

# Feasibility, Cost and Decarbonization Potential of Clean Pathways for Heavy-Duty Road Transportation

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## Introduction

- Heavy-duty vehicles (HDVs) are responsible for ~36% of on-road greenhouse gas emissions.
- Battery electric trucks (BETs), fuel-cell electric trucks (FCETs), and low-carbon liquid fuels are being developed to decarbonize HDV fleets.
- In this project, we evaluate the technological feasibility, life-cycle emission reduction potential, and carbon abatement cost for HDVs.

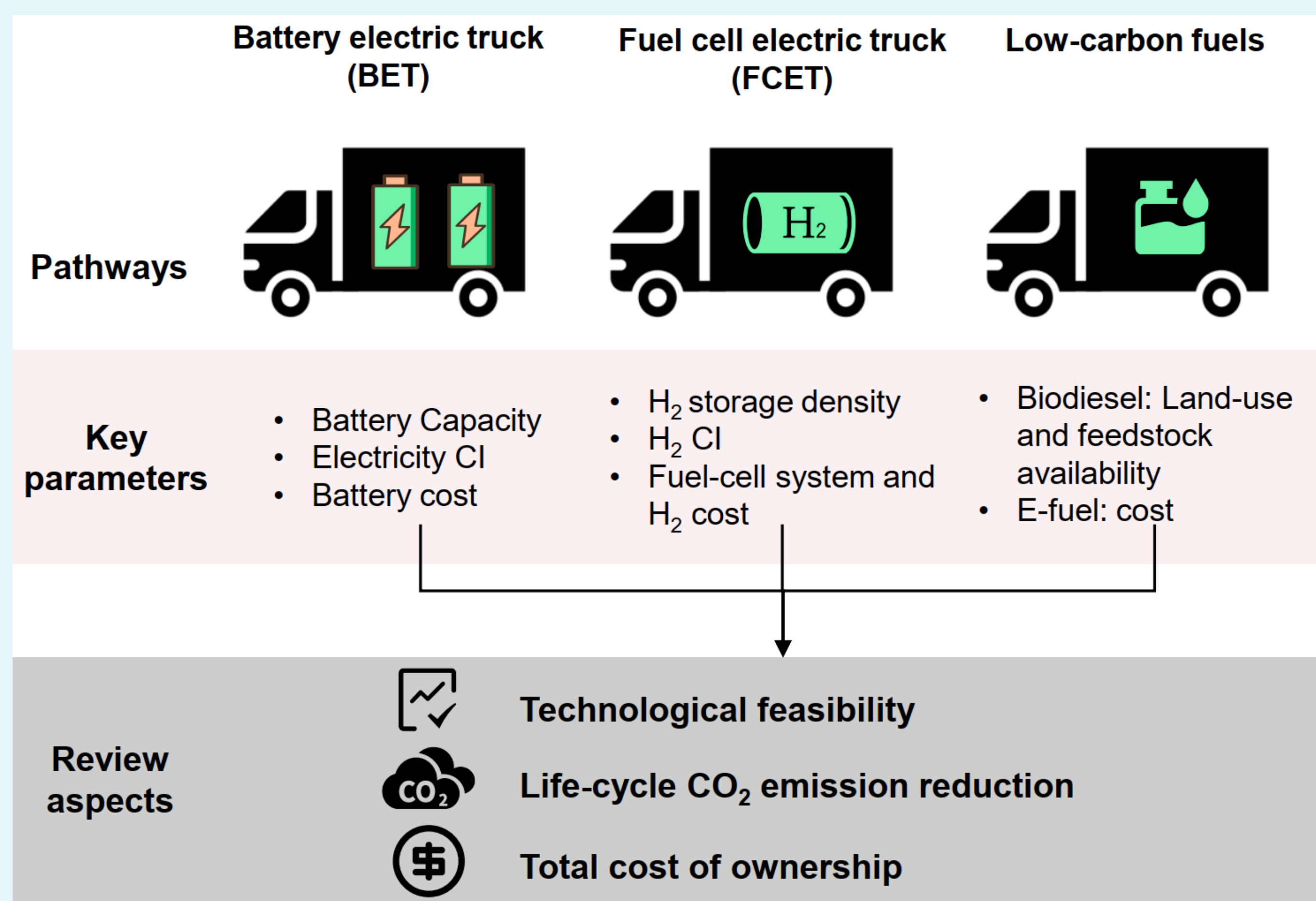


Figure 1. Clean transition pathways for heavy-duty fleets

## Technological feasibility

We propose Equivalent Energy Density (EED) to evaluate the feasibility of clean HDV fleet pathways.

