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Implications of Sustainability for the United States Light-Duty Transportation Sector

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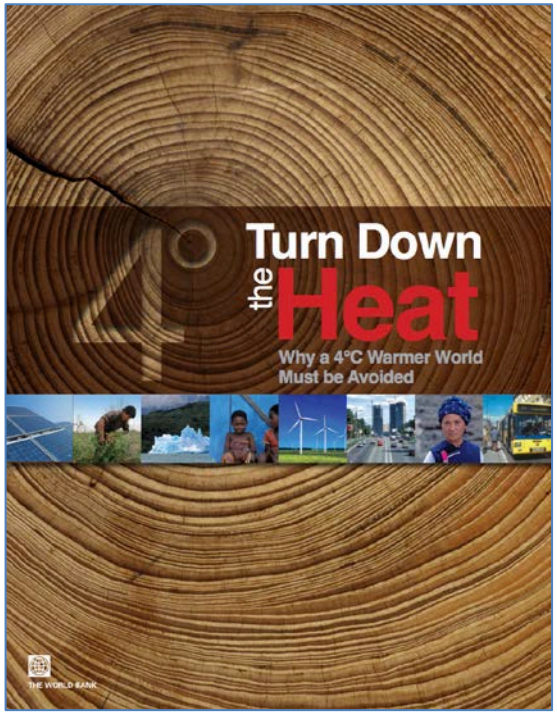
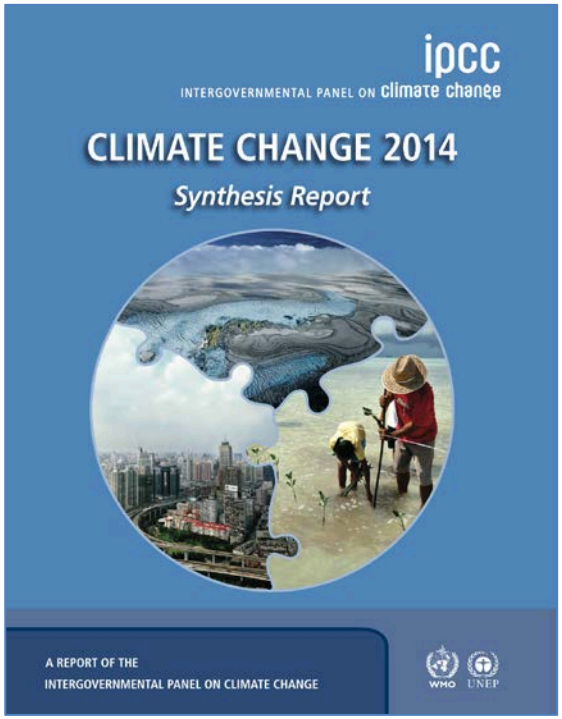
2017 TRB Annual Meeting
Alternative Fuel and Advanced Technology Vehicles Workshop
Washington, D.C.
January 12, 2017

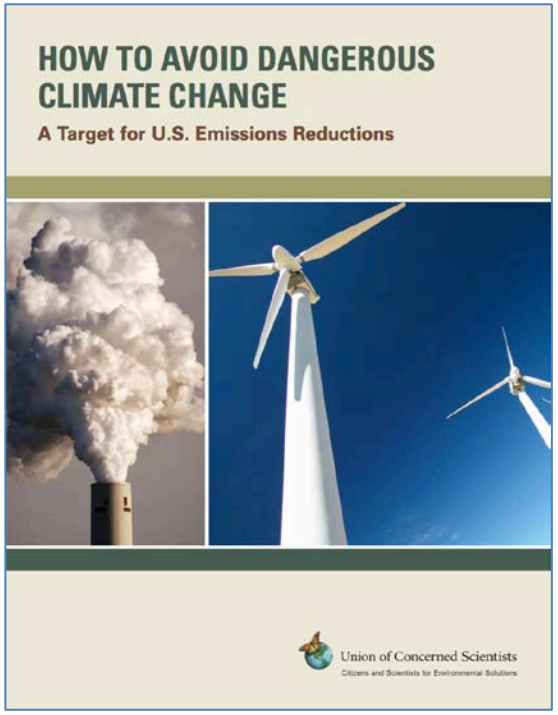
NREL/PR-5400-67768

The Science is settled

We have to reduce CO_2 emissions.

