

# Progress in Low-and-Zero Carbon Fuels

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# Rapidly Changing Industry to Meet Zero Emissions Targets

## Norway Says All Cars in the Country Will Be 100% Electric

Just 10 years until the death of fossil fuels.

EU approves effective ban on new fossil fuel cars from 2035

## Porsche ups its investment in 'e-fuels'

## Toyota, Cummins eye hydrogen-combustion engines

Exclusive: EU drafts plan to allow e-fuel combustion engine cars

*California to Ban the Sale of New Gasoline Cars*

**This new device captures CO2 from trucks as they drive**

Hydrogen fuel cells seek transport niches EVs can't reach

California regulators OK \$1 billion for EV charging project

Transport sector should embrace life-cycle analysis to raise standards in emissions reporting

DOE launches \$8B program for clean hydrogen hubs across US



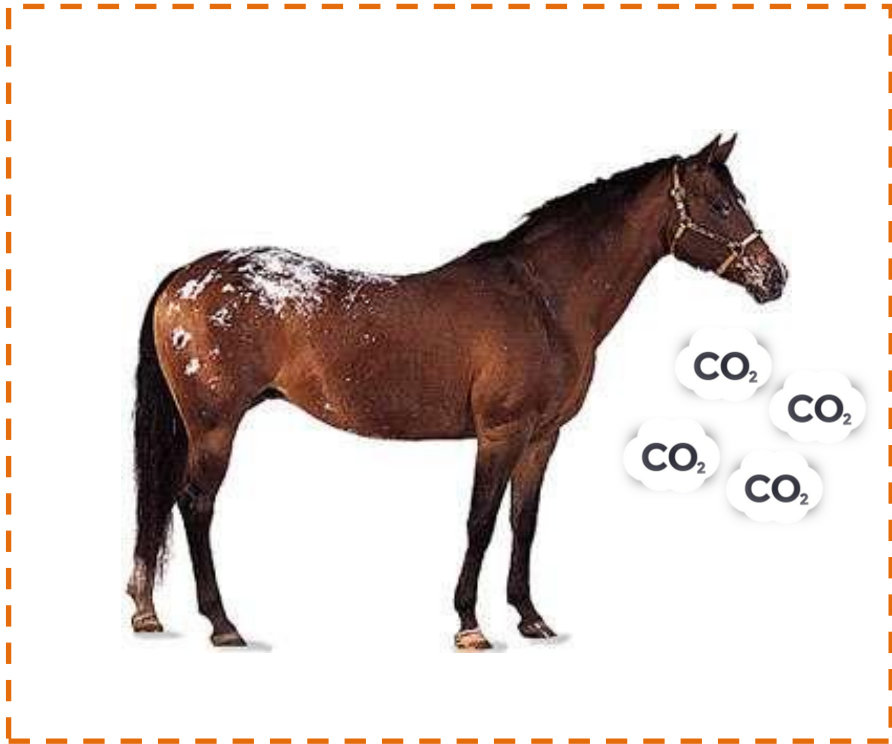
# “Last Technology Standing”



# A Comprehensive List of Zero Emissions Transport Options



# Can We Actually Achieve 'Zero Emissions' ?

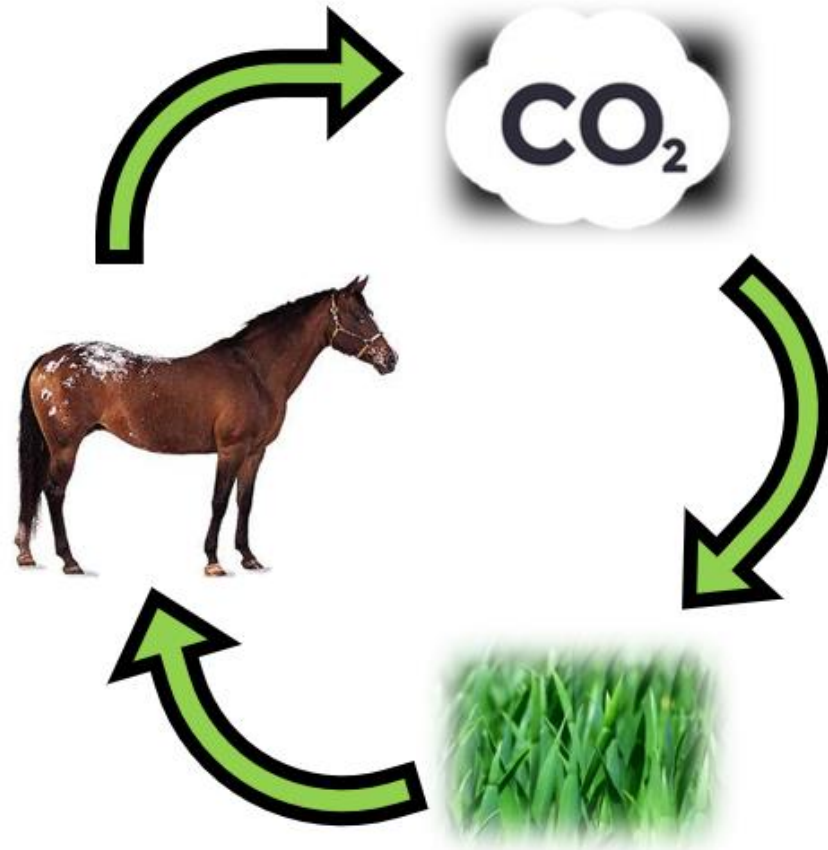


- 4 mph walk
- 55 L lung capacity
- 36 breaths per minute
- 5,940 liters per mile
- 530 g/mile CO<sub>2</sub>
  - 16.8 mpg equivalent



