China's Trajectories beyond Efficiency: CO_2 Implications of Maximizing Electrification and Renewable Resources through 2050

中国超越效率的发展轨迹：到2050年，最大限度实现电气化和使用可再生资源对CO_2 减排的影响

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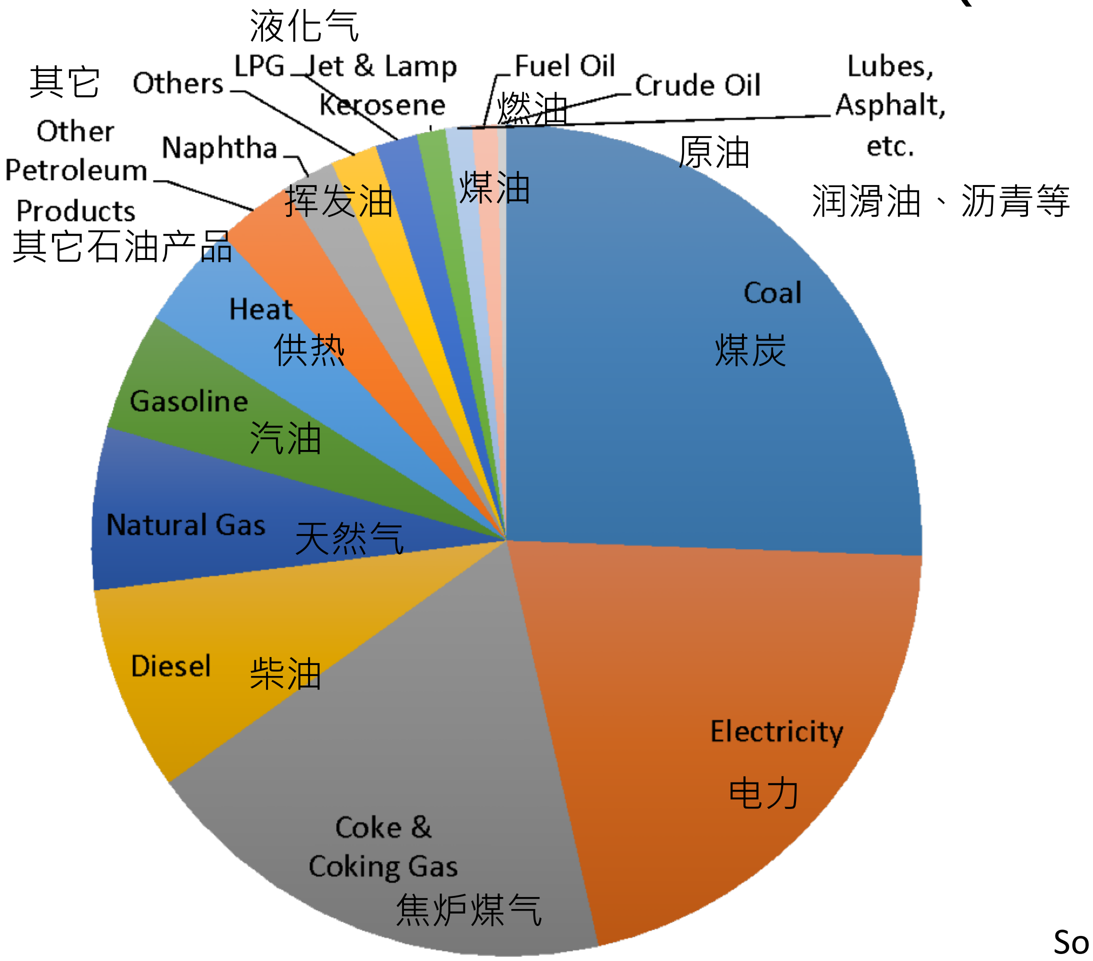
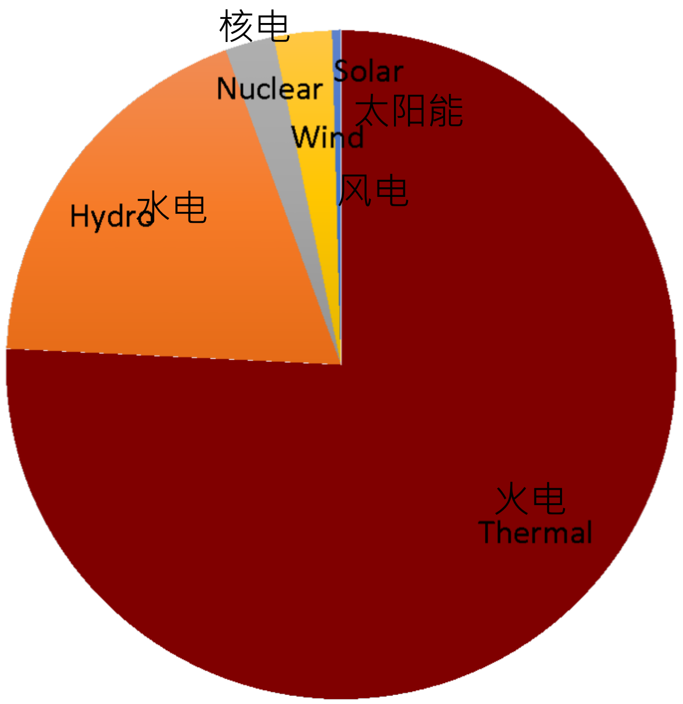
2017 ECEEE Summer Study

