OAK RIDGE National Laboratory

Smoky Mountains Mobility Conference

Low lifecycle carbon fuels for hard-to-electrify transportation sectors

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U.S. DEPARTMENT OF ENERGY

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FOR THE US DEPARTMENT OF ENERGY

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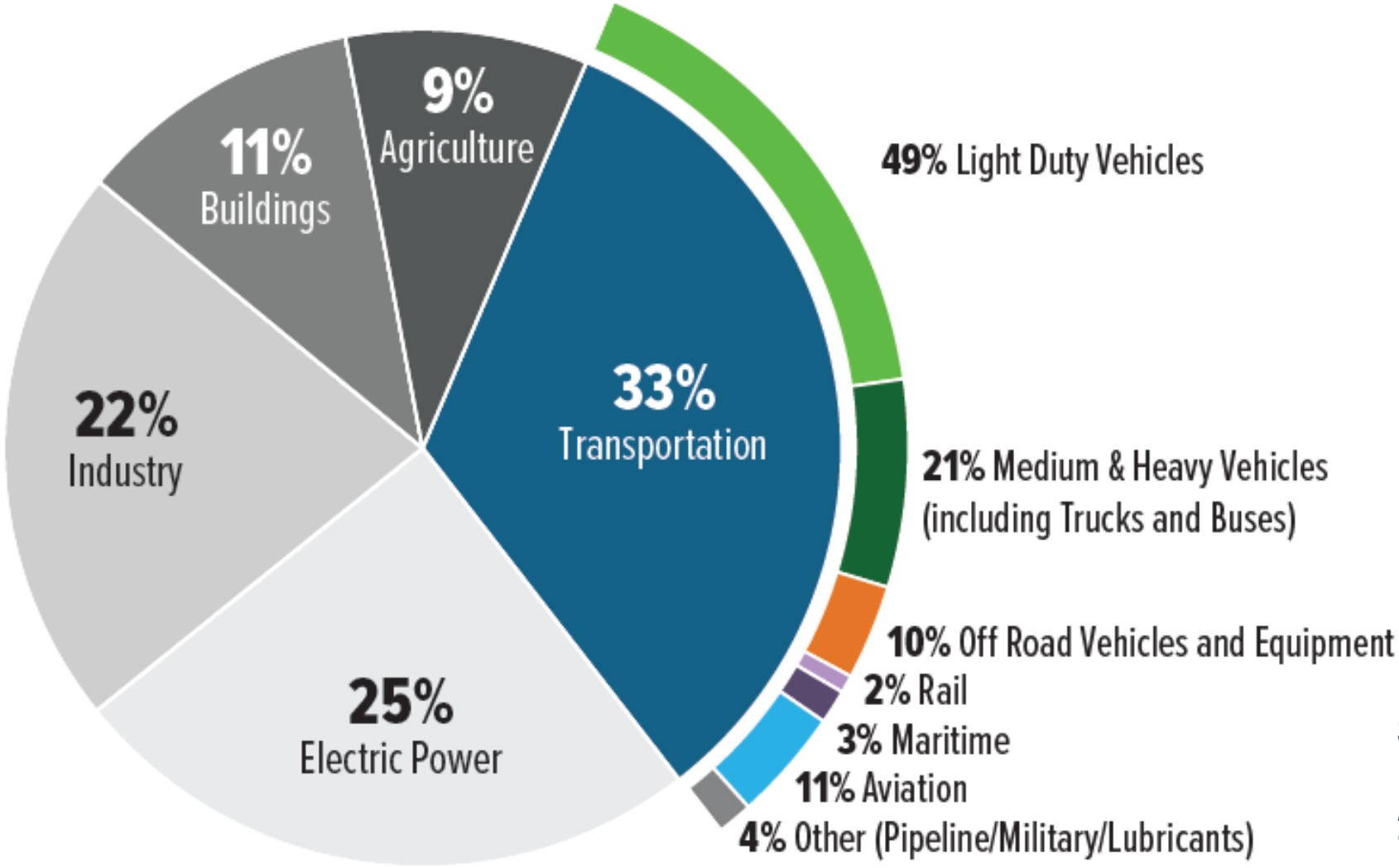
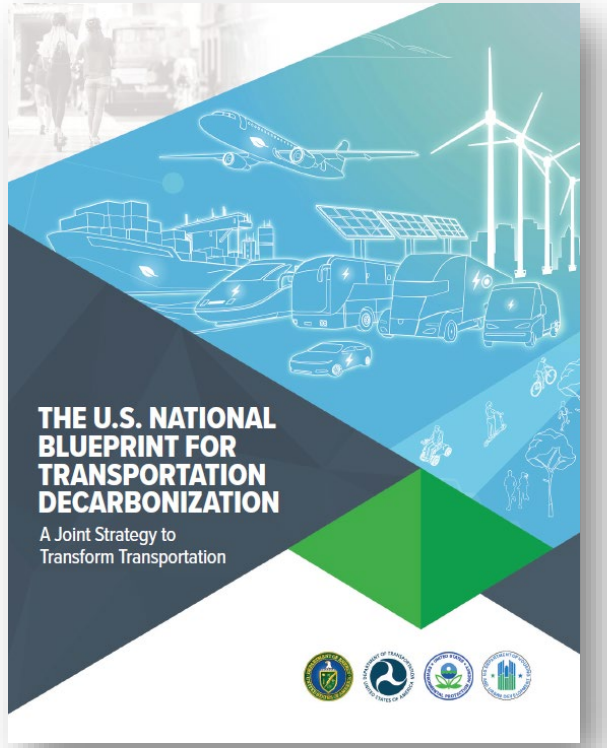
Feedback: Jim Szybist, Scott Curran, Todd Toops

