Historical Overview of the Transportation and Fuel Landscape

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CATF Transportation Decarbonization Program
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Where are we?
A 2024 snapshot

Figure 2.1a Energy Consumption by Sector, 1949–2023
(Quadrillion Btu)

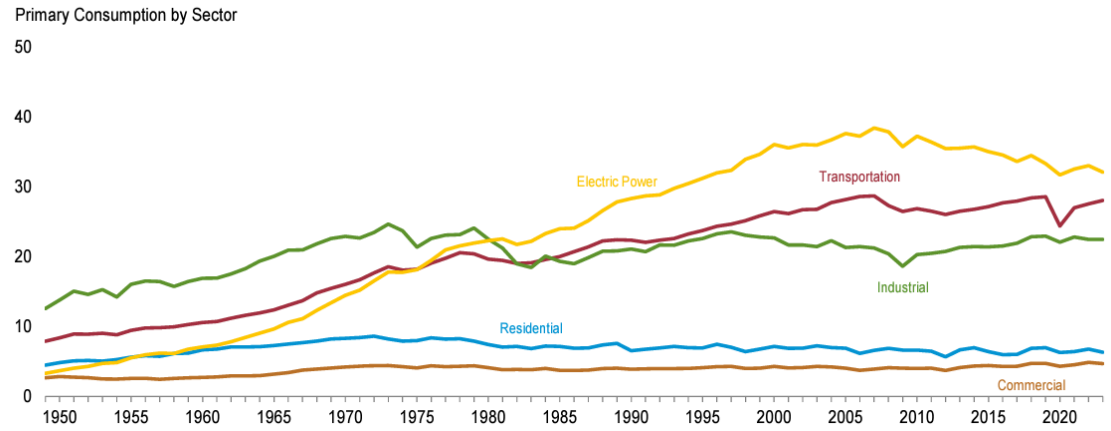
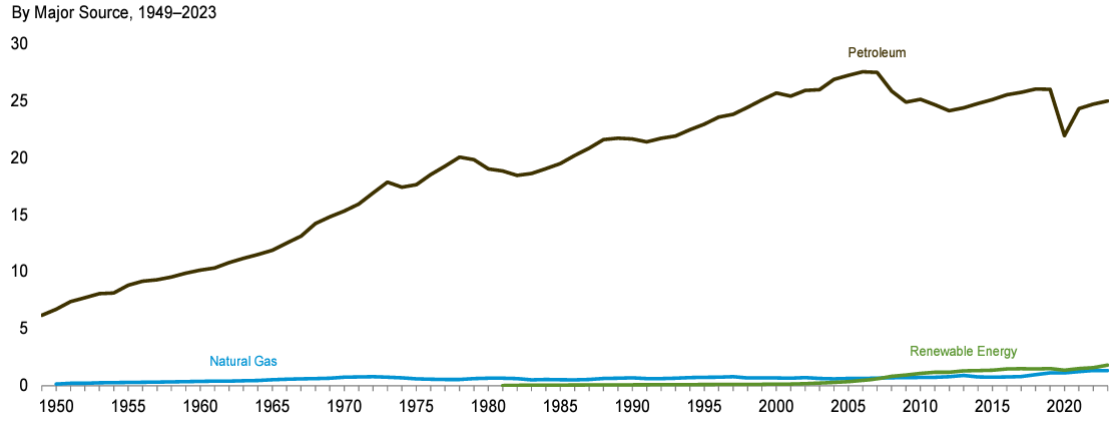
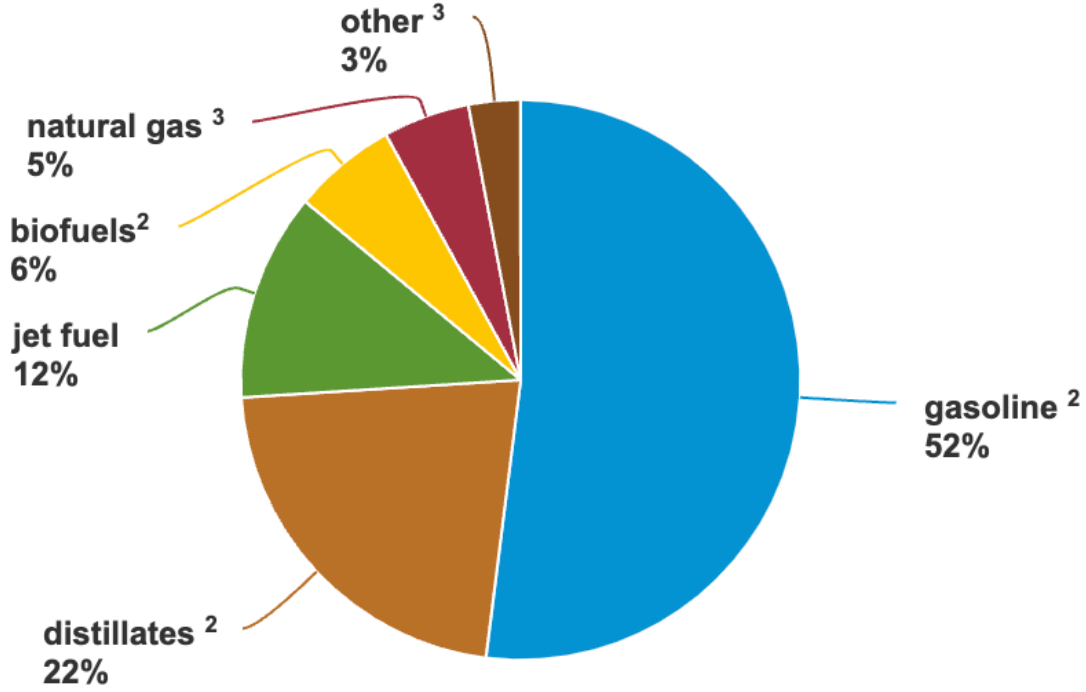


