

Challenges and Solutions to Net Zero CO₂ in the Transportation Sector

SOUTHWEST RESEARCH INSTITUTE®

Dr. Terry Alger

Executive Director, Sustainable Energy and Mobility



Southwest Research Institute

75 Years of Improving Transportation

- Established in 1947 to improve the world through advanced science and technology
- We specialize in “Bridging the Valley of Death” from deep sea to deep space



Fuels and Lubricants Testing for OEMs and DOD



Working with the EPA to establish emissions standards and testing procedures

Developing new engine and vehicle technologies to meet CAFE and CAA requirements

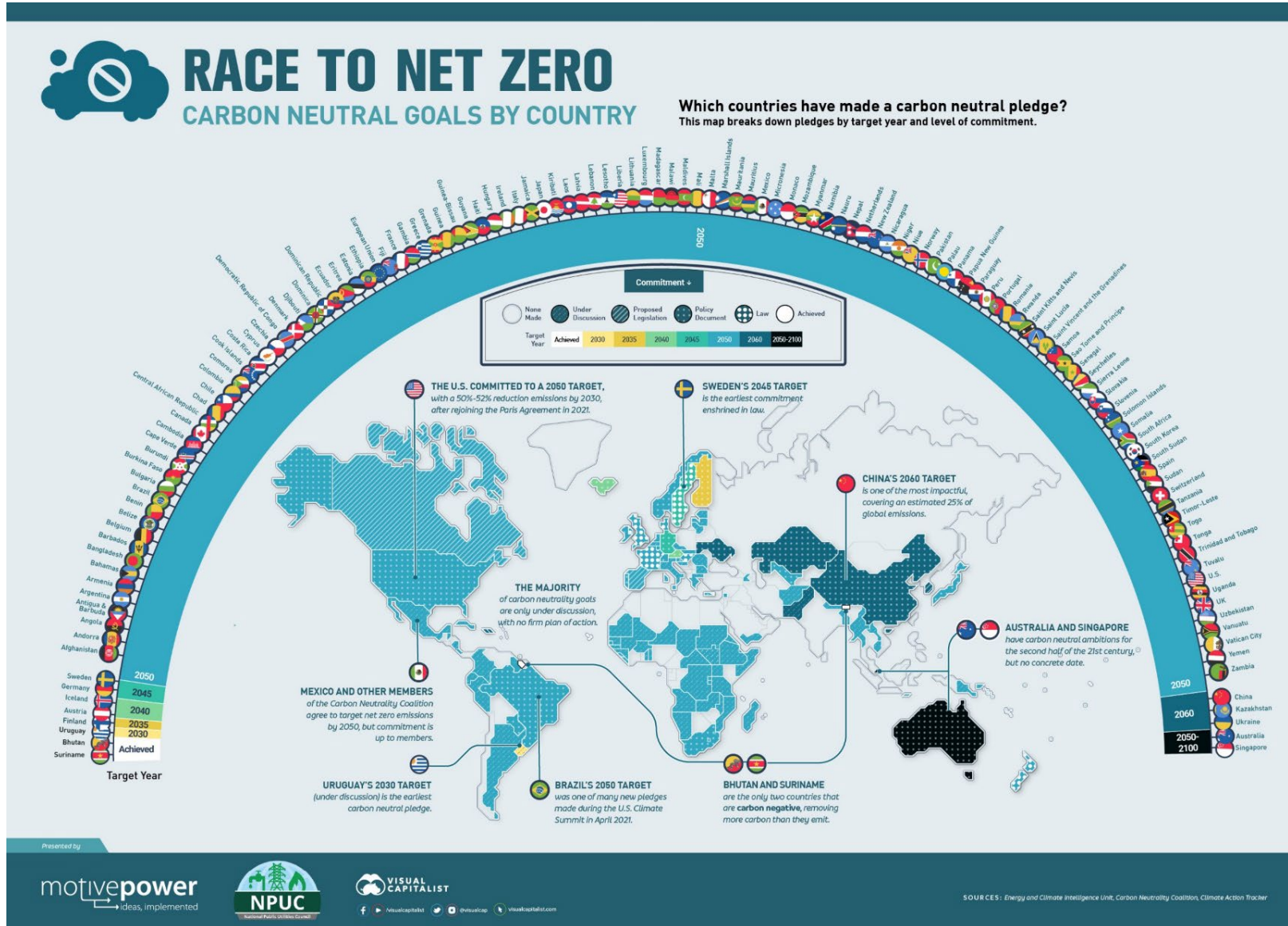
Developing new technologies to solve the challenges of net-zero transportation



POWERTRAIN ENGINEERING

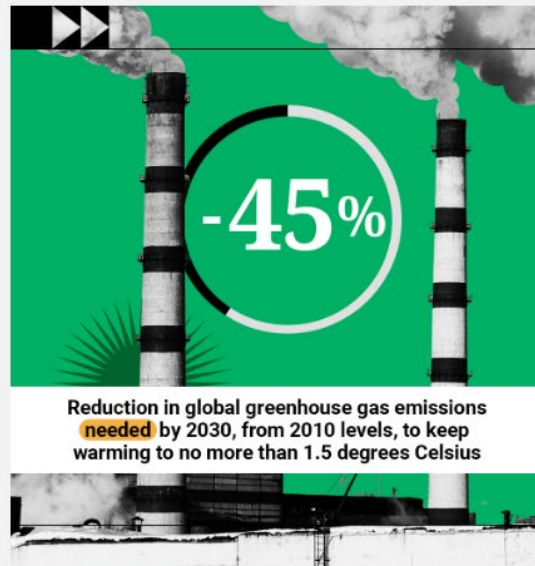


Will Our Future Be “Net Zero”?