Non-road transportation responsible for ~9% of total US GHG emissions

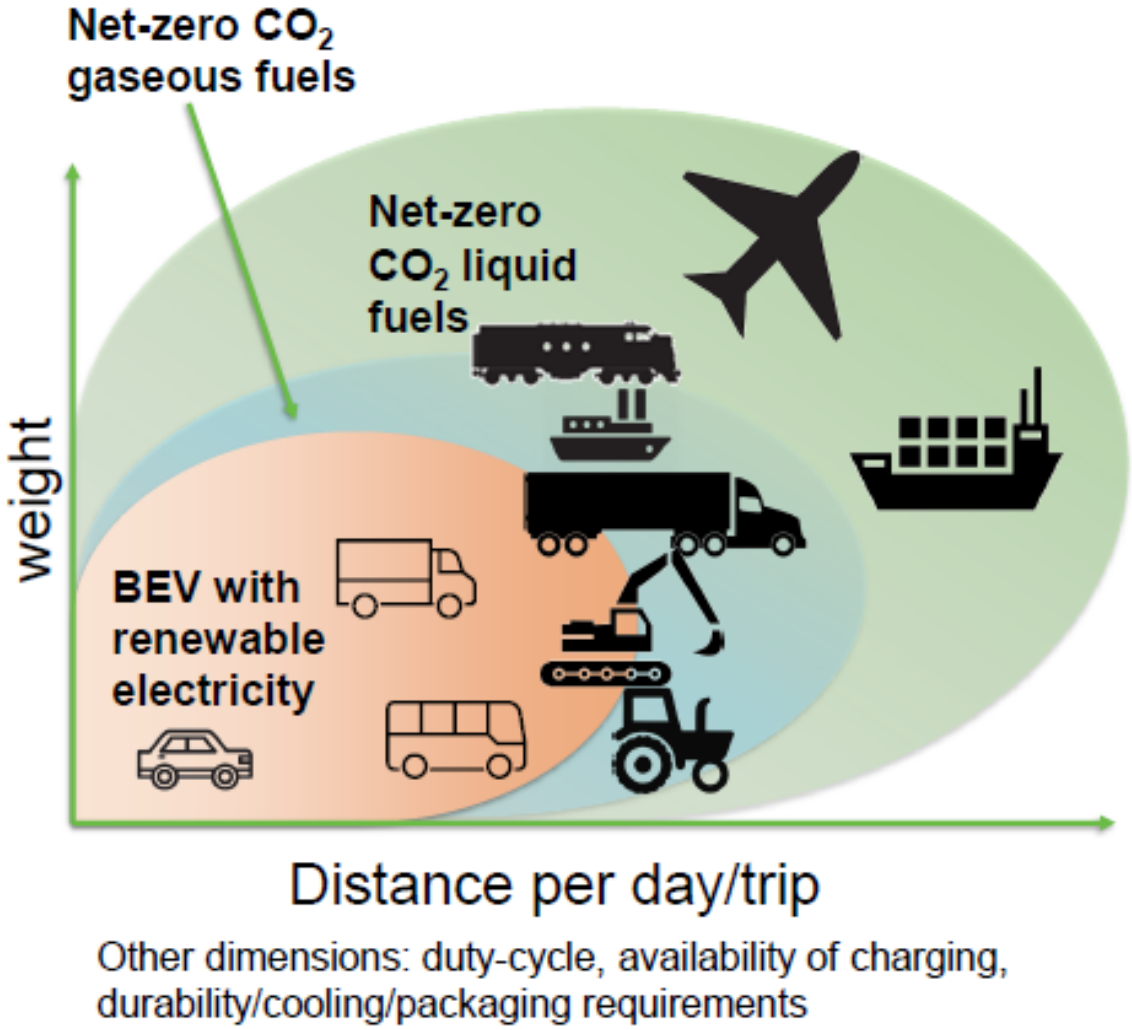




Share expected to grow due to:
1. electrification of other sectors
