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Assessment of Energy Strategies for China's Heavy-duty Trucks and the Potential for Electrification
中国重型卡车能效战略评估及电动化发展潜力

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2021年3月25日

China Energy Group 中国能源组

Founded in 1988 – have worked collaboratively with U.S. and China for 33 years

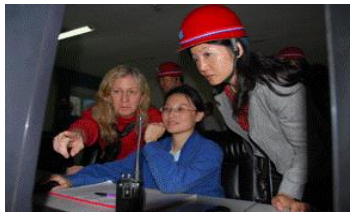
1988年创立 – 与中国合作33年

- ~ 12 staff members

  12 位全职人员， 包括科学家，科学工程研究员

- 20+ current projects

  目前项目数量超过20个



Mission:宣言：

Developing impactful, science-based energy and environmental solutions with China

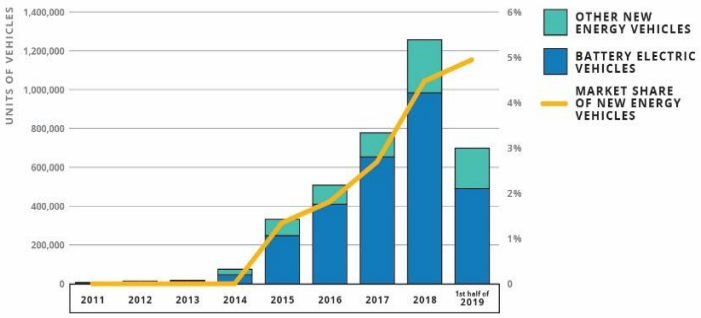
与中国一起开发具影响力的、科学的能源和环境解决方案

China's Policy Context for Transport Electrification
中国在交通领域电动化方面的政策背景

- Under the Paris Climate Accord, China committed to peak its CO_2 emissions by 2030 or earlier
- In late Sept. 2020, President Xi pledged China to achieve carbon neutrality before 2060
- China's transport sector consumes 10% of energy, but more than 50% of oil
- China has become a leader in promoting New Energy Vehicles in the passenger car market

- 中国在《巴黎气候协定》下承诺2030年或更早实现CO_2排放达峰
- 2020年9月下旬，习主席做出了中国努力争取2060年以前实现碳中和的承诺
- 中国交通领域的能源消耗量占比为10%，但原油消耗量占比超过50%
- 在汽车市场上，中国已成为新能源汽车第一大国

FIGURE 1-13
Sales of New Energy Vehicles in China (2011-1st Half of 2019)



Source: China Energy Outlook, 2019.

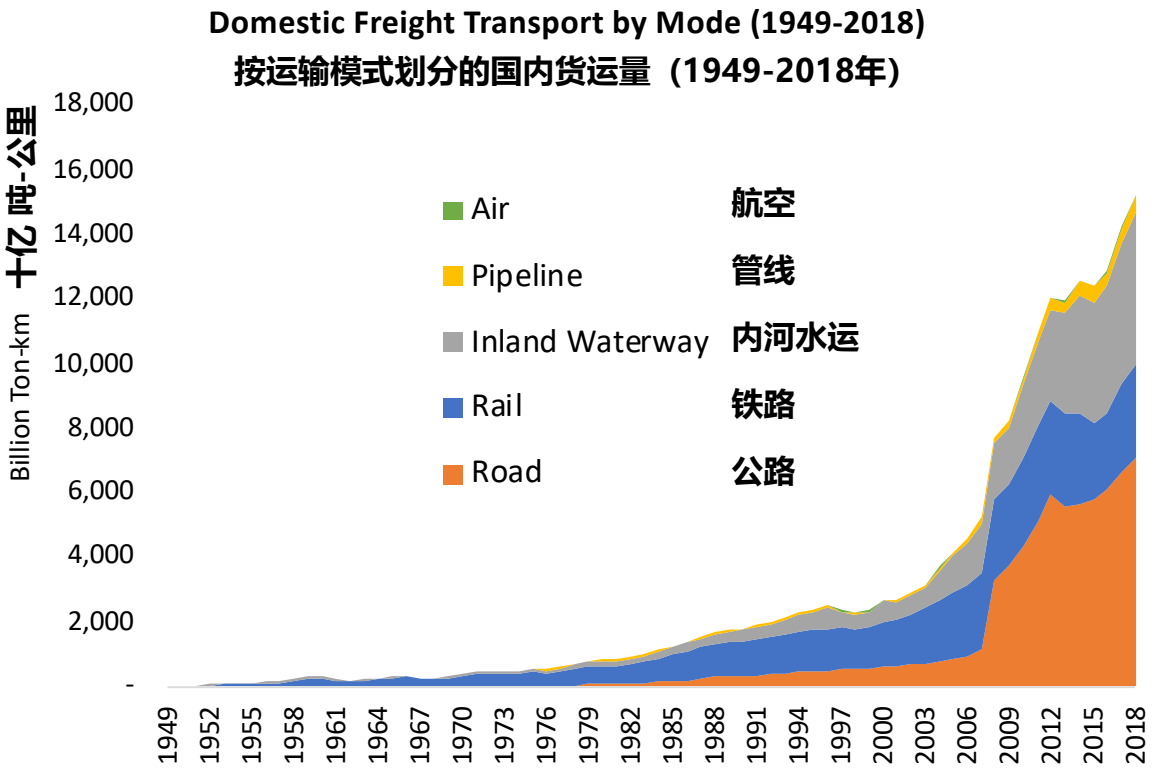
Is China's success in electrifying light-duty transport replicable for decarbonizing its heavy-duty trucking sector?
中国在轻型车领域的电动化（低碳化）成功经验能否复制到重型卡车领域？