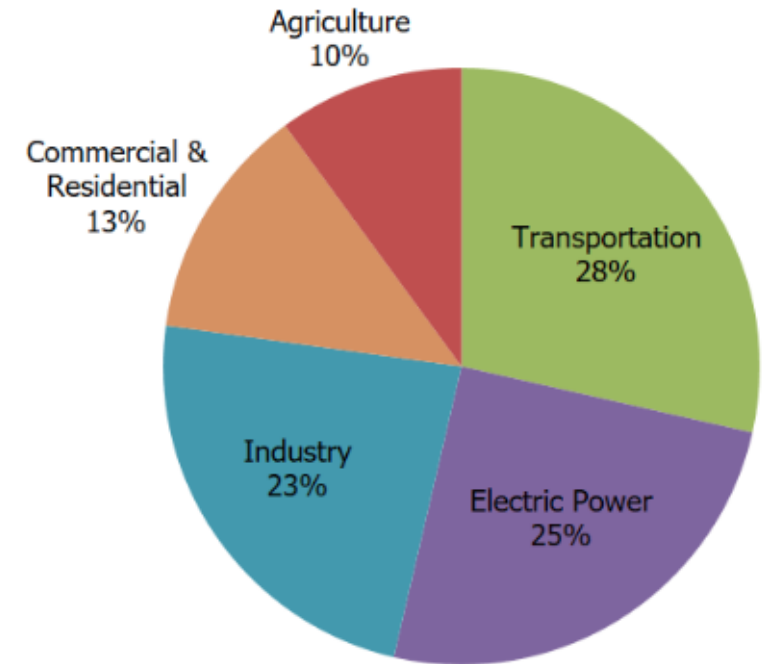
“Net Zero” Offers Significant Challenges and Opportunities

