

Sustainable Transportation Energy Pathways (STEPS)

Prospects for Reducing Energy Use and GHGs from Freight Transport

Asilomar Conference
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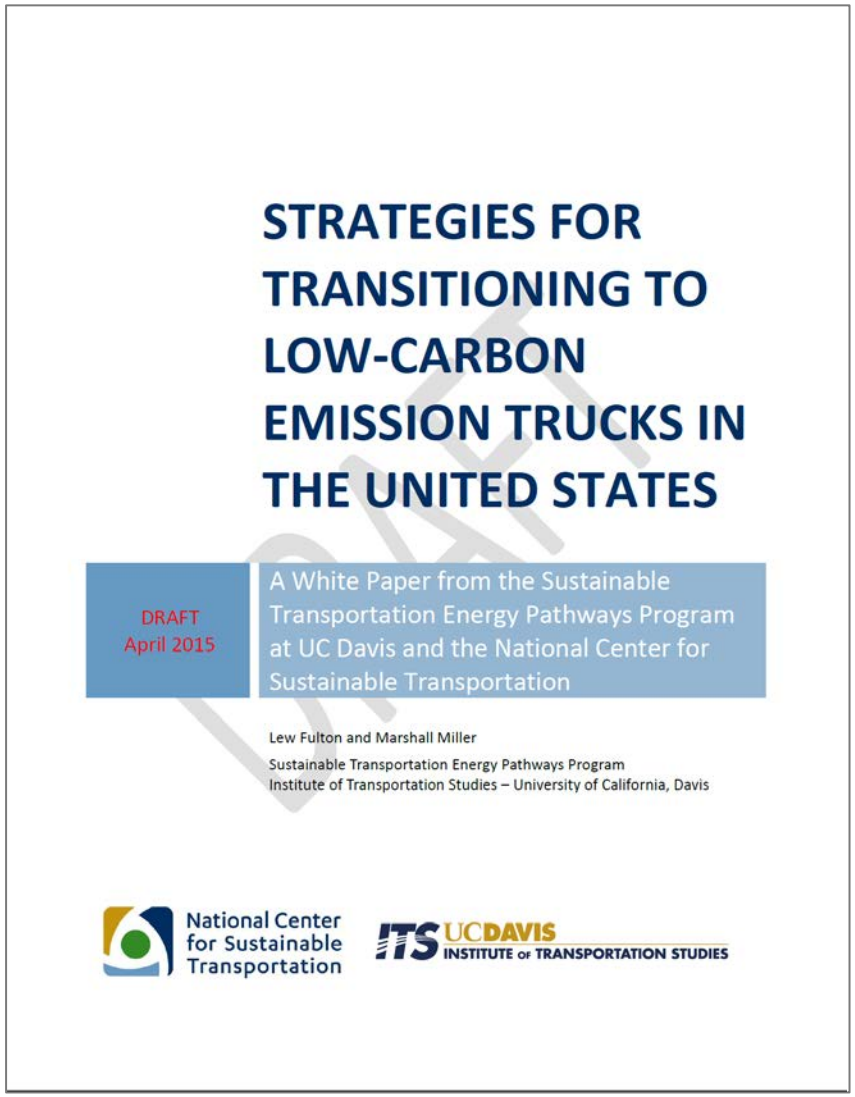
New STEPS Truck Reports 2015



STRATEGIES FOR TRANSITIONING TO LOW-CARBON EMISSION TRUCKS IN THE UNITED STATES

DRAFT
April 2015

A White Paper from the Sustainable Transportation Energy Pathways Program at UC Davis and the National Center for Sustainable Transportation