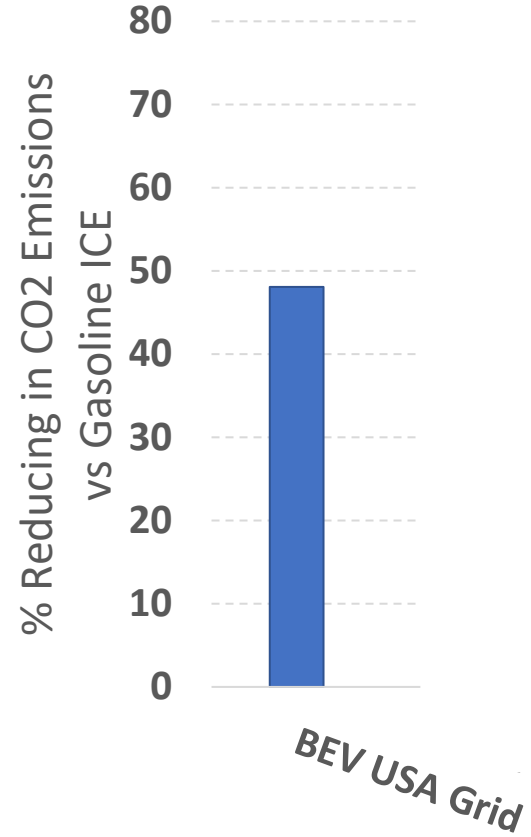
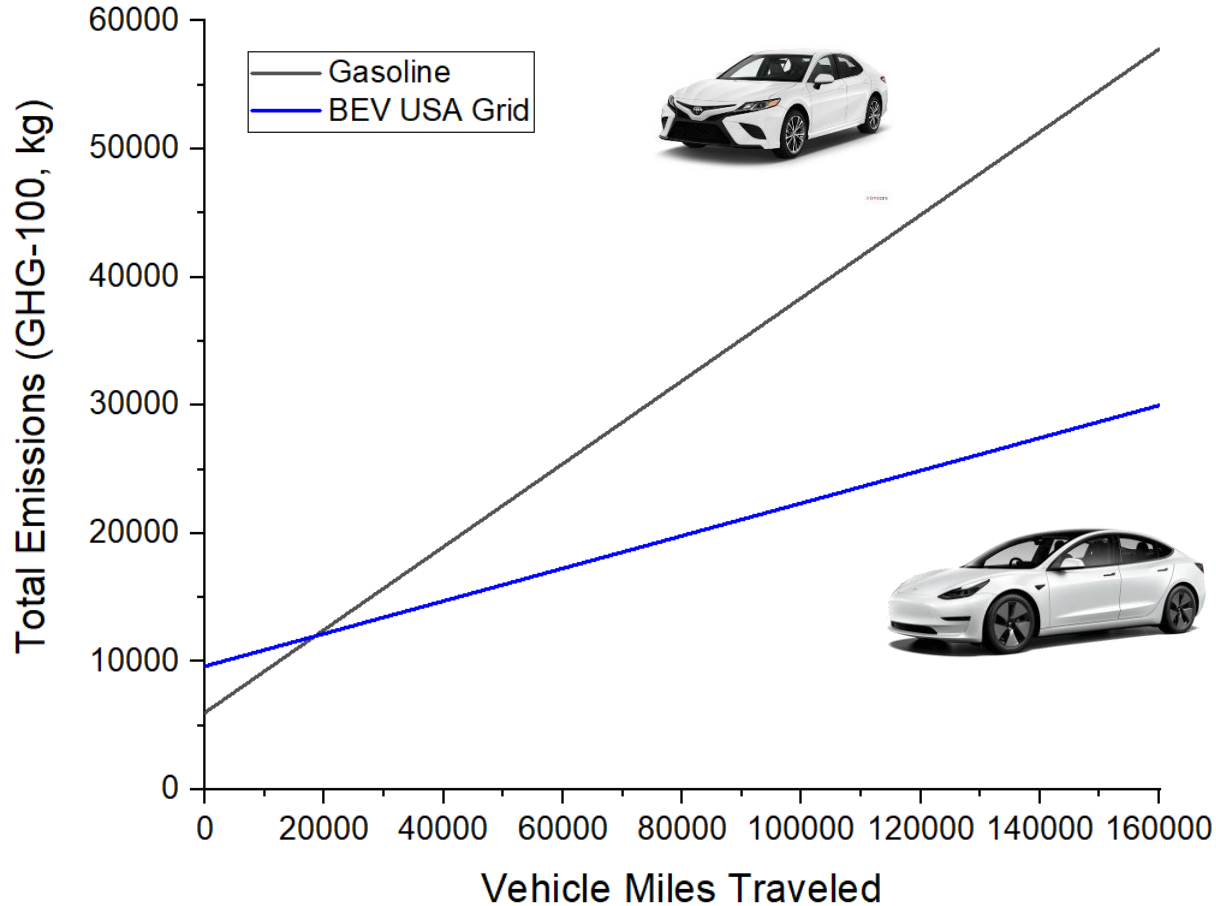
- By our current regulatory definition, the horse would emit double the CO<sub>2</sub> compared with most modern sedans
- This nonsensical example highlights the need for life-cycle analysis