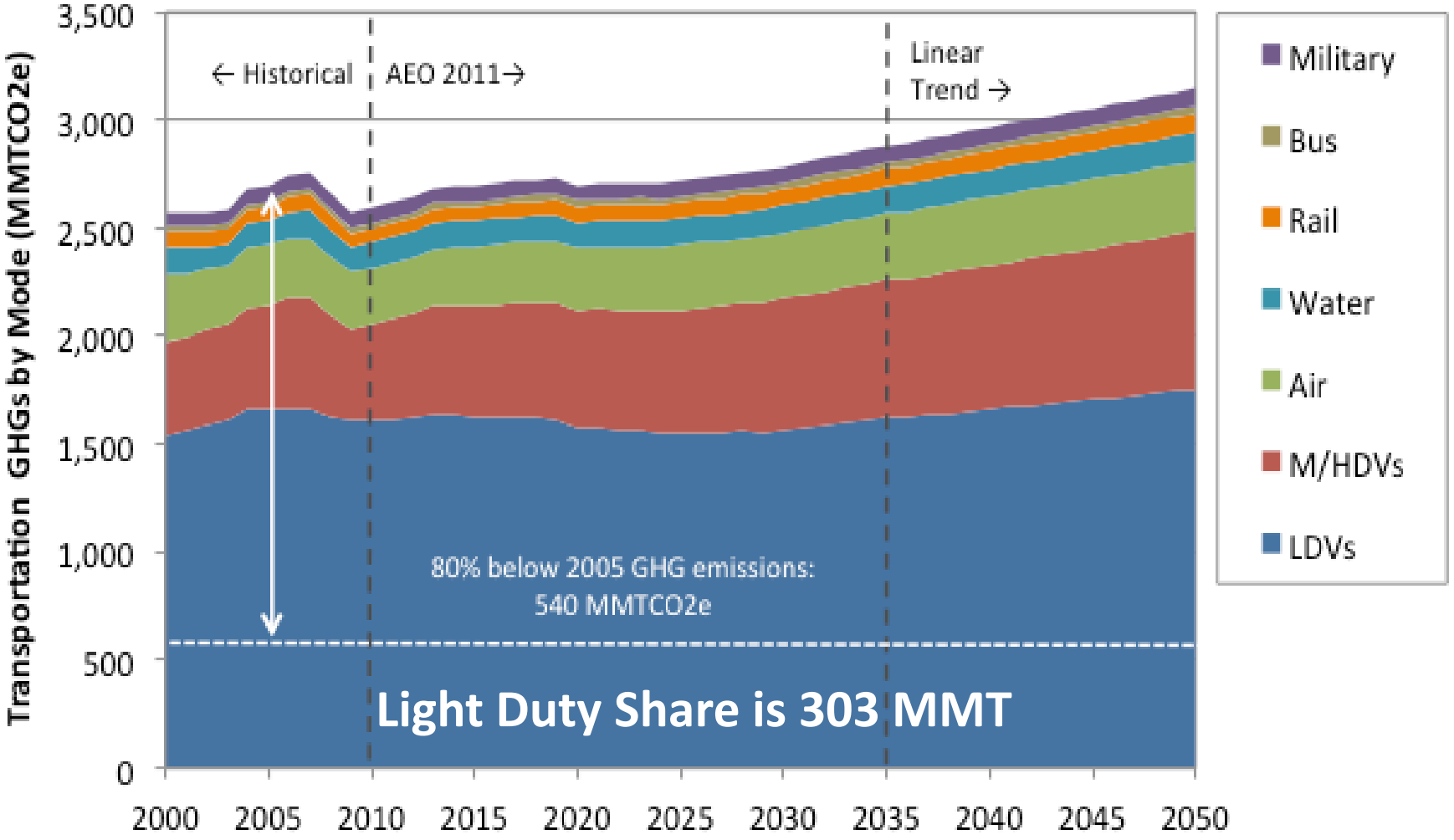






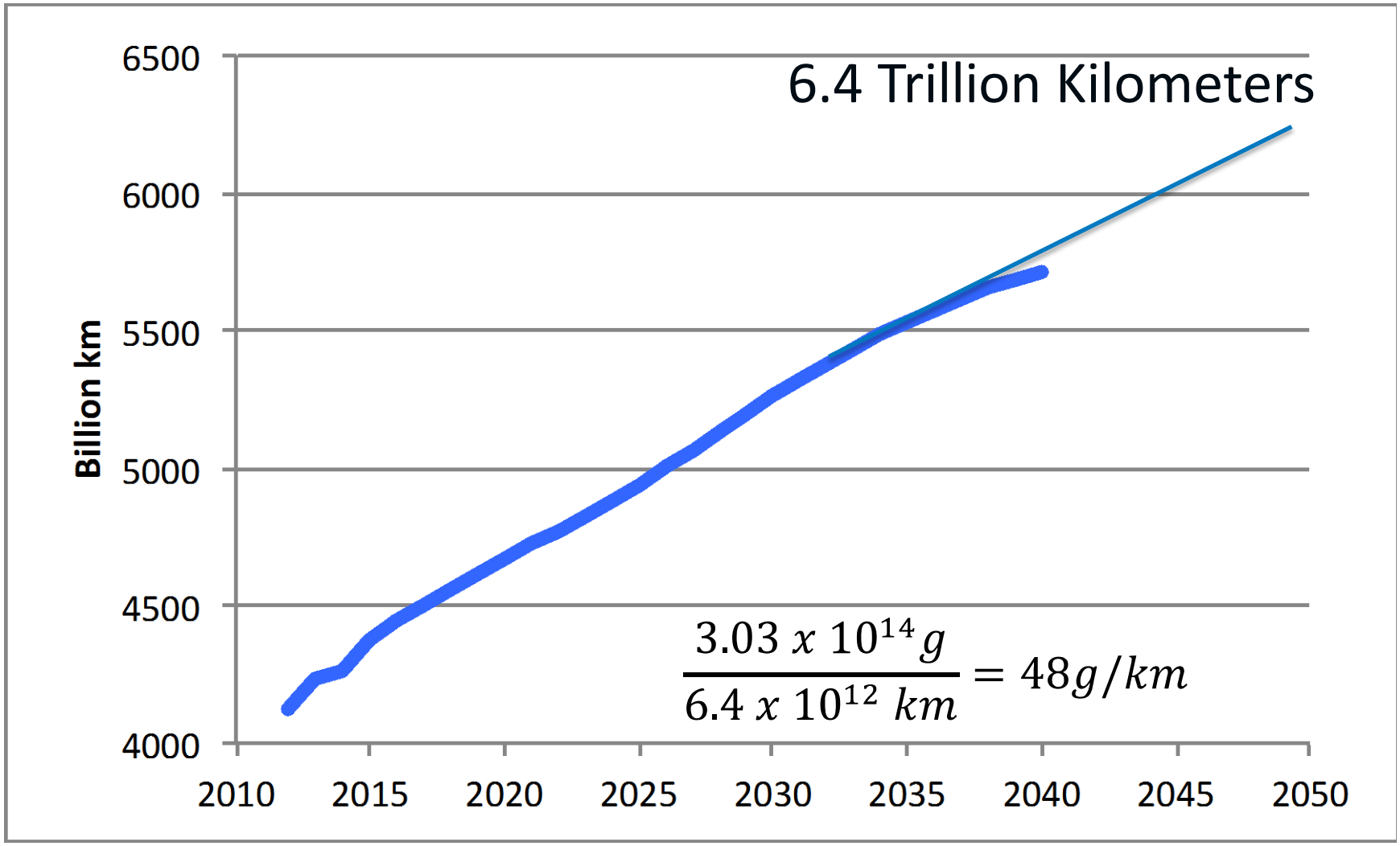
At least 80% in by 2050

Transportation GHG Emissions



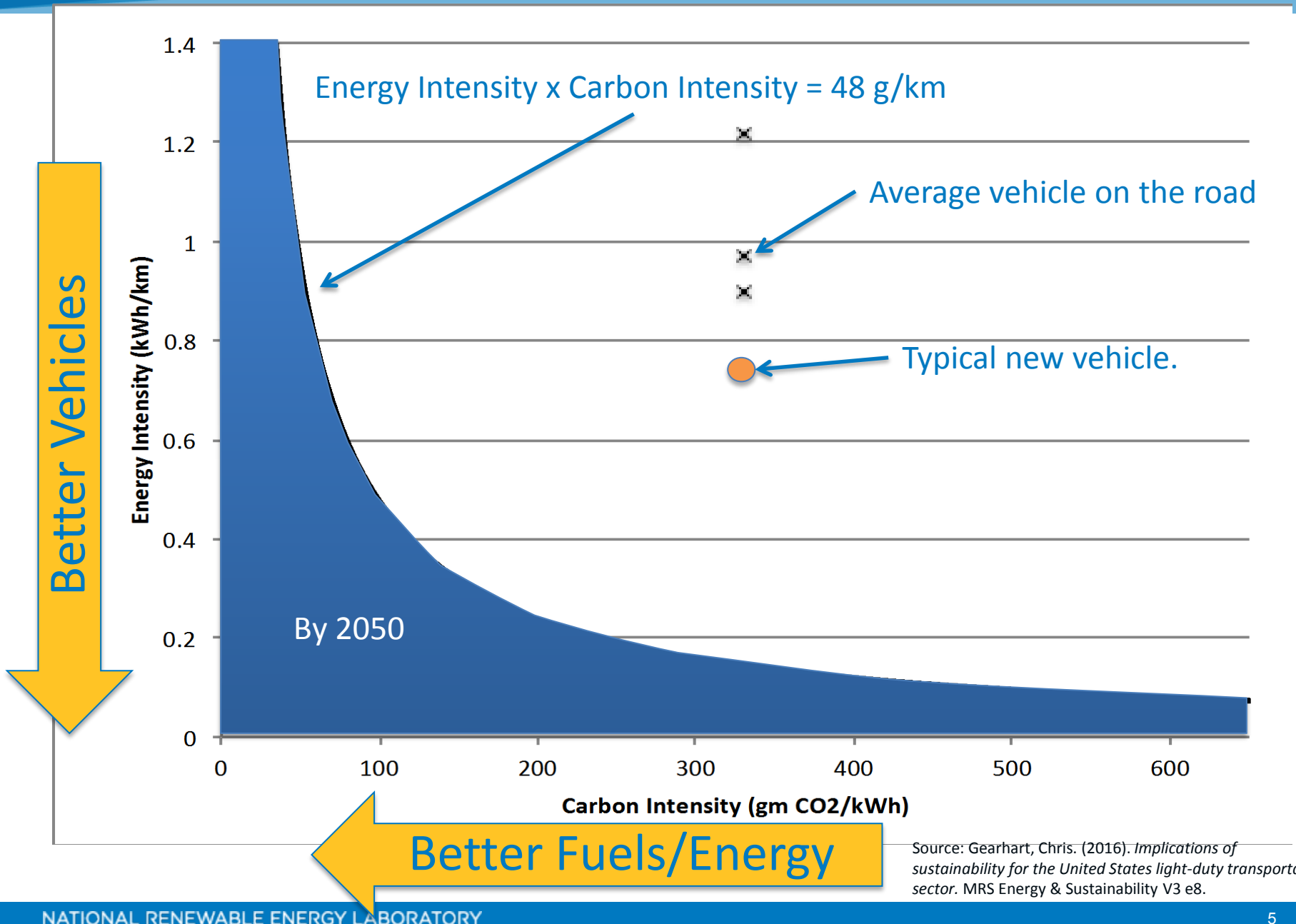
Source: Melaina, M.W.; Heath, G.; Sandor, D.; Steward, D.; Vimmerstedt, L.; Warner, E.; Webster, K.W. (2013). *Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity, and Retail Availability for Low-Carbon Scenarios.* Transportation Energy Futures Series.