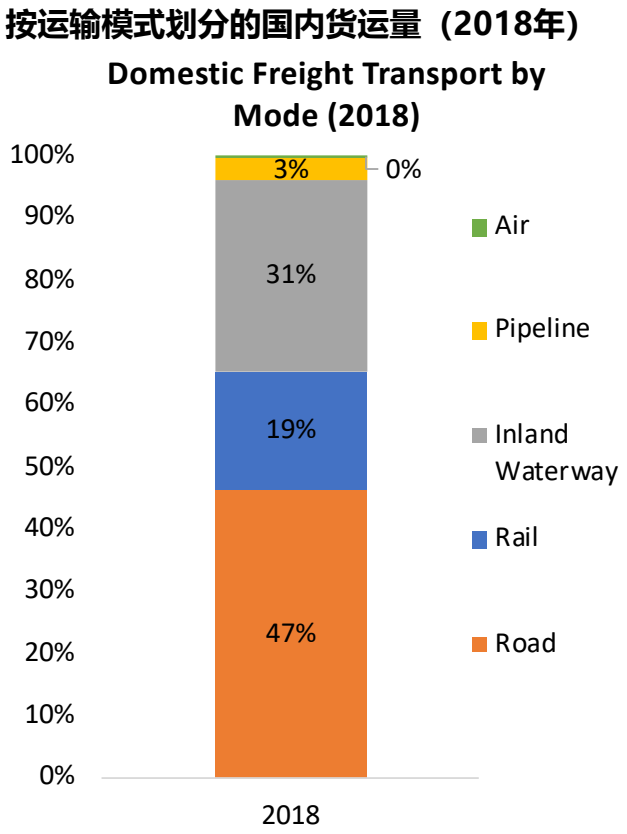
- Globally, heavy-duty trucks are difficult to decarbonize, and contribute to significant air pollution
  - Account for 10% of global vehicles but 40% of transport CO_2
  - Particulate matter (PM) and nitrogen oxides (NO_x) emissions from diesel vehicles account for half of on-road emissions in U.S. and China
  - $PM_{2.5}$ emissions from heavy-duty trucks can be 1-2 orders of magnitude higher than light-duty vehicles
  - Travel 100,000 - 150,000 km/year in China
- Least efficient vehicles due to weight and larger loads; energy efficiency standards only exist in 6 countries

- 重型卡车低碳化是一个全球性难题，并且重型卡车带来的空气污染问题也十分严峻
  - 占全球车辆总量的10%，但是占交通领域二氧化碳排放的40%
  - 无论在美国还是中国，柴油车的颗粒物（PM）和氮氧化物（NO_x）排放均占到道路车辆排放总量的一半左右
  - 重型卡车的$PM_{2.5}$排放量要比轻型车高出1-2个量级
  - 在中国每年行驶10万到15万公里
- 因为重量和负载量，很多重卡能效低下；全球只有六个国家有重卡的能效标准

Road freight has grown significantly in recent years, and now accounts for nearly half of China's domestic freight transport

近年来道路货运量显著增长，占中国国内货运总量的仅半数



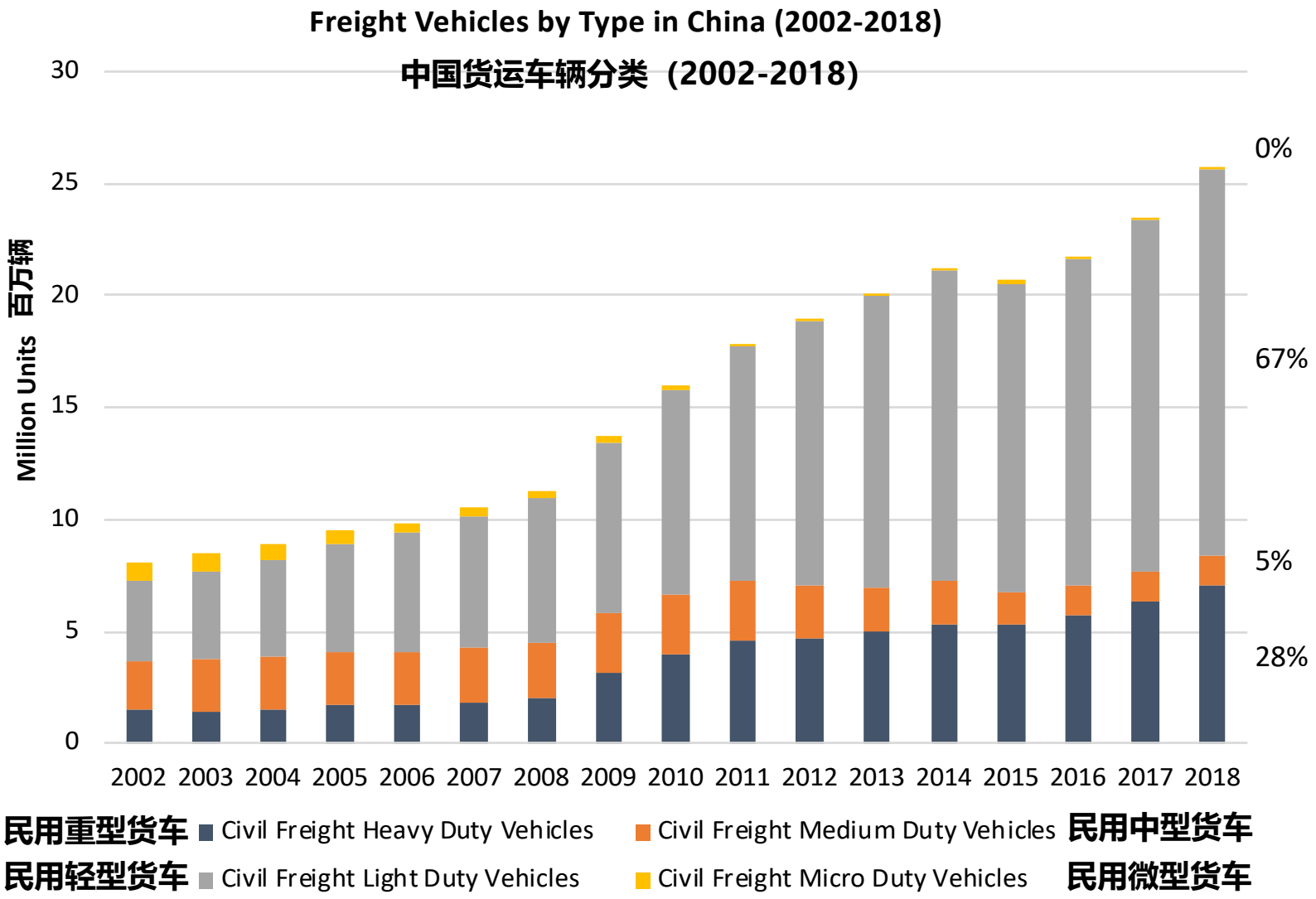


Source: China National Bureau of Statistics, 2019

来源：国家统计局 2019年

Heavy-duty vehicles (>14 tonnes)'s share of freight vehicles rising quickly over time, from 18% in 2002 to 28% in 2018