# Life-Cycle Analysis Gives Context



# BEV with USA Grid

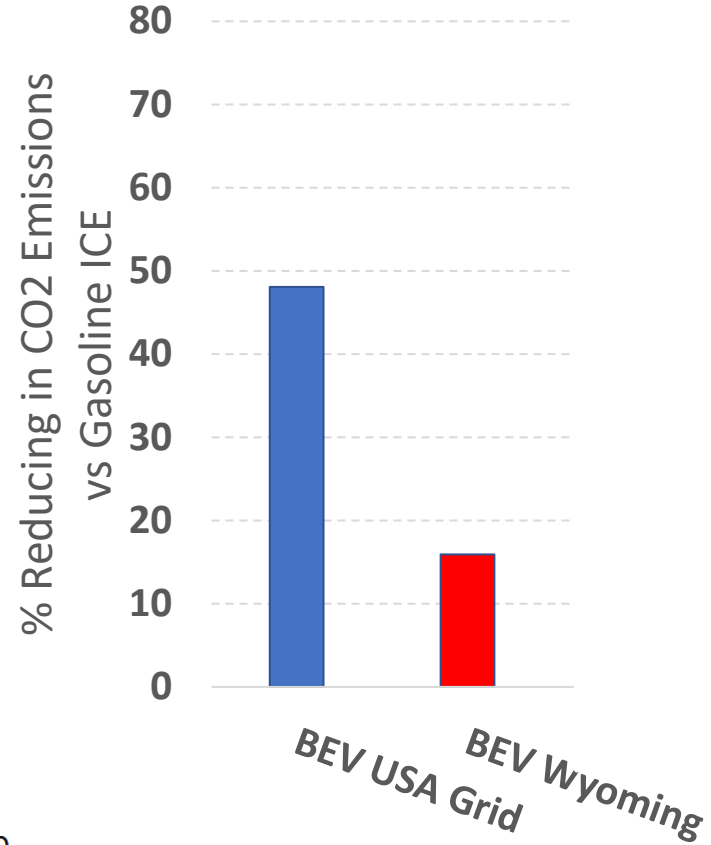
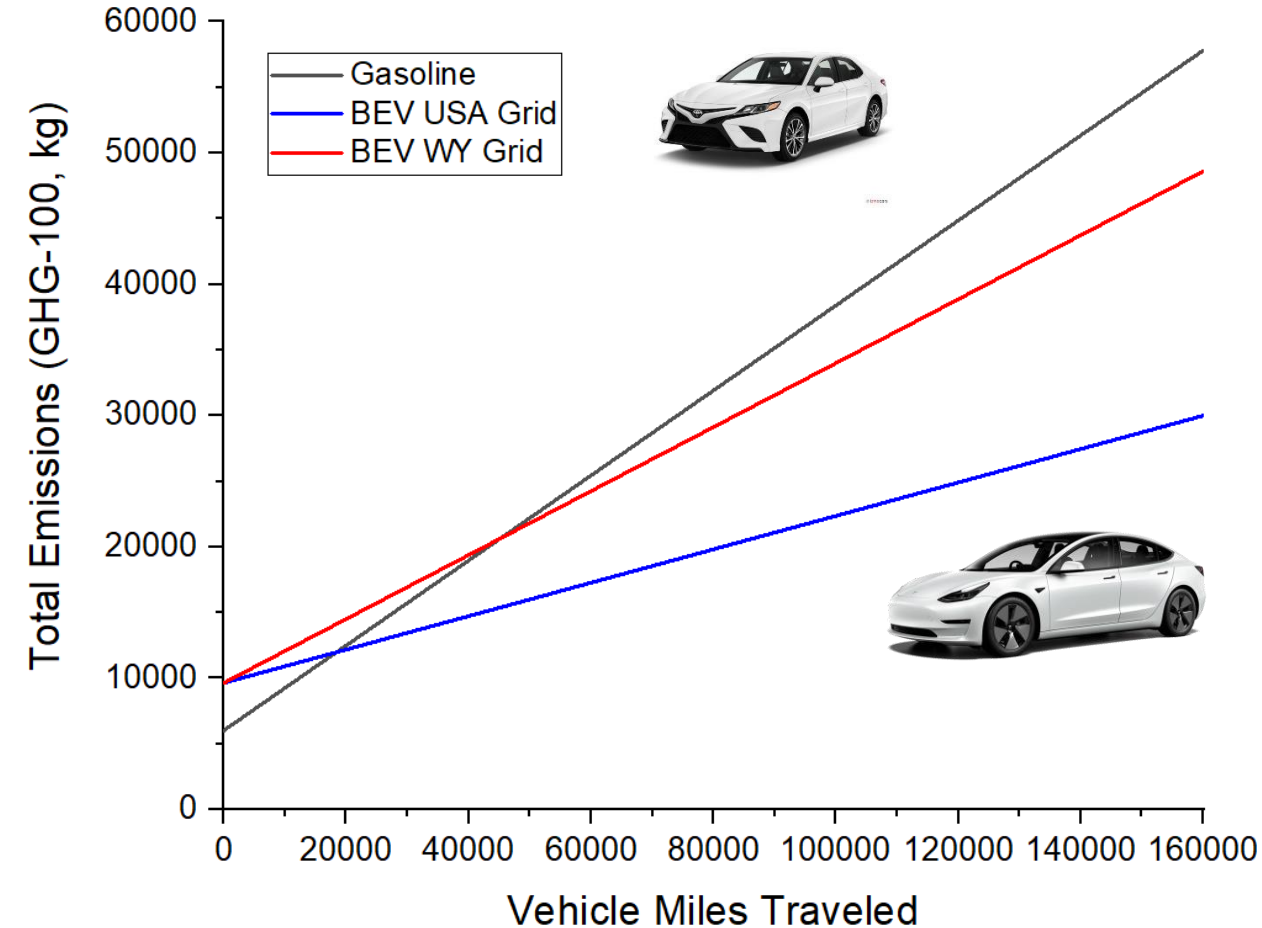
## Sedan Lifecycle Emissions



Zhang, L., Conway, G., Bitsis, D., Smith, I. et al., "Light Duty Vehicle Life Cycle Analysis," SAE Technical Paper 2021-01-0789, 2021, <https://doi.org/10.4271/2021-01-0789>.