Projected driving distance



AEO 2015 projection out to 2040. Linear extrapolation out to 2050

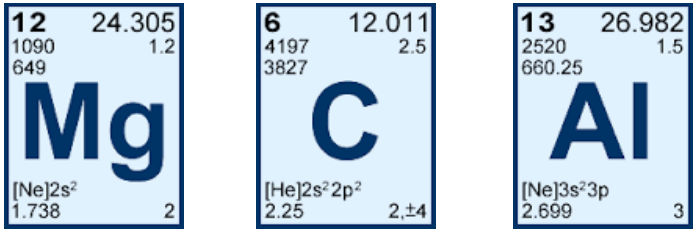
What does sustainable transportation mean?

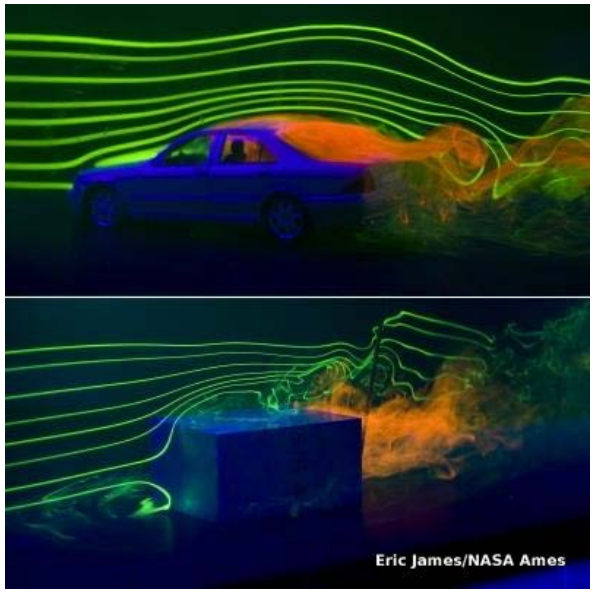


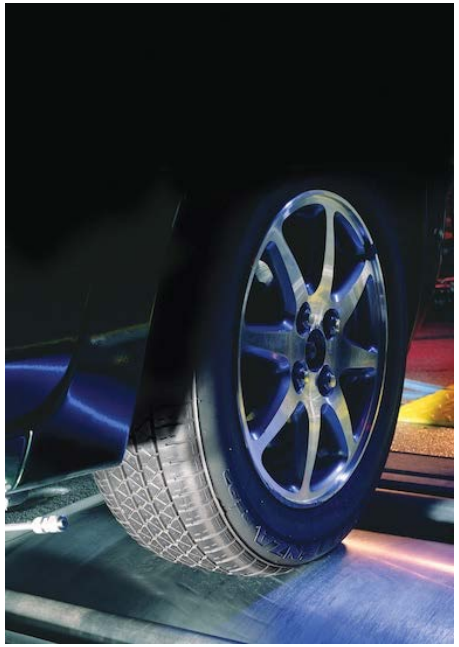
Source: Gearhart, Chris. (2016). *Implications of sustainability for the United States light-duty transportation sector.* MRS Energy & Sustainability V3 e8.

Improvements that help all powertrains

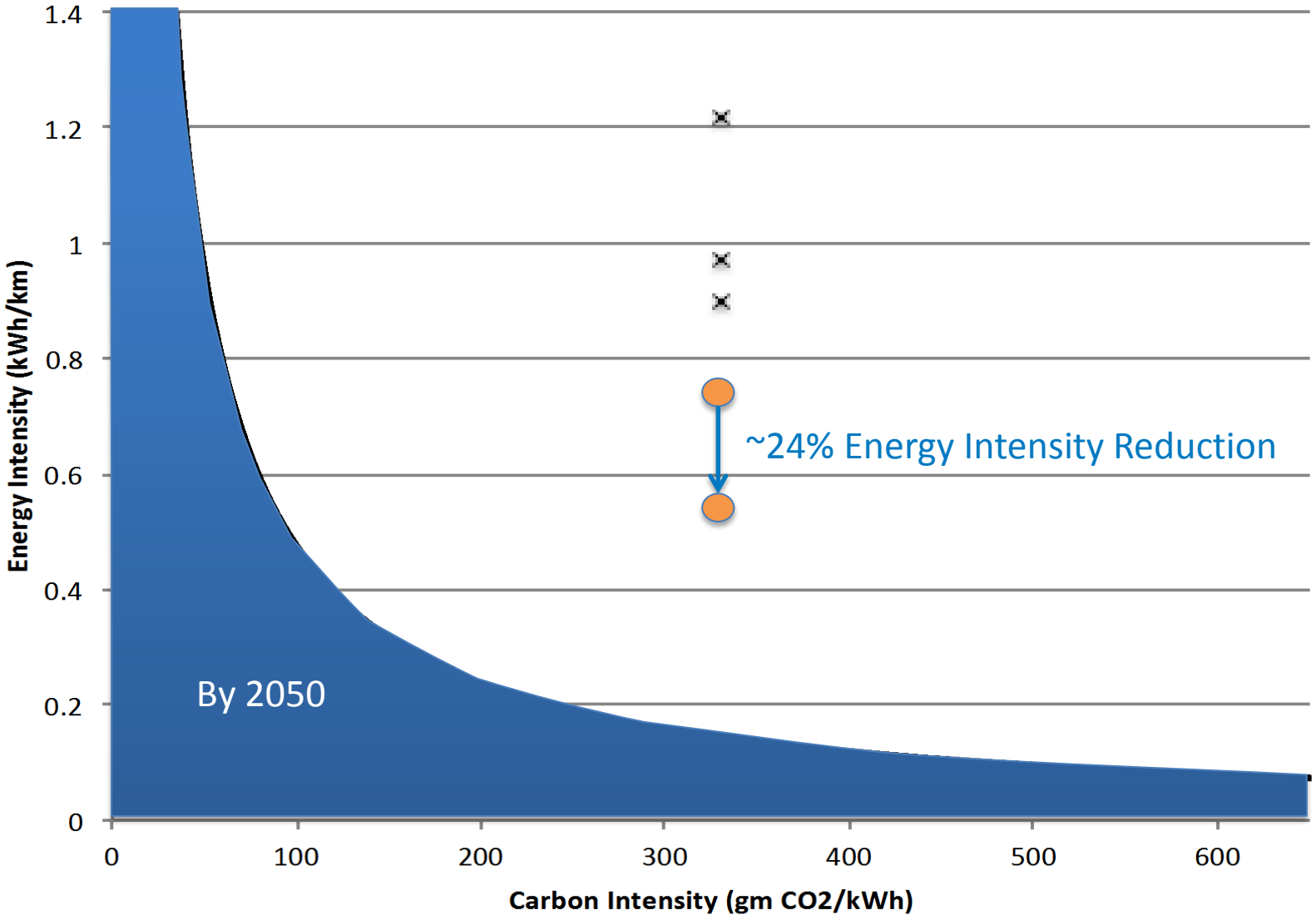
- Light weight materials (20%)
- Aerodynamic Drag (20%)
- Rolling Resistance (16%)
- Reduced Auxiliary Loads (21%)







