Accelerating Deep Decarbonization of US Transportation Modes

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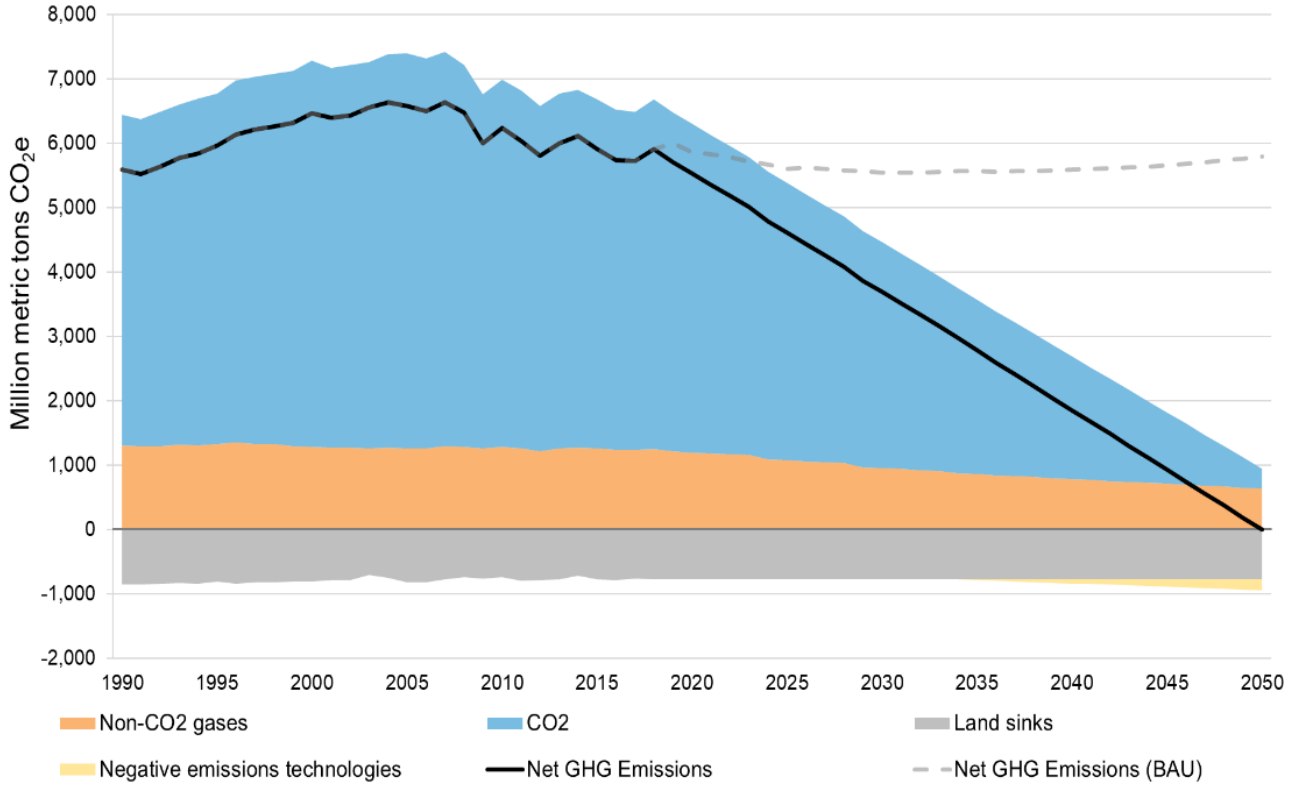
Motivation

- 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_2e/y of all greenhouse gases and 5 Gt CO_2/y, partially offset by a large CO_2 sink from its managed forests