# BEV with Wyoming Grid

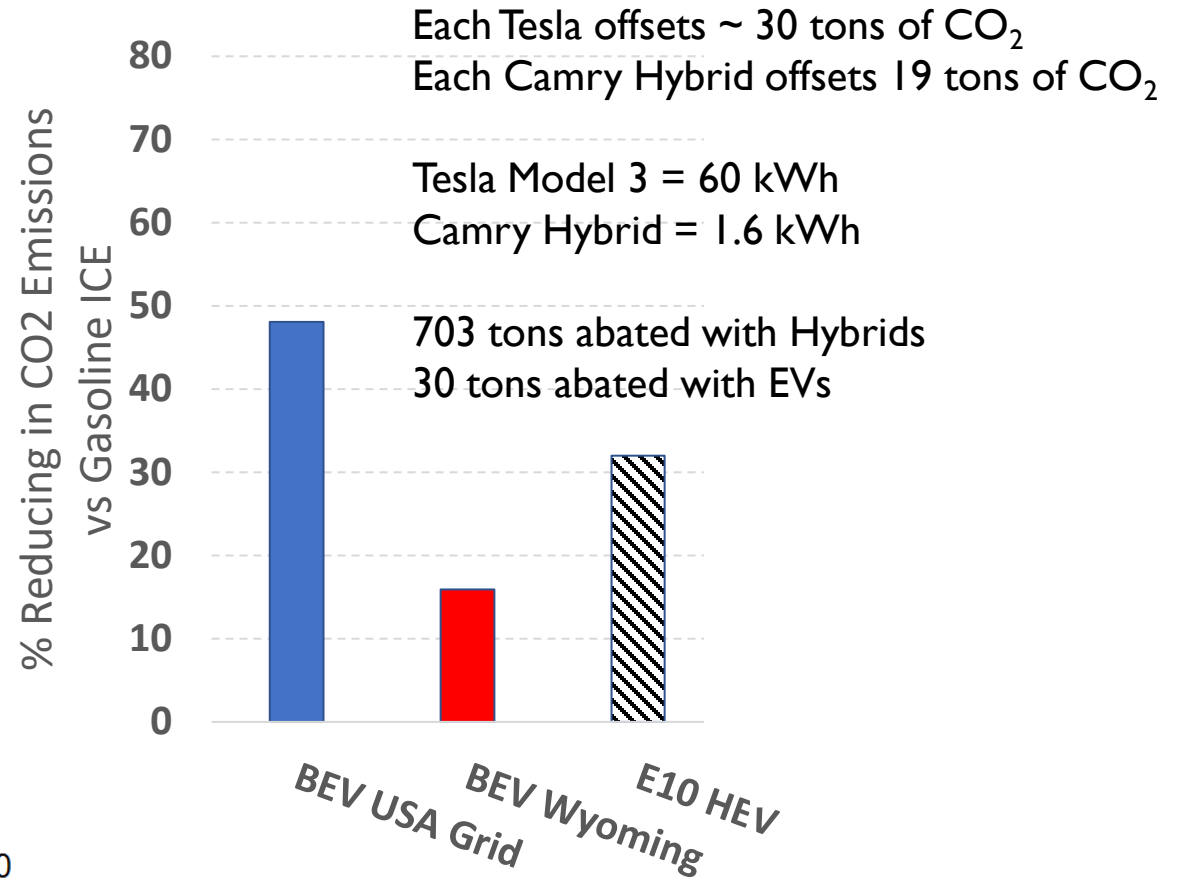
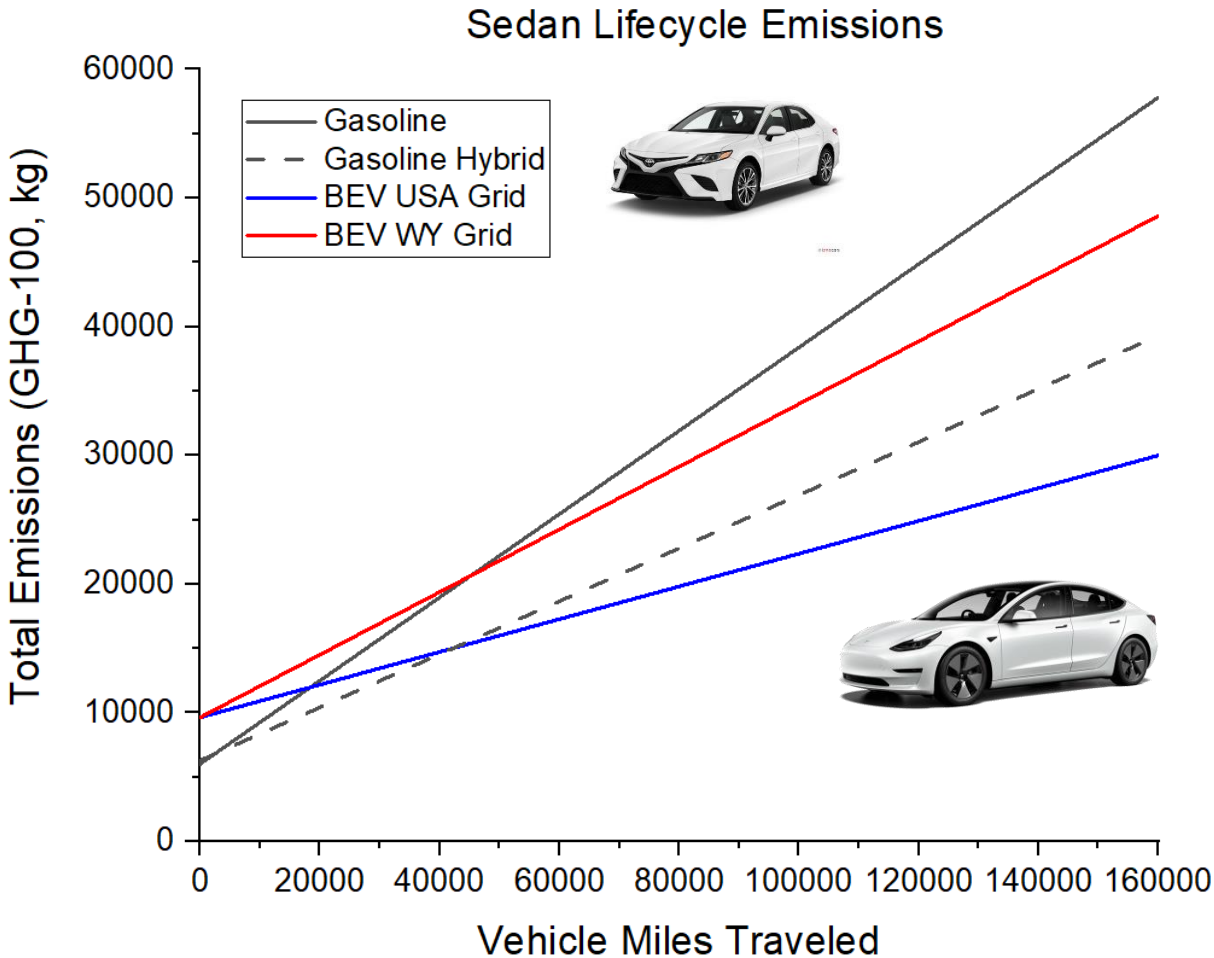