Improvements that help all powertrains



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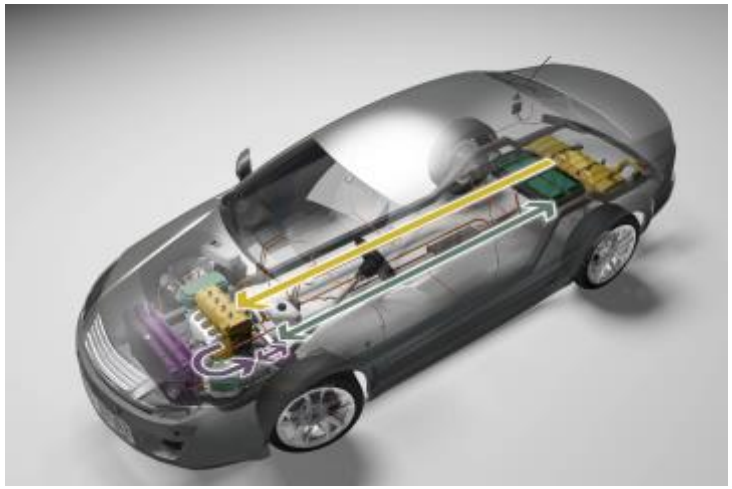
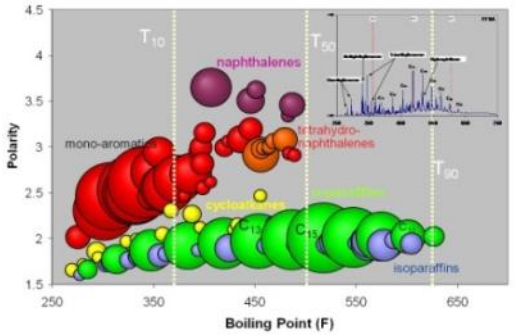
Internal Combustion Engine and Drive Line Improvements

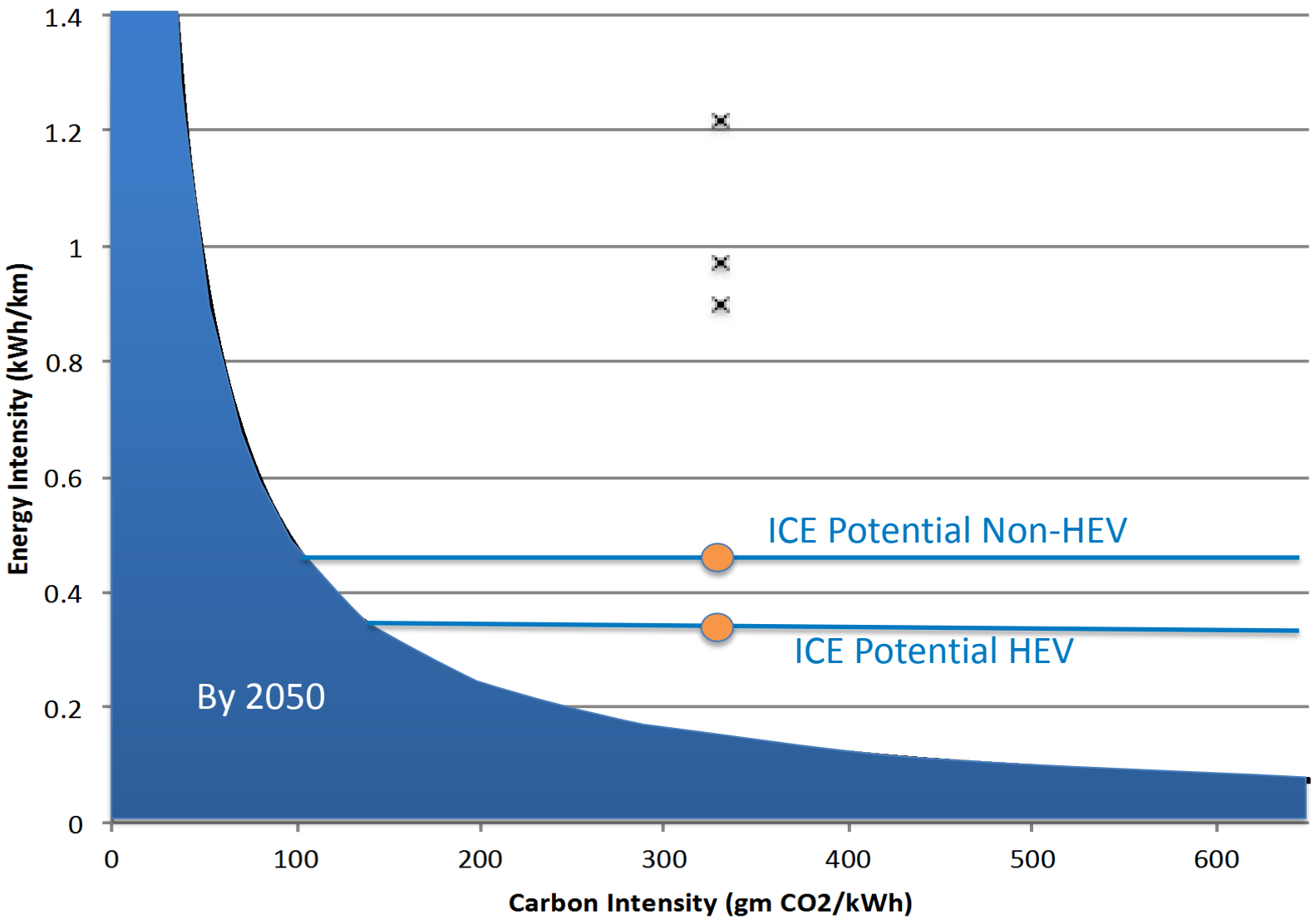
- Reduce pumping losses
- Reduce friction
- Increase thermal efficiency
- More efficient transmissions
- Full Hybridization
  - More efficient engine operation
  - Down size engine
  - Regenerative braking





Top photo by Dennis Schroeder, NREL
Bottom photo courtesy of Cummins
Illustration and figure by NREL