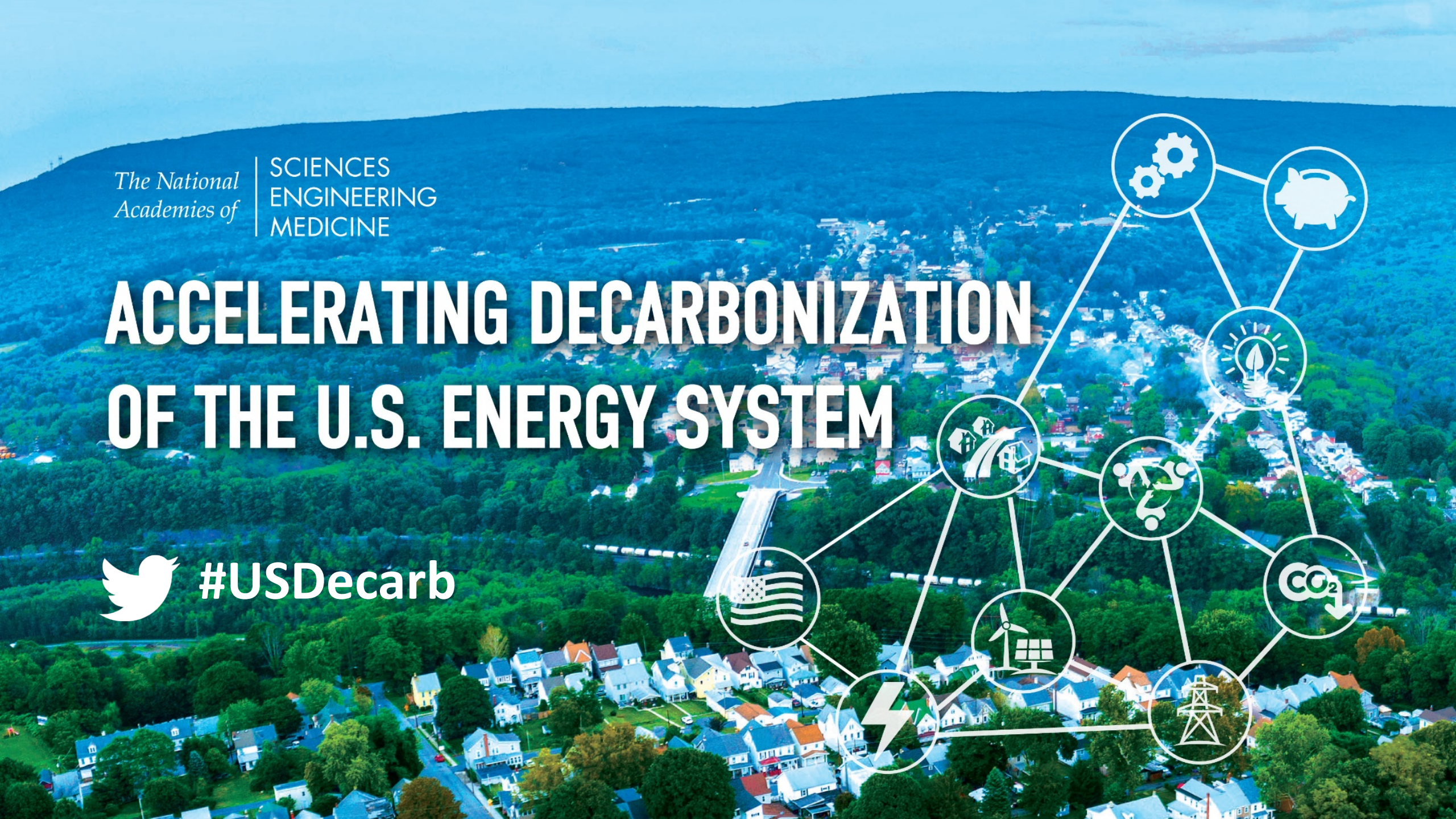
Job Loss and Creation

- Net Zero Pathway has enormous implications for the types of employment available.
- Job loss in the petroleum and coal industry.
- Job creation for renewable energy, power transmission lines, carbon capture and storage, vehicle charging, building energy efficiency and research.
- Could mean many opportunities for new graduates worldwide!