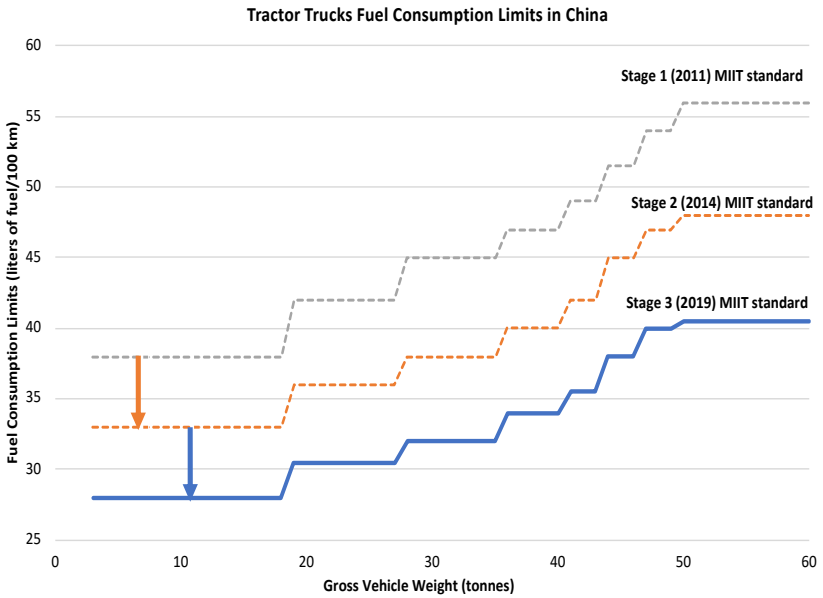
重型车（>14吨）在货运车辆中的占比快速增长，从2002年的18%增至2018年的28%



Source: China National Bureau of Statistics, 2019
来源：国家统计局 2019年

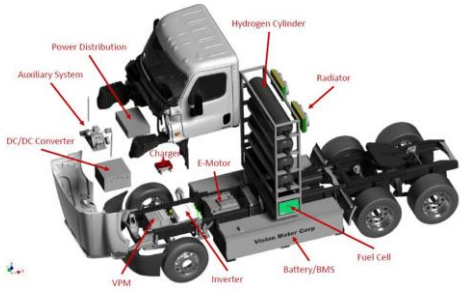
In China, policy support for decarbonizing HDTs is growing
中国不断出台相关政策，支持重型卡车低碳化

- National fuel economy standard for heavy-duty vehicles enter into Stage 3 in 2019, with ~15% improvement from Stage 2
- Regional and city-level targets and subsidies for phasing-out diesel vehicles
- Supporting policies for New Energy trucks:
  - R&D and manufacturing
  - National development subsidies since 2015 (extended to 2022)



Fuel Consumption Limits of Tractor Trucks in China

- 2019年，重型商用车第三阶段燃料消耗量限值实施，在第二阶段基础上加严了~15%
- 地方和城市层面也在出台目标和补贴措施，加速柴油车更新淘汰
- 出台新能源卡车支持政策
  - 研发与生产
  - 国家自2015年开始实施推广补贴（补贴政策已延长至2022年）



But China also faces unique challenges to decarbonizing its HDT sector, including market structure and supply chain issues

但中国在重型卡车低碳化方面也面临着特殊挑战，涉及市场结构和供应链等方面的问题

- Individual ownership model exacerbates challenges of NEV trucks' high upfront costs
  - 71% truck drivers own their vehicles, resulting in decentralized decision making
  - 84% of truck purchases made through loans and debts - sensitive to high upfront costs of alternative heavy-duty trucks
- Market fragmentation
  - Five domestic manufacturers dominate the tractor-truck market, but market for trailers manufacturing and other specialty trucks are very fragmented with small, scattered and low-quality manufacturers
- Resource and supply chain considerations
  - Increased global demand for critical metals (lithium, cobalt, graphite, platinum) could lead to a surge in resource prices and potential trade issues

- 私人车主所有制模式加剧了新能源汽车高昂的前期成本所带来的挑战
  - 71%的卡车司机本身就是车主，导致市场较为分散，难以做出统一化决策
  - 84%的卡车是通过贷款或分期购买的，因此对于新能源卡车较为高昂的前端价格十分敏感
- 制造市场分散
  - 国内的牵引车市场主要由五家主流生产企业占据，但挂车和其他卡车市场较为分化，存在一些小规模、分散化且产品质量较差的生产企业
- 资源和供应链方面的顾虑
  - 随着全球对关键金属（锂、钴、石墨、铂）需求的不断增加可能会导致价格飙升和潜在的贸易问题

Reducing Oil Consumption in Heavy-Duty Freight Vehicles
降低重型卡车的燃油消耗

1. Short-term Strategies Assessment 短期战略评估

- Efficiency improvement 提高能效
- LNG Fuel switch to LNG trucks LNG燃料替代
- Systemic improvement in operations and logistics 运营和物流系统改善

2. Emerging Technologies Assessment 新兴技术的评估

- Battery electric trucks 纯电动卡车
- Catenary trucks 电缆卡车
- Hydrogen fuel cell trucks 氢能/燃料电池卡车
- 动态充电卡车 Dynamic charging trucks

- Techno-economic status, challenges 技术经济情况和挑战
- Barriers to large-scale deployment 大规模推广的障碍
- Resource and energy demand 资源和能源需求
- Scalability potential 规模化推广潜力

3. Pathways and Implications for China 对中国的影响

- Policy and programs implications 政策和项目影响
- Resources, energy, emission implications 资源、能源和排放影响

Methods 方法

- Literature review 文献综述
- Techno-economic analysis 技术经济分析
- LEAP modeling and scenario analysis LEAP模型和情景分析
- Case studies 案例分析
- Domestic and international expert interviews 采访国内和国际专家

We use China 2050 DREAM Model to assess possible energy and emission pathways of technology and policy development
我们利用中国2050DREAM模型分析技术和政策发展可能带来的的能源和排放路径

- Bottom-up end-use model provides unique mid- to long-term energy outlook based on physical, non-linear drivers and cross-sector linkages

  根据物理的、非线性驱动因素和各领域之间的相互影响建立了自下而上的终端模型，形成特定的中长期能源预期

- Under development for 14 years, based on published statistics and reports, international and Chinese experts' input and review