2035 Potential ICE



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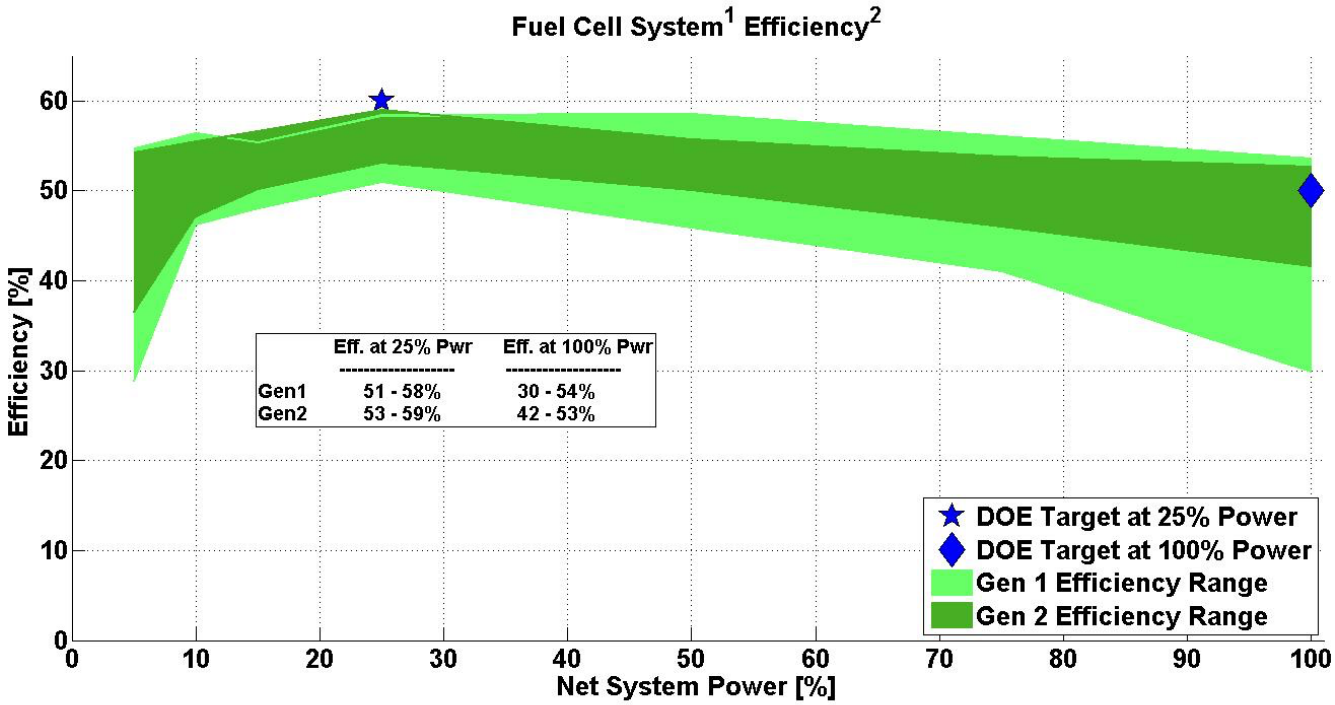
Fuel Cell Electric Vehicles

- Fuel cell system 59% efficient



[1] Gross stack power minus fuel cell system auxiliaries, per DRAFT SAE J2615. Excludes power electronics and electric drive.

[2] Ratio of DC output energy to the lower heating value of the input fuel (hydrogen).

[3] Individual test data linearly interpolated at 5,10,15,25,50,75,and 100% of max net power. Values at high power linearly extrapolated due to steady state dynamometer cooling limitations.

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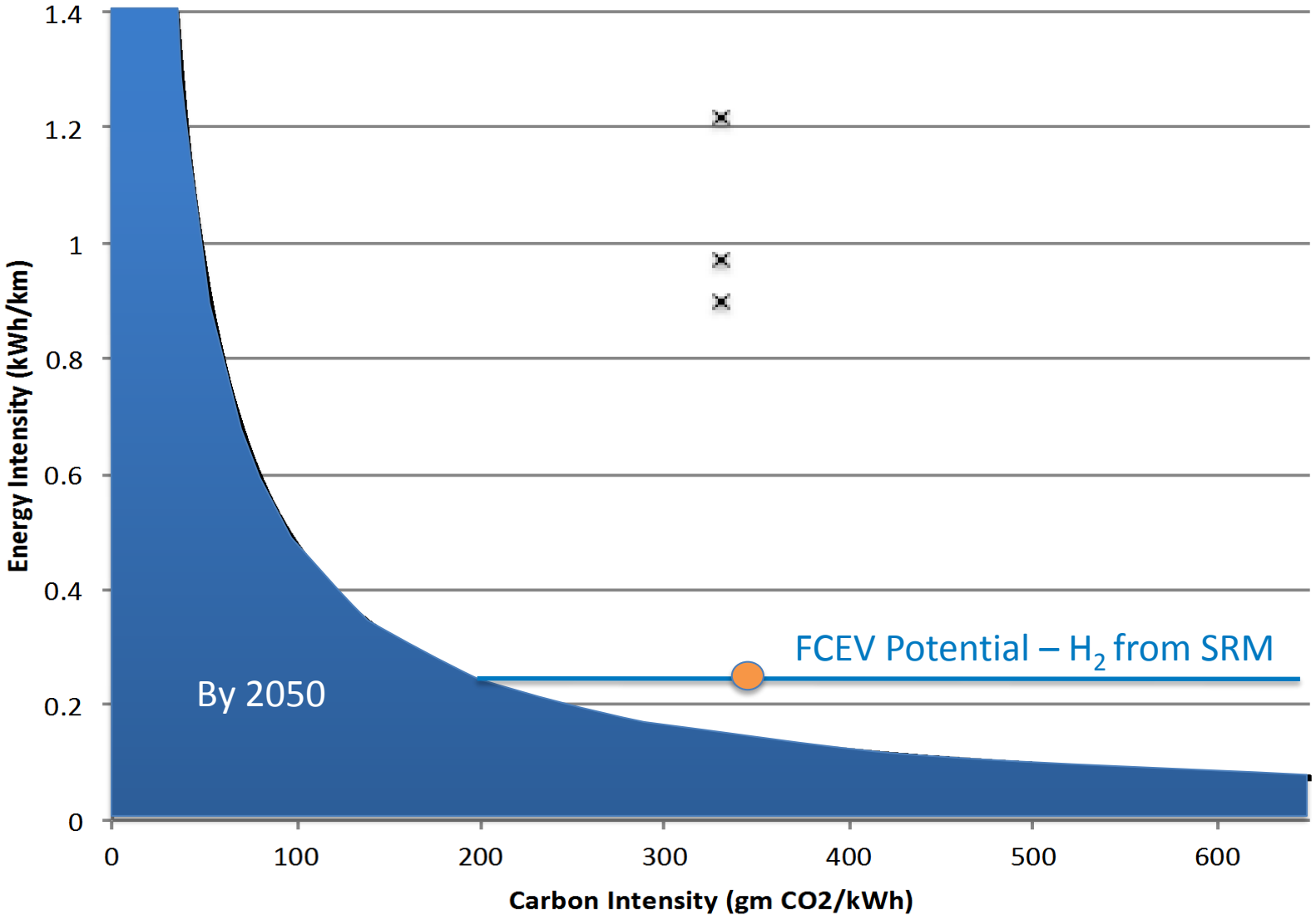
2035 Potential FCEV