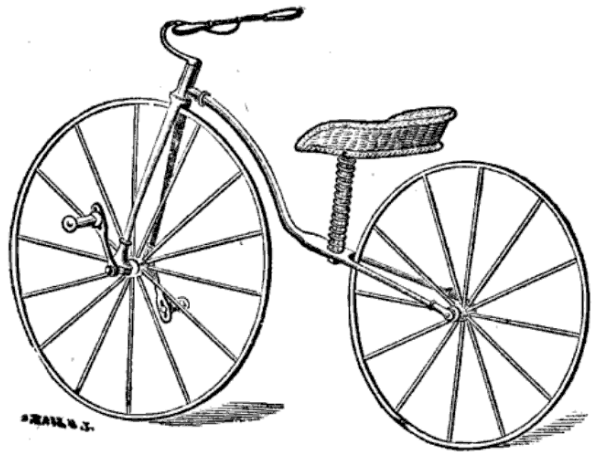
Figure 2.5 Transportation Sector Energy Consumption
(Quadrillion Btu)





Consumption data: https://www.eia.gov/totalenergy/data/monthly/pdf/sec2.pdf
Energy carrier shares: https://www.eia.gov/energyexplained/use-of-energy/transportation.php

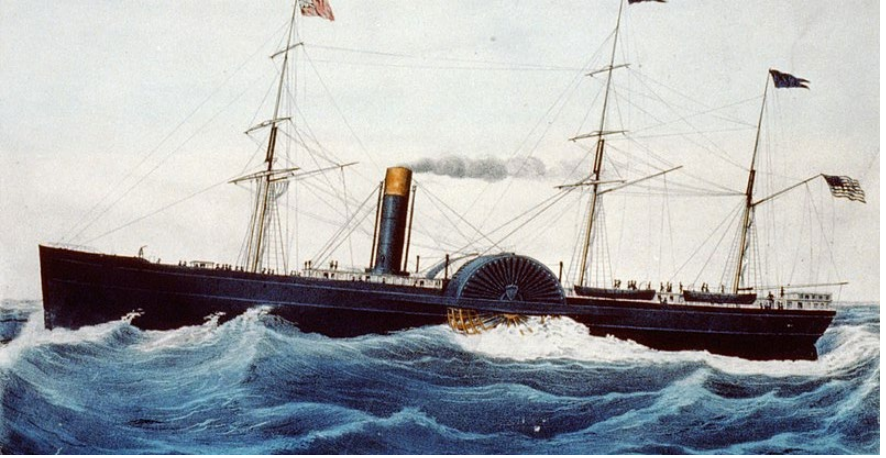
Where have we been? An incomplete history of transportation fuels



In the beginning

- 4000 BCE: Domestication of horses
  - 20 pounds of hay per day per horse
- 3000 BCE: First sailing vessels
  - Wind—variable but free
- 1800s: First pedal-powered bikes
  - Tour de France riders consume 5000-8000 kcal per day

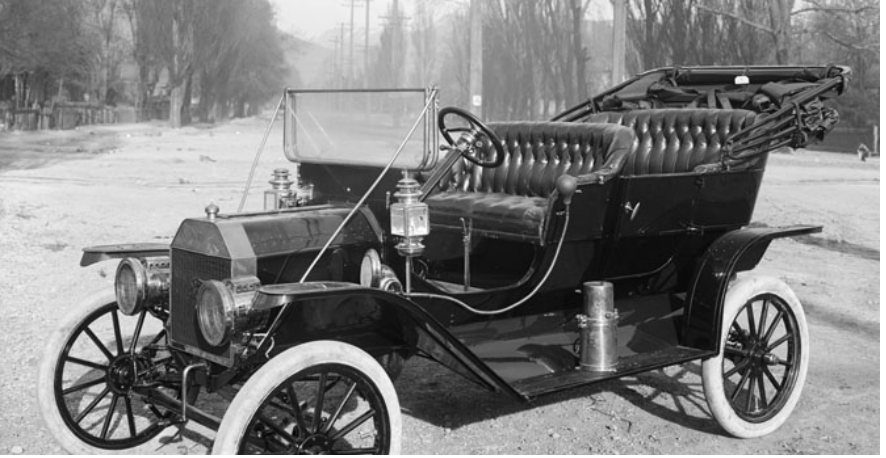
Images (top to bottom): Rawpixel, Wikipedia, Wikipedia



1800s: Steam, and a bit of electricity

- Steam powered ships and trains combusted wood and coal to power boilers
  - Coal generally outcompeted wood, due to higher energy density
  - Wood-fueled trains persevered in US into late 1800s, to the detriment of North American forests
- Electric trolleys were commonplace in many US cities by 1890s
  - Trolley companies typically owned their own (usually coal-fired) power plants
  - Inter-city passenger rail lines were powered by electricity