Current national plans fall short of what is required

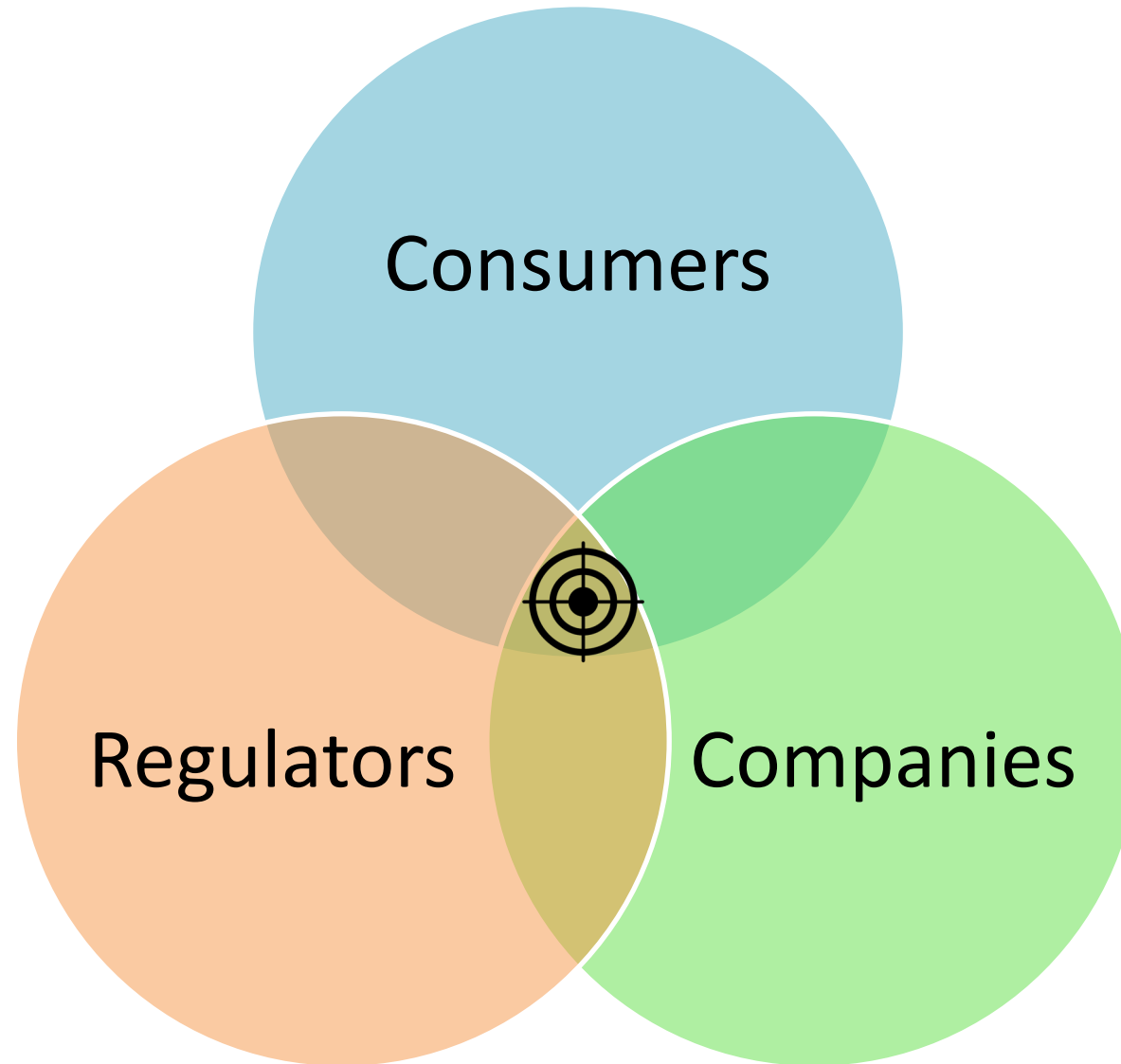


Many of the required technologies have yet to be developed / invented

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2021



And What Does “Sustainable” Mean Anyway?



What's the Right Solution?



Industry is Rapidly Changing 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

This new device captures CO2 from trucks as they drive

California to Ban the Sale of New Gasoline Cars

Hydrogen fuel cells seek transport niches EVs can't reach

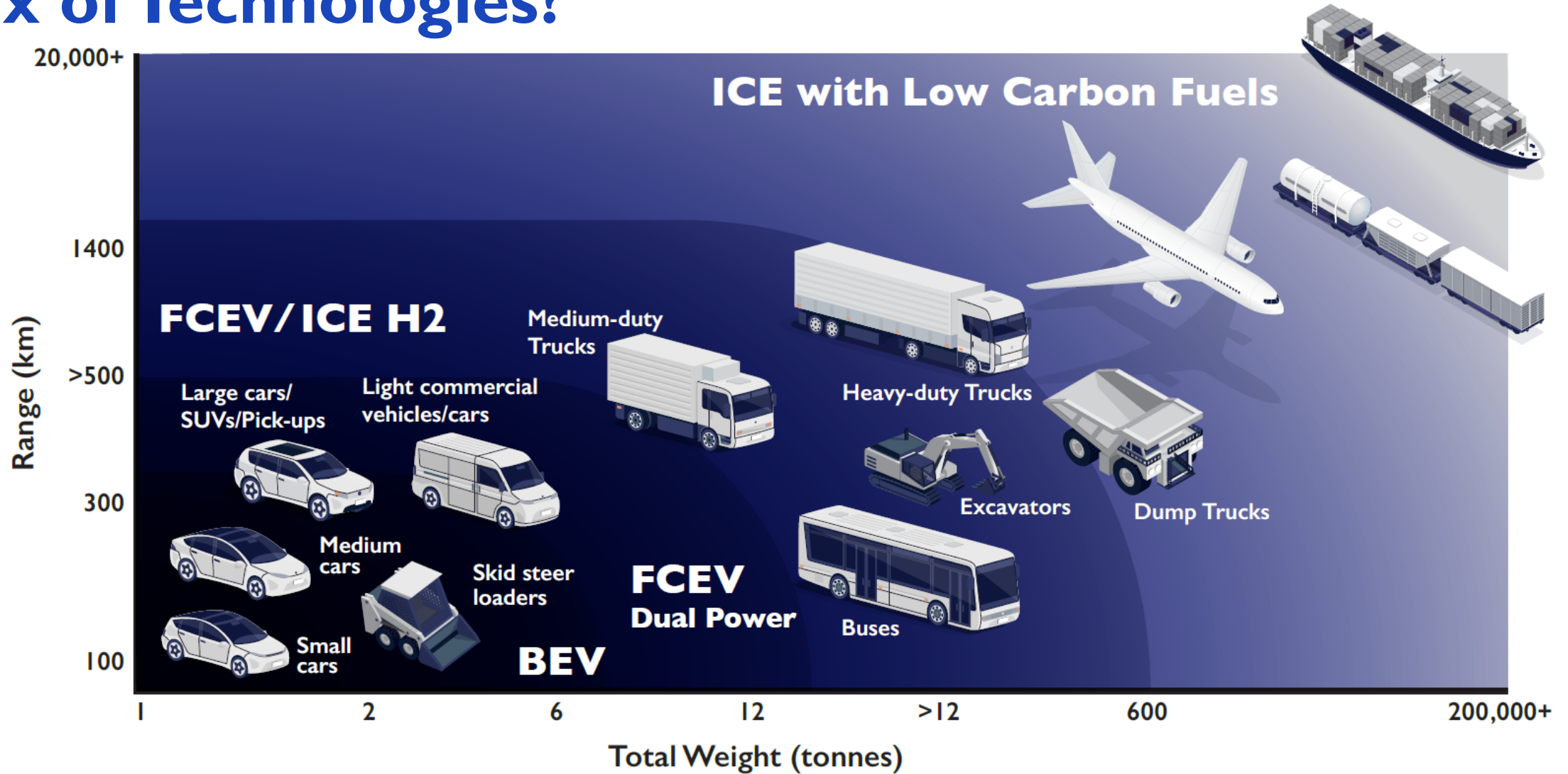
California regulators OK \$1 billion for EV charging project

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

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



Is The Future of Low / Zero Carbon Transportation a Mix of Technologies?