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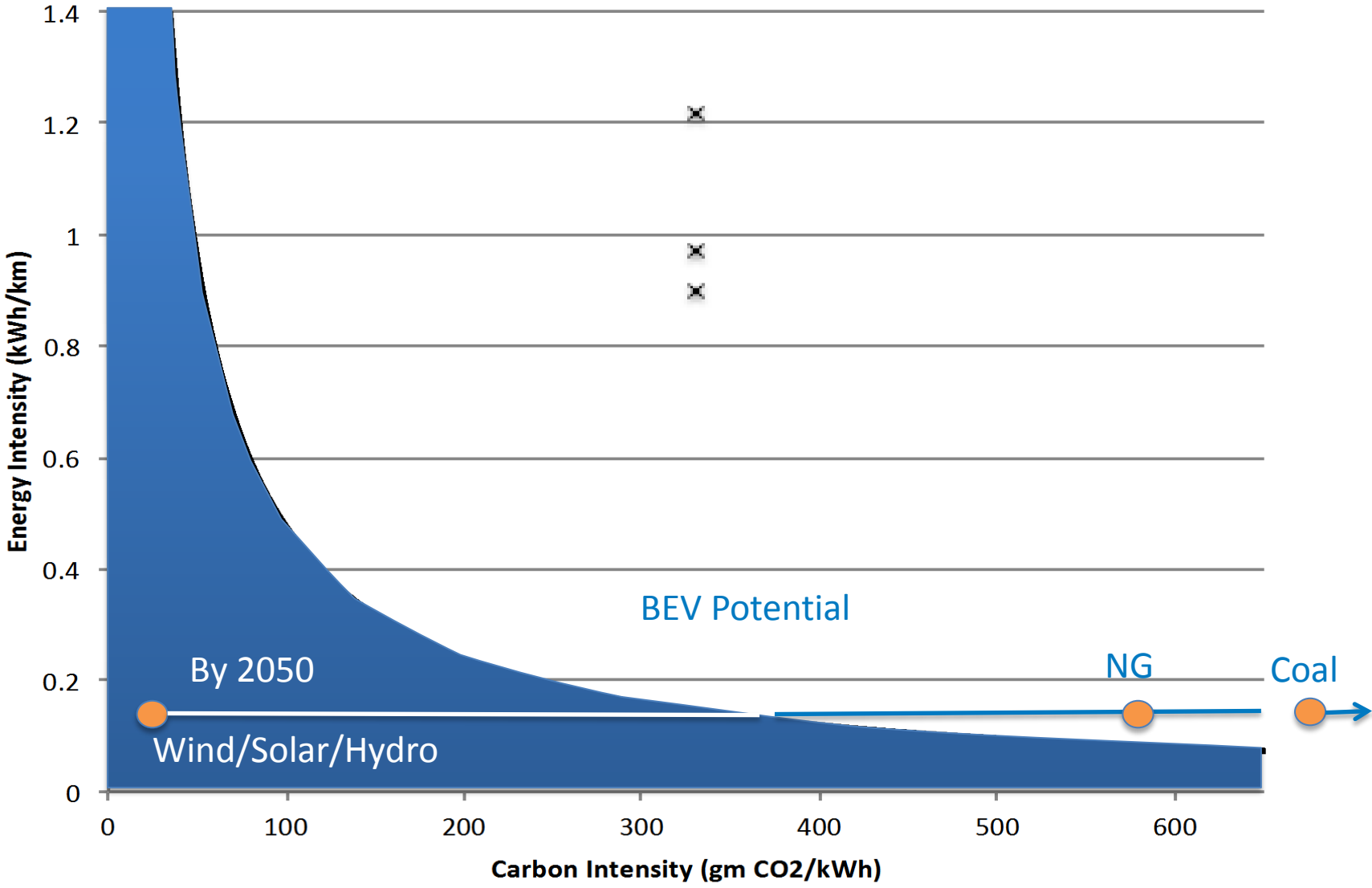
2035 Potential BEV



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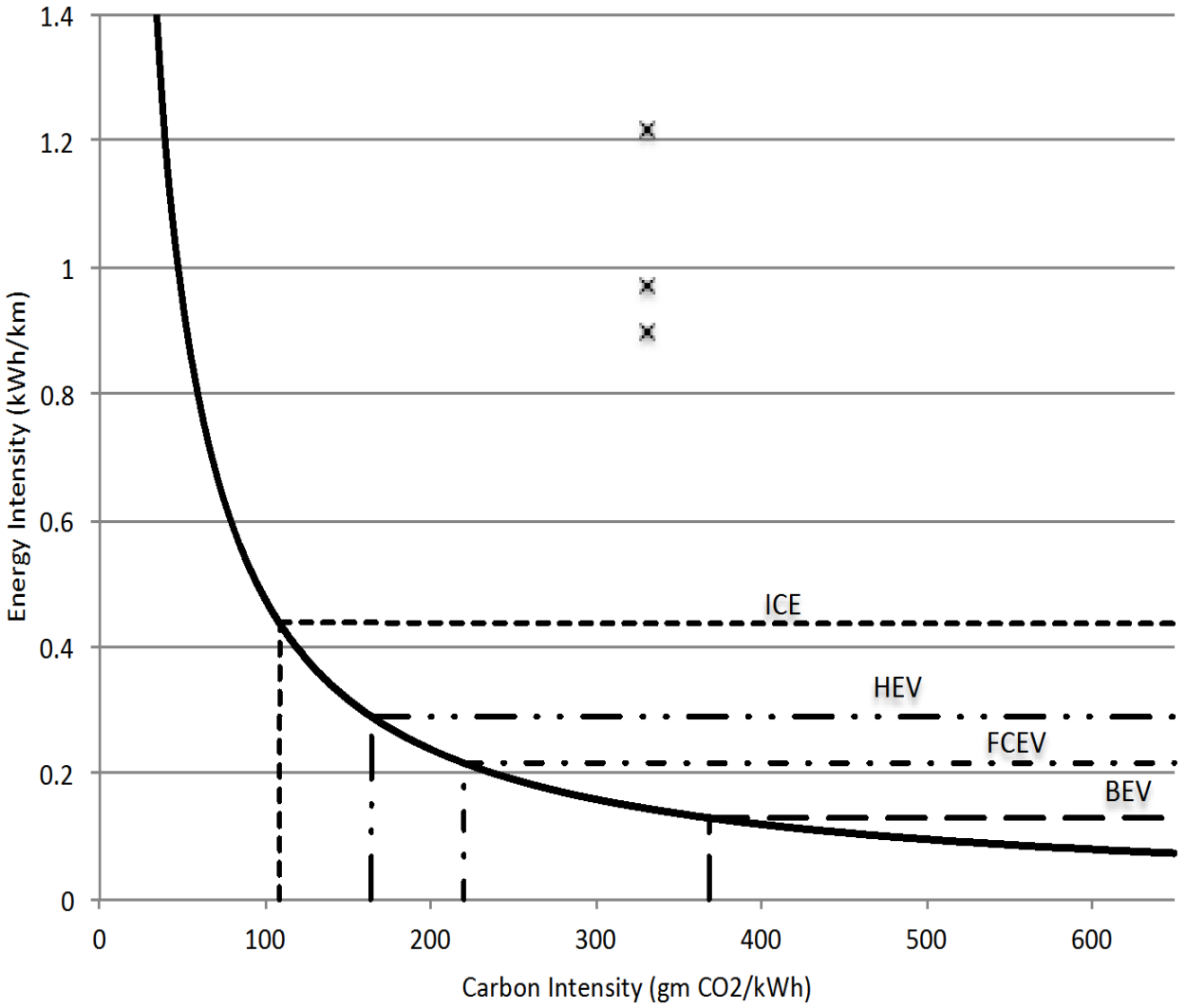
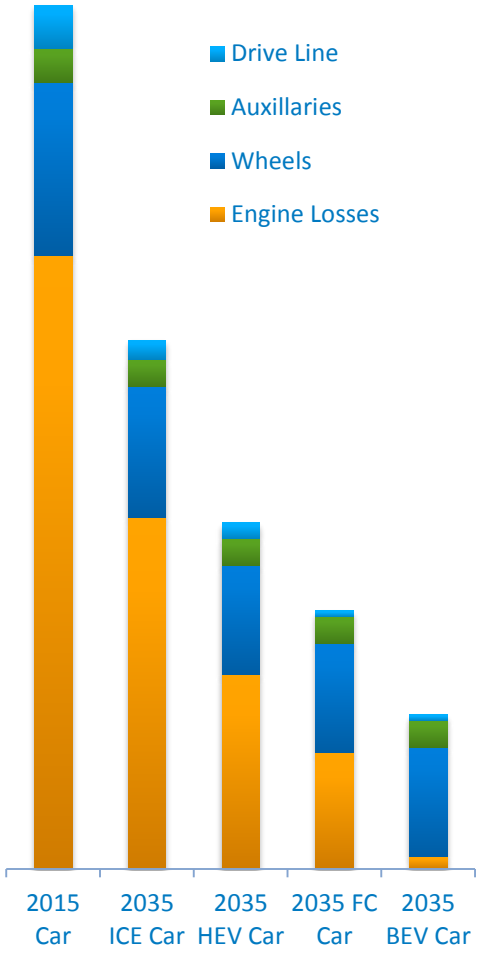
Better Vehicles