China's energy system is coal-based
基于煤炭的中国能源体系

China Final Energy Consumption (2014): 3139 Mtce
中国能源消费总量（2014）：31.39亿吨标煤



Electricity: 21% of total
电力：占能源消费总量的21%

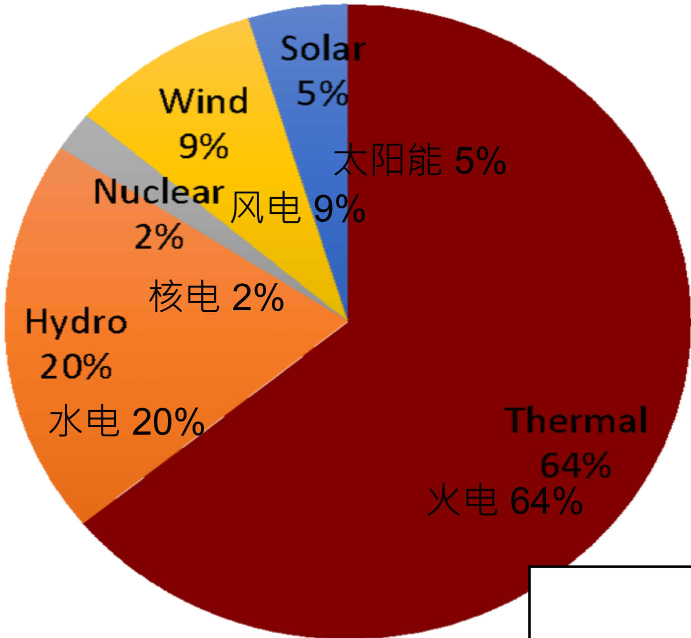


Source: China National Bureau of Statistics
中国国家统计局

Thermal installed capacity and generation dominates China's power system
中国电力系统中火电装机容量与发电量占主导地位

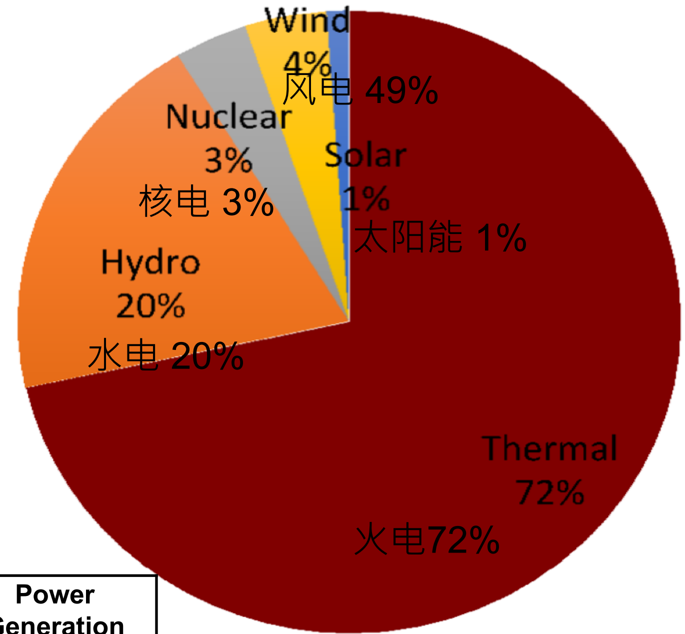
Installed Capacity by Fuel in 2016 (GW)

2016年装机容量（GW）



Power Generation by Fuel in 2016 (TWh)

2016年发电量（TWh）



	Installed Capacity 装机容量 (GW)	**Power Generation 发电量 (TWh)**
Thermal 火电	1054	4289
Hydro 水电	332	1181
Nuclear 核电	34	213
Wind 风电	149	241
Solar 太阳能	77	66
Total 总计	**1646**	**5990**

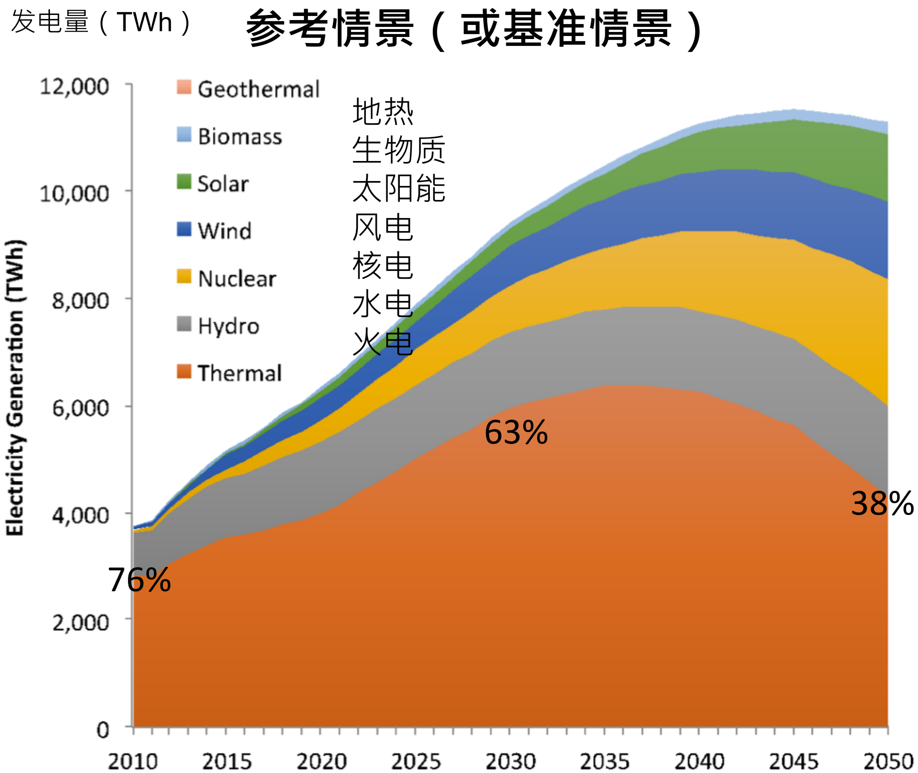
First Priority: Power System Decarbonization