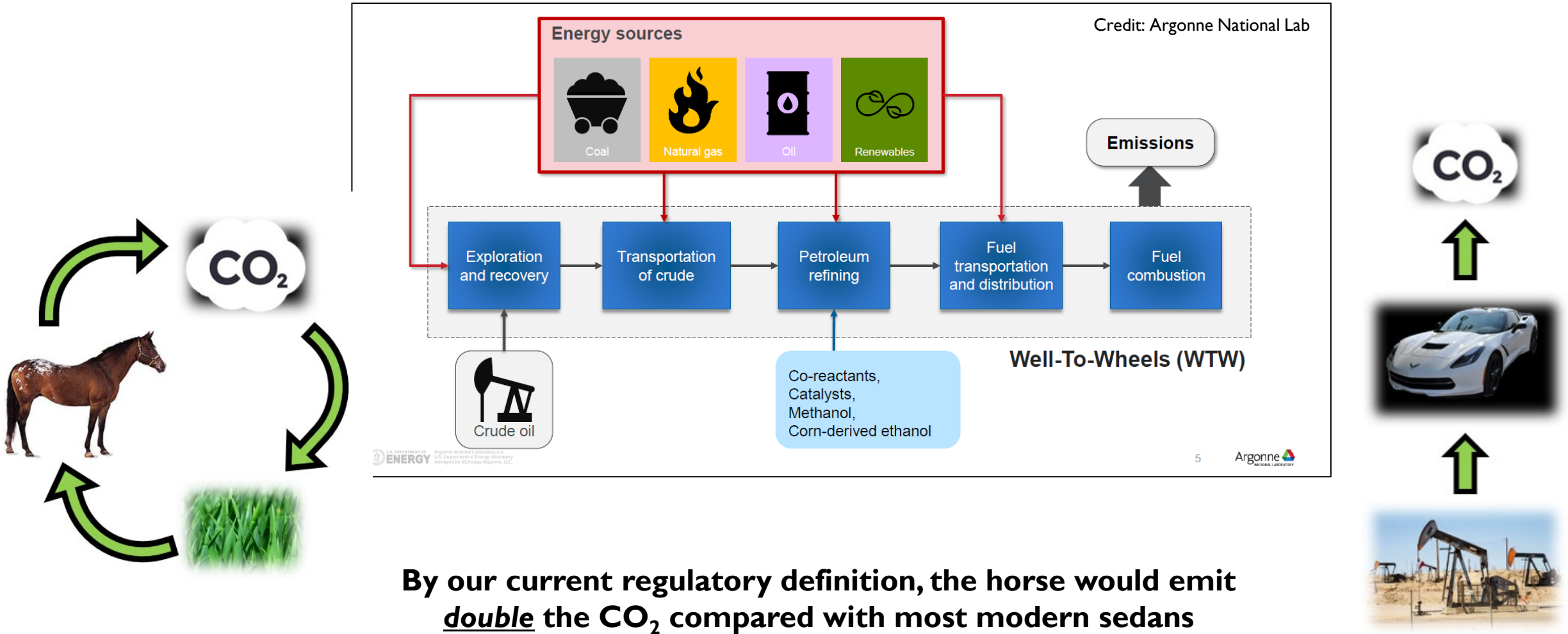


Or Will It Be “Last Man Standing?”



Can We Actually Achieve 'Zero Emissions' ?