Images (top to bottom): Wikipedia, ExplorePAHistory.com, Wikipedia



1900-2000: The petroleum century

- 1859: Edwin “Colonel” Drake successfully drills for oil in Titusville, PA. Earliest refineries opened earlier in 1850s.
- Late 1800s-early 1900s: Oil begins replacing coal as fuel for steam trains and ships; main drivers are regional coal shortages and oil’s relative ease of handling. Churchill-led commission hastened British Navy’s conversion to oil (1912).
- 1908: Ford introduces Model T. High-quality, mass-produced internal combustion engines could make use of energy-dense gasoline, which had previously been a dangerously explosive byproduct of refining processes.
- 1910: Diesel engine first demonstrated. By the 1970s, nearly all US highway trucks, trains, and water transport are fueled with diesel.
- 1920s: Gasoline powered buses displace inter-urban electric trains.
- 2007: ExxonMobil market valuation at $504 billion.

All images: Wikipedia

1900-2000: Alt fuels on the margins

- 1940s: Ammonia buses in Belgium
- 1950s+: Coal-to-liquids in South Africa
- 1950s+: Nuclear-powered marine vessels
- 1970s: Battery-powered cars

Photos (top to bottom): NH3 Fuel Association, Renew Africa, AustinEV

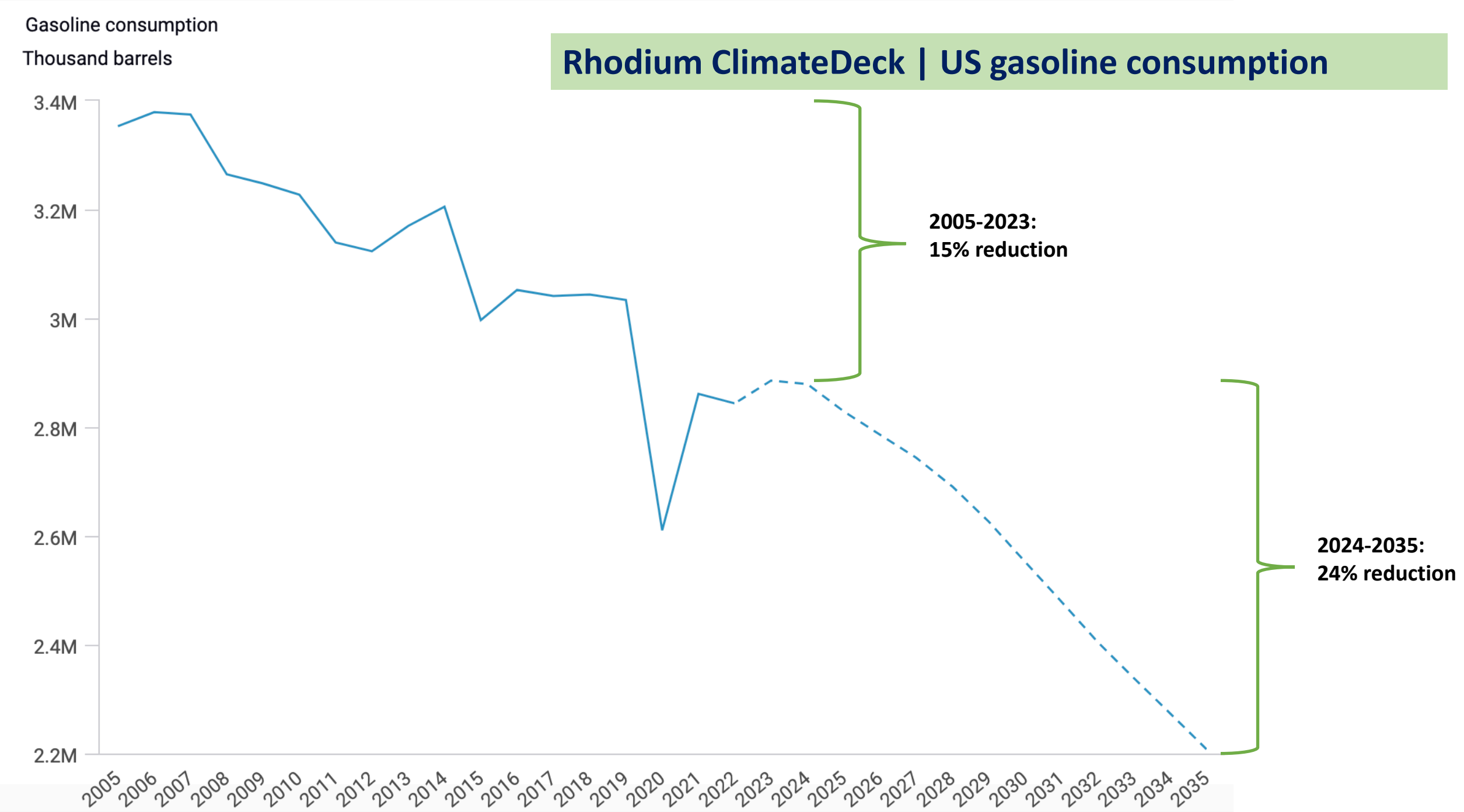
2000-2024: Alt fuels make in-roads

- Biofuels:
  - US RFS1 (2005), RFS2 (2007), Iowa
  - EU Biofuels Directive (2003), RED (2009+)
  - Brazil: 34% EtOH blend rate (energy basis)
  - Lifecycle emissions vary significant among biofuel types
- Natural gas: investment in NG-fueled trucking soared then cratered in 2010s
- Electric drivetrains
  - HEVs: Toyota Prius (1997), Jeep Wranger 4xe (2021)
  - BEVs: Tesla Model S (2012), Rivian EDV (2021), BYD Seagull (2024)
  - H2 FCEVs: transit buses, light rail, Class 8 trucks…