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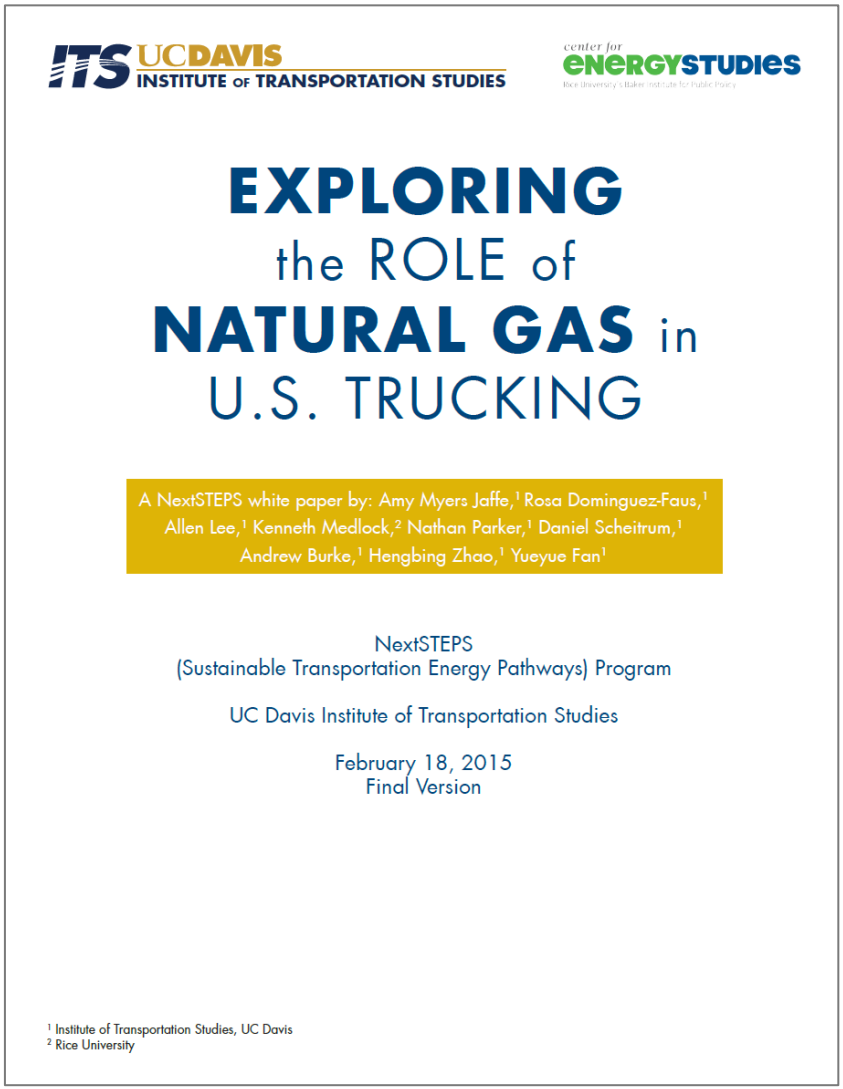

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EXPLORING the ROLE of NATURAL GAS in U.S. TRUCKING

A NextSTEPS white paper by: Amy Myers Jaffe,[1] Rosa Dominguez-Faus,[1] Allen Lee,[1] Kenneth Medlock,[2] Nathan Parker,[1] Daniel Scheitrum,[1] Andrew Burke,[1] Hengbing Zhao,[1] Yueyue Fan[1]