2. mode-shifting

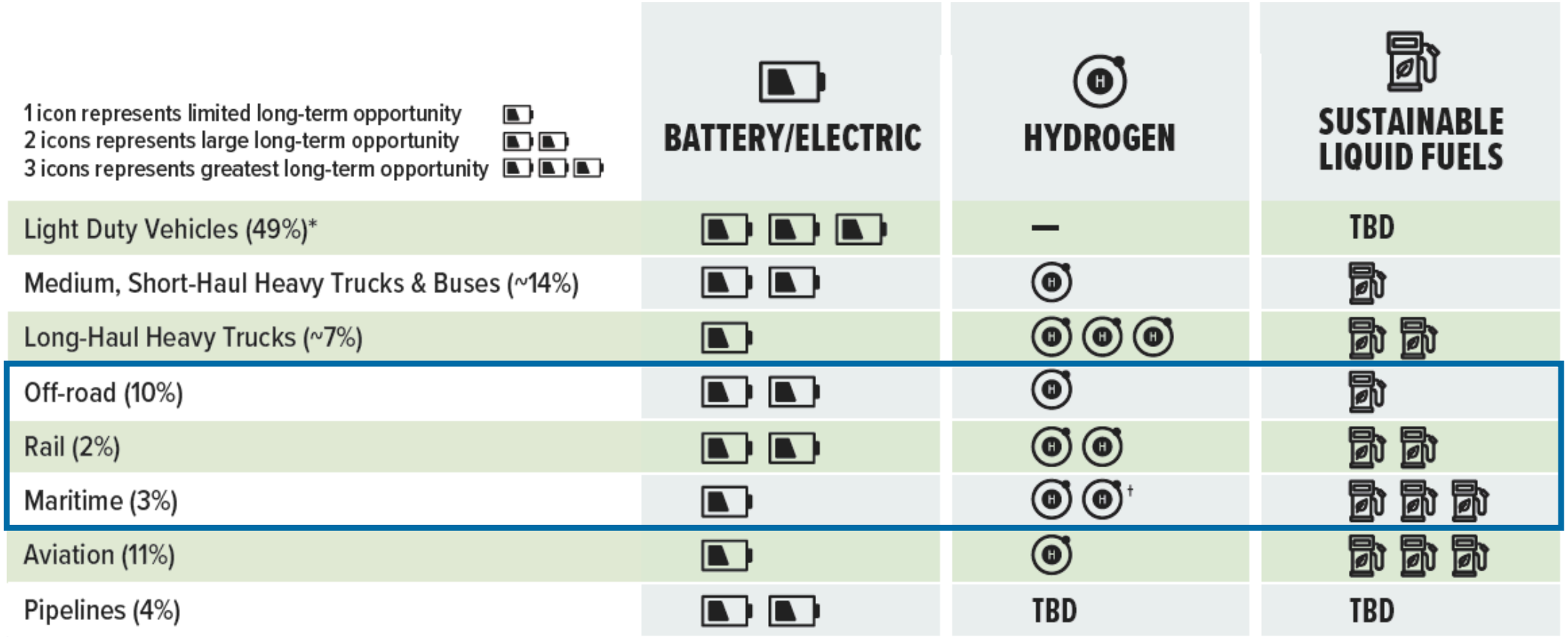
From the U.S. National Blueprint for Transportation Decarbonization
https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf

