

# Accelerating Deep Decarbonization of US Transportation

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# Thanks to ASCE!

- I have been a member for over four decades!
- I have served on numerous committees and published extensively in ASCE journals over the years.
- I have enjoyed opportunities for networking and learned a great deal from my colleagues!
- Many challenges and opportunities still coming!

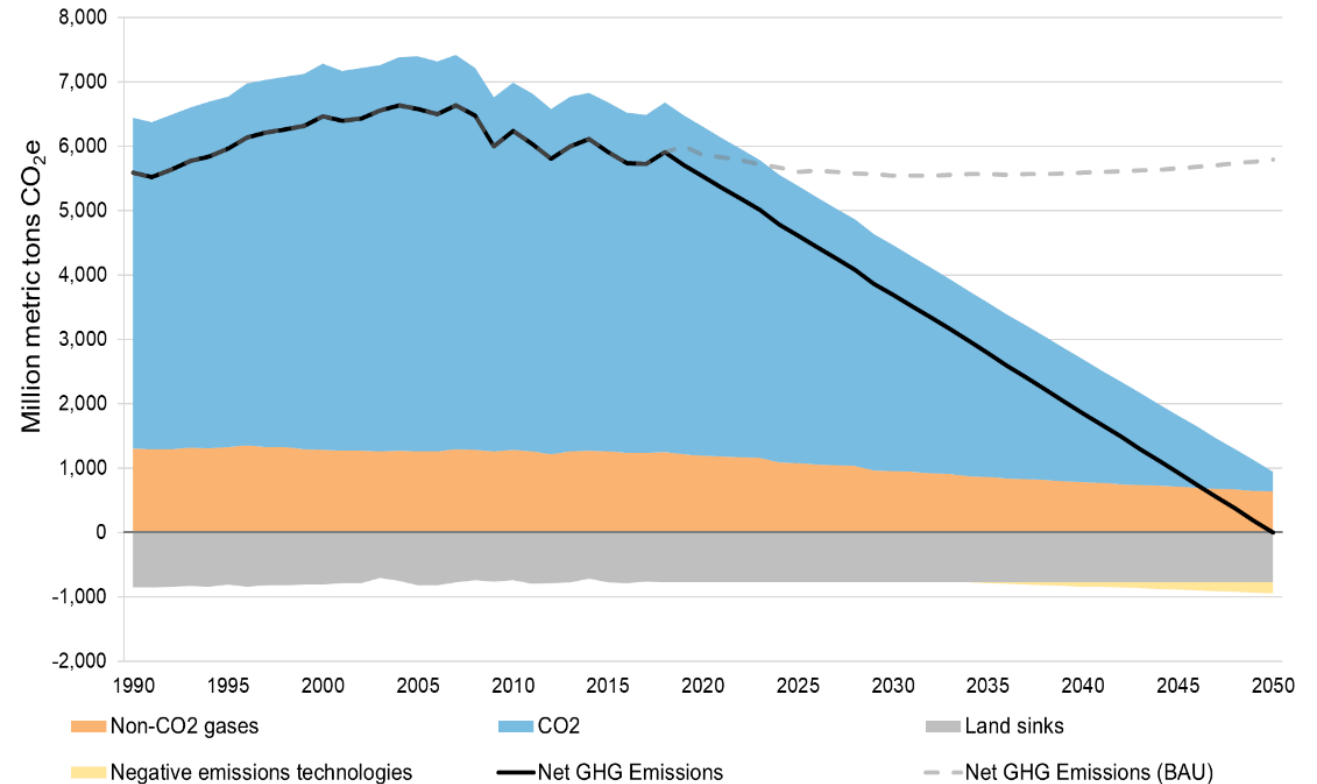
# Motivation

- Climate change with sea level rise, heat, drought, extreme weather.
- Conventional air emissions health effects.
- Long term sustainability as fossil fuels are a finite resource.
- Ongoing technology development in alternatives to fossil fuels but lack of US manufacturing
- Political tides may be turning towards decarbonization

