)
- 充分入住，根据设定点（供暖为16摄氏度，制冷为25摄氏度）在达到或低于设定点时启动供暖和制冷。

- Time-of-use prices with 5 price intervals including a super-peak in early evening—all locations use same electric, gas, and coal price assumptions, no price inflation
- 分时电价，包括5个价格区间，包括傍晚早期的超峰电价。所有地点使用相同的电、燃气和煤炭价格假设，没有价格通胀。

- Surplus PV sent to the grid earns coal on-grid tariff or 50% of coal on-grid tariff at midday, reflecting future efforts to deal with duck curve
- 多余的光伏电力注入电网可以按煤电上网电价计算或中午时段的煤电上网电价的50%，反映了未来应对鸭子曲线的努力。

Can PV support winter heating?光伏能源是否能支持冬季供暖?

Winter solar output in most China regions is relatively balanced with summer output
大部分中国地区的冬季太阳能输出与夏季输出相对平衡。



RH Gas Coal

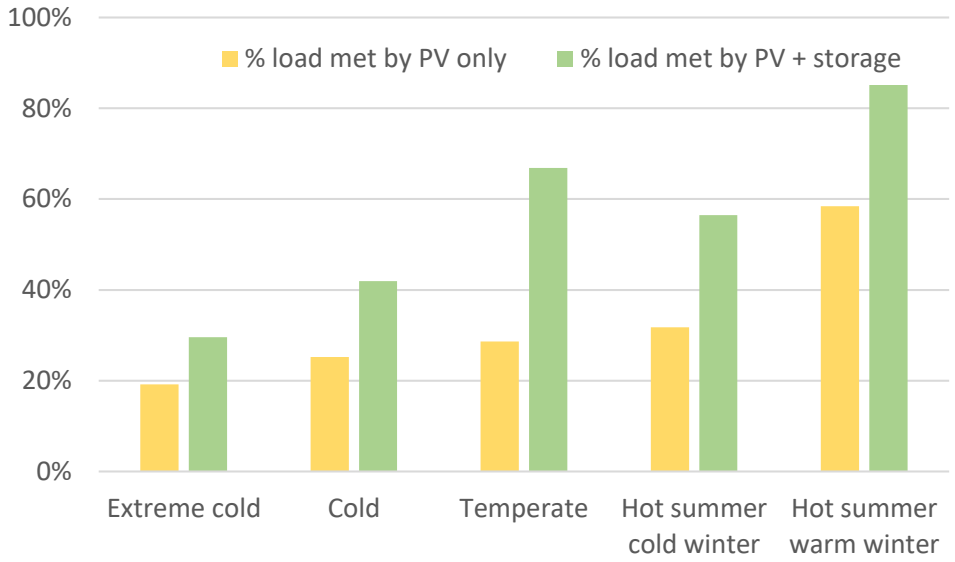
- n/a winter temp
- Uneconomical
- Payback 4-6 years
- Payback 3-4 years
- Payback under 3 years

Source: Anders Hove, OIES 2023

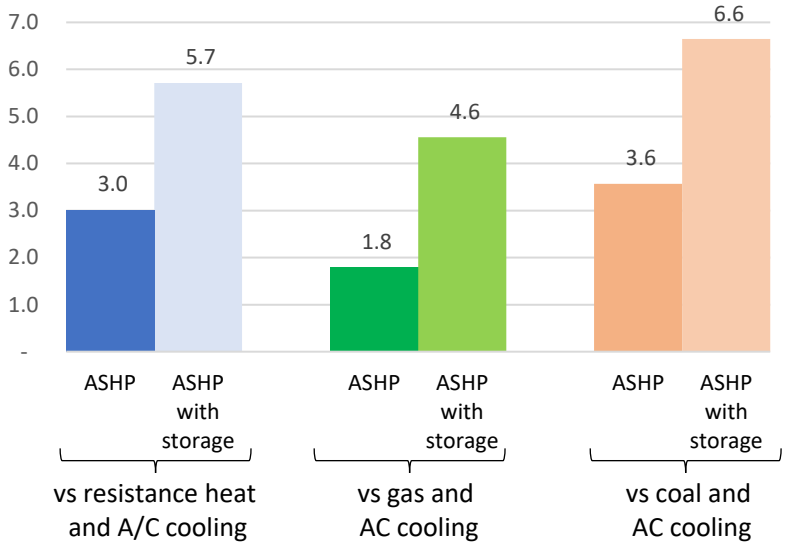
- The analysis considered payback periods of heat pumps versus installing new resistance heating, new gas heating, or new clean coal heating
- 分析考虑了热泵与安装新的电阻式供暖、新的燃气供暖或新的清洁煤炭供暖之间的回收期
- Payback periods were attractive for the key provinces of Shandong, Henan, and Jiangsu for all three cases
- 对于山东、河南和江苏这三个关键省份来说，回收期在所有三种情况下都具有吸引力
- The best payback periods were observed versus gas heating, followed by resistance heating, and coal heating last
- 与燃气供暖相比，回收期最好，其次是电阻式供暖，最后是煤炭供暖
- The warmest provinces with the least heating load offered the lowest economic benefit for efficient heat pump adoption
- 最温暖、供暖负荷最低的省份对于高效采用热泵的经济效益最低

Is China's coastal region suited to PV?中国的沿海地区适合光伏发电吗?