NextSTEPS
(Sustainable Transportation Energy Pathways) Program

UC Davis Institute of Transportation Studies

February 18, 2015
Final Version

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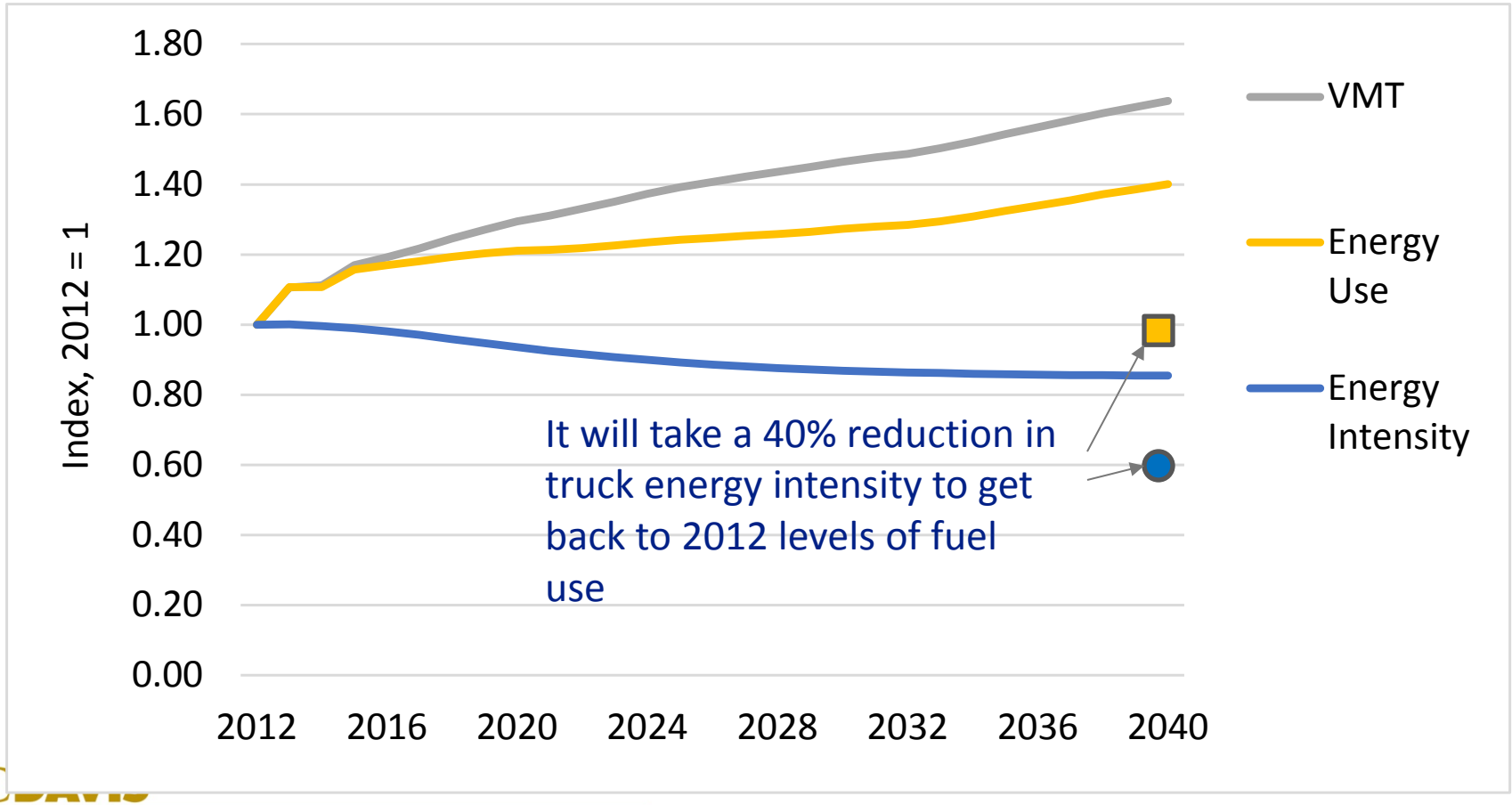
EIA AEO 2015: truck travel grows 60% to 2040

These suggest that with Phase I standards we get a flattening of energy use, but not a decline; Phase II might get us to 30-40% overall reduction in energy intensity and close to a return to 2012 levels of energy use.