# Climate Change and Decarbonization

Limiting climate change to substantially less than 2 degrees Celsius requires global emissions to reach net-zero by mid-century (IPCC 2018)

U.S. emissions for 2019 were 6 Gt CO<sub>2</sub>e/y of all greenhouse gases and 5 Gt CO<sub>2</sub>/y, partially offset by a large CO<sub>2</sub> sink from its managed forests



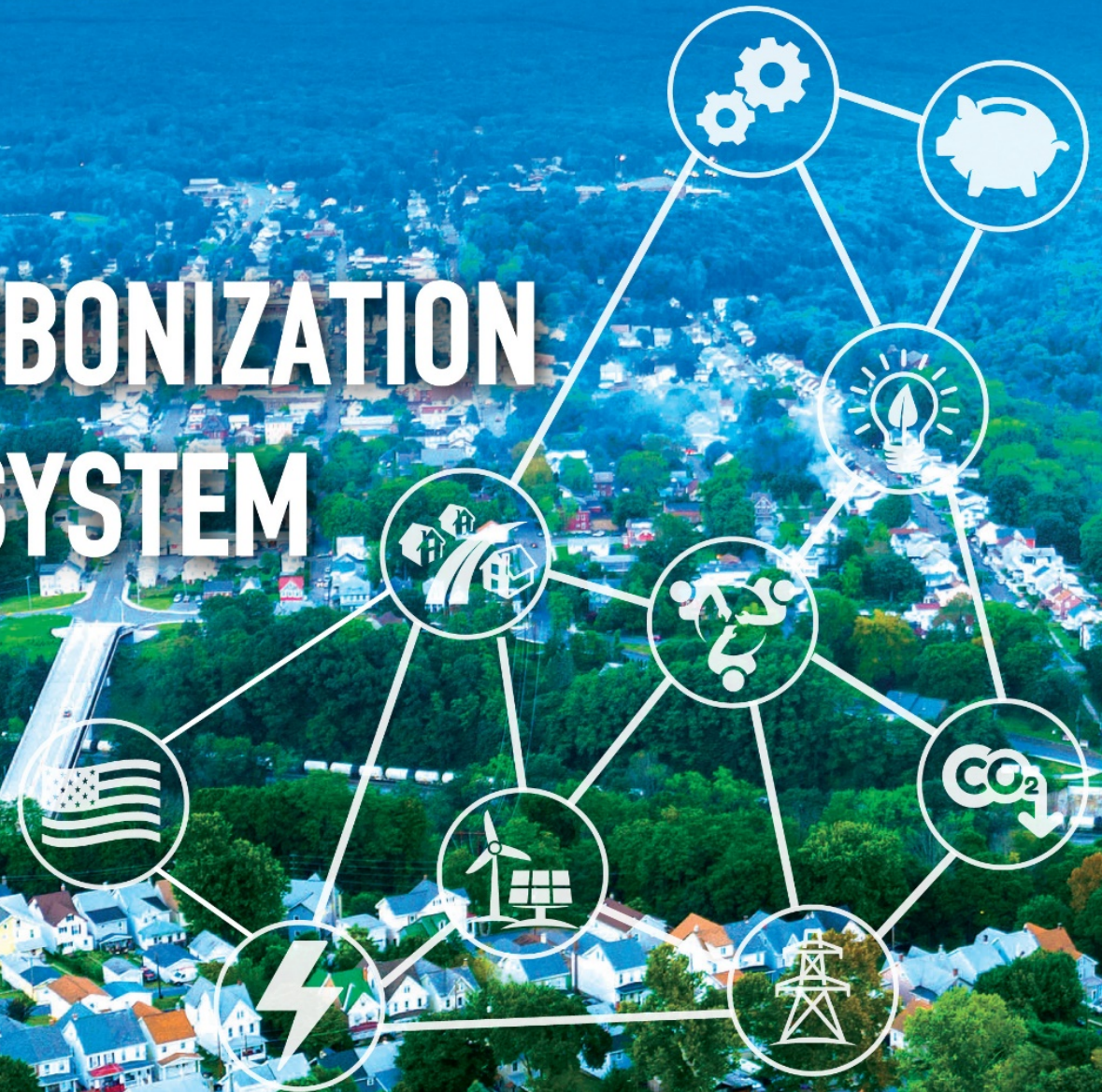
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# ACCELERATING DECARBONIZATION OF THE U.S. ENERGY SYSTEM