A Life-Cycle Approach Can Drive Decision Making



Decarbonization Strategies are a Function of the Regulations

With Life-Cycle Analysis Regulations

- *Biofuels*



- *Renewable Fuels*



- *E-Fuels (Synthetic Fuels)*



Without Life-Cycle Analysis Regulations

- *BEVs*



- *FCEV*

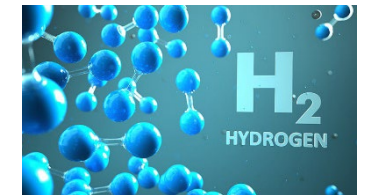


- *ICE*

- *Hydrogen*

- *Ammonia*

- *High H:C Fuels*



- *Carbon Capture*



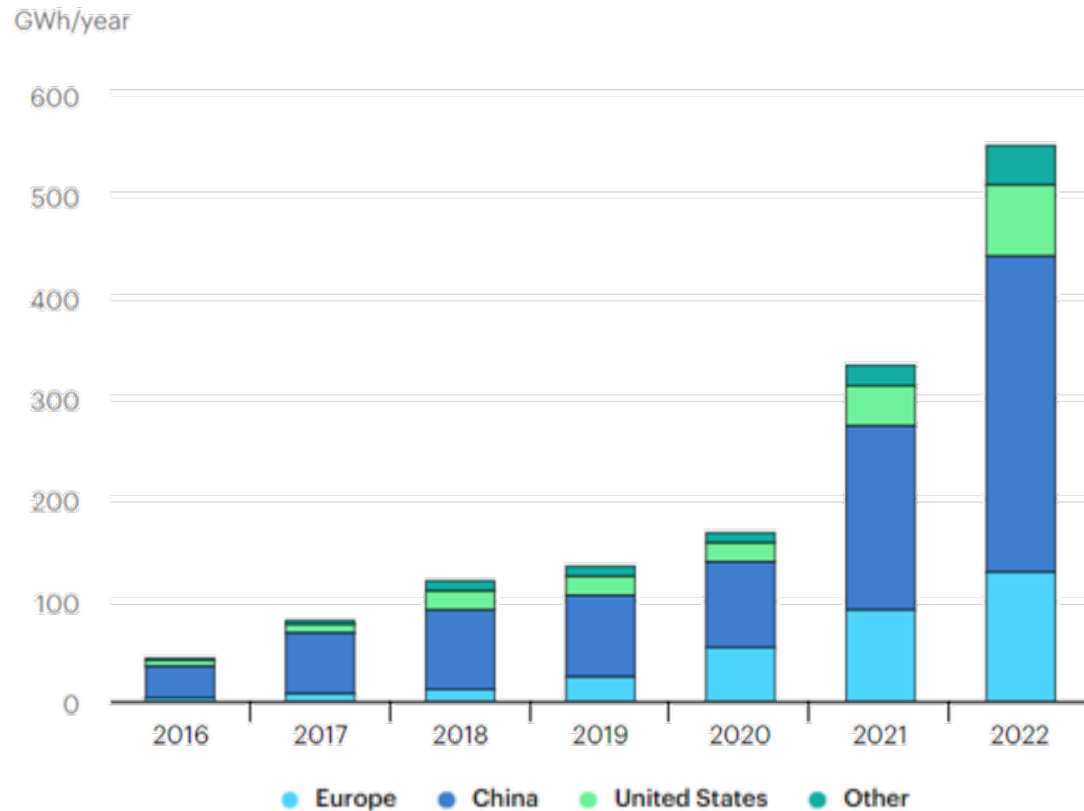
Credit:Aramco

Focus on BEV's

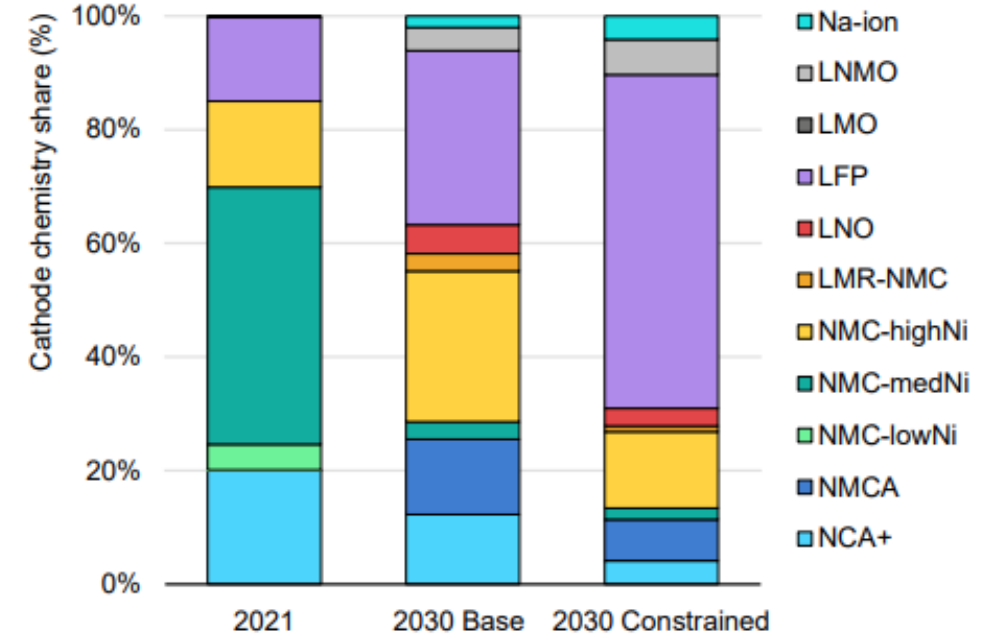
Battery Material Projections

Battery demand by region, 2016-2022

Open ↗



Light-duty vehicle battery chemistry projections, Constrained Chemistry and Base cases, 2021 and 2030