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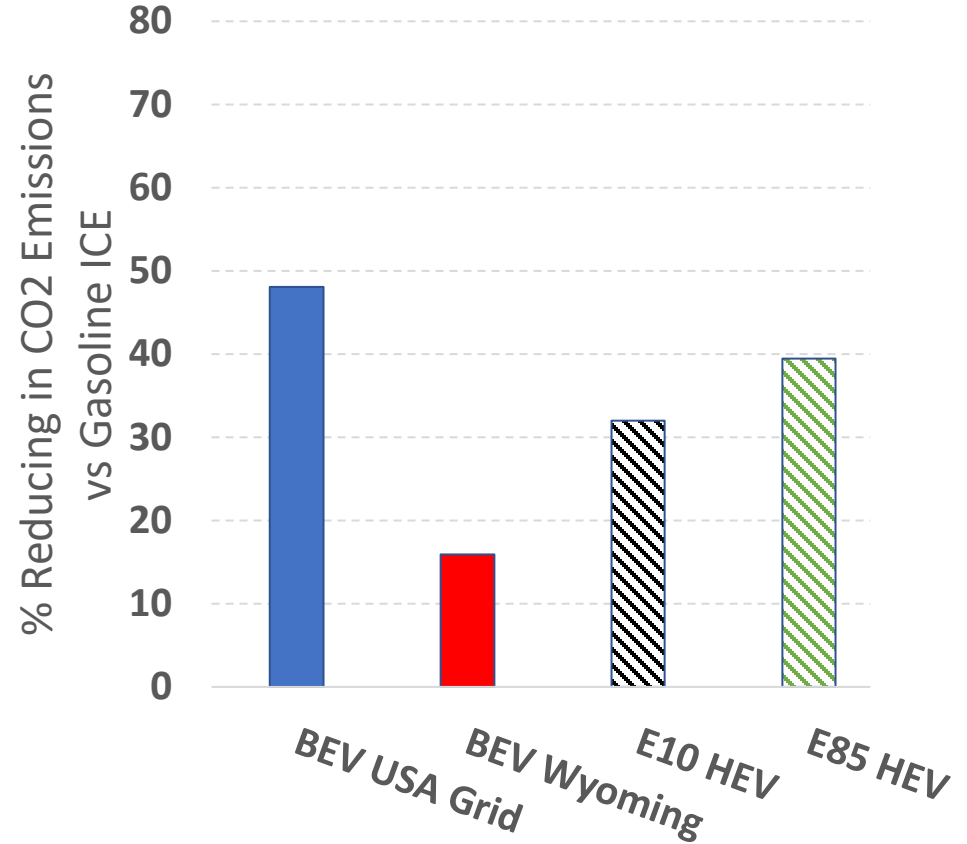
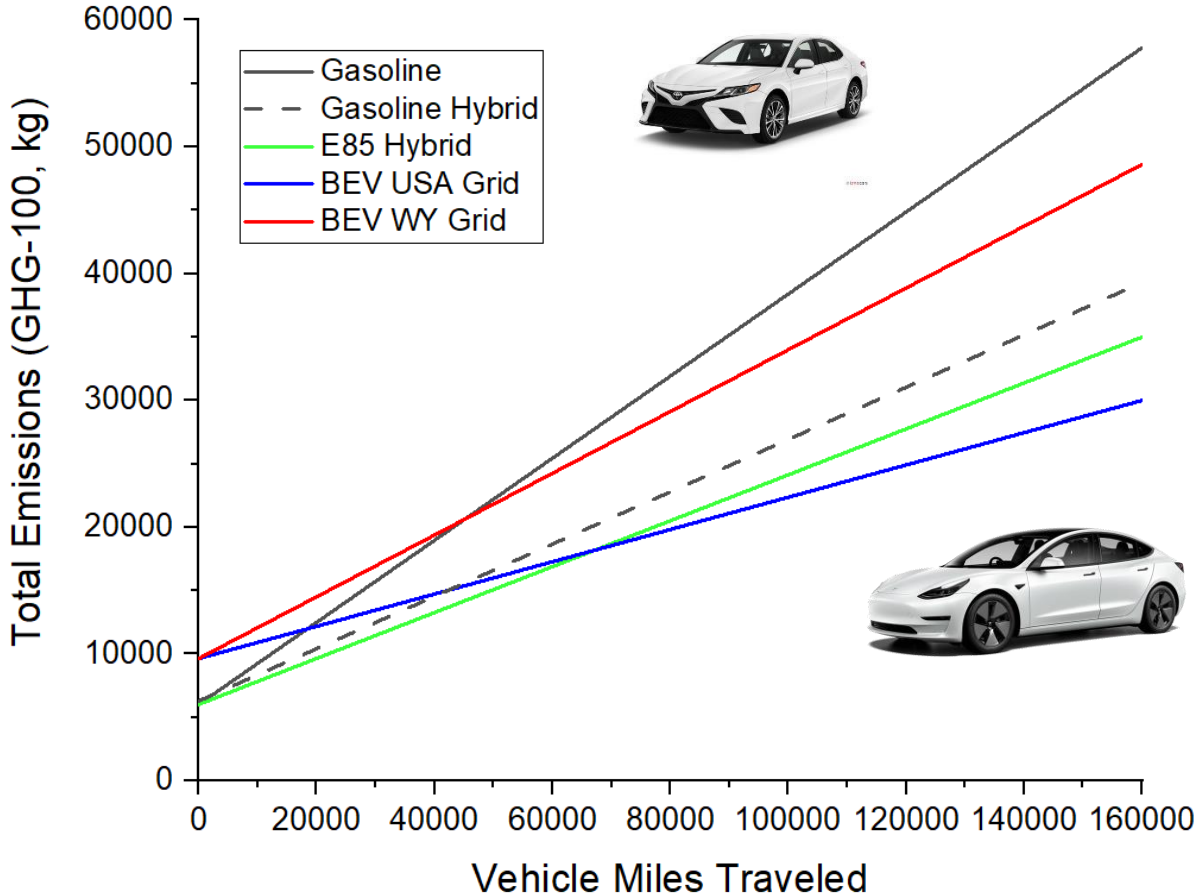
# Hybrid Powertrain