第一步：电力系统脱碳

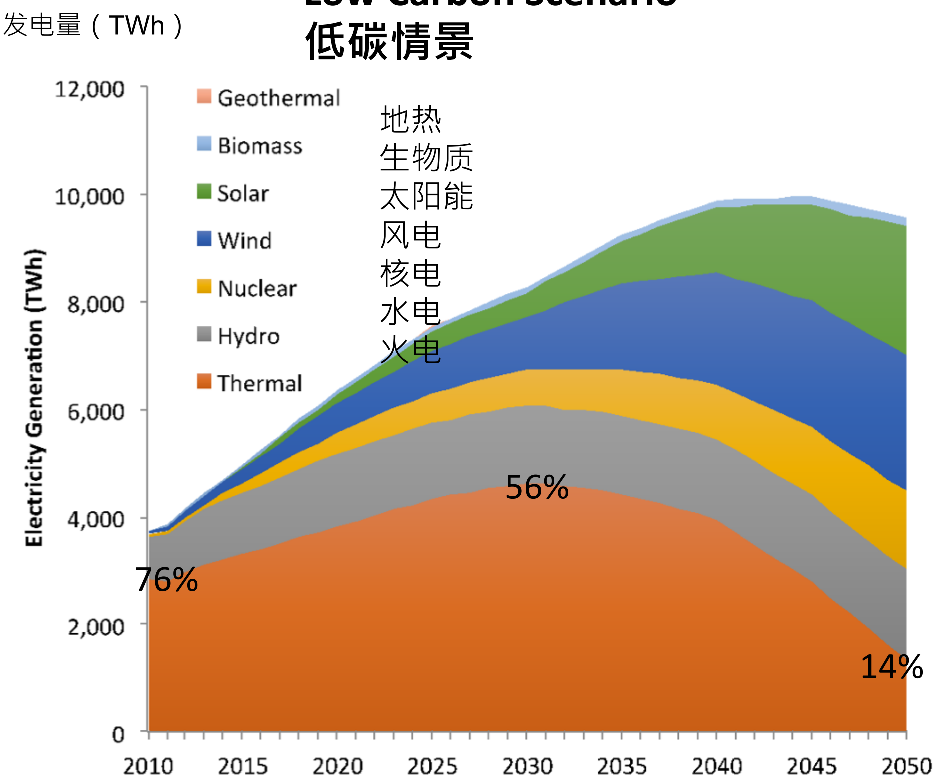
China’s electricity generation has huge potential for decarbonization
中国发电脱碳有巨大潜力

China’s Electricity Generation by Fuel
中国发电量状况

Reference Scenario
参考情景（或基准情景）



Low Carbon Scenario
低碳情景



Source: Khanna, N. et al. 2017. "China's Trajectories beyond Efficiency: CO_2 Implications of Maximizing Electrification and Renewable Resources through 2050." *2017 ECEEE Summer Study Conference Proceedings*.

来源：Khanna, N. et al. 2017. “中国超越效率的发展轨迹：到2050年，最大限度实现电气化和使用可再生资源对CO2 减排的影响”。 2017年ECEEE夏季学习会议。

Overview of China 2050 DREAM Modeling Methodology
中国2050年DREAM建模方法概述

Motivation and Purpose 动机与目的

- Few global energy models of energy demand by end-use
- China needs a model with end-use detail to plan and evaluate energy efficiency policies, programs and targets for:
  - *Short-term:* 2020, 2020 energy, CO_2 intensity reduction
  - *Long-term strategic planning:* 2050 development pathways
  - 很少的能源终端需求模型
  - 中国需要一个具有终端利用细节的模型，来规划和评估能效政策，方案和目标：
  - 短期：2020年，2020年能源，二氧化碳减排强度
  - 长期战略规划：2050年发展路径

Capabilities & Strengths 能力与优势

- Bottom-up model of energy demand by end-use captures:
  - Stock turnover models
  - Potential for efficiency improvement by technology
  - Energy, CO_2 and SO_2 emissions impacts of efficiency programs and technology trends
- Energy intensity reduction potential disaggregated by:
  - End use sector
  - Saturation, usage
  - Technology size/scale
  - 获取终端能源需求的自下而上的模型：
    库存周转模式
    技术提高效率的潜力
    能源，二氧化碳和二氧化硫排放对效率与技术发展趋势的影响
    能源强度降低潜力分解为：
    终端利用部门
    饱和度，利用
  - 技术尺度/规模

Key Outcomes 主要成果

- 2010-2011 study - only modelers to show a peak and plateau in China's energy and CO_2 emissions
- Reinventing Fire: China – informed China's 13th FYP, INDCs, US-China negotiations running up to US-China Joint Announcement on Climate Change and the Paris Agreement
- 2010-2011研究 - 只有建模者研究表明的中国能源和二氧化碳排的高峰与稳定阶段。
  重塑能源：了解中国"十三五"规划，中美关系，美中关于气候变化联合声明和巴黎协议的谈判

Second Priority: Electrification of the Economy and Additional Renewables

第二步：经济电气化与增加可再生能源

Scenarios are developed to evaluate impact of electrification and renewables

用以评估电气化和可再生能源影响的情景设计

- Reference（参考情景）:
  - Only considers policies in place as of 2010 with autonomous efficiency improvements and limited fuel switching 仅考虑截至2010年的政策，包括自主提高效率和有限的燃料转换
- Cost-effective Efficiency and Renewables（成本效益效率和可再生能源）:
  - Includes additional cost-effective efficiency improvements and fuel switch in demand and supply-side在需求和供应侧包括额外性的成本效益效率提升与燃料转换
- Maximum Electrification（最大限度电气化）:
  - Maximized (additional) electrification in buildings for cooling, industry and transport 用于建筑制冷、工业和运输的最大限度（额外）电气化
- Maximum Deployment of Renewable Energy（最大化部署可再生能源）:
  - Additional adoption of renewable heat and biomass in industry, solar in buildings 在工业中额外采用可再生供热与生物质能，建筑物中利用太阳能