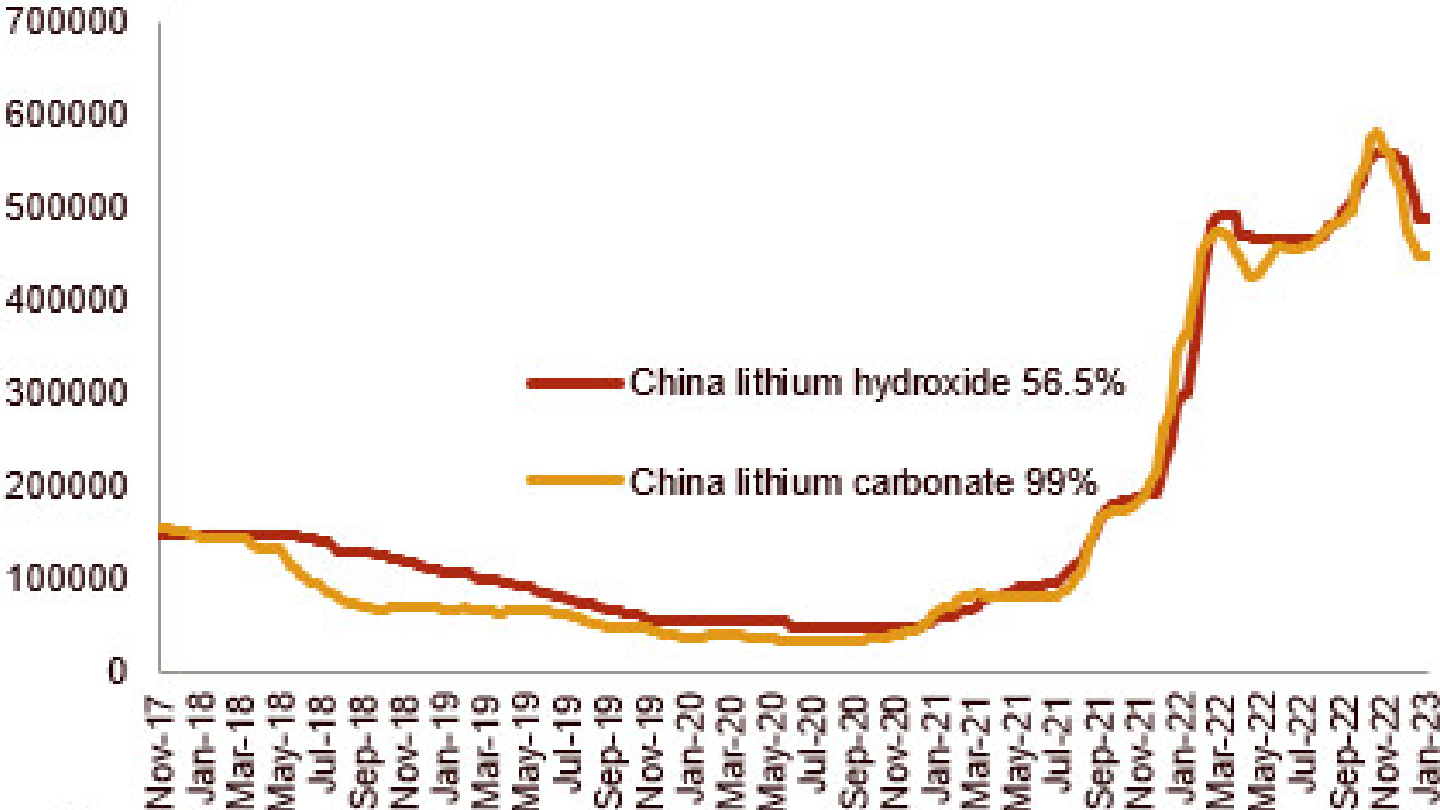
IEA. All rights reserved.

What do all these chemistries have in common?

Battery Material Projections

The Challenge of Supply and Demand

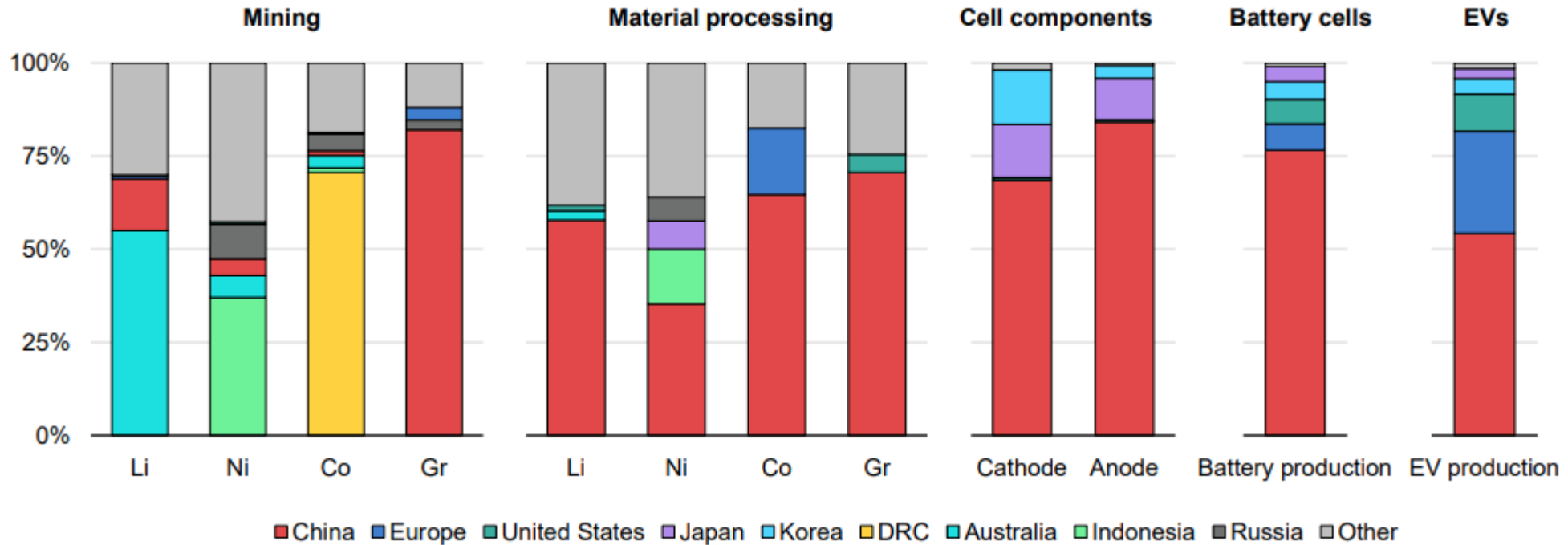
China lithium prices (CNY/MT)