Non-road sectors are “hard-to-electrify” due to load, range, remote locations, and other application requirements



M. Weismiller, “Decarbonization of Hard to Electrify Vehicles,” presentation to ASME ICEF 2021

U.S. National Blueprint for Transportation Decarbonization envisions a mix of electrification, hydrogen and sustainable liquid fuels for non-road sectors



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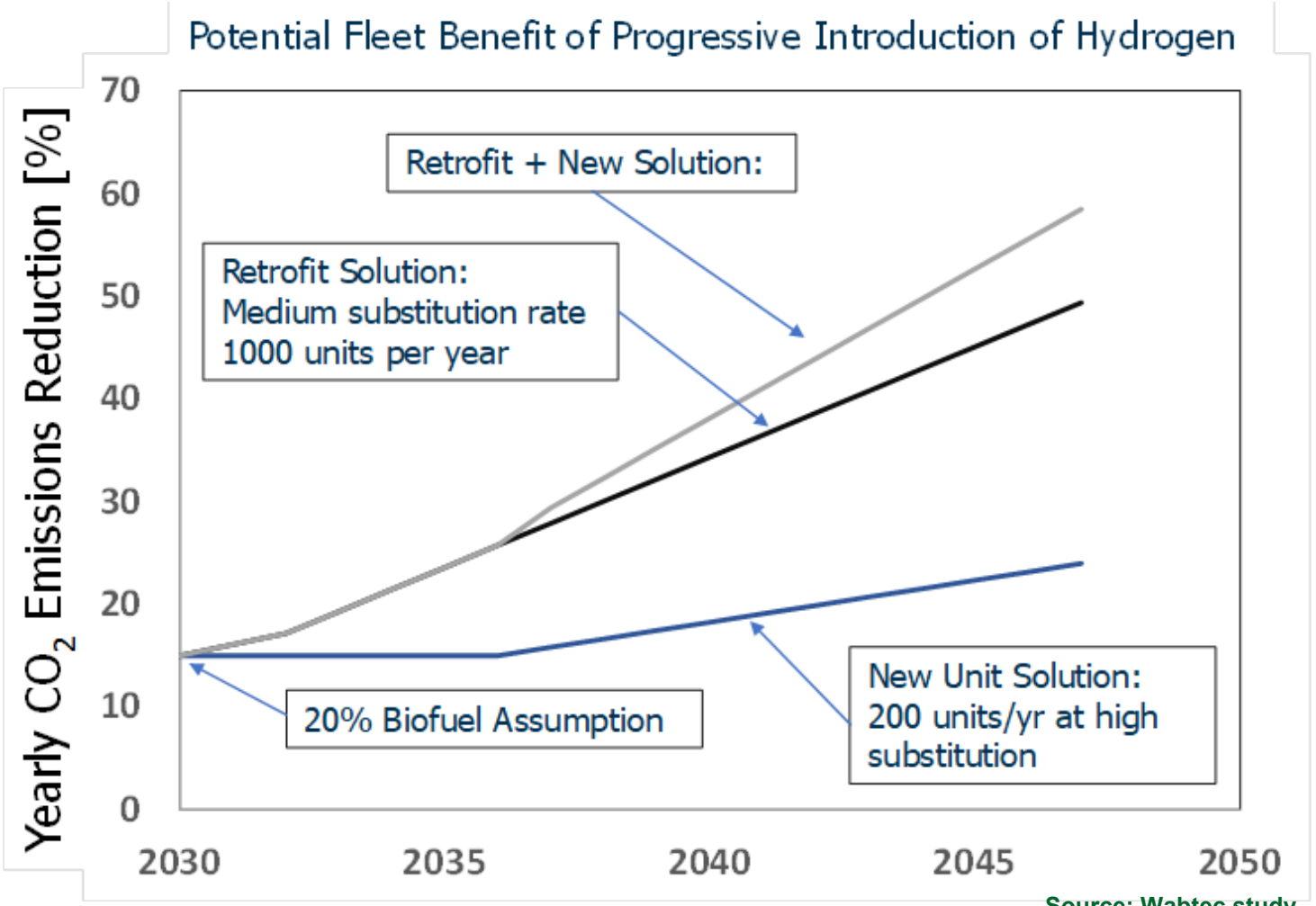
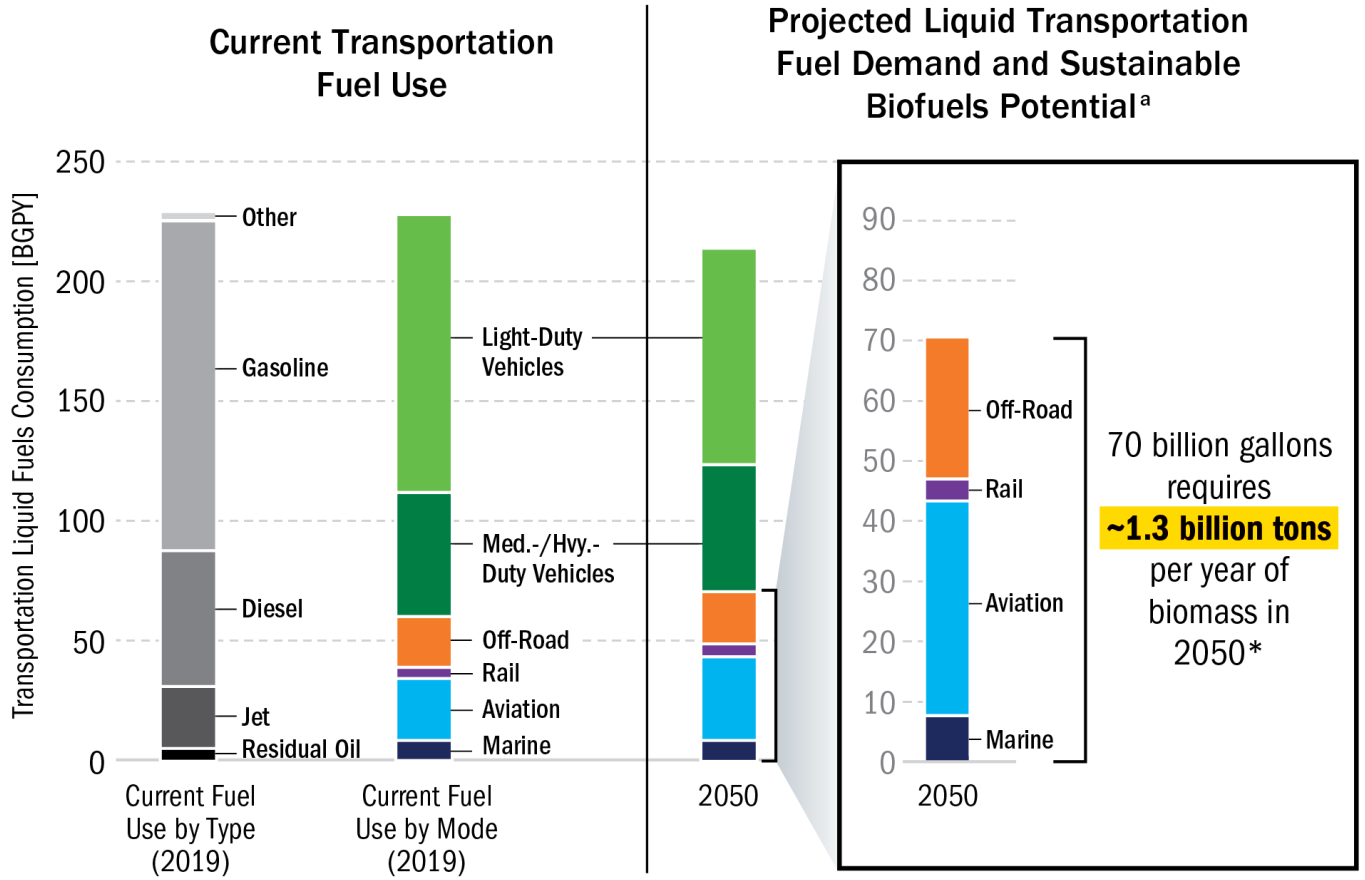
Many non-road vehicles have 30+ year lifetimes, driving the need for diesel engine retrofit solutions to achieve substantial near-term GHG reductions