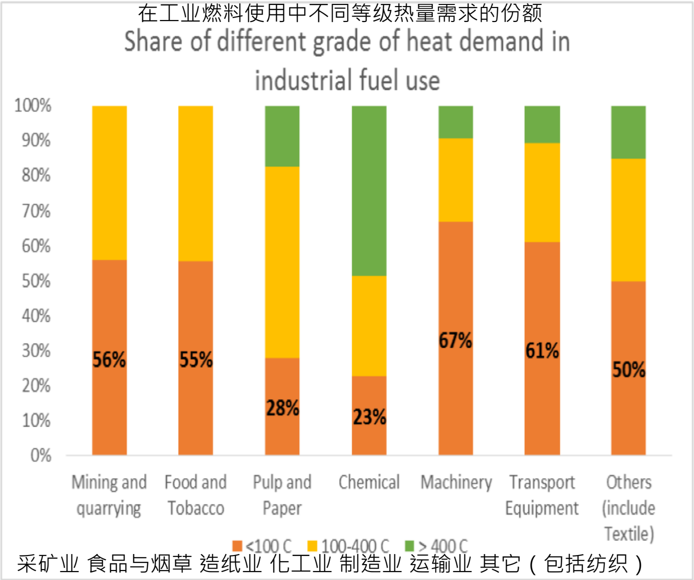
Key Assumptions in Maximum Electrification Scenario
最大限度电气化情景中的关键假设

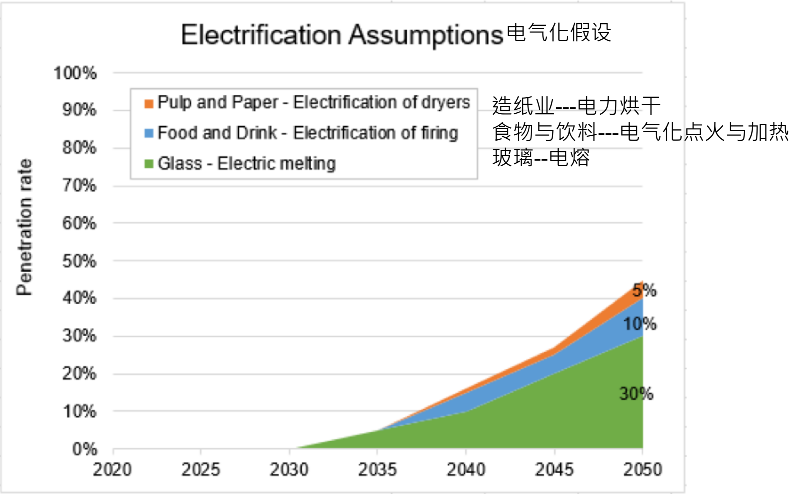
	2010	2050 Reference	2050 Maximum Electrification
Transport			
Passenger Vehicles	0% EV shares	10% EV share in private cars, 30% EV share in taxis and fleet car markets	75% EV share in private cars, 100% EV share in taxi and fleet car markets
Trucks	0% plug-in hybrid diesels	0% plug-in hybrid diesels	18% plug-in hybrid diesel share in medium-duty trucks, 50% plug-in hybrid diesel share in light-duty trucks
Industry			
Glass Industry	0% electric melting	0% electric melting	30% electric melting to replace fossil fuel melting
Food and Beverage Industry	0% electrification of firing	0% electrification of firing	10% electrification of firing to replace coal-firing
Pulp and Paper Industry	0% electric dryers	0% electric dryers	5% electric dryers to replace heat dryers
Commercial Buildings			
Heating	1.5% air source heat pump	10-25% share for air source heat pump depending on climate zone	40-90% share for air source heat pump depending on climate zone
Cooling	0.5% ground source heat pump share	0% ground source heat pump share	20-25% share for ground source heat pump depending on climate zone
Water Heating	0% heat pump water heater share	0% heat pump water heater	48% heat pump water heaters
Residential Buildings			
Heating	1.5% air source heat pump	10%-80% share for air source heat pump depending on climate zone	40-100% share for air source heat pump depending on climate zone

Maximum Renewable Deployment Scenario include additional non-conventional renewable deployment in buildings and industry

可再生能源利用最大情景包括建筑和工业中额外的非常规可再生能源利用

Industry: low-temperature renewable heat and biomass (工业：低温可再生能源和生物质能)





Commercial Buildings: maximize adoption of solar thermal technologies for heating, cooling and water heating

- Heating: solar thermal heating share increase to 8% by 2050
- Cooling: solar thermal AC share increase to 15-30% (depending on climate zone) by 2050
- Water heating: solar water heater increase to 30% by 2050