Photos (top to bottom): Reuters, Wikipedia, Wikipedia

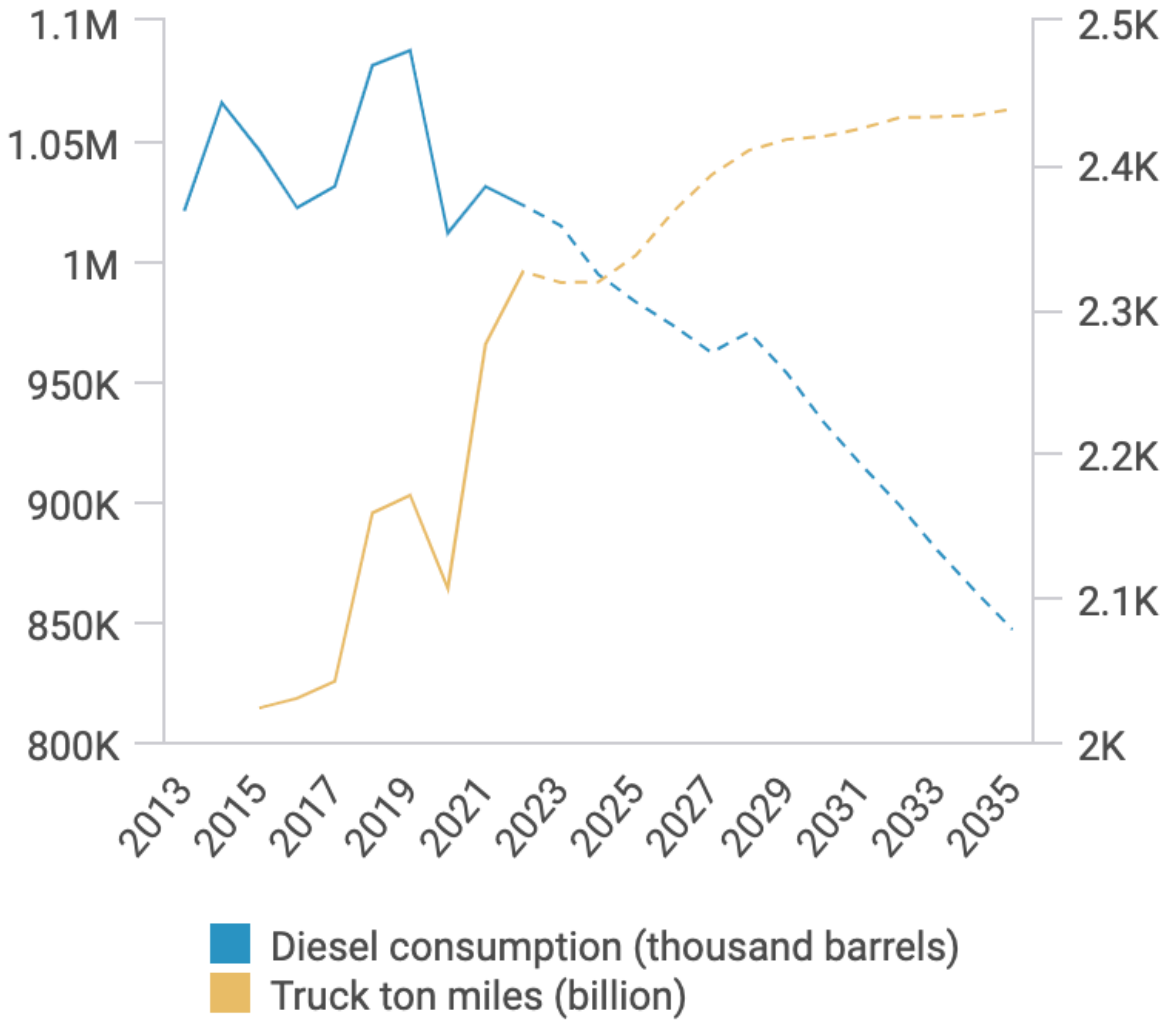
Where are we going? The evolving future of transportation fuels