### Key Findings:

- BETs meet >35% of daily travel needs of tractor-trailers without additional charging; >88% with one intermediate stop
- FCETs meet >67% of daily travel needs without refueling

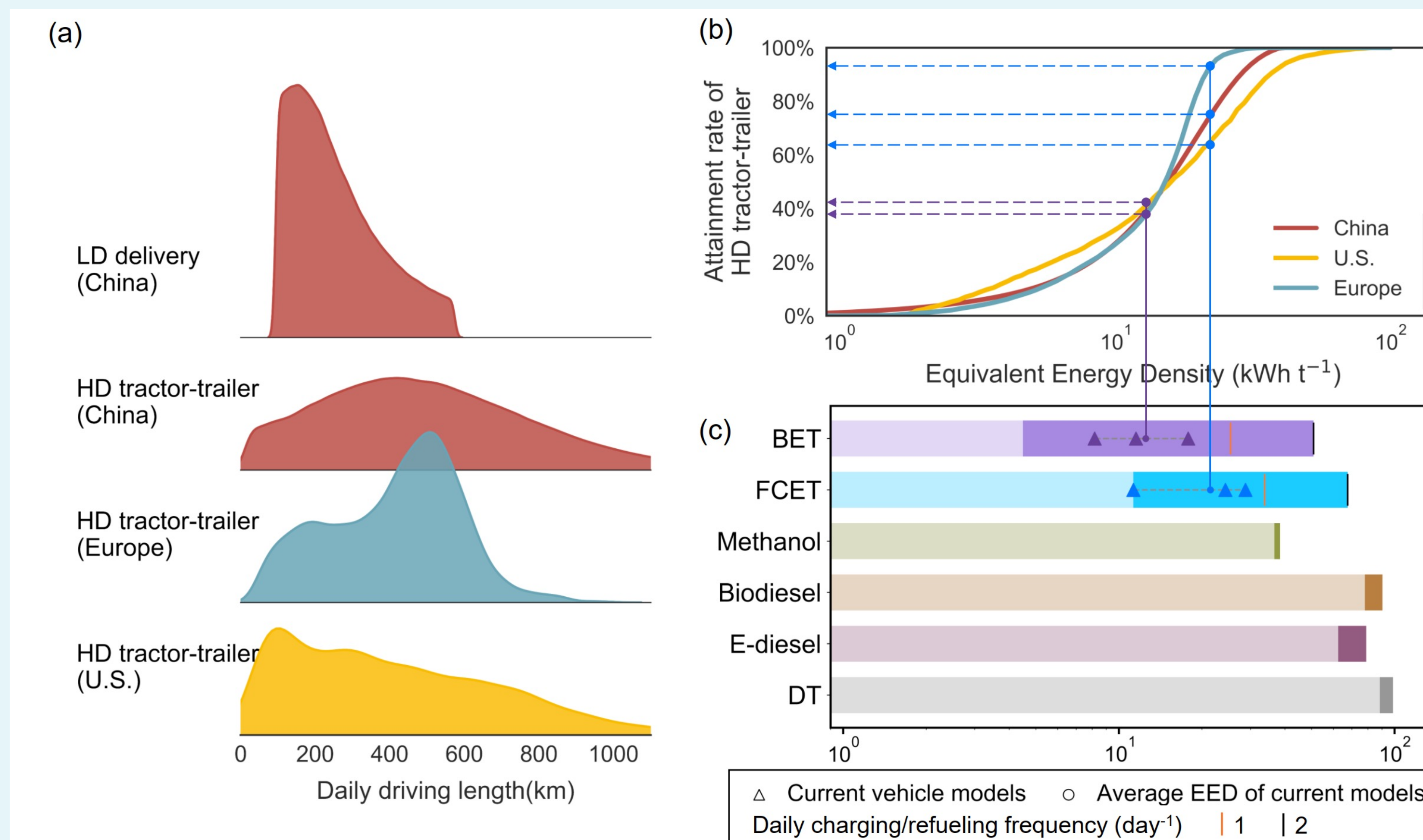


Figure 2. (a) Distribution of daily mileage in different regions. (b), Attainment rates of heavy-duty (HD) vehicles as a function of equivalent energy density (EED). (c) EED ranges of HD vehicles by fuel type for 2020-2040.

## Life-cycle emissions and carbon abatement cost

### Emission reduction and total cost of ownership:

- BETs and FCETs could reduce life-cycle CO<sub>2</sub> emissions by **27%-58%** compared diesel trucks but face barriers like high vehicle and hydrogen costs, and insufficient infrastructure
- BETs in most markets could achieve cost effectiveness by 2030, while FCETs appear unlikely to become cost-effective before 2040

### Current carbon abatement costs for HDVs:

- BETs: \$405-667 per tCO<sub>2</sub>
- FCETs: \$753-3,800 per tCO<sub>2</sub>
- Biodiesel/e-fuel: \$220-1,453 per tCO<sub>2</sub>

Benchmark: electricity (\$20-100/tCO<sub>2</sub>); passenger vehicles (<\$140/tCO<sub>2</sub>)