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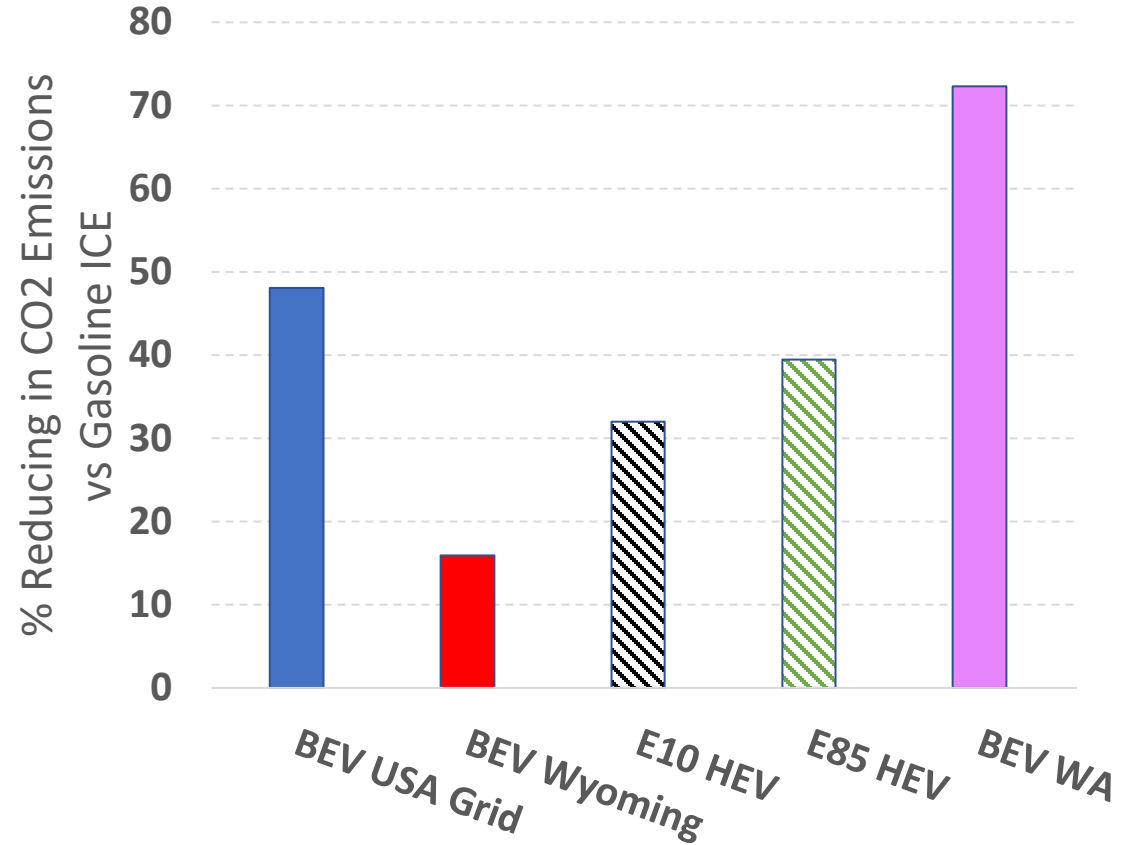
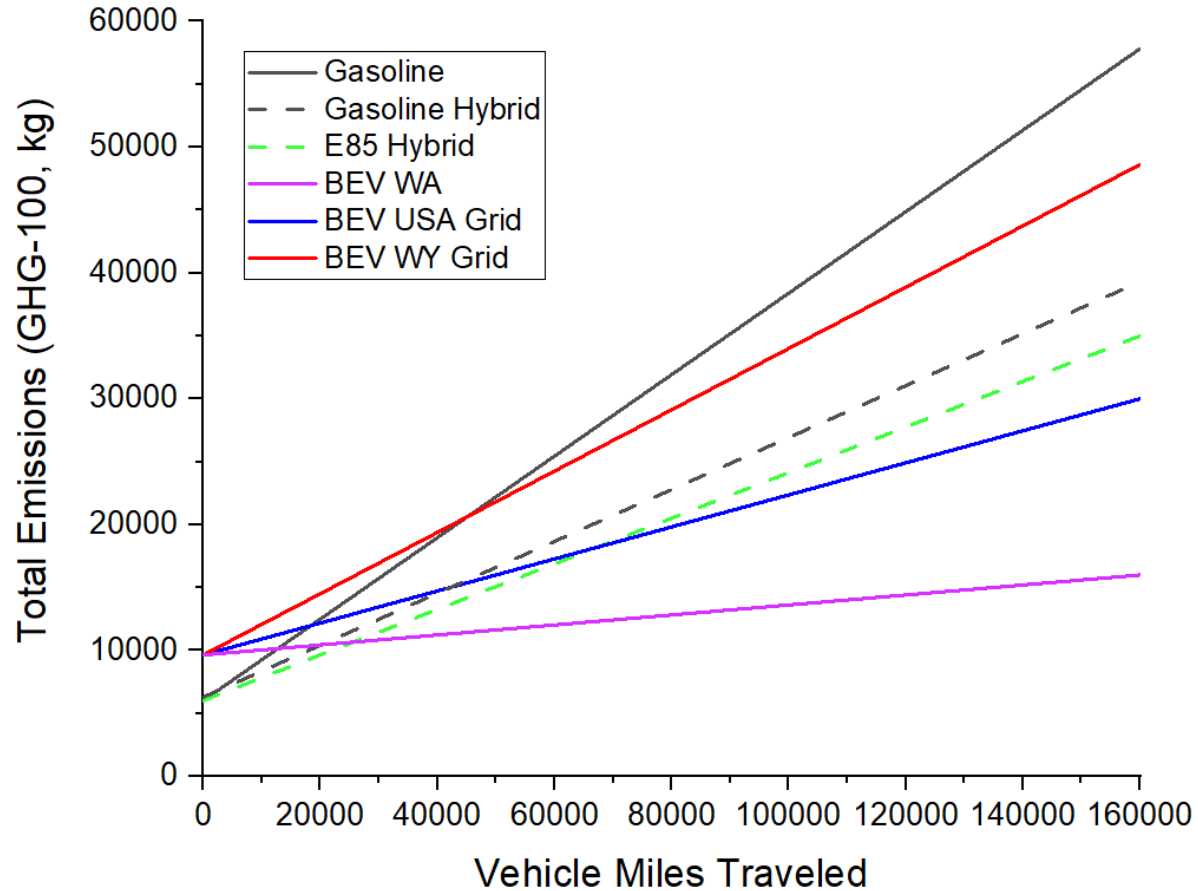
# Bio Fuel (E85) Hybrid