Rhodium ClimateDeck | US gasoline consumption

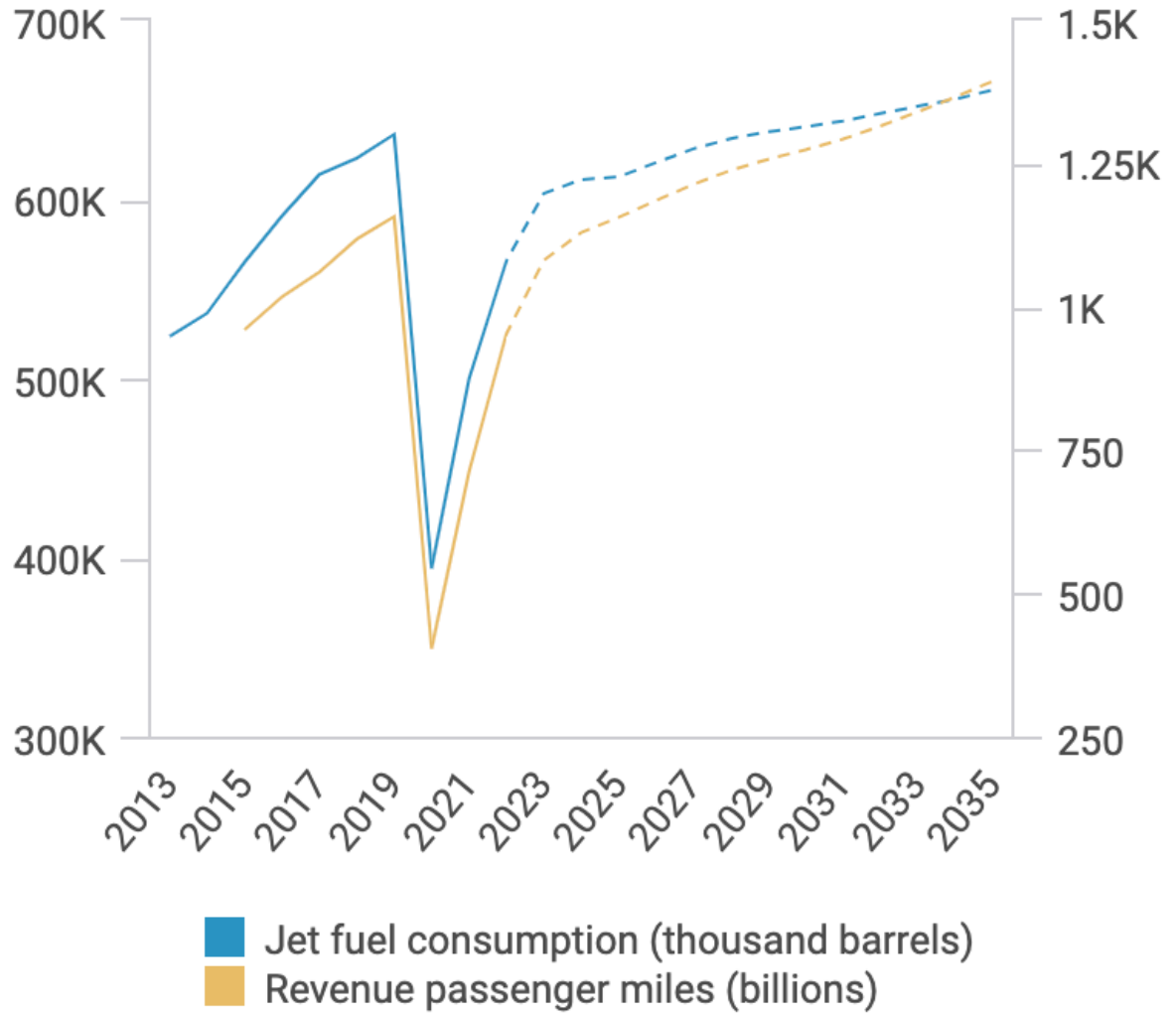


Rhodium ClimateDeck | US diesel & jet fuel consumption

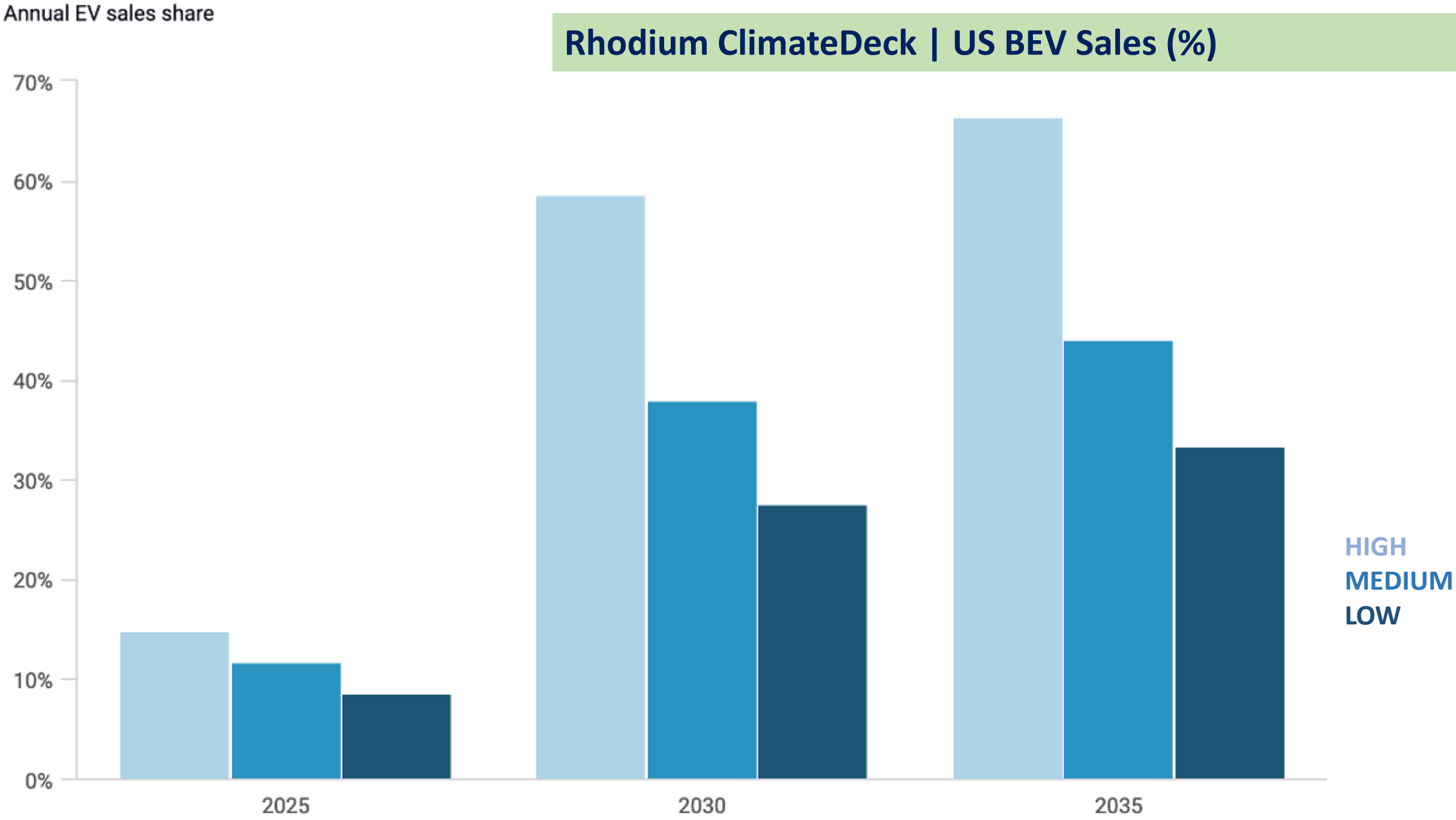