Source: Bloomberg



US 'EV Independence'



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- **US is heavily reliant on friendly and non-friendly states to supply EVs**
- Battery circularity is required

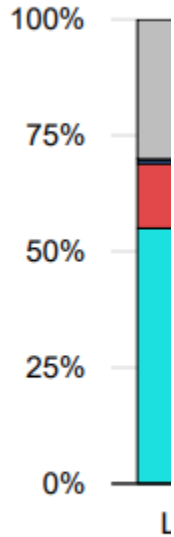
US 'EV Independence'

Commodities

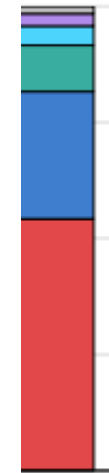
China curbs graphite exports in latest critical minerals squeeze

Reuters

October 20, 2023 3:03 AM CDT - Updated 3 days ago



EVs

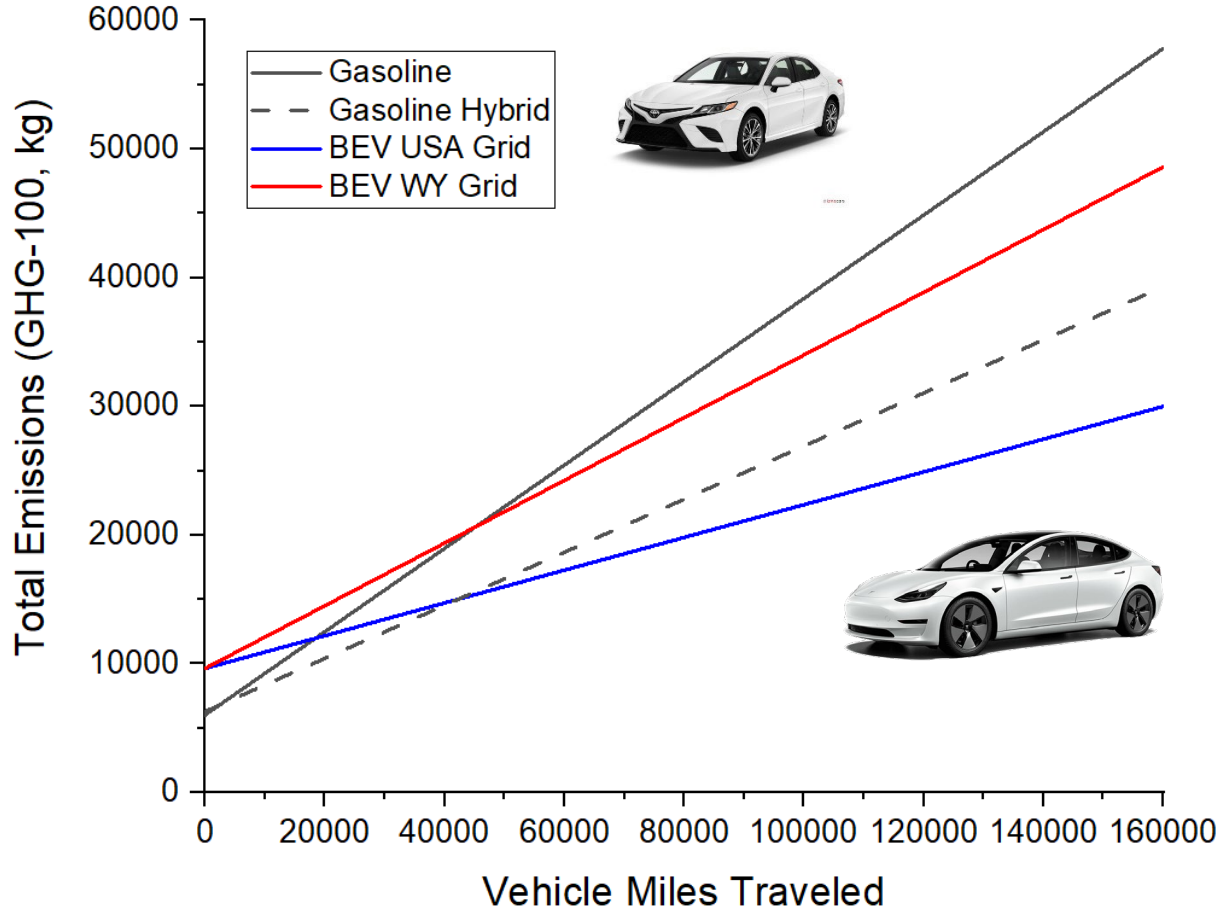


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What is the Best Use of Our Current Resources

Sedan Lifecycle Emissions



Each Tesla offsets ~ 30 tons of CO₂
Each Camry Hybrid offsets 19 tons of CO₂

Tesla Model 3 = 60 kWh
Camry Hybrid = 1.6 kWh

11.9 tons CO₂ abated per kWh with Hybrids
0.5 tons CO₂ abated per kWh with EVs

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>.