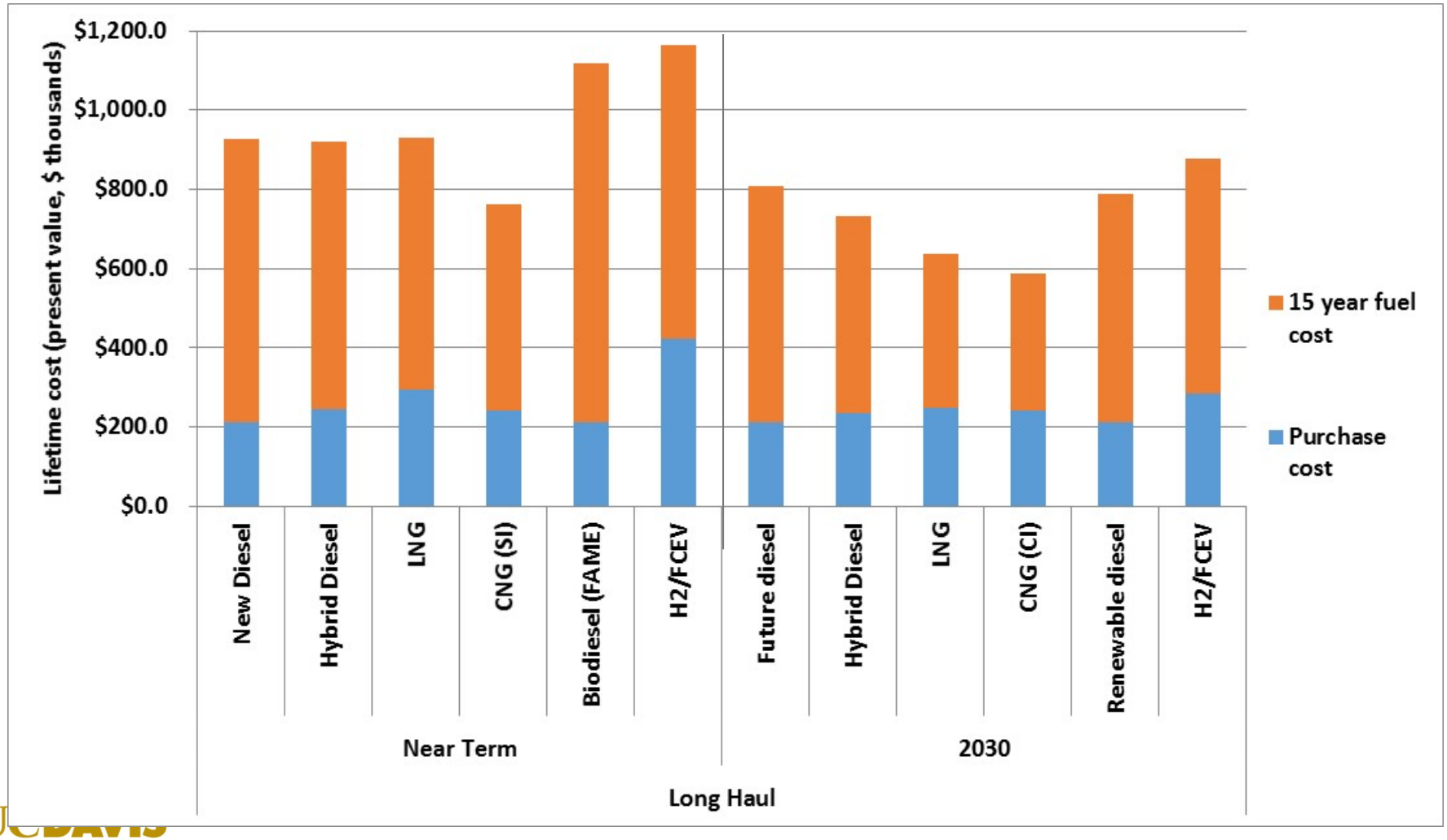


Large potential, but also major challenges with technology/fuel options

Vehicle Technology	Commercial status	Efficiency, Range, and Vehicle Cost	Barriers/issues
Conventional diesel/gasoline	Presently dominate all truck types	(baseline technology)	Relatively heavy emitters of GHGs
Hybrid, plug-in hybrid	Commercial in heavy-duty pickups and buses. Expected to play a significant role in all types	Increase in efficiency Increased range Increased cost	Reduce GHGs but reductions are modest compared to fuel cell and electric
LNG/CNG	Commercial in almost all types. Significant market in buses, MD urban.	SI NG engines have lower efficiency, Likely decrease in range Increase in first cost	At best, small GHGs benefit except with RNG. Infrastructure immature