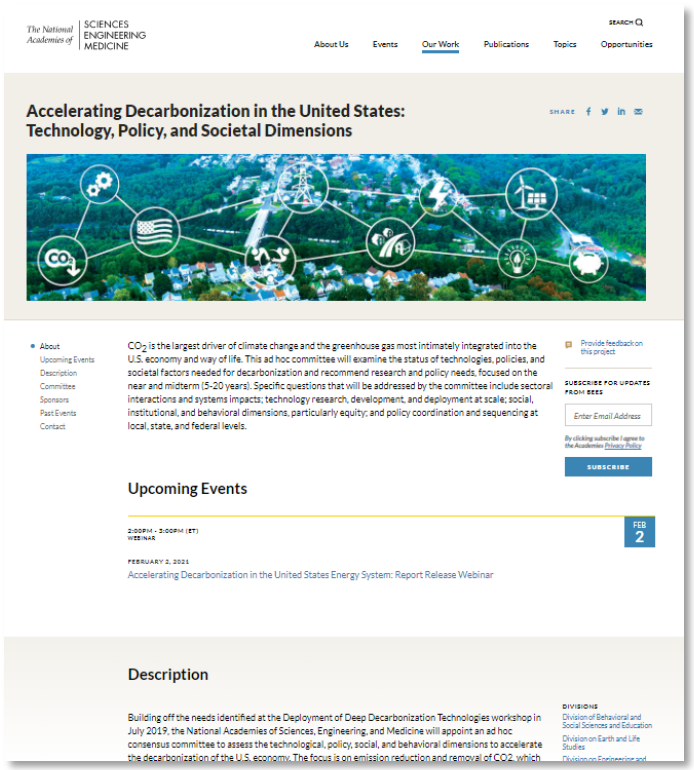
The National Academies of SCIENCES ENGINEERING MEDICINE

ACCELERATING DECARBONIZATION OF THE U.S. ENERGY SYSTEM

#USDecarb



About the Study



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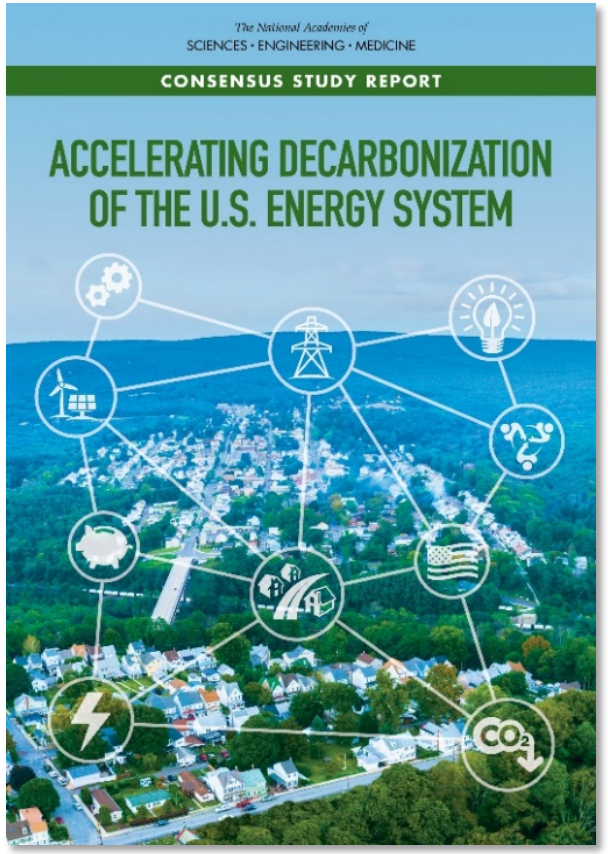
The committee was asked to evaluate the status of technologies, policies, and societal factors needed for decarbonization and recommend research and policy needs.

This first report focuses on **near and mid-term (5-20 years)** high-value policy improvements, research investments, and approaches required to put the U.S. on a path to achieve long-term net-zero emissions.

The second report (expected 2022) will assess a **wider spectrum of technological, policy, social, and behavioral dimensions** of deep decarbonization and their interactions.

Sponsored by the Alfred P. Sloan Foundation, Heising-Simons Foundation, Quadrivium Foundation, Gates/Breakthrough Energy, ClearPath Foundation, and Incite Labs, with support from the National Academy of Sciences Presidents Fund.

Report Scope



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Federal actions over the next ten years to put the US on a **fair and equitable path to net-zero in 2050**.

Sectors considered include **CO_2, transportation, electricity, industry, buildings, and biofuels**.

Not asked to determine whether the nation should move to net zero, only how to get there. Other GHGs, sinks created by forestry practices, and cropping practices that enhance soil carbon are not discussed in detail.