Source: Wabtec study

K.D. Edwards et al., "Implementing low lifecycle carbon fuels on locomotive engines – CRADA with Wabtec," presentation to 2024 DOE Vehicle Technologies Office Annual Merit Review

DOE estimates that US fuel consumption in the off-road, rail, marine, and aviation sectors could require 1.3 billion tons of biomass in 2050 (excluding on-road)



[a] The Base case and Expanded scenario bars above are reported on a GGE basis

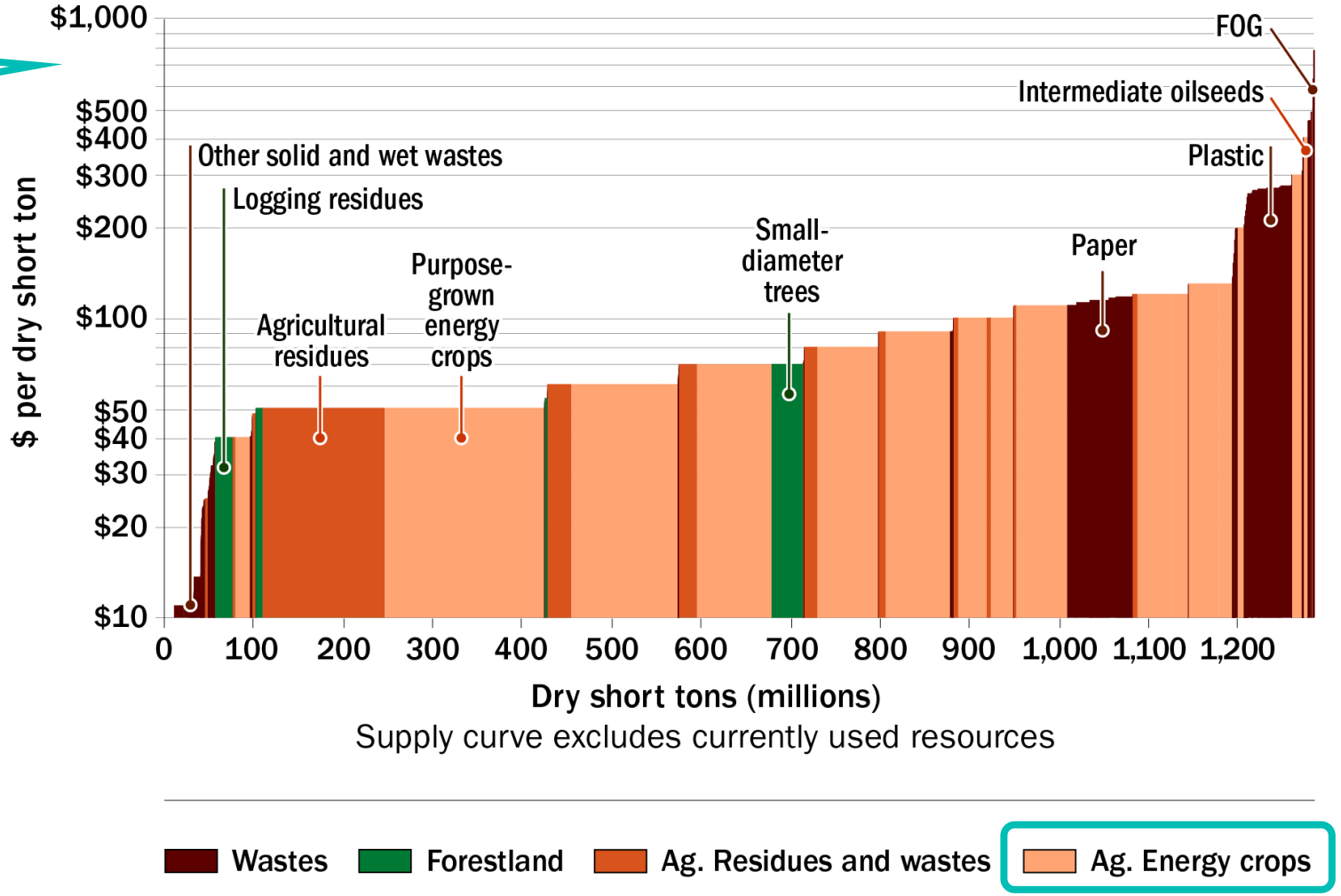
* Assumes a conversion rate of 55 gallons per ton