Fuel cell	Extensively tested in buses and cars. Timeline for commercialization in other vehicle types could be 10-20 years	Large increase in efficiency Decreased range Increase in cost	Hydrogen infrastructure lacking. Fuel cell durability/life span is a concern
Battery electric	Near commercial in some applications, mainly medium duty urban	Large increase in efficiency, but large decrease in range Currently high cost	Vehicles with significant annual mileage may not be able to adopt. Battery life an issue

Long-haul truck lifecycle costs: near term and long term

- Using a societal cost approach, fuel costs dominate
- Natural gas competitive, Biodiesel and H2 FCEVs less so



Abundant natural gas is changing the economics and creating opportunities in the medium/heavy duty trucking sectors, but…

- **STEPS (Jaffe et al, 2015) study finds that natural gas fuel cost advantage (over petroleum) is not sufficient to launch a national network for long-haul trucking in US**

- Likely would need support to get well over 1% long-haul truck share to have a chance to sustain the market.

- Barriers to development for LNG national fueling network include high station network costs and high cost/emissions issues of CI NG engines.

- Heavy traffic, high volume markets such as California and the U.S. Great Lakes region would be easiest location to overcome chicken egg barriers.

Major players are reassessing market potential; policy context may be critical aspect to launch of successful US national network.

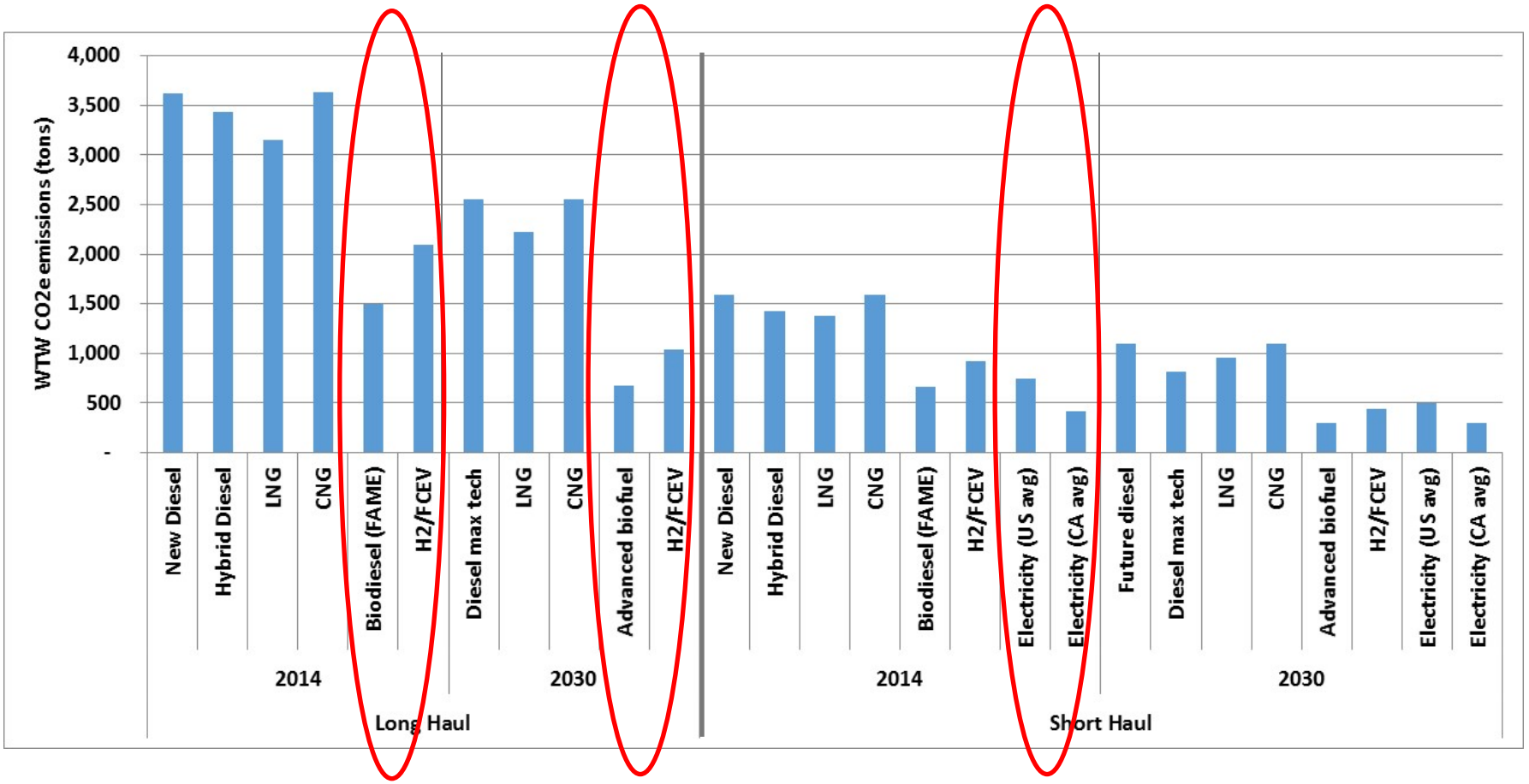
Our WP - fuel requirements and assumptions