#USDecarb



# Technology Goals



## Electrify energy services in transportation, buildings, and industry

Examples include moving half of vehicle sales (all classes combined) to EV's by 2030, and deploying heat pumps in one quarter of residences.



## Improve energy efficiency and productivity

Examples include accelerating the rate of increase of industrial energy productivity (dollars of economic output per energy consumed) from the historic 1% per year to 3% per year.



## Produce carbon-free electricity

Roughly double the share of electricity generated by carbon-free sources from 37% to 75%.



## Expand the innovation toolkit

Triple federal support for net-zero RD&D.



## Plan, permit, and build critical infrastructure

Examples include new transmission lines, an EV charging network, and a CO<sub>2</sub> pipeline network.

# Socio-Economic Goals



## Strengthen the U.S. economy

Use the energy transition to accelerate US innovation, reestablish US manufacturing, increase the nation's global economic competitiveness, and increase the availability of high-quality jobs.



## Support communities, businesses, and workers

Proactively support those directly and adversely affected by the transition



## Promote equity and inclusion

Ensure equitable distribution of benefits, risks and costs of the transition to net-zero.

Integrate historically marginalized groups into decision-making by ensuring adherence to best practice public participation laws.

Ensure entities receiving public funds report on leadership diversity to ensure non-discrimination.



## Maximize cost-effectiveness

# Context of Talk

- Goal: Net Zero Carbon Emissions by 2050 for Transportation Modes.
- Given fleet turnover, infrastructure longevity and research time, 2020-2030 decade is critical.
- Focus on United States, but actions relevant to other countries. China has pledged to be net zero by 2060.
- Focus on Transportation but need to consider power generation, liquid fuel and vehicle production industries. Actions relevant for all carbon generating entities.