What about Hydrogen...?

H₂-ICE vs Fuel Cell vs BEV

H₂-ICE



- Drop-in replacement
- Existing manufacturing base
- Robust operation
- Lowest initial cost

FCEV



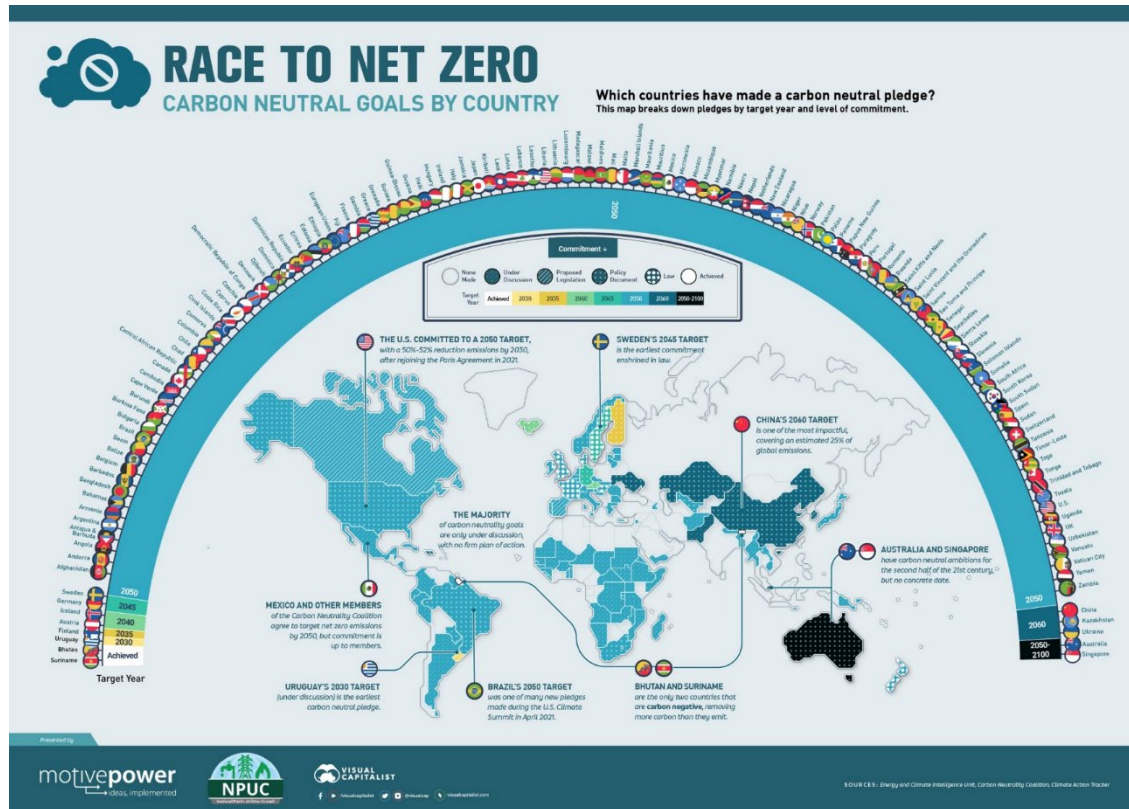
- Zero Tailpipe emissions
- High *conversion* efficiency
- Smaller battery size

BEV



- Zero Tailpipe.
- Low maintenance costs
- Low operating cost
- Synergies with automation

The Road To “Net Zero”



- Many potential pathways
 - BEV
 - HEV
 - FCEV
 - H2 ICE
 - eFuels
 -
- Many of the technologies on the path are immature
 - Even more developed ones are not fully ready to be deployed at scale
- Significant opportunities for innovation

What Would ChatGPT Advise?

In the form of a Sonnet...

GT

Write a sonnet about the future
of transportation in the USA



In future's realm where transport takes its flight,
Innovation soars with boundless grace,
With whispers of a world both sleek and bright,
A tapestry of progress we embrace.

No longer bound by roads that wind and bend,
Autonomous and swift, our cars will glide,
Their electric hearts with eco-love they'll send,
Through urban landscapes, nature's beauty side by side.

Hyperloops will race beneath the ground,
Magnetic levitation, speeds untamed,
In tubes, a world where time and space are bound,
Connecting souls, through endless tunnels, framed.

The skies, a canvas for electric wings,
From drones to planes, where modern transport sings.
In virtual worlds, we'll teleport our dreams,
With virtual realities, we'll roam,

From holographic beams to sentient machines,
The future's tapestry, a vivid poem.
The future of transportation, bright and bold,
Innovation's endless journey we'll behold.

Thank you

Terry Alger

Executive Director, Sustainable Energy and Mobility

talger@swri.org

210-522-5505

Nov 16, 2023 to Nov 17, 2023
San Antonio, TX, United States



<https://www.swri.org/event/life-cycle-analysis-transportation-symposium>