- By 2030, much lower GHG feedstock production/fuel supply pathways would need to be well on their way to replacing current higher GHG pathways, with >80% reductions per unit of fuel by 2050
- California has a significantly cleaner grid than the US average, so has a "head start" for both electricity and hydrogen decarbonization

	2014	2030	2050
Hydrogen	100% from natural gas reforming	50% from NG, 50% from electrolysis from grid electricity	100% from very low carbon electricity
Electricity	Average grid mix	Average grid mix, significantly decarbonized	Grid must be almost completely decarbonized
Biofuel	Mostly soy-based biodiesel	Renewable diesel, 50% from cellulosic pathways	100% very low GHG renewable diesel

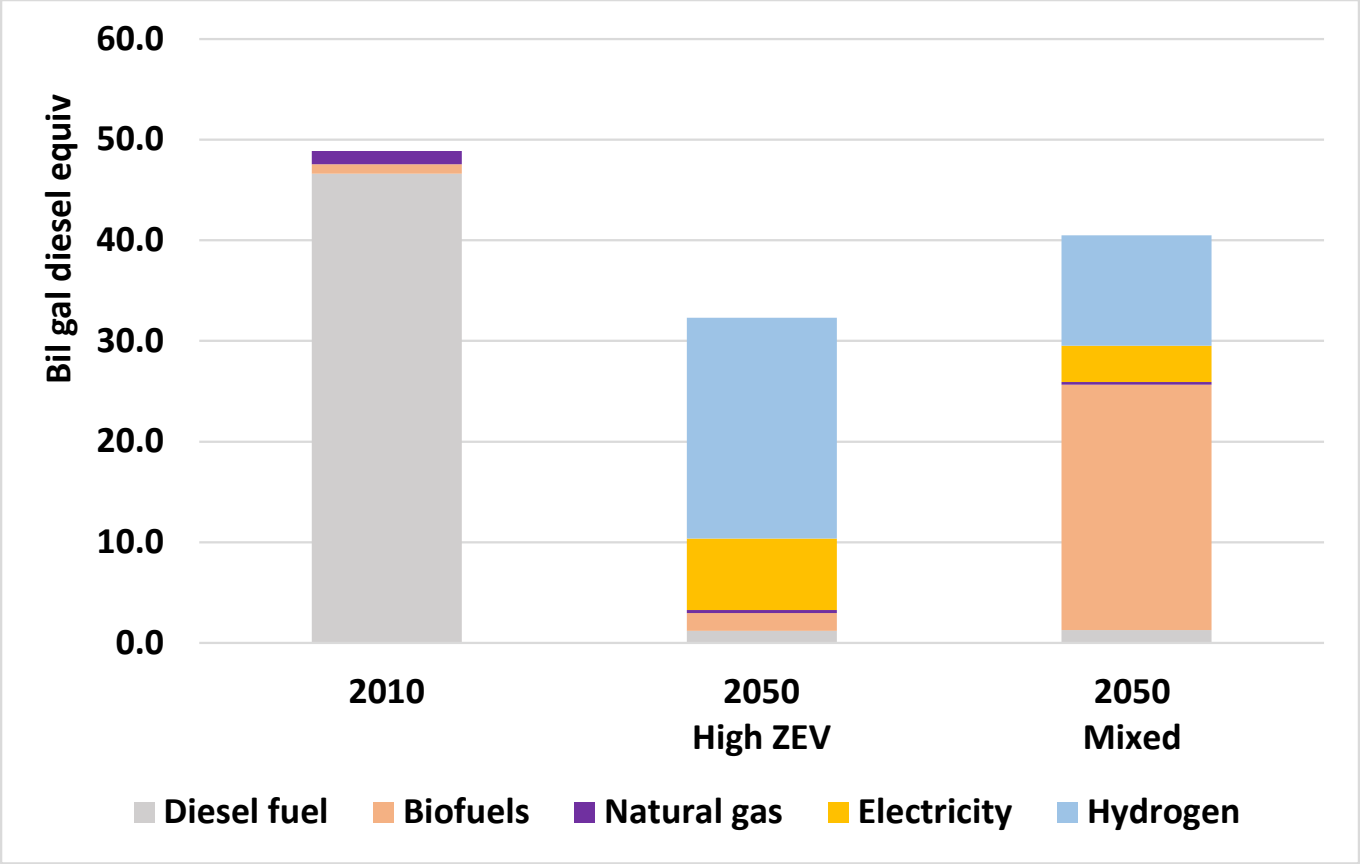
With those assumptions, CO2 reduced dramatically in 2030 (or post 2030) time frame