# Numerous Deep Decarbonization Studies Exist

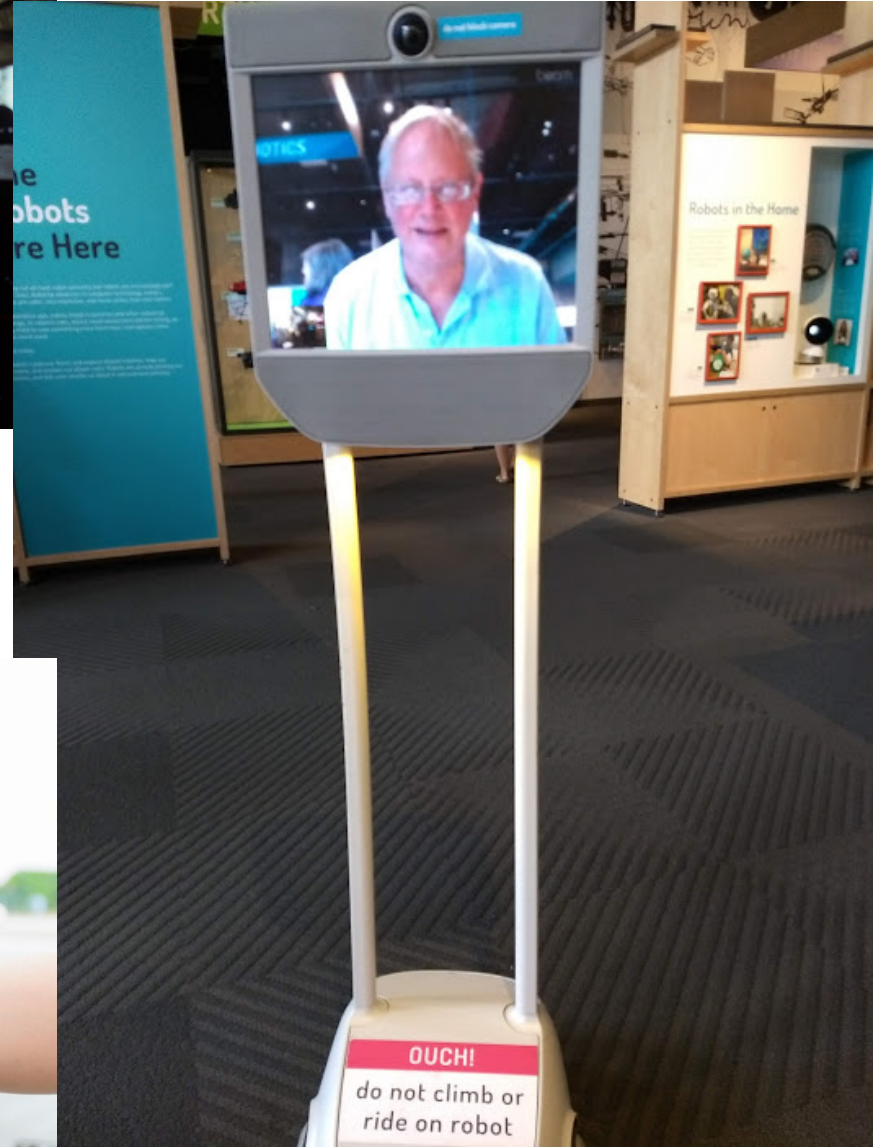
- Global, Regional (e.g. European Union), National and Statewide Studies.
- Varying time frames and goals.
- Varying attention to costs, milestones and policy options.
- Often scenario based.

# Million Metric Tons of CO2 Emission (US EPA)

Year	1990	2005	2018
Passenger cars	612	643	764
Light-duty trucks	312	491	306
Other trucks	229	400	432
Buses	8	12	21
Motorcycles	2	2	4
Commercial Aircraft	110	133	130
Other Aircraft	78	59	44
Ships and Boats	46	44	37
Rail	39	50	42
Pipelines	36	32	49
Lubricants	12	10	9

# 1. Improve Energy Efficiency and Productivity

- Increase vehicular fuel efficiency (e.g. light weight vehicles with automation safety and new materials).
- Switch to non-motorized modes of travel (e.g. bicycle and walking)
- Switch to more energy efficient modes (e.g. trucking to rail or water, single occupancy vehicles to shared vehicles, and air travel to rail).
- Reduce travel (e.g. tele-work and reduced sprawl)
- Reduce congestion (e.g. fewer crashes with automation and connectivity)
- Improve energy efficiency in battery and vehicle manufacture.



# Costs of Energy Efficiency and Productivity Measures Vary

- Some energy efficiency measures have both private and social positive net benefits, but typically require a capital investment followed by cost savings (e.g. more fuel efficient vehicles).
- Some energy efficiency measures are inconvenient or risky (e.g. will shared ride services be shunned in a post-pandemic world?).
- Policy instruments include standards, tax incentives, grants, procurement requirements, and others.

## 2. Electrify Transportation as Much as Possible

- Plug-in battery electric vehicles become dominant, especially in urban areas.
- Can fuel cell vehicles become competitive with BEV for long hauls?
- Charging and hydrogen infrastructure available throughout the US.
- Railroads can be BEV, fuel cell or connect to power lines.
- Ships switch to fuel cell, nuclear or low carbon liquid fuels.