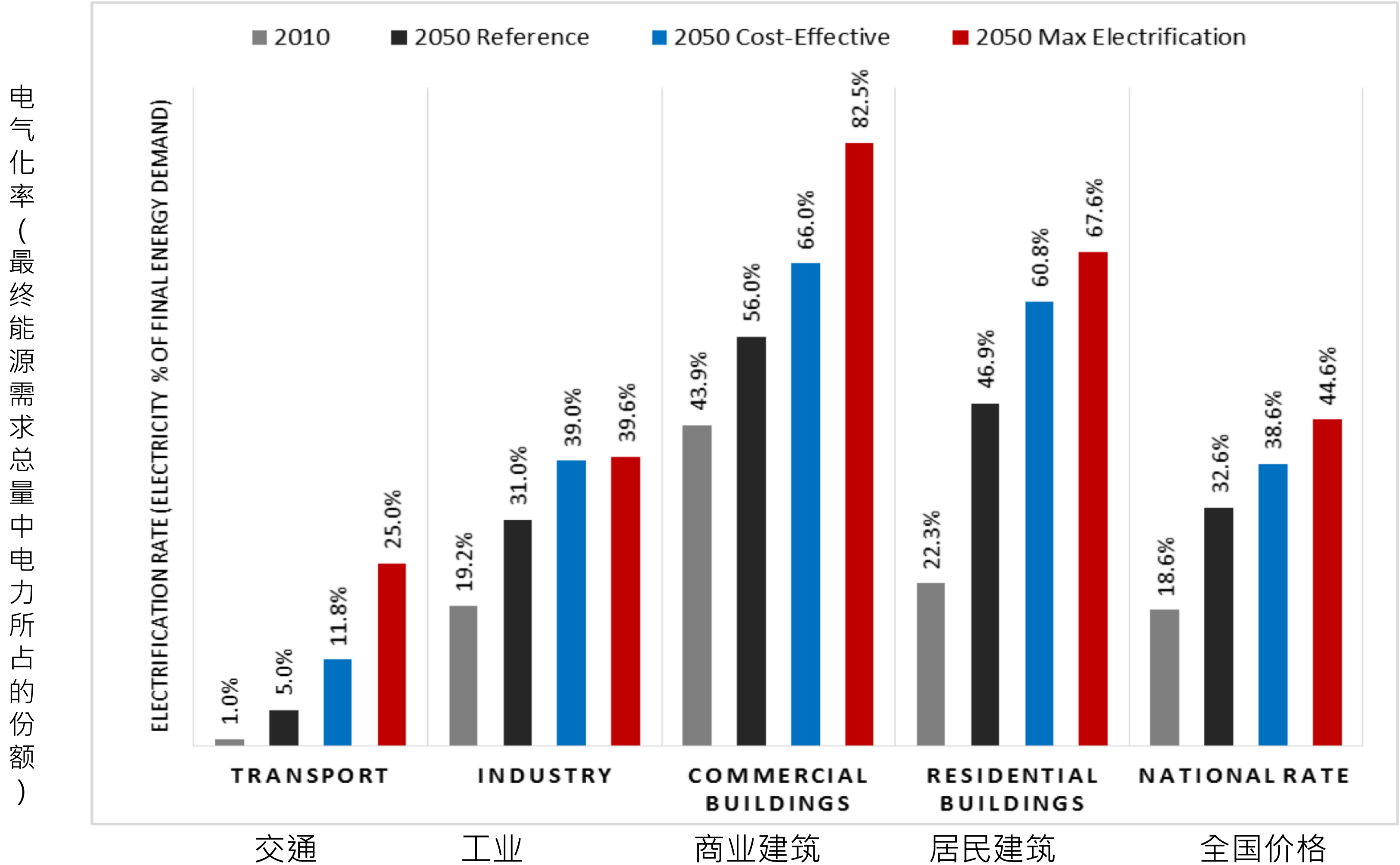
商业建筑：最大限度地采用太阳能技术进行供暖、制冷和水暖

采暖：到2050年，太阳能热采暖份额增加到8%

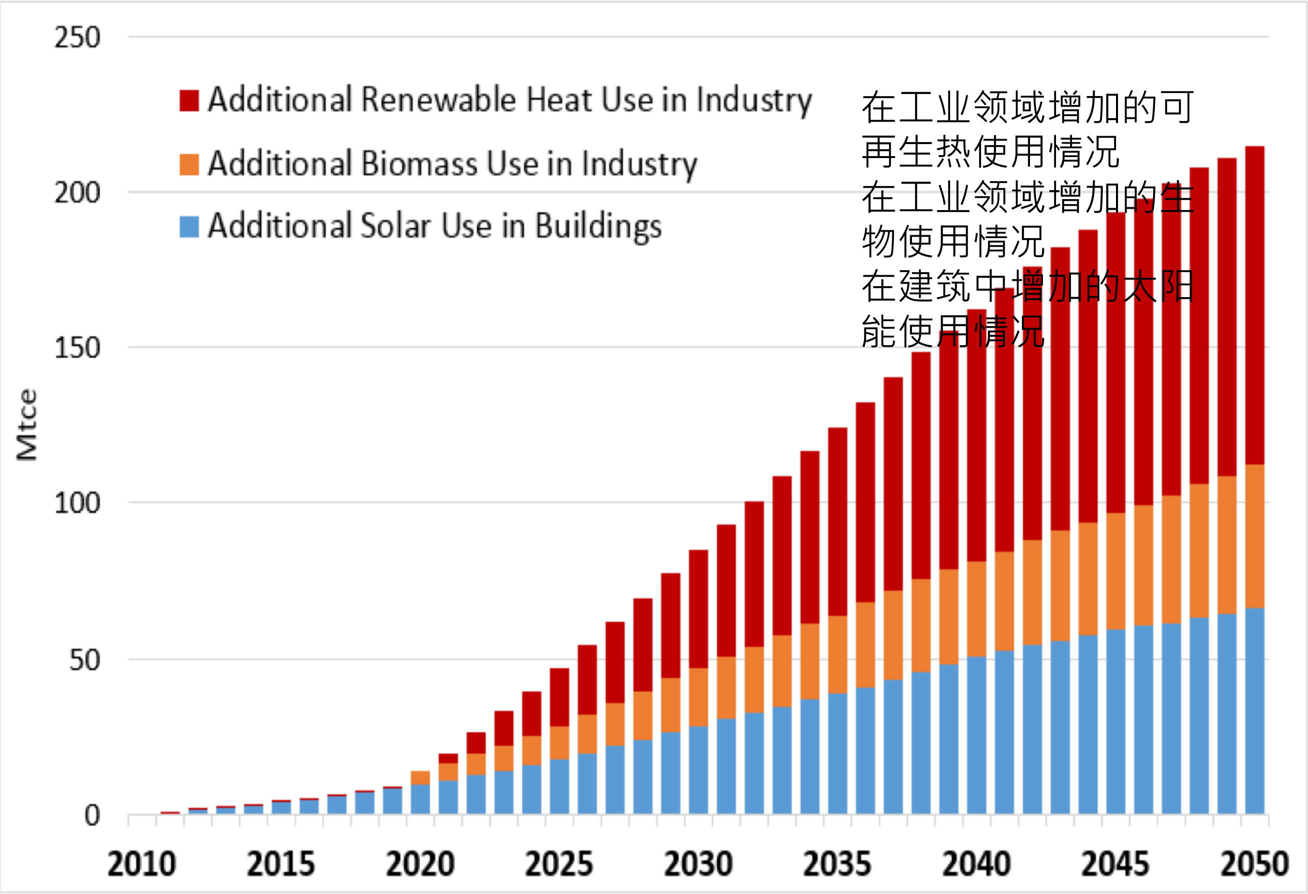
制冷：到2050年，太阳能热利用空调份额增加到15-30%（取决于气候区）

水暖：到2050年，太阳能热水器增加到30%

Significant potential for electrification across all sectors, but electricity still only accounts for 45% of final energy use with maximized electrification