- Advanced biodiesel, H2/FCEV and Electricity reach very low levels



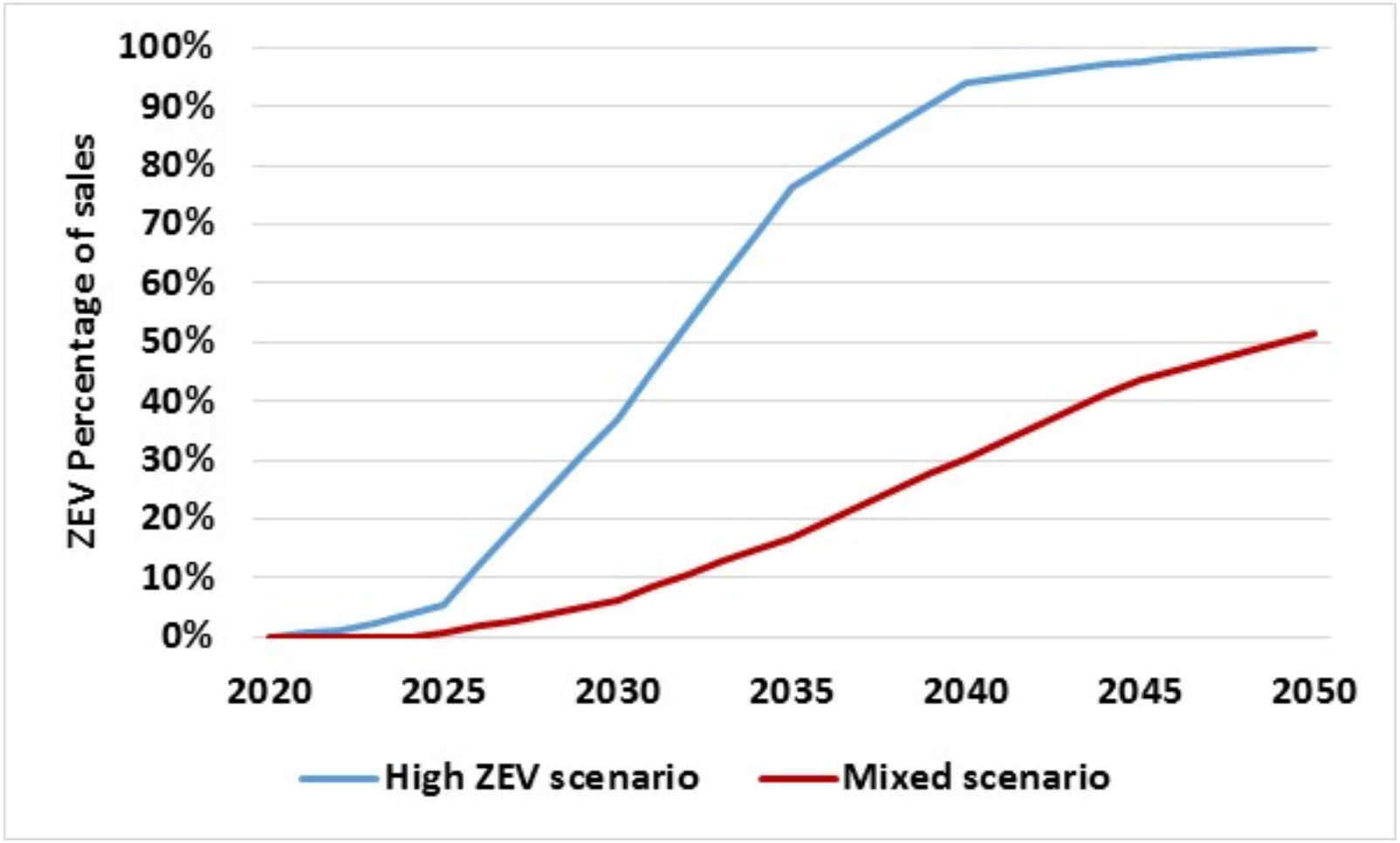
Here are two ways to achieve an 80% reduction by 2050 in GHG in trucking...both are very challenging

- Mixed case would require a doubling of current US biofuels use for all purposes and must provide at least 80% reductions in GHG compared to base fuel
- Hydrogen use in the ZEV case would be about twice U.S. production for all purposes and must be deeply decarbonized, e.g. from "waste" wind/solar power



ZEV scenario sales must ramp up very quickly after 2025…

Slower ramp up needed in Mixed case (along with biofuels ramp-up), or for a substantially lower GHG reduction target (e.g. 50% rather than 80%)



Conclusions and Policy Considerations

- National and CA efficiency/GHG standards will hopefully help offset truck travel growth to keep CO2 stable
- If we don't have large quantities of very low net GHG biofuels, we will need large numbers of ZEV trucks
  - In CA, given air quality standards, ZEVs may be needed anyway
- This probably means fuel cell trucks, at least for long haul
- The ramp up for these trucks would need to be dramatic for an 80% scenario in 2050, and would need to start soon.
  - Lower percentage targets may be needed.
- Either strong fiscal incentives or something like a ZEV mandate for trucks might be needed to get us on this path.