### 3. Decarbonize Power Generation

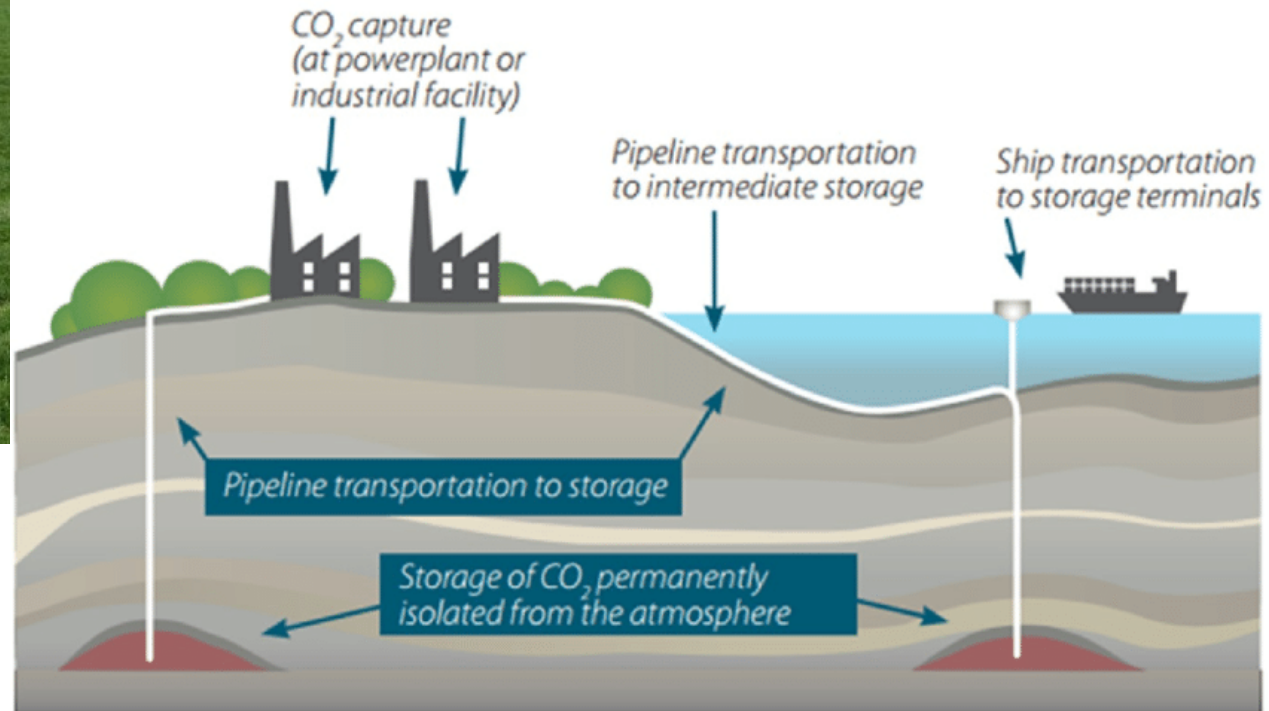
- Increase renewable power generation share dramatically (e.g. solar, geothermal and wind).
- Insure stable supply of power (e.g. battery or pump storage).
- Preserve nuclear generation
- Manage the transition of coal fired power plants to carbon capture and sequestration.