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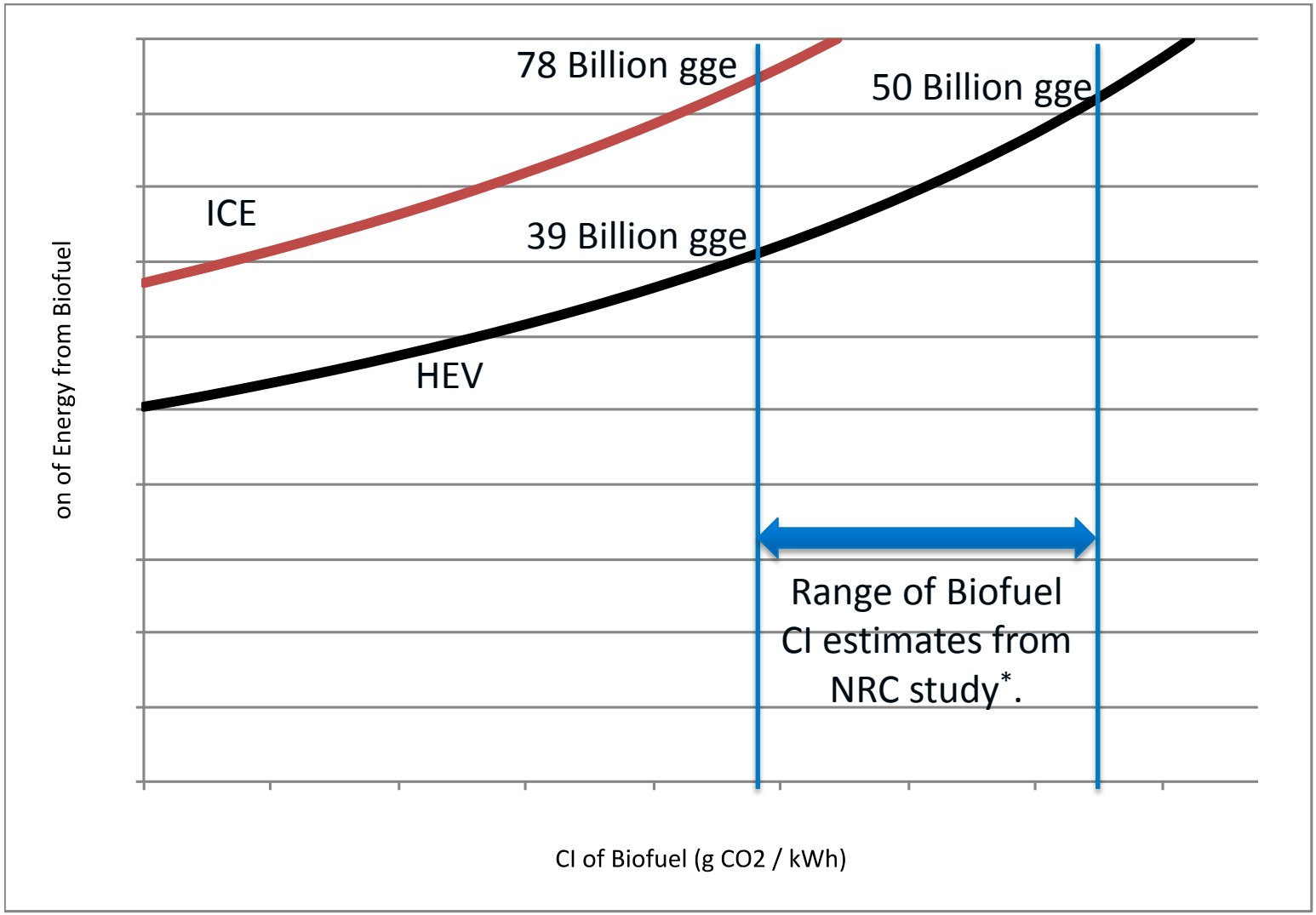
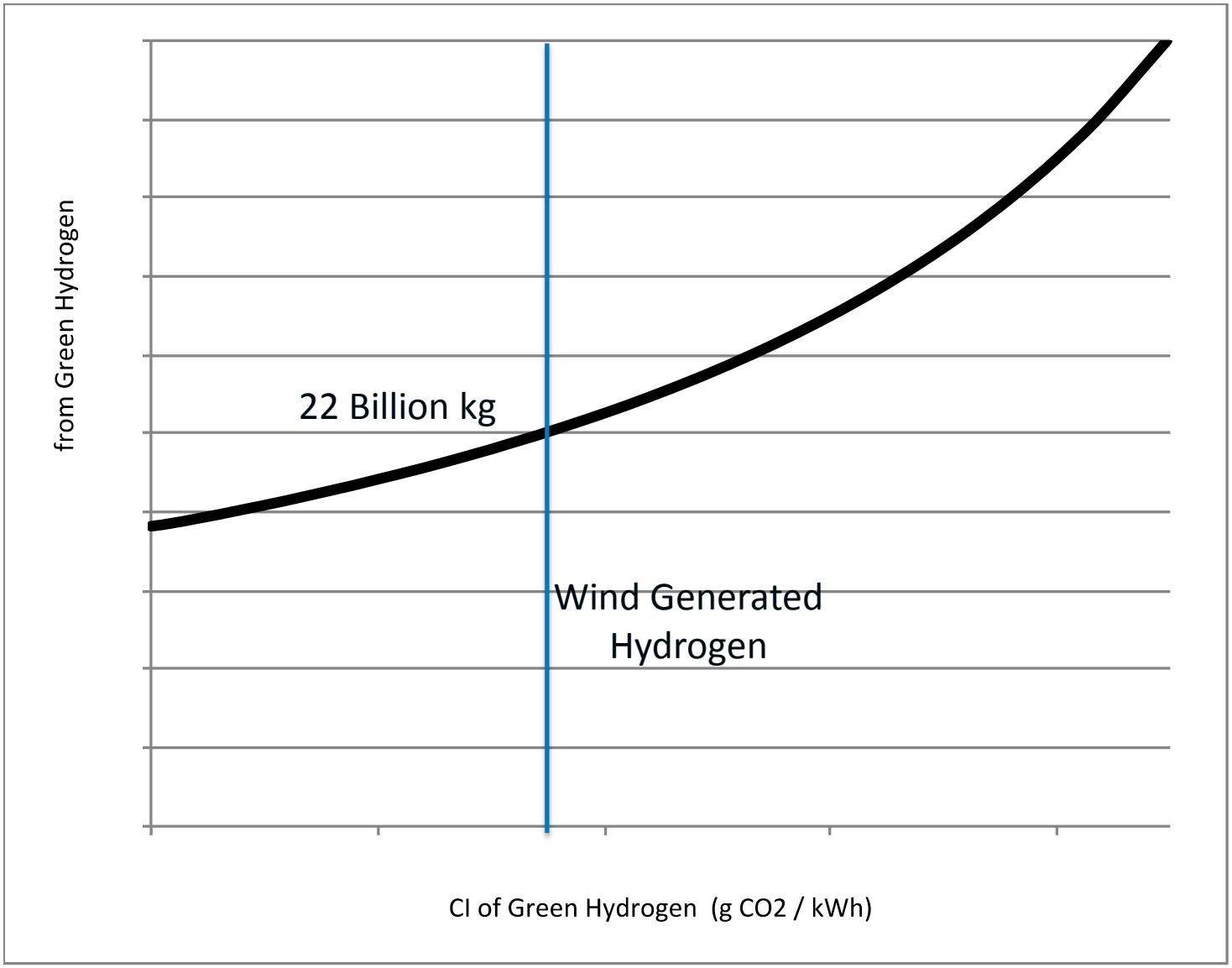
With low-carbon biofuel