各个领域的电气化潜力巨大，但是即使最大限度电气情况下电力也仅仅占最终能源使用的45%



Additional fossil fuel displacement feasible by maximizing renewable adoption in demand sectors
通过在需求领域最大化可再生能源接纳程度，增加化石燃料排放量



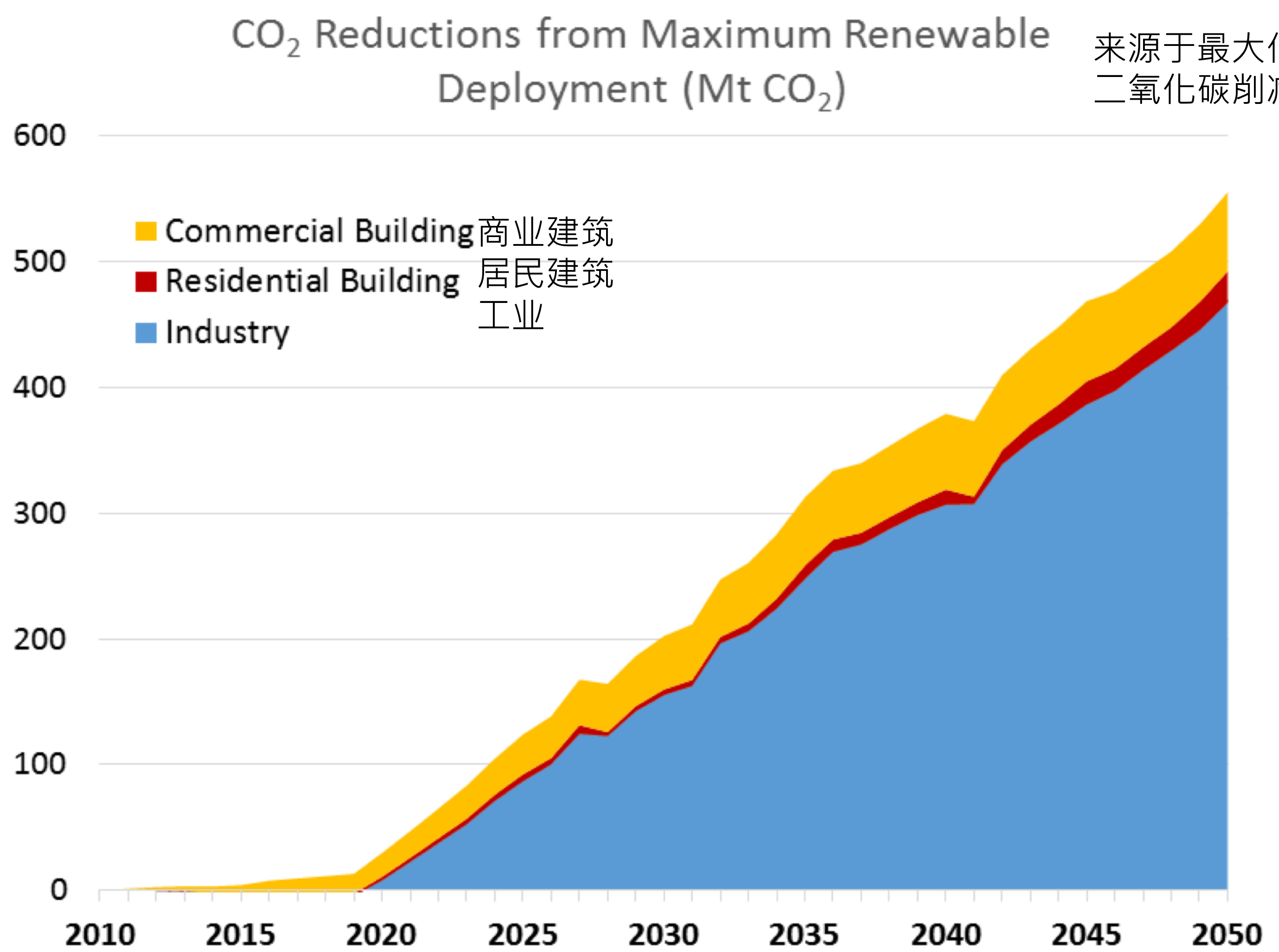
By 2050, additional renewables can displace annually:
截止到2050年，增加的可再生能源每年可以排放