Sedan Lifecycle Emissions



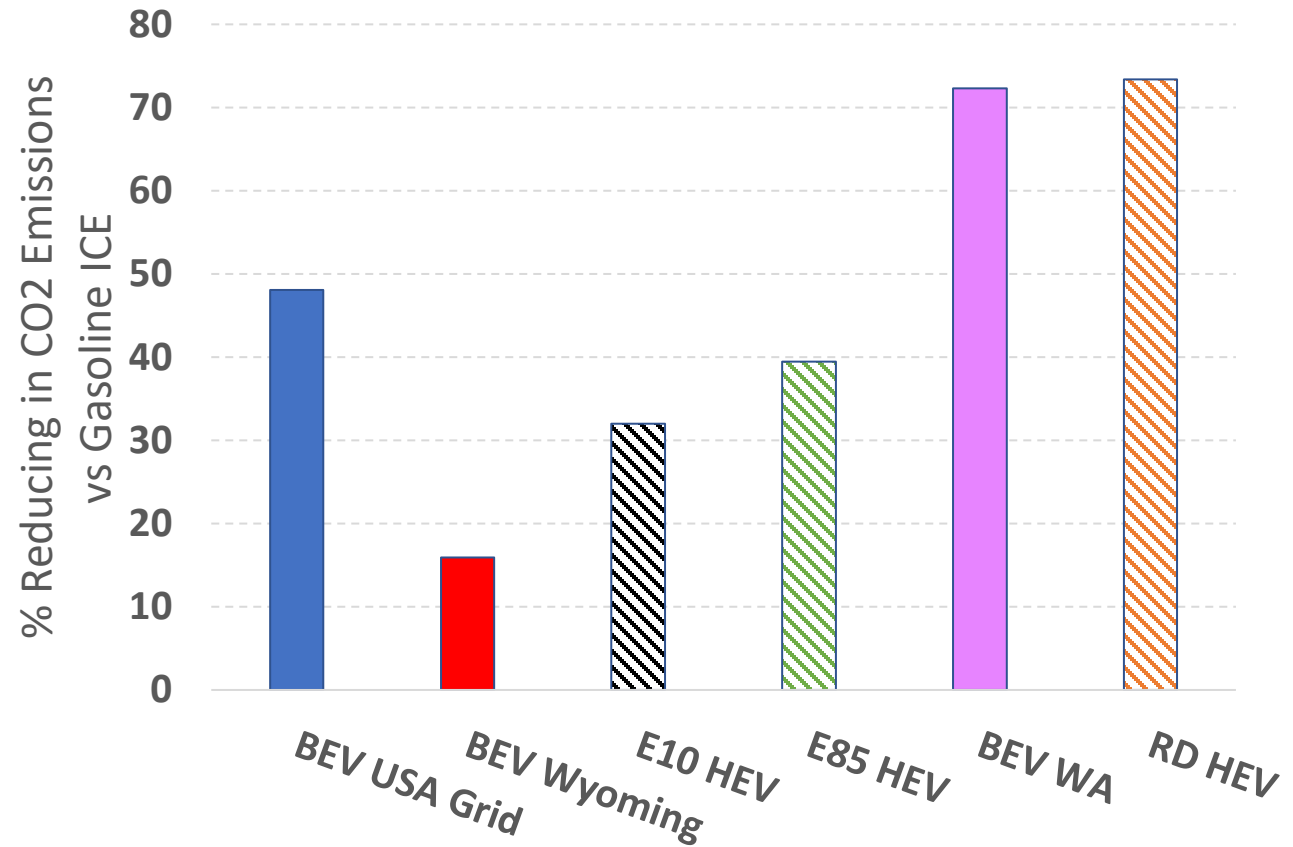
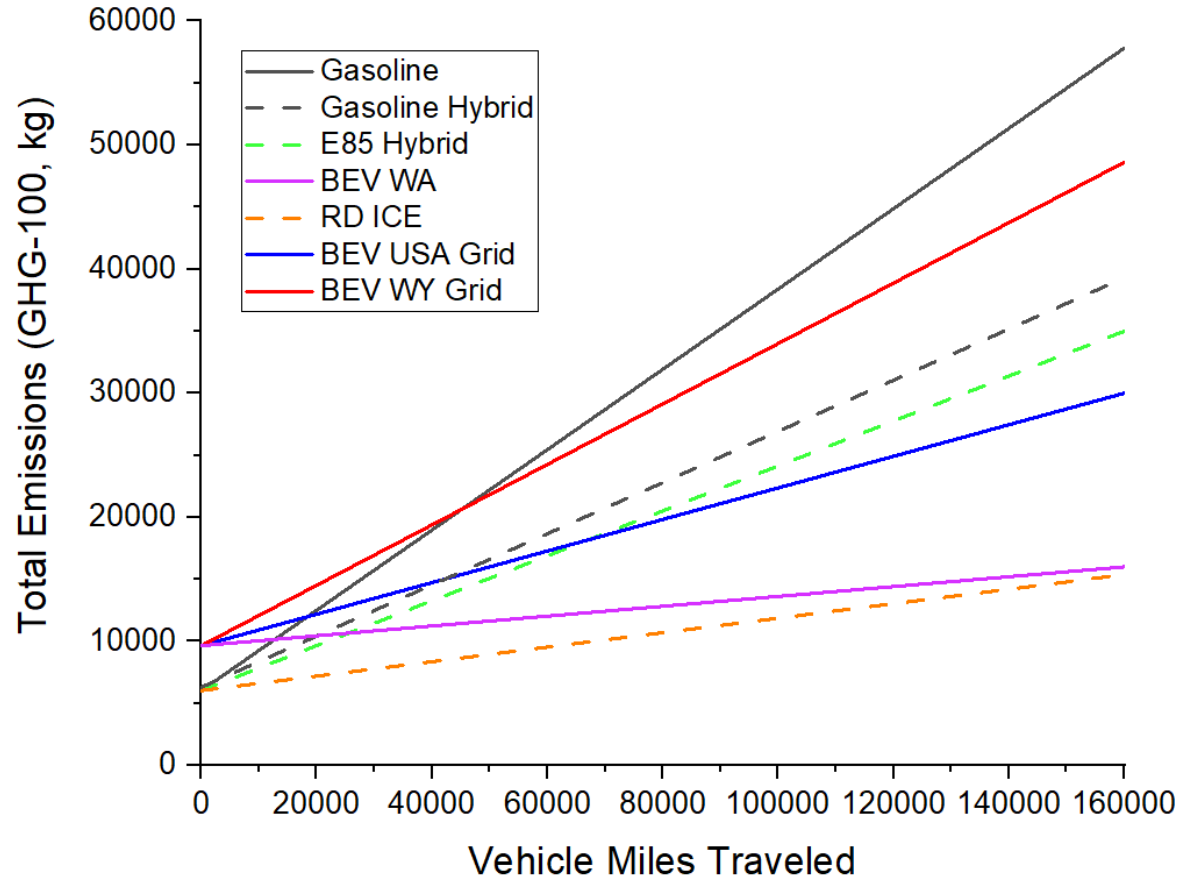
# BEV with Washington Grid