  基于公开的数据和报告，以及国内外专家的意见，在过去14年中不断对模型进行完善

KAYA Identity:茅阳一碳排放公式

Energy Consumption = Activity x Energy Intensity　能耗 = 活动 x 能源强度

Emissions = Fuel Consumption x Fuel-specific Emission Factor 排放 = 燃料消耗量 x 燃料的排放因子

- Transport sector:交通领域：
  - Detailed demand and technologies for 17 transport modes

    17种交通方式的具体需求和技术
  - Heavy-duty trucks: stock turnover model, 4 fuel technologies

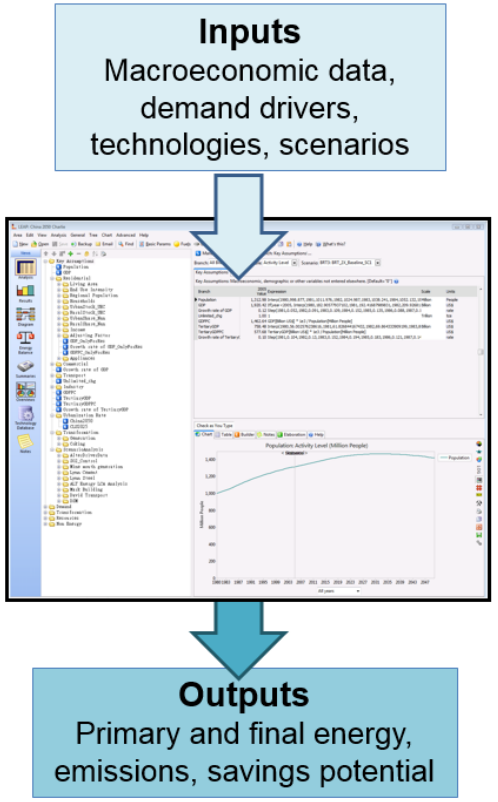
    重型卡车：库存周转模型，4种燃料技术
- Scenario analysis for future outlooks

  未来展望的情景分析
  - Change key input parameters (activity, efficiency, fuel share) to represent technology development or policy-driven scenarios

    改变关键的输入参数（如活动量、能效和燃料比例）来代表技术发展或者政策驱动的情景

LEAP Software Platform
LEAP软件平台输入

输入: 宏观经济数据、需求驱动因素、技术和情景

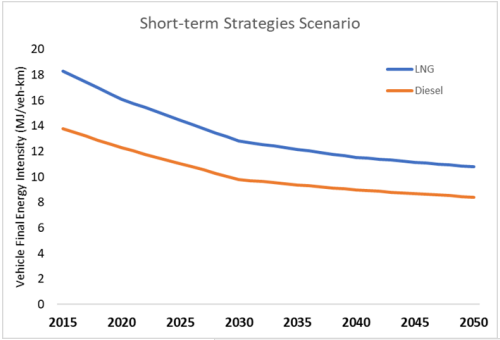


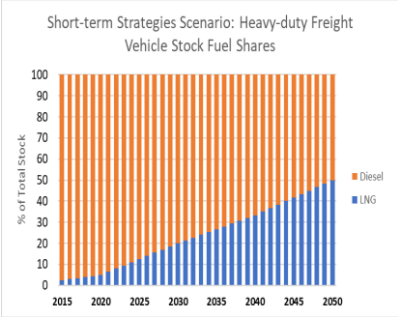
输出：和最终能源消耗、排放和节能减排潜力

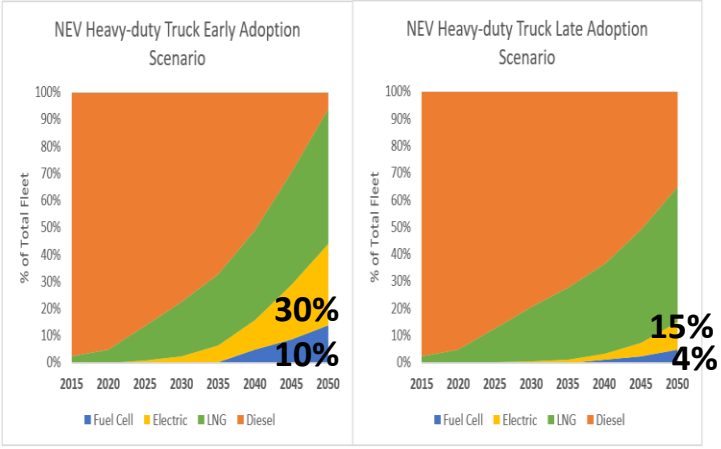
We use scenario analysis to analyze different *possible* pathways of NEV HDT development
我们通过情景分析来评估不同的新能源重型卡车潜在发展路径

- ***Reference Scenario:*** baseline scenario assuming continuous efficiency improvement and fuel switching towards LNG
- ***Short-term Strategies Scenario:*** full adoption of
  - Technical efficiency improvements (1.4-1.5%/year)
  - Commercialized cleaner LNG trucks: 50% LNG trucks in total fleet by 2050 (vs. 30%)
  - Operations and logistics improvements: 15% reduction in 2050 freight activity
- ***Early NEV Adoption***: earlier and accelerated deployment of battery electric and fuel cell HDTs starting in 2020 and 2035, respectively
- ***Late NEV Adoption:*** slower deployment of battery electric and fuel cell HDTs in 2020 and 2040, respectively

- **基准情景：**基线情景，假设能效不断的提高和转向液化天然气(LNG)替代燃料
- **短期策略情景：**
  - 完全采用技术性的能效提升（每年1.4-1.5%）
  - 采用更清洁燃料的商用卡车（2050年液化天然气卡车达到50%）
  - 运营和物流运输改善：到2050年降低15%的重卡活动量。
- **新能源较早采用情景：**较早并加速推广纯电动重卡（2020年）和燃料电池重卡（2035年），到2050年分别占重卡保有量30%和10%
- **新能源较晚采用情景：**较晚推广应用纯电动重卡（2020年）和燃料电池重卡（2040年），比重增加缓慢，到2050年分别占重卡保有量的14%和5%。