Diesel consumption (left) vs truck ton miles traveled (right)



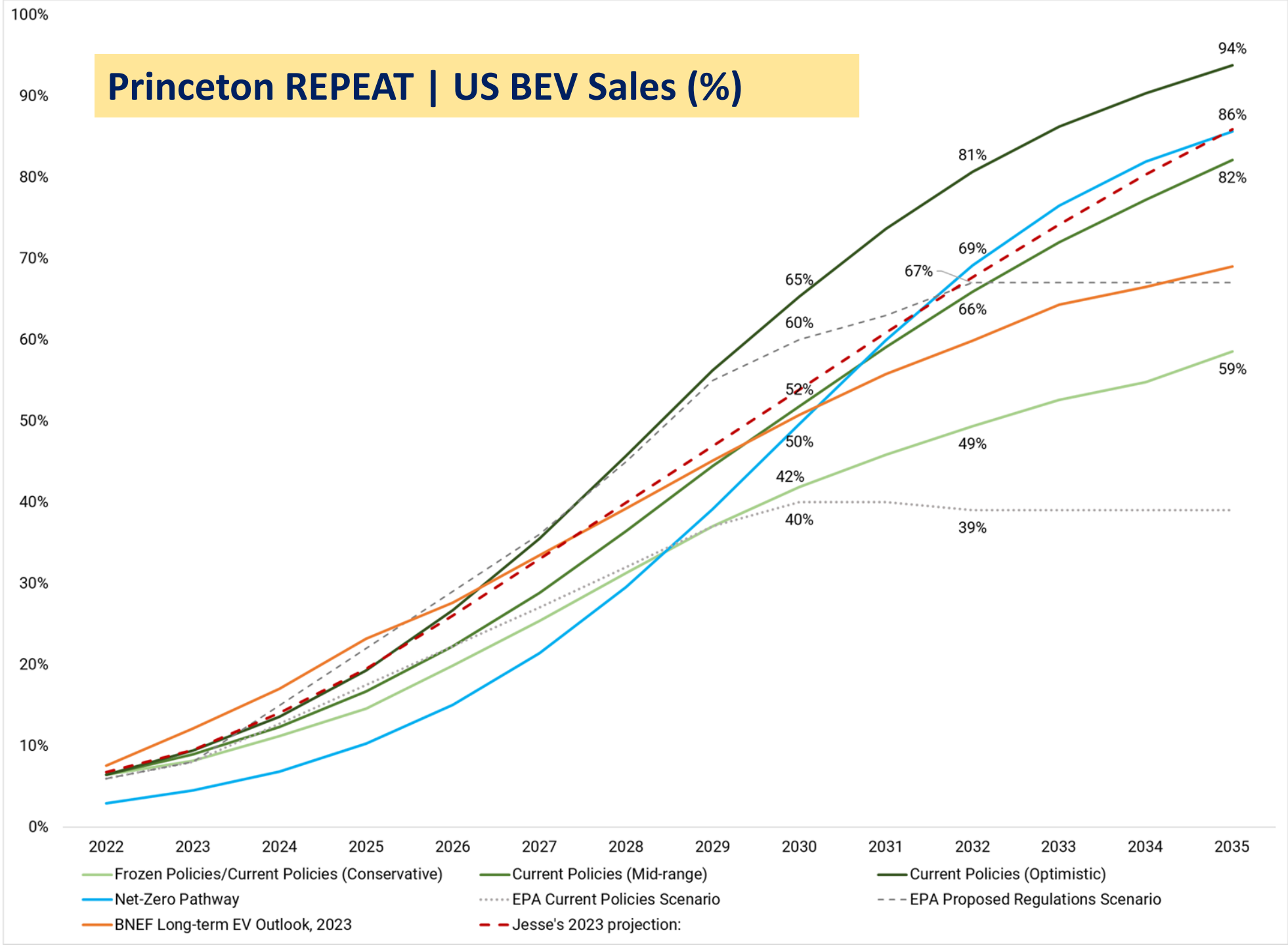
Jet fuel consumption (left) vs revenue passenger miles (r...