- 85 Mtce Coal煤
- 7 Mtce Coke焦炭
- 54 Mtce Natural Gas 天然气
- 45 Mtce Heat热
- 26 Mtce Electricity 电

Note: 1 Mtce = 29.27 petajoules

550 Mt CO_2 can be displaced annually beyond cost-effective fuel switching by Max Renewable Deployment by 2050

超越成本效益的燃料转换，通过最大化部署可再生能源每年可有550Mt的 CO_2 被取代



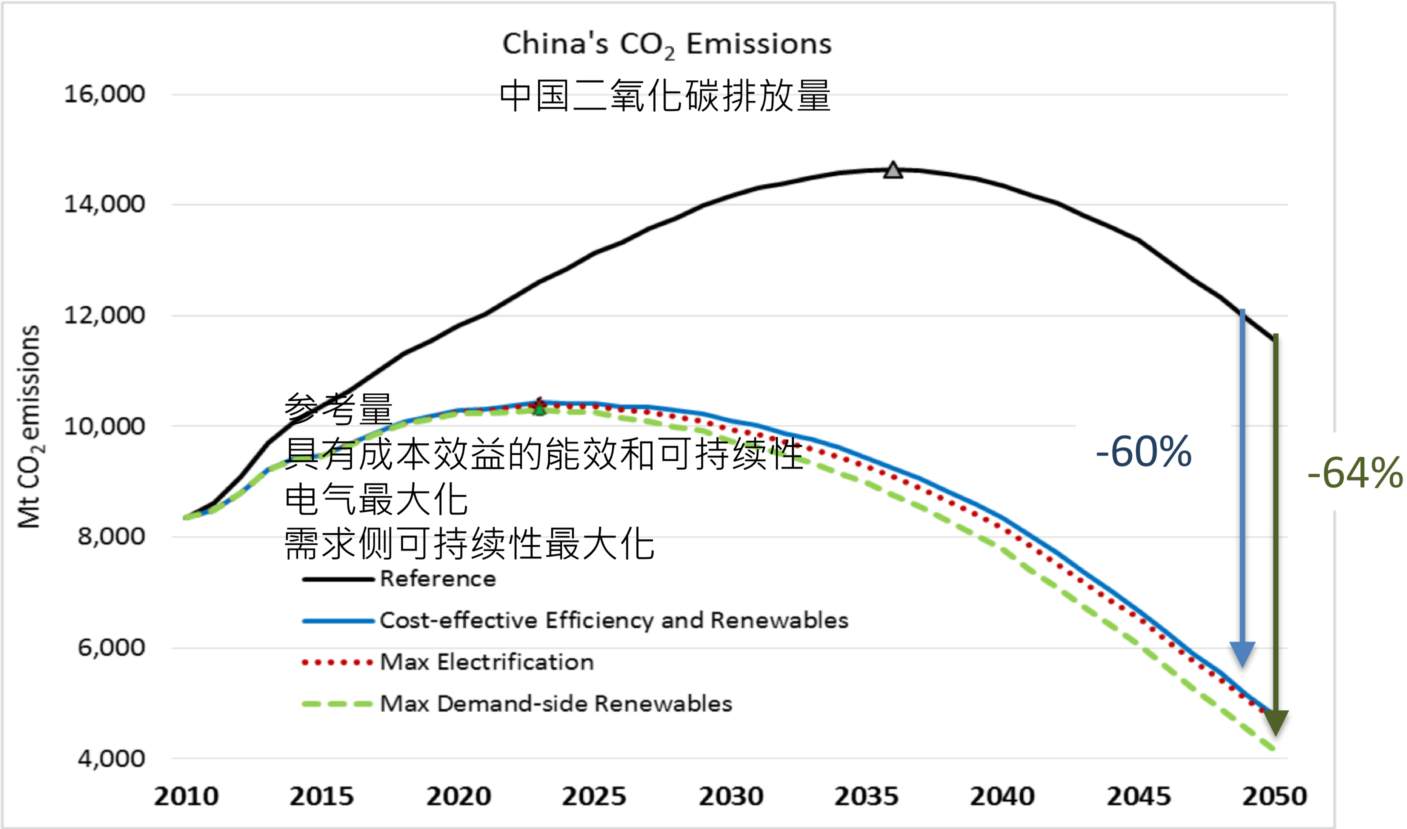
来源于最大化可利用率统筹中的二氧化碳削减量

More solar heating, cooling and water heating
更多的太阳能制热，制冷和水加热

Biomass & Renewable Heat
生物质能和可再生热能

CO_2 could peak as early as 2023 with maximized efficiency, electrification and renewables