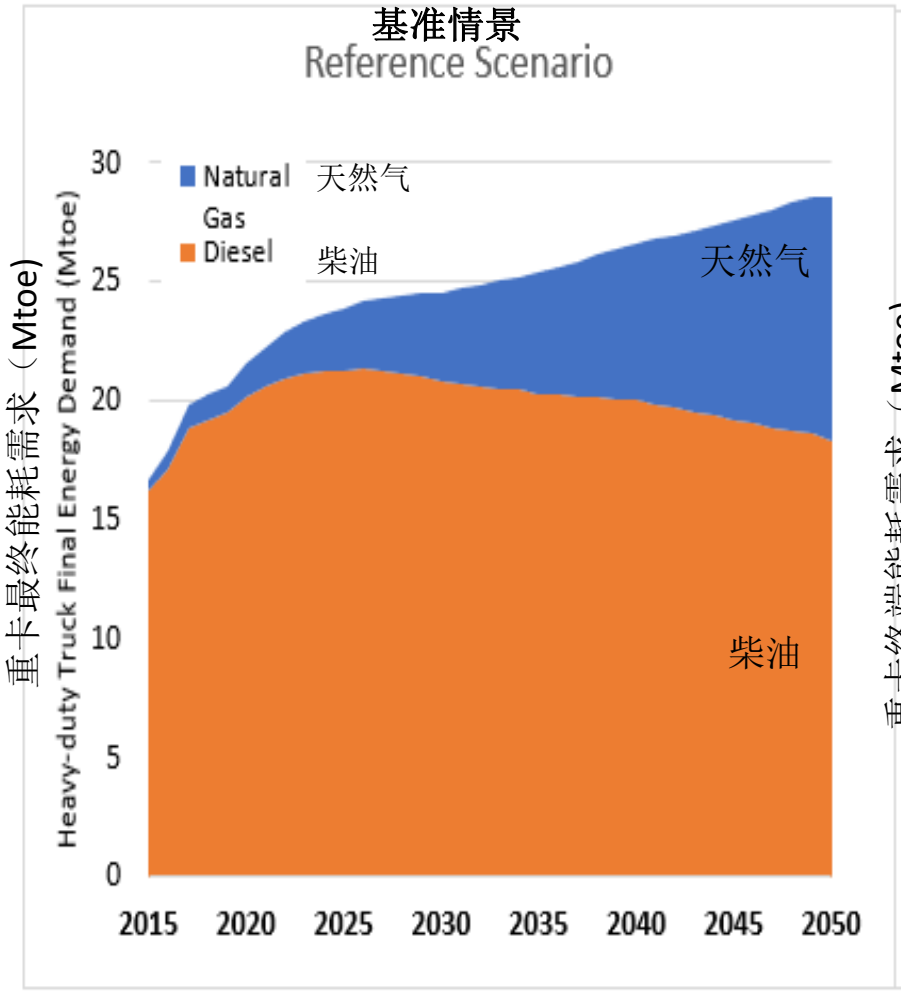


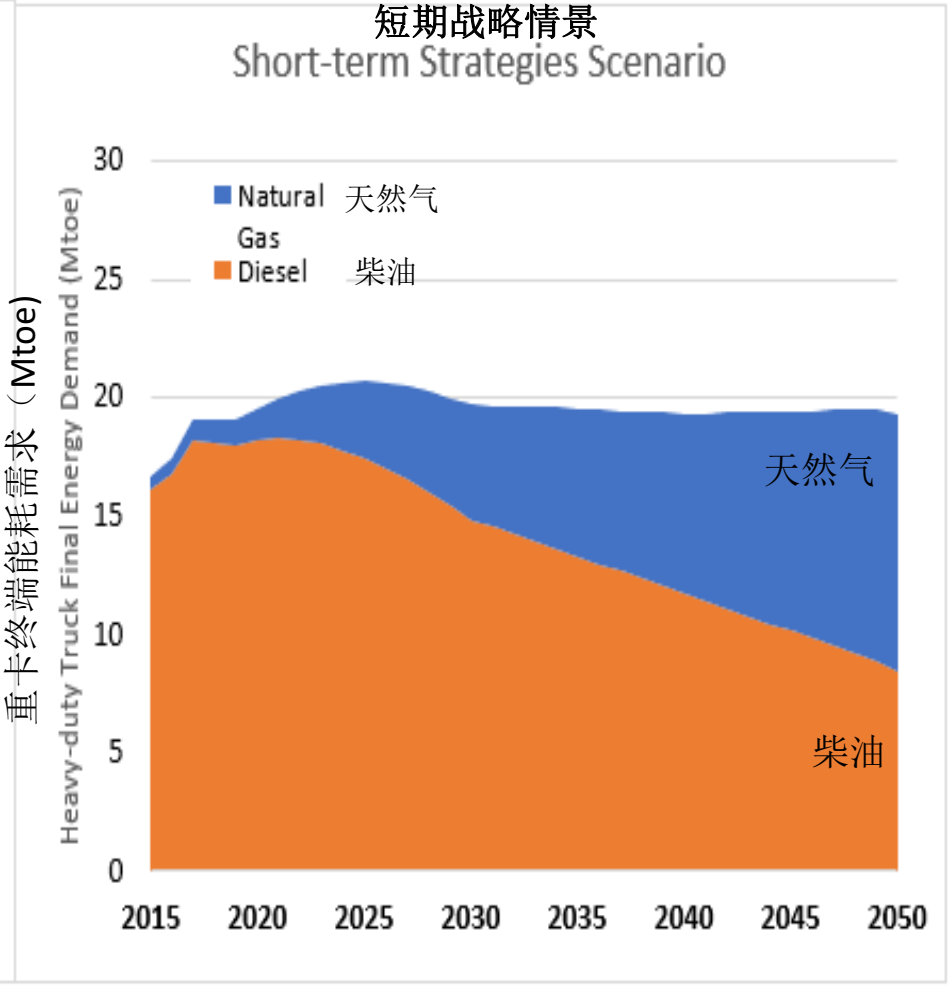




Short-term strategies can help peak and stabilize HDT energy by 2025, and significantly reduce diesel levels after mid-2020s