Rhodium ClimateDeck | US BEV Sales (%)

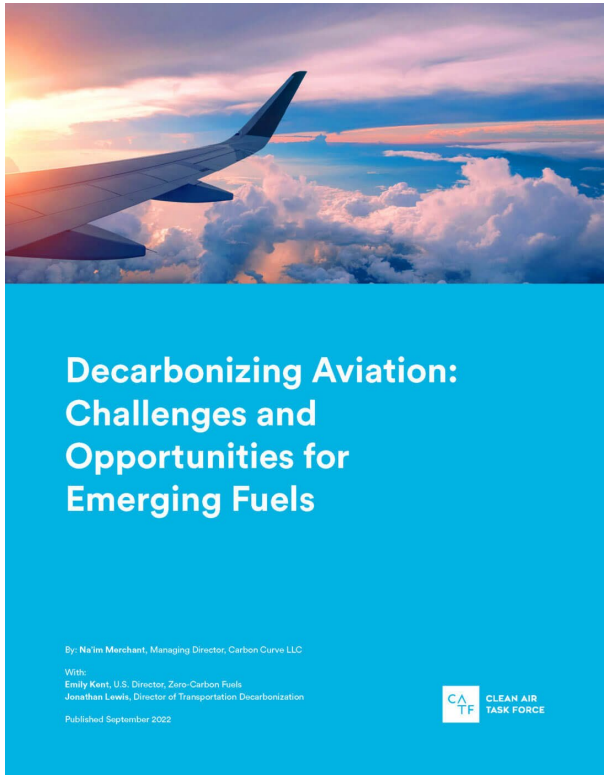


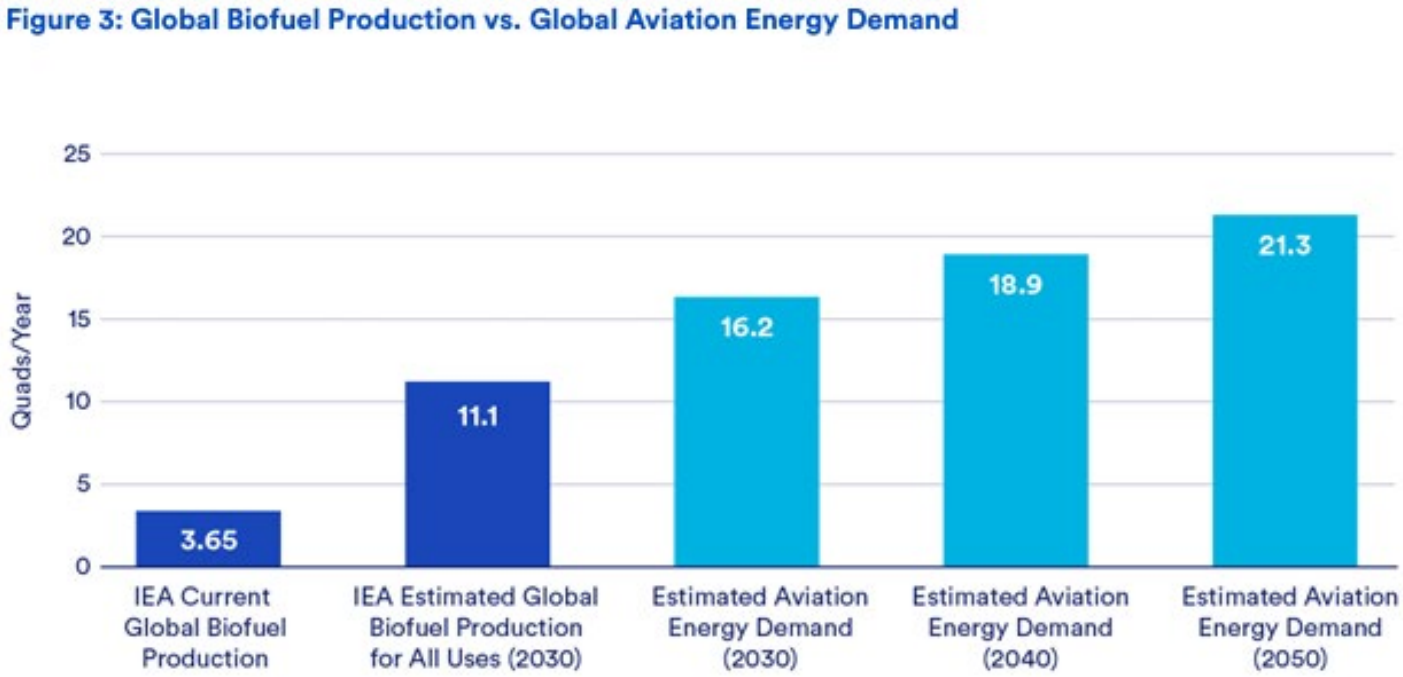
Princeton REPEAT | US BEV Sales (%)



Implications of multi-sector decarbonization on the supply of low-C energy carriers?