Sedan Lifecycle Emissions

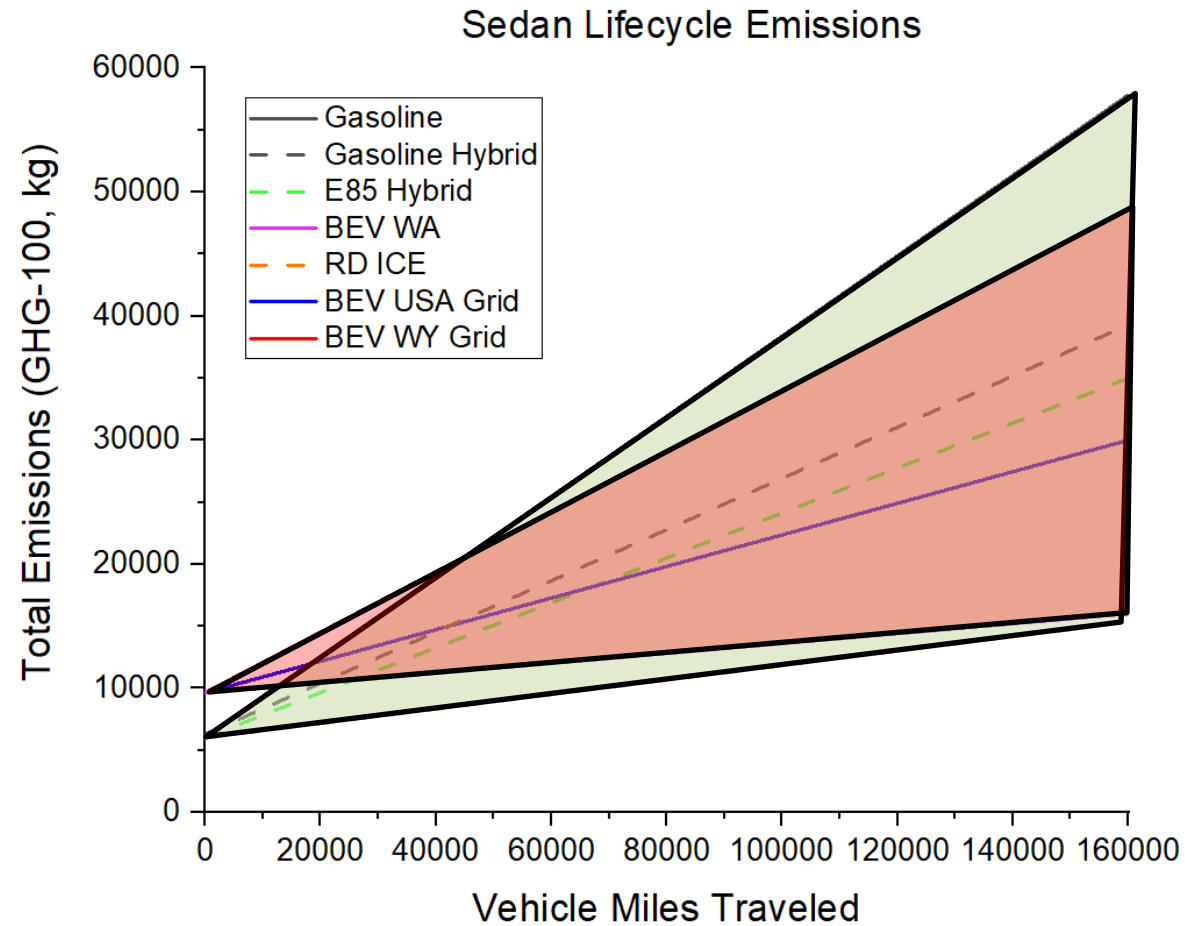


# Renewable Diesel

Sedan Lifecycle Emissions



# Comparing Technologies



ICE

BEV

# Decarbonization Strategies

## With Life-Cycle Analysis Regulations

- *Biofuels*
  - Bioethanol
  - Biodiesel
- *Renewable Fuels*
  - Renewable Diesel / HVO
- *E-Fuels (Synthetic Fuels)*
  - Using renewable energy to separate  $H_2O$  and  $CO_2$  to create synthetic fuel base:
  - Further reformation to 'upgrade' to gasoline



## Without Life-Cycle Analysis Regulations

- *BEVs*
- *FCEV*
- *ICE*
  - *Hydrogen*
  - *Ammonia*
  - *High H:C Fuels will help*
- *Carbon Capture*



Credit:Aramco

# EPA Proposal on LCA / Hydrogen

- **LD/MD Multi-pollutant Rule:**

- EPA is also proposing that the requirement for upstream emissions accounting for BEVs ...would be removed under the proposed program; thus, BEVs would continue to be counted as zero grams/mile

- **EPA GHG Phase 3:**

- “we are proposing to include vehicles using engines fueled with neat hydrogen in 40 CFR 1037.150(f) so that their CO<sub>2</sub> tailpipe emissions are deemed to be zero and manufacturers are not required to perform any engine testing for CO<sub>2</sub> emissions.”

Where do we go from here?