This report is broadly compatible with recent announcements from the Biden Administration. It was developed by an expert panel without prior consultation with the Administration.

Committee Roster

Stephen W. Pacala, Chair, Princeton University

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Danielle Deane-Ryan, Libra Foundation

Kelly Sims Gallagher, Tufts University

Julia H. Haggerty, Montana State University

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Varun Rai, University of Texas at Austin

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Esther S. Takeuchi, Stony Brook University

Susan F. Tierney, Analysis Group

Jennifer Wilcox, University of Pennsylvania

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_2 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

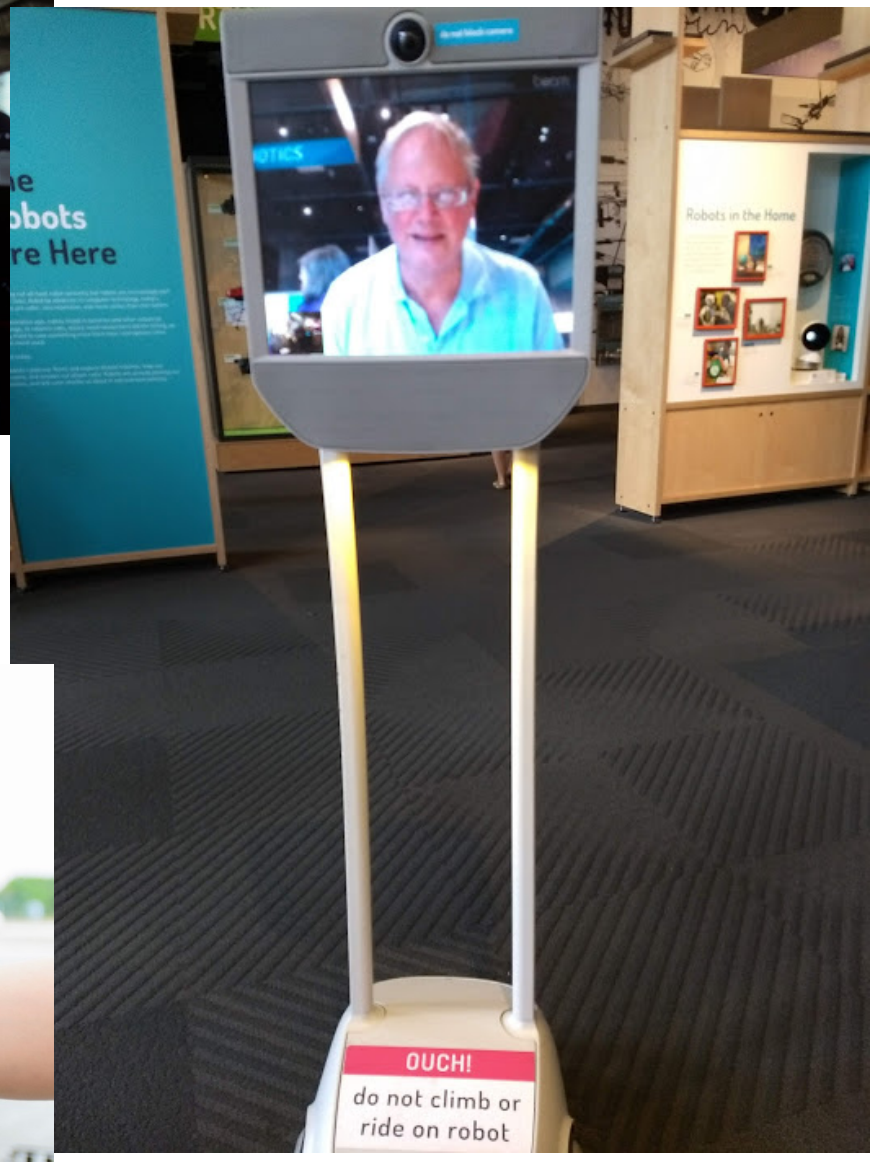
Actions for a Net-Zero Pathway

1. Improve energy efficiency and productivity
2. Electrify transportation as much as possible
3. Decarbonize power generation
4. Build critical network infrastructure
5. Tackle non-energy greenhouse gas emissions
6. Innovate to create a net-zero toolkit