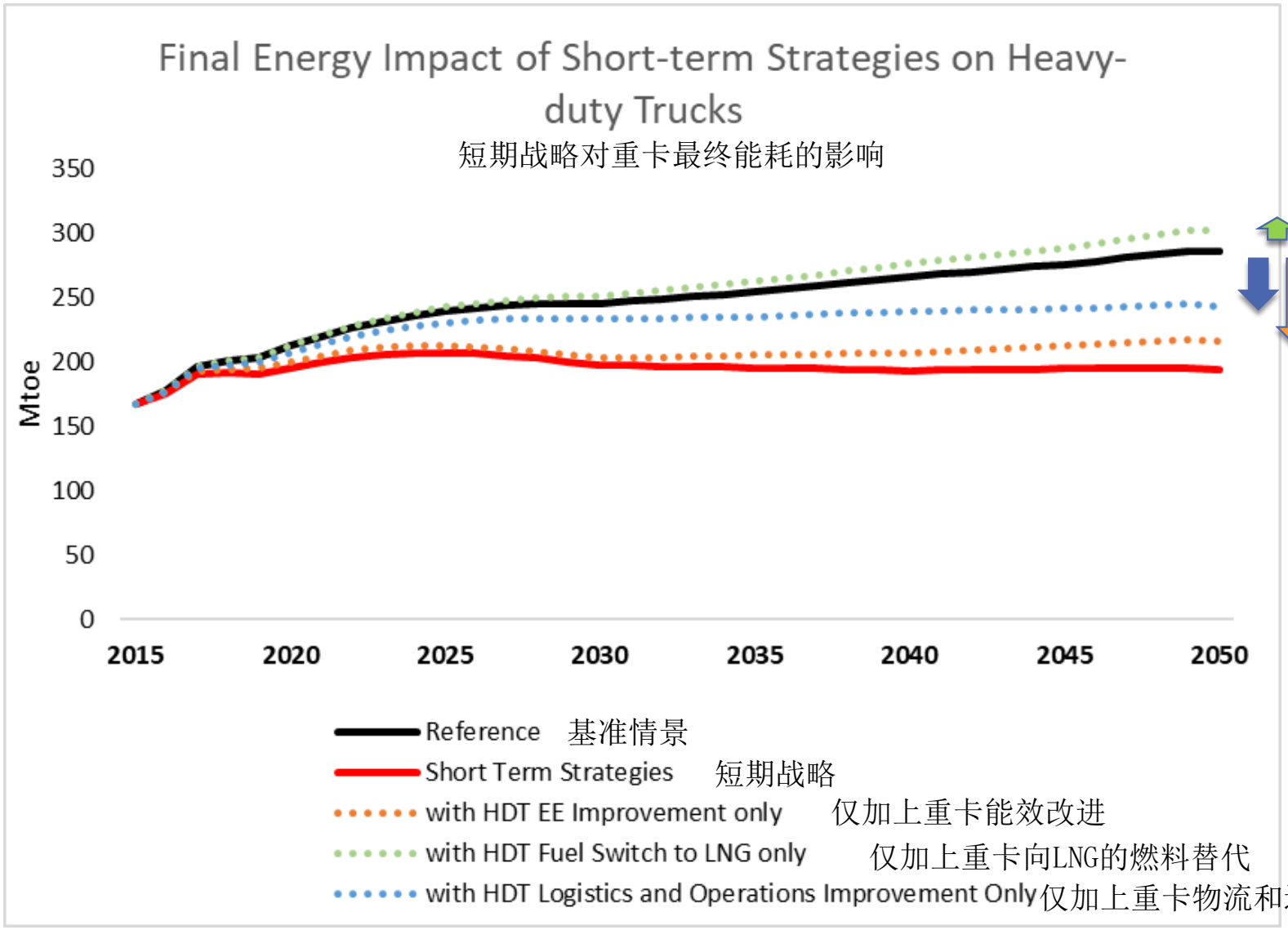
短期战略可以帮助重卡能耗在2025年达峰并保持稳定，可以在2025年以后显著降低柴油消耗



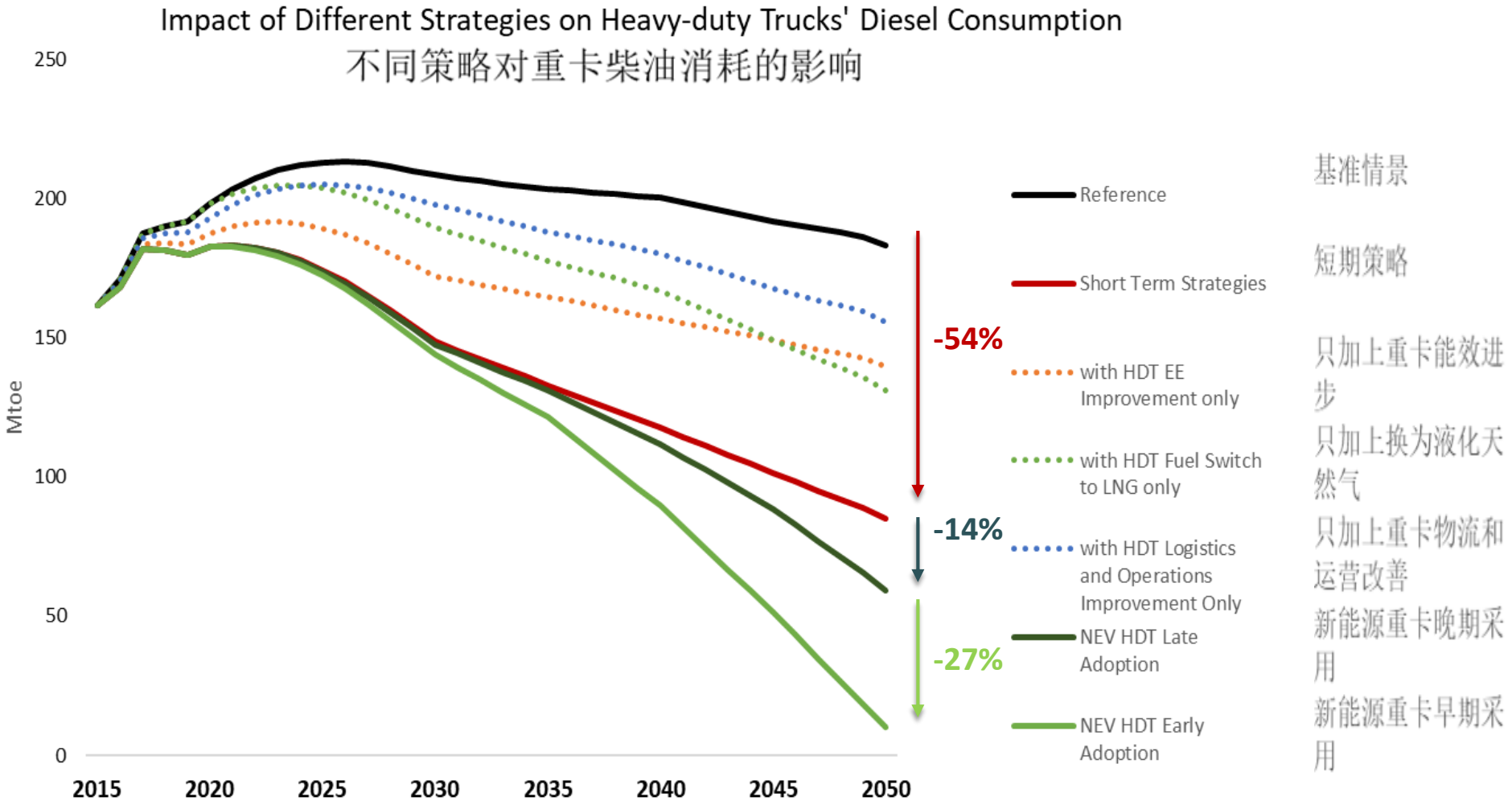


Energy efficiency improvement has largest potential in reducing HDT energy use, while LNG trucks slightly increase total energy use