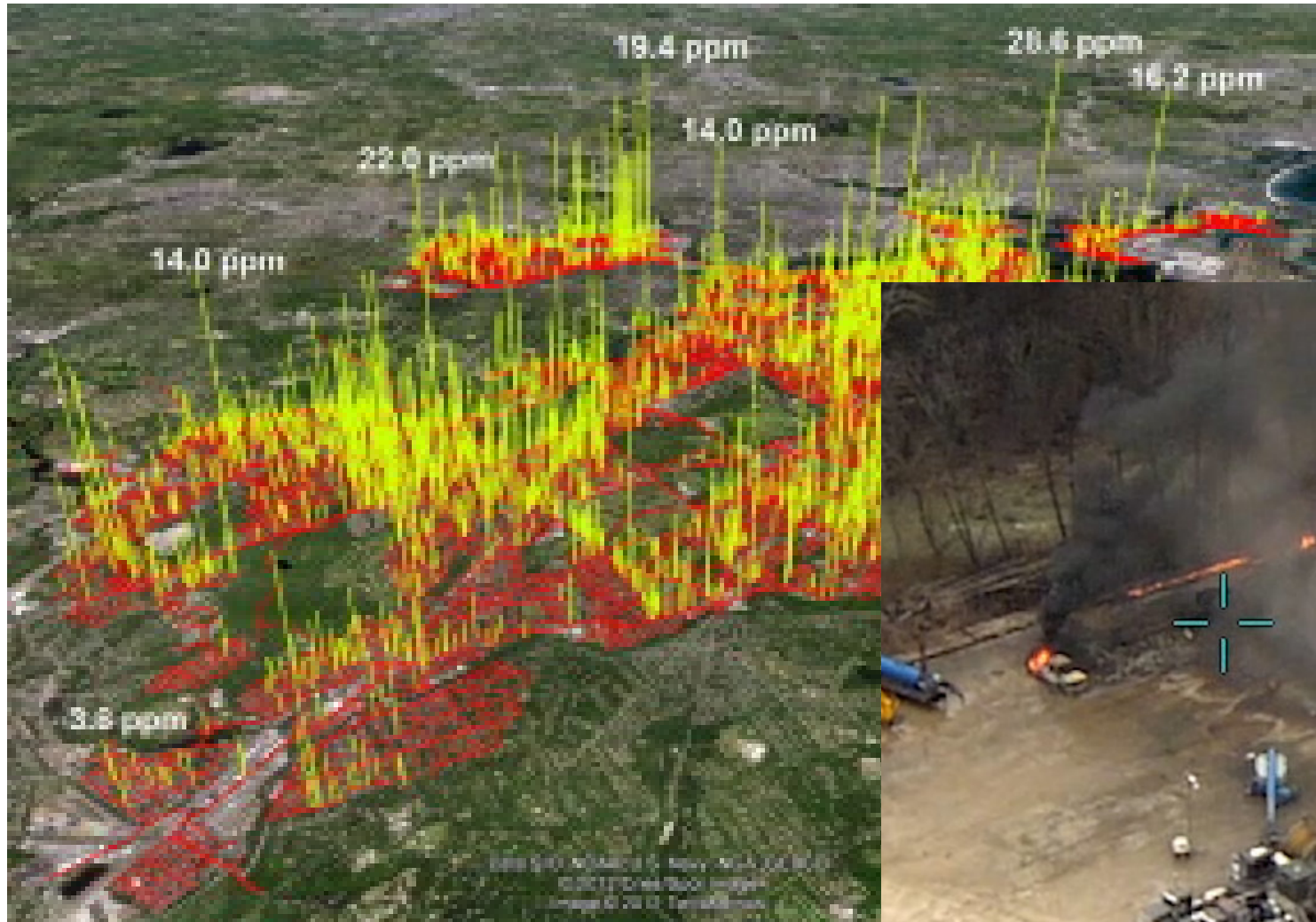
## 4. Build Critical Infrastructure

- Electricity transmission and charging stations.
- Hydrogen filling stations.
- Carbon capture and storage infrastructure.
- Catenary for railroads.
- Connectivity for energy efficiency.



## 5. Non-energy greenhouse gas emissions

- Industrial process improvement (e.g. cement)
- Enhance land and water sequestration of carbon
- Reduce non-CO<sub>2</sub> greenhouse gas emissions (e.g. methane and hydrofluorocarbons). Leaking pipelines are an issue here.



## 6. Pursue useful innovations

- Zero emission hydrogen production.
- Synthesis of low carbon production liquid methane and liquid hydrocarbon fuels.
- New manufacturing processes (e.g. hydrogen direct reduction of iron, energy efficient cement)
- Carbon dioxide capture and storage processes.
- High yield bioenergy crops.
- Direct air capture of carbon dioxide.

# Possibilities for Deep Decarbonization

- Six action areas for moving forward.
- Not easy but doable.
- Sustainable engineering can be supportive and critical for this effort.
- Socio-economic goals are also critical.