2023 Billion-Ton Report. M. H. Langholtz (Lead). Oak Ridge, TN: Oak Ridge National Laboratory. doi: 10.23720/BT2023/2316166

ORNL estimates 1.1–1.5 billion tons of biomass available in the US in a mature market, but costs increase significantly at higher utilization

log scale

biomass cost (excludes processing)



2023 Billion-Ton Report. M. H. Langholtz (Lead). Oak Ridge, TN: Oak Ridge National Laboratory. doi: 10.23720/BT2023/2316166

Industry is looking at other low lifecycle carbon fuels to meet decarbonization goals in the hard-to-electrify sectors

Hydrogen	Ammonia	Methanol	Biodiesel
H_2	NH_3	CH_3OH	$CH_3 (CH_2)_{\sim 14} COOCH_3$
zero carbon	zero carbon	low lifecycle carbon (from biomass, renewable NG, CO_2)	low lifecycle carbon
4x diesel vol (as liquid) 7x diesel vol (as gas)	3x diesel vol	2x diesel vol	1.1x diesel vol
pre-ignition knock	hard to ignite low flame speed high HOV toxic	hard to ignite high HOV	no significant combustion challenges
NOx	NH_3, NOx, N_2O	HCs (CH_2O?)	NOx?
			

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ORNL has several ongoing DOE and DOT funded projects on solving challenges for using H_2, NH_3, and CH_3OH in diesel engines for non-road applications

Fuel	**Hydrogen**
Partners	CRADA with Wabtec
Funding	DOE VTO, DOT FRA
Approach	diesel pilot CI
Targets	100% diesel compatible >50% H_2 for retrofits >90% H_2 for new engines

CRADA: cooperative research and development agreement; CI: compression ignition; SI: spark ignition; DME: dimethyl ether

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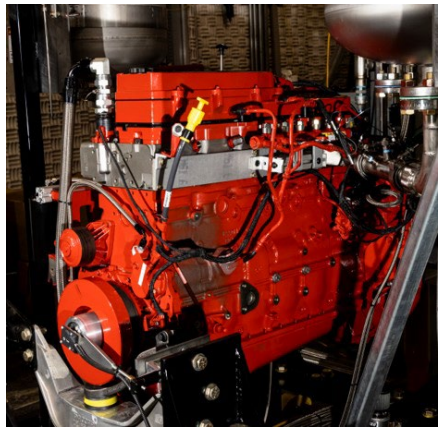

Fuel	Hydrogen	Ammonia
Partners	CRADA with Wabtec	Cummins
Funding	DOE VTO, DOT FRA	DOE VTO, DOT MARAD
Approach	diesel pilot CI	diesel pilot CI H_2-assisted CI (onboard NH_3 to H_2) SI
Targets	100% diesel compatible >50% H_2 for retrofits >90% H_2 for new engines	Maximize NH_3 utilization while minimizing NH_3, NOx, and N_2O emissions

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Approach	diesel pilot CI	diesel pilot CI H_2-assisted CI (onboard NH_3 to H_2) SI	diesel pilot CI DME-assisted CI (onboard CH_3OH to DME) prechamber SI
Targets	100% diesel compatible >50% H_2 for retrofits >90% H_2 for new engines	Maximize NH_3 utilization while minimizing NH_3, NOx, and N_2O emissions	Maintain engine performance while running on 100% methanol

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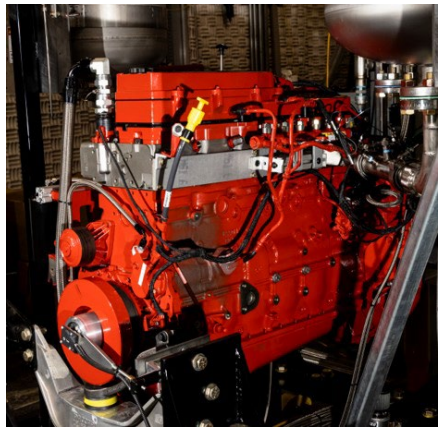

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