能效提高对降低重卡能耗的潜力最大，LNG（液化天然气）卡车会轻度增加目前重卡的总能耗



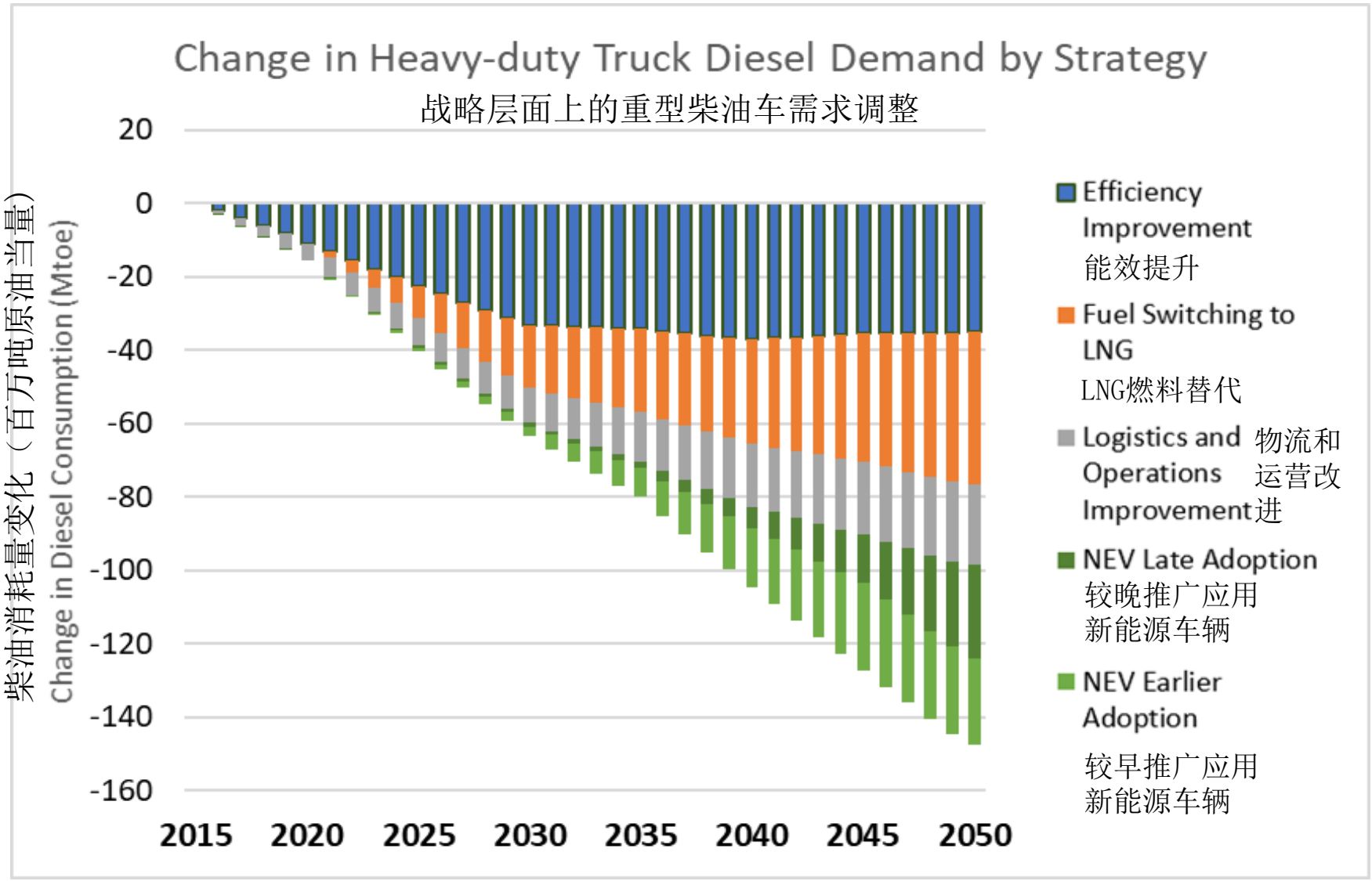
Total of 94% reduction possible by 2050 if NEV trucks are also deployed earlier
如果较早推广应用新能源重卡，到2050年可降低94%的柴油消耗量



Note: EE: Energy Efficiency; NEV: New Energy Vehicles (i.e. battery electric and fuel cell)