Proportion of annual heat pump household load met by PV versus PV plus storage, by climate region
按照气候区域划分的光伏发电与光伏加储能对热泵家庭负荷的年度满足比例



Payback period of air-source heat pump with and without storage, versus alternatives 空气源热泵带有储能和不带储能的投资回收期，与其他替代方案相比



Source: Anders Hove, OIES 2023

- Self-consumption of PV output is strongly encouraged by Chinese policy, due to local distribution grid constraints
- 由于当地配电网的限制，中国政策大力鼓励光伏输出的自主消费
- Heat pump adoption can boost self-consumption in winter months in Cold regions to around 25%; 40-50% with 2 hours of storage
- 热泵在冬季寒冷地区可以将自耗提升至约25%；若配备2小时储能则可达到40-50%。
- However, adding storage doubles the capital cost, substantially increasing payback periods
- 然而，添加储能会使成本翻倍，大幅增加回收期

Payback attractive, but policy barriers remain
回收期有吸引力，但政策障碍仍然存在

- Payback period for pairing heat pumps with existing PV is attractive versus gas and resistance heat
- 与天然气和电阻热相比，将热泵与现有光伏配对的回报期具有吸引力

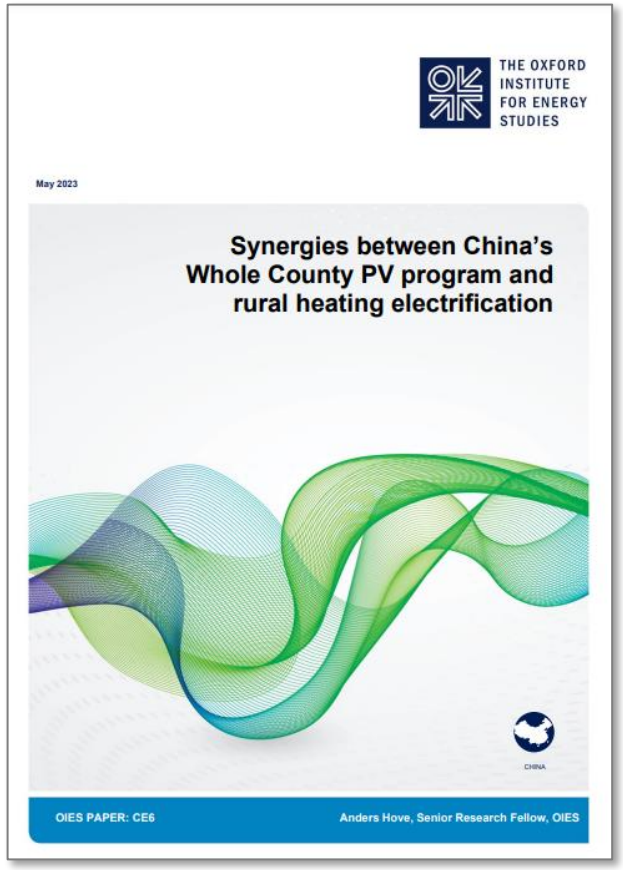
- Payback depends on household heating load, which in turn depends on occupancy at temperature set points, which may be lower in the poorest households
- 回收期取决于家庭供暖负荷，而家庭供暖负荷又取决于温度设定点上的居住情况，而最贫困家庭的温度设定点可能较低。

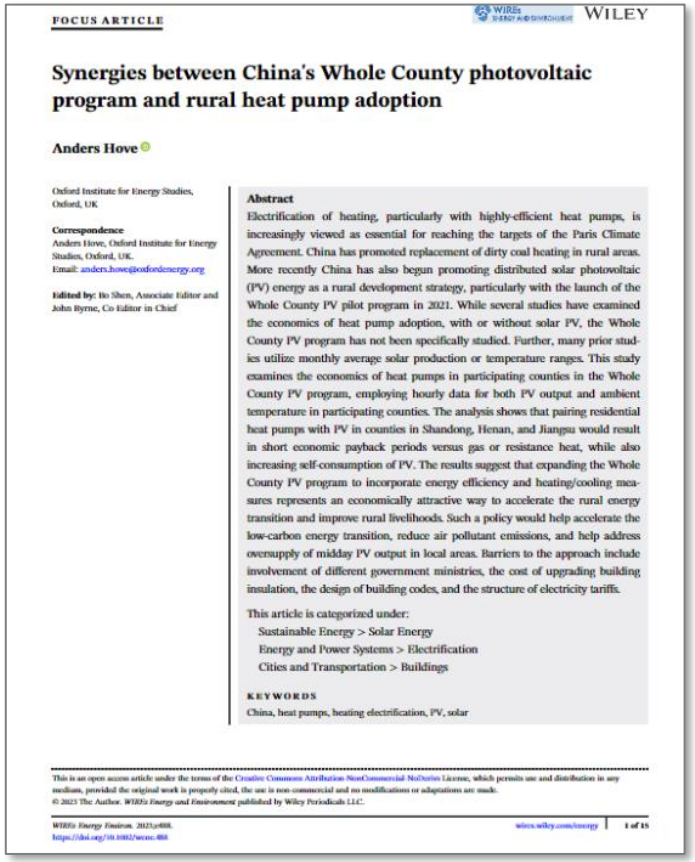
- Major barriers include:
- 主要障碍包括：
  - Different ministries responsible for heating and energy efficiency versus PV
  - 负责供暖和能效的部门与负责光伏的部门不同

  - Poor awareness of the economic benefits of heat pump adoption, familiarity with coal
  - 对采用热泵的经济效益认识不足，熟悉煤炭

  - Resistance to upfront expenditures and lack of low-cost financing options
  - 对前期支出的抵制和缺乏低成本融资选择

Full study available for free download 完整的研究可免费下载





https://www.oxfordenergy.org/publications/synergies-between-chinas-whole-county-pv-program-and-rural-heating-electrification/

- Next phase of project will look at pairing rural PV with heat pumps and EV charging
- 项目的下一阶段将研究将农村光伏与热泵和电动车充电配对的情况