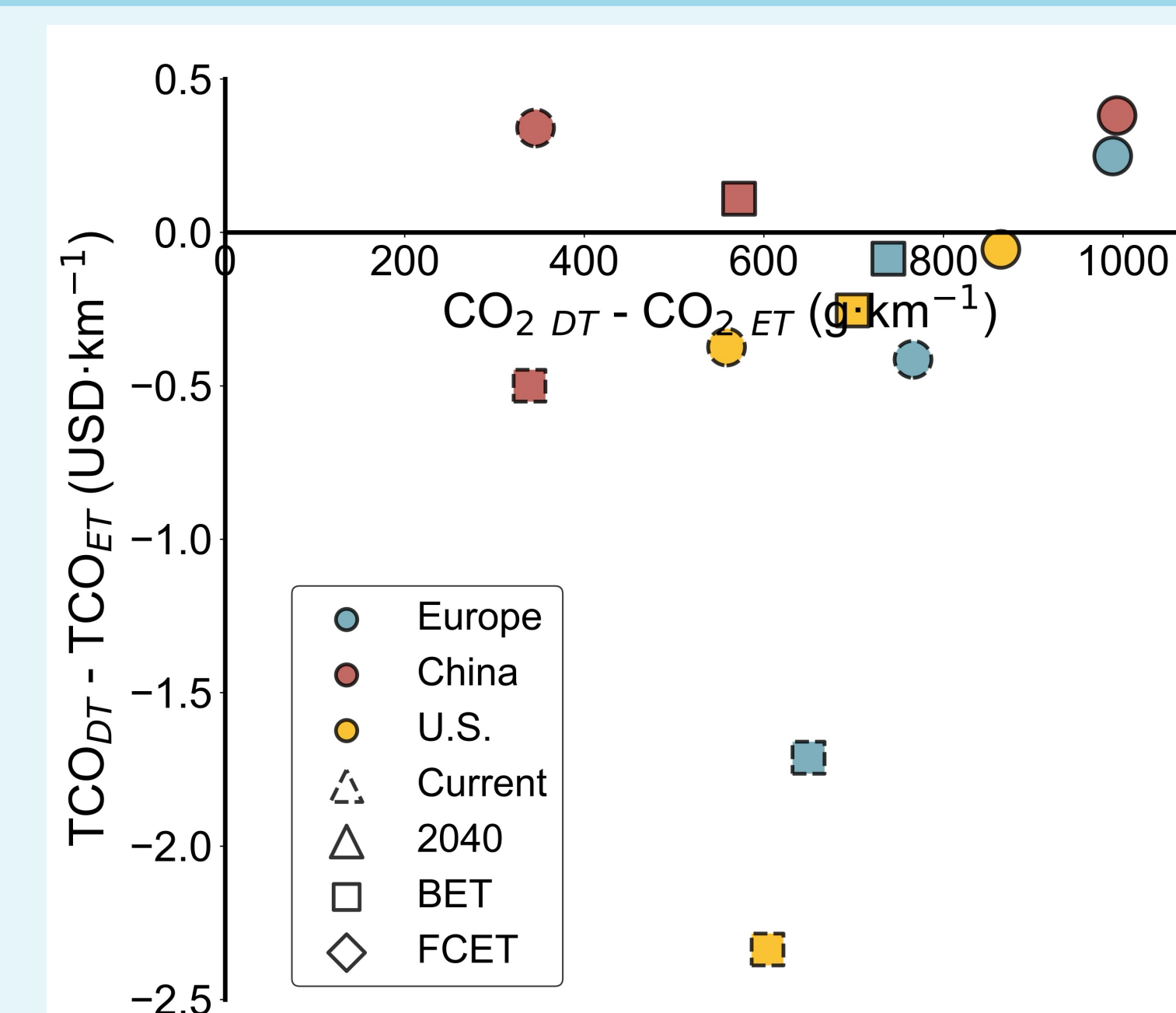


Figure 3. Carbon abatement cost in 2040 for heavy-duty tractor-trailers in China, the US and the EU

## Key Takeaways

- BETs are the most promising near-term pathway** for urban and regional freight, especially in China and Europe where cost competitiveness has been achieved.
- Improved battery density (220 Wh/kg)** could enable >70% of BETs to meet diesel truck mileage with one charge per day by 2040.
- FCET competitiveness depends on green H<sub>2</sub> availability.** As grids decarbonize, FCETs need renewable H<sub>2</sub> to match BET emissions. H<sub>2</sub> energy efficiency is 3-4x lower than direct electrification.
- BETs offer lower carbon abatement costs** than FCETs across China, Europe, and the US, both now and projected to 2040.
- Policy support is essential:** ZEV mandates, renewable fuel standards, financial incentives, and infrastructure planning are all needed to accelerate adoption.
- Fleet-tailored strategies** are required - no single technology satisfies all HDV applications across sectors and regions.