2015 US production of ethanol about 10 billion gge** – Need a 4 to 8 fold increase by 2050

*2015 – NRC *Transitions to Alternative Vehicles and Fuels* **http://ethanolrfa.org/resources/industry/statistics/

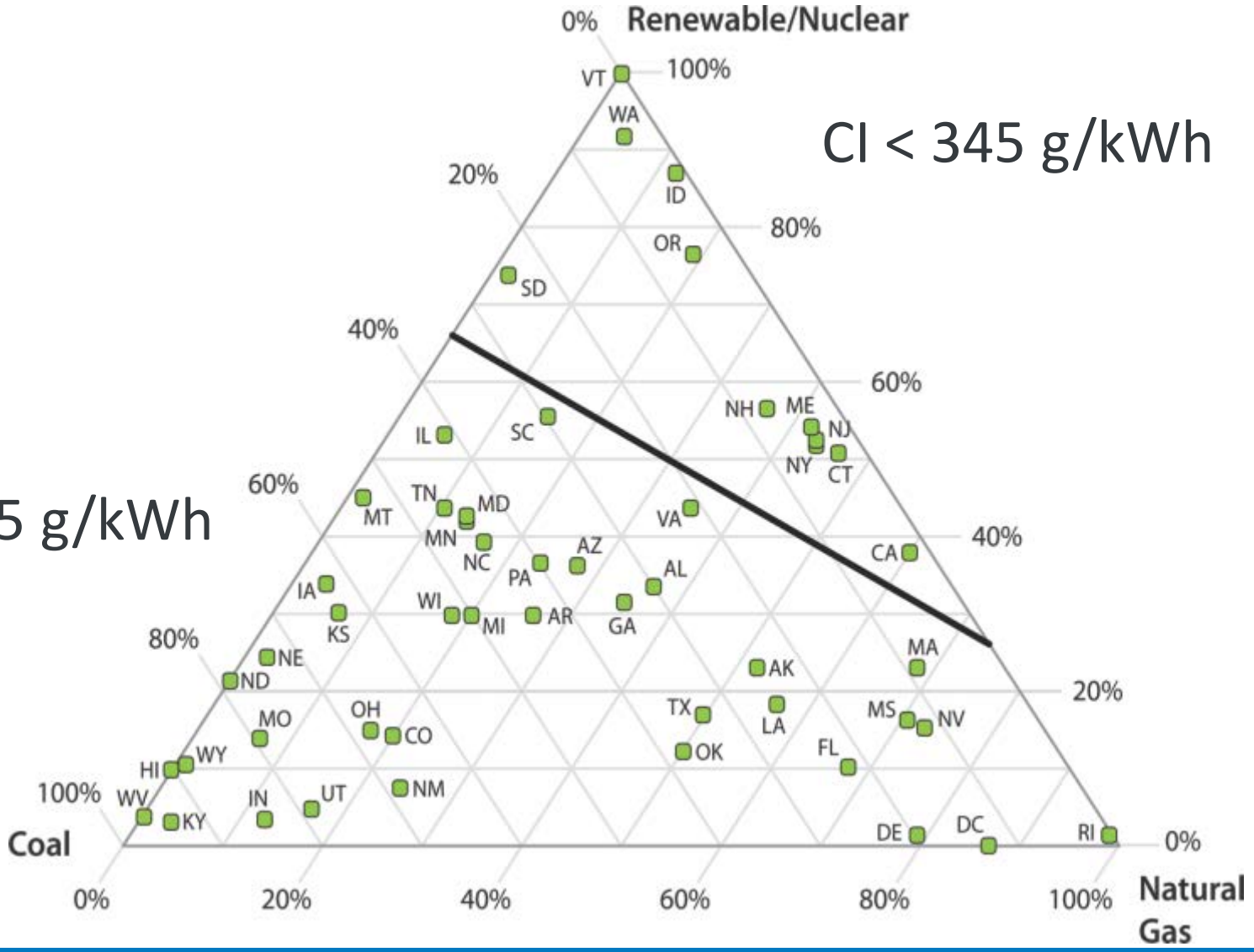
Low carbon hydrogen needed



Improved Electric Grid

CI < 345 g/kWh

CI > 345 g/kWh

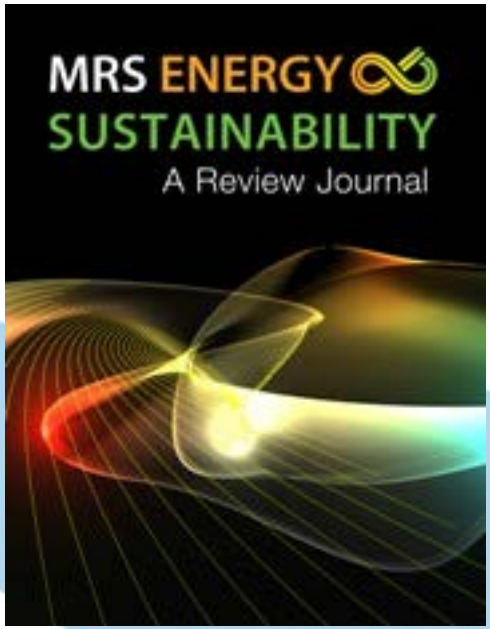


Priorities

- More efficient engines running on high fractions of biofuels
- 40 to 80 billion gge of biofuel
- Infrastructure to produce and distribute 10s of billions of kg renewable hydrogen
- Better power electronics, batteries, motors, and fuel cells
- EV charging solutions to break current range issues.
- Grid electricity at less than 345 g CO_2 per kWh

Thank You!

For more details please refer to



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MRS Energy & Sustainability-A Review Journal, Volume 3

DOI: https://doi.org/10.1557/mre.2016.8

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