- Decarbonizing the transportation sector by mid-century is complicated by (among other things) potential constraints on the supply of key fuels.



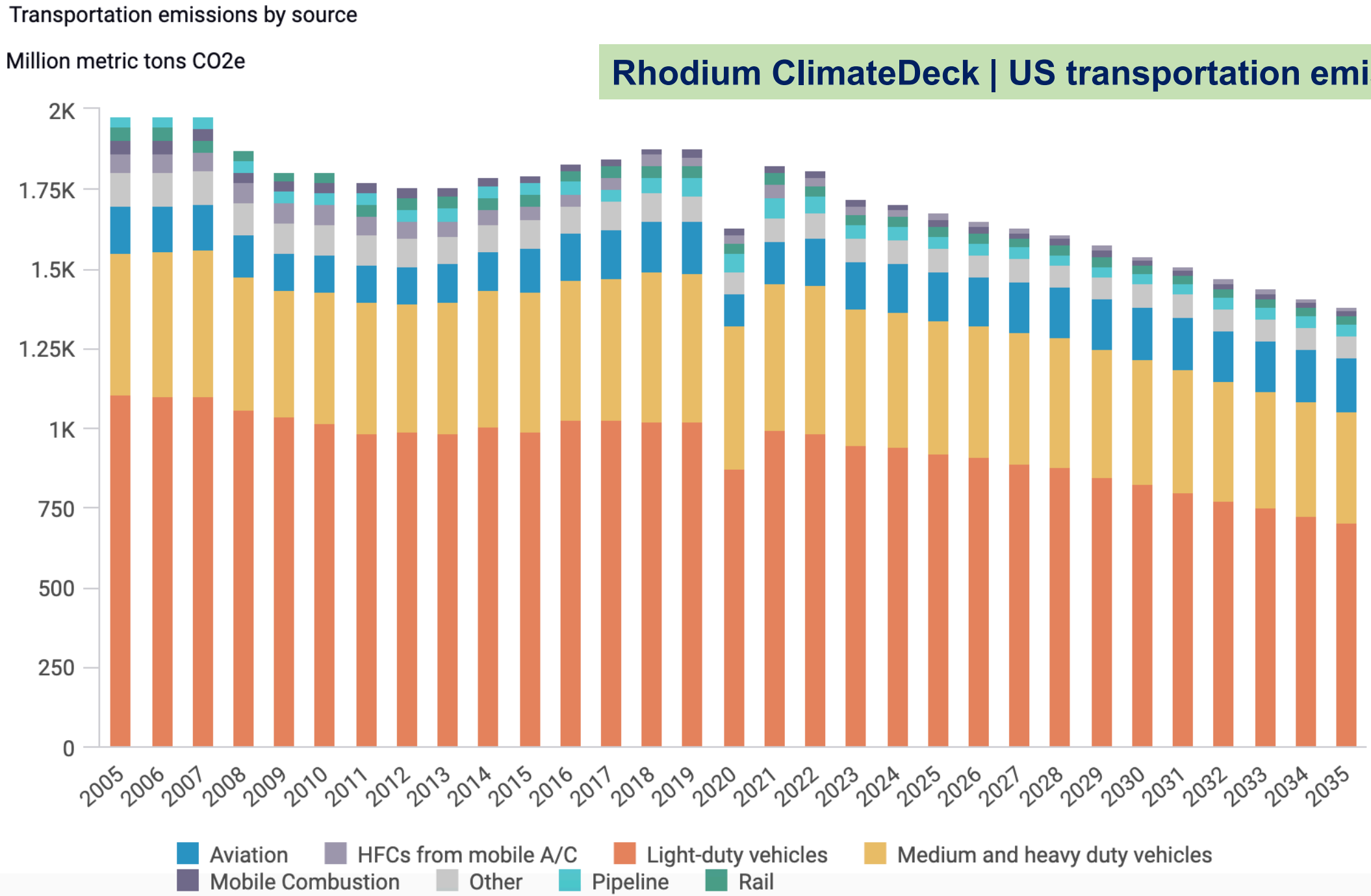


Policy Drivers

Climate policy will necessarily play a major role in shaping transportation fuel markets

- What do we have in the United States?
  - Vehicle standards (tailpipe emissions limits, ZEV mandates)
  - A biofuel consumption mandate (US RFS)
- What (else) do we need?
  - Performance standards that require gradual but deep reductions in fuels' carbon intensity (gCO_2e per unit of energy). Robust lifecycle analyses for determining fuels' CI need to be coupled with safeguards that protect against over-reliance on limited or unsustainable fuels or feedstocks (because LCAs are imperfect and insufficient).

Rhodium ClimateDeck | US transportation emissions



Thank you

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