最大化能效，最大限度电气化和使用可再生能源，到2023年二氧化碳排放即可达峰



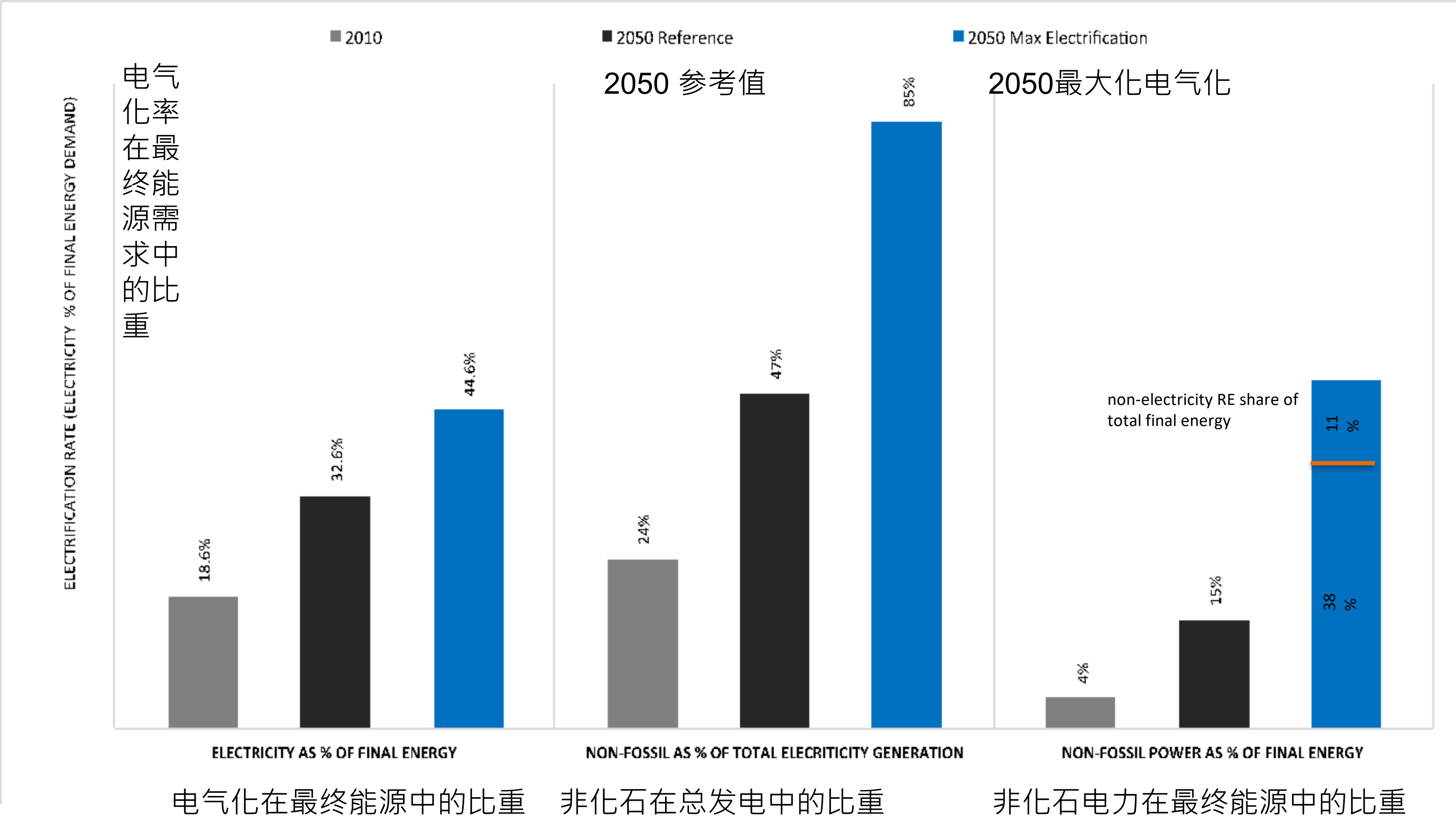
Cumulative CO_2 reductions beyond cost-effective efficiency and renewables to 2050:

- Max Electrification: 3.98 Gt CO_2
- Max Renewables: 13.2 Gt CO_2

到2050年，累积的二氧化碳减排量超过了具有成本效益的能效和可再生能源
最大限度电气化：3.98 Gt CO_2
最大化使用可再生能源：13.2 Gt CO_2

Non-fossil power could reach 30% of China's total final energy consumption by 2050

到2050年，非化石电力会达到中国总能耗的30%



Conclusions and Policy Implications
结论与政策意义

- China can achieve its 2030 CO_2 peaking target through several pathways, and reduce annual CO_2 by 60+% by 2050中国可以通过几种方式达到她在2030年的二氧化碳峰值的目标，并在2050年之前每年减少60+%的二氧化碳
- China's CO_2 emissions can peak as early as 2023 with only cost-effective efficiency and fuel switching, but must overcome barriers including:仅在具有成本效益的能效和燃油切换的情况下，中国二氧化碳在2023年即可达到峰值，但必须清除以下几个障碍
  - Lack of resources and knowledge for efficiency improvements缺乏对能效改善的资源和技术
  - Distorted tariff and energy prices扭曲的税率和能源价格
  - Regional unemployment concerns and limited alternatives for fuel switching in some sectors一些部门的区域性失业问题和燃料转换替代方案有限
- Additional research needed to disentangle impact of cost-effective efficiency versus fuel switching, supply-side vs. demand-side electrification额外的研究需要解决成本效益效率与燃料转换，供应方面与需求方电气化的影响

Significant policy shifts needed to achieve additional CO_2 reductions from maximizing renewables and electrification:

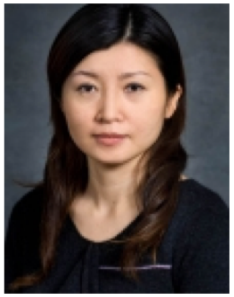
为了在实现最大限度使用可再生能源和电气化中增加二氧化碳的减排量，需要进行重大的政策转变

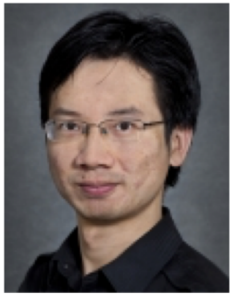
- Interdependence between electrification and decarbonization of power sector, which requires resolving existing challenges and renewable integration 电力部门的电气化与脱碳相互依存，需要解决现有的挑战和可再生能源的整合

- Supporting policies and programs including subsidies, pilots can help promote distributed demand-side renewable technologies 支持包括补贴在内的政策和项目，向导可以帮助促进分布式需求侧可再生能源技术的发展

- Greater awareness and capacity building on low temperature renewable heat use in industrial sectors needed – more crucial to start now given large scale and decentralized nature of Chinese industries 提高工业部门低温可再生热利用的意识和能力建设，这对于当前具有大规模和分散化特点的中国更为关键

Thank You!
谢谢！



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