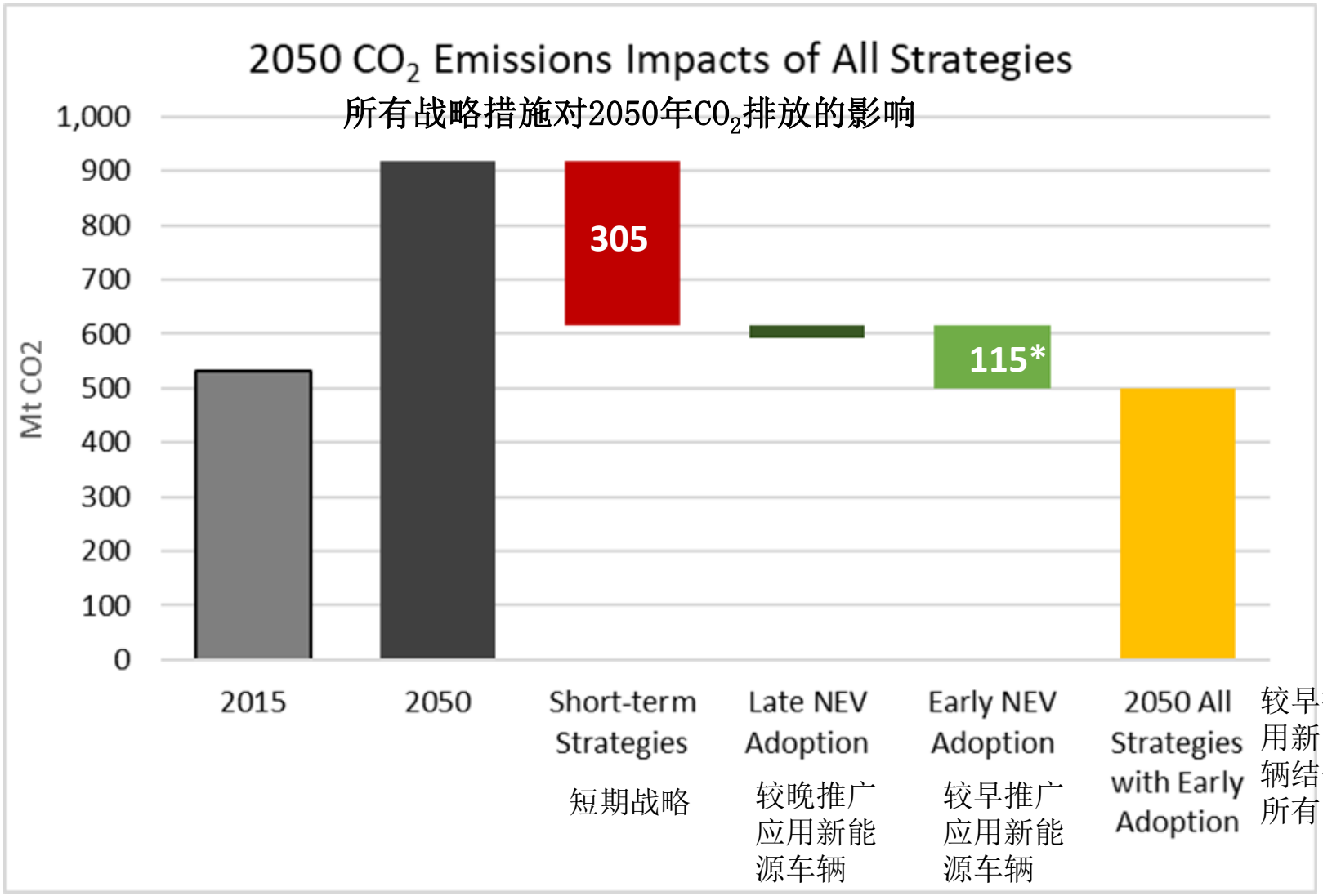
Efficiency improvement has the greatest potential in the near-term, followed by switching to LNG and NEVs in the longer term

短期角度，能效提升方面的潜力是最大的；长期角度则应向LNG和新能源过渡



In 2050, short-term strategies and early adoption of NEVs could reduce annual CO_2 emissions by 45%

2050年，在短期战略和较早推广新能源卡车的共同作用下可实现年CO_2排放降低45%



*Note: estimated CO2 reductions highly dependent on our assumptions about market adoption rates and power sector decarbonization

注：CO_2减排量评估很大程度上取决于我们对市场渗透率和电力行业低碳化的假设条件

Based on our findings, near-term policy implications for the 14th and 15th Five-Year Plan period (2021 – 2030) include:

根据这些研究结果，对“十四五”和“十五五”的近期政策影响包括：

- A mix of technologies, rather than a single NEV technology, is needed for maximum CO_2 and diesel reductions
- Policy support needed through policies and programs such as technology-neutral GHG reduction performance standards and fiscal policies
- Government-led or public-private partnerships needed to coordinate and optimize strategic siting of infrastructure networks, including coordination with light-duty road transport sectors
- R&D investment needed in high density batteries and fuel cell stacks, infrastructure for transporting hydrogen from electrolysis from renewables

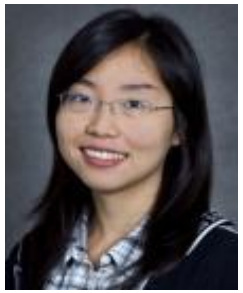
- 最大程度地降低二氧化碳排放和减少柴油消耗需要多种技术，而非某一项单一的新能源卡车技术
- 需要通过政策和不同项目提供政策支持，例如技术中性的温室气体减排绩效标准和财政政策
- 政府主导或者公私伙伴关系应该协调和优化基础设施网的战略选址，包括与轻型货运部门之间进行协调
- 需要对高能量密度电池和燃料电池堆研发进行投资，需要基础设施来运输和利用由可再生能源电解而生产的氢

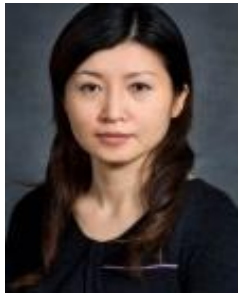
Key Findings
主要结论

- Existing technical improvements in energy efficiency, and increasing adoption of LNG and NEV trucks can lead to sizable diesel reductions in the near-term, with diesel peaking as early as 2025
- CO_2 reduction impact of NEVs will be closely linked to pace of power sector decarbonization
- Efficiency improvements and switching to NEVs have additional co-benefits in reducing air pollution, including SOx, NOx, and PM emissions
- Policies and programs need to be developed now to support diverse solutions to reduce diesel and emissions from heavy-duty trucking, including R&D for NEV technologies and investment in charging infrastructure
- Logistics and operational efficiency improvements are significant, but may be harder to achieve and will need institutional changes as well as new enabling technologies

- 利用现有的能效技术提升、推广LNG和新能源卡车应用，能够在短期内实现非常可观的柴油消耗量削减，最快可在2025年实现柴油消耗量达峰
- 新能源卡车所能带来的CO_2减排量与电力行业的低碳化进程息息相关
- 能效提升和推广新能源卡车辆同时还能带来空气污染物减排方面的协同收益，包括减少SO_x，NO_x和PM排放
- 现在需要出台不同的政策和项目，为降低重型卡车燃油消耗量和排放提供多重解决方案，包括新能源卡车技术的研发以及投资建设充电基础设施等
- 物流和运营方面的能效提升也具有重要意义，但由于涉及到体制调整以及新技术应用，可能实现起来较为困难

Acknowledgments and Contact
鸣谢与联系方式



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