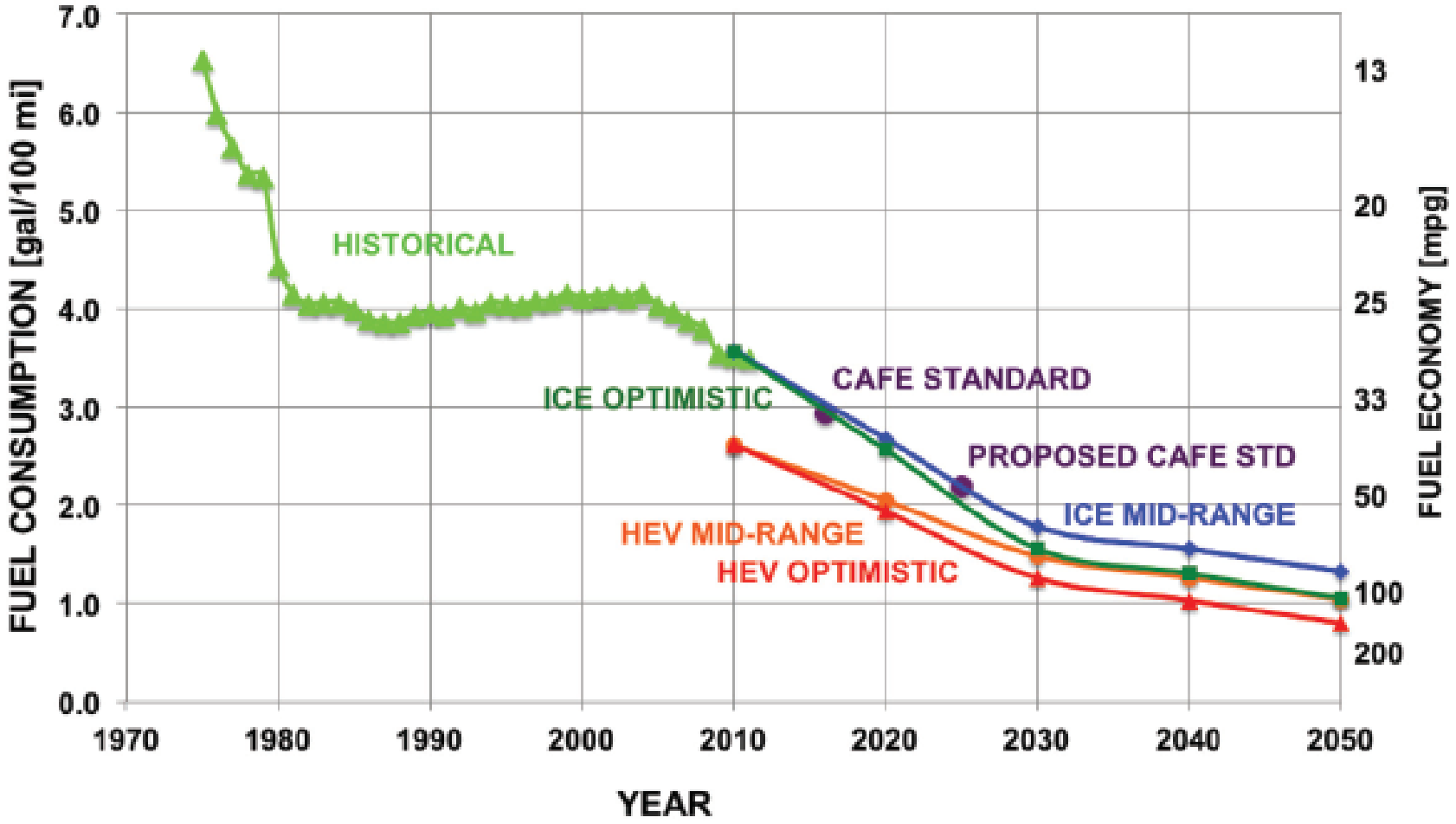
But also pursue socio-economic goals at the same time!

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.


Robots in the Home
OUCH!
do not climb or
ride on robot

Fuel Efficiency has been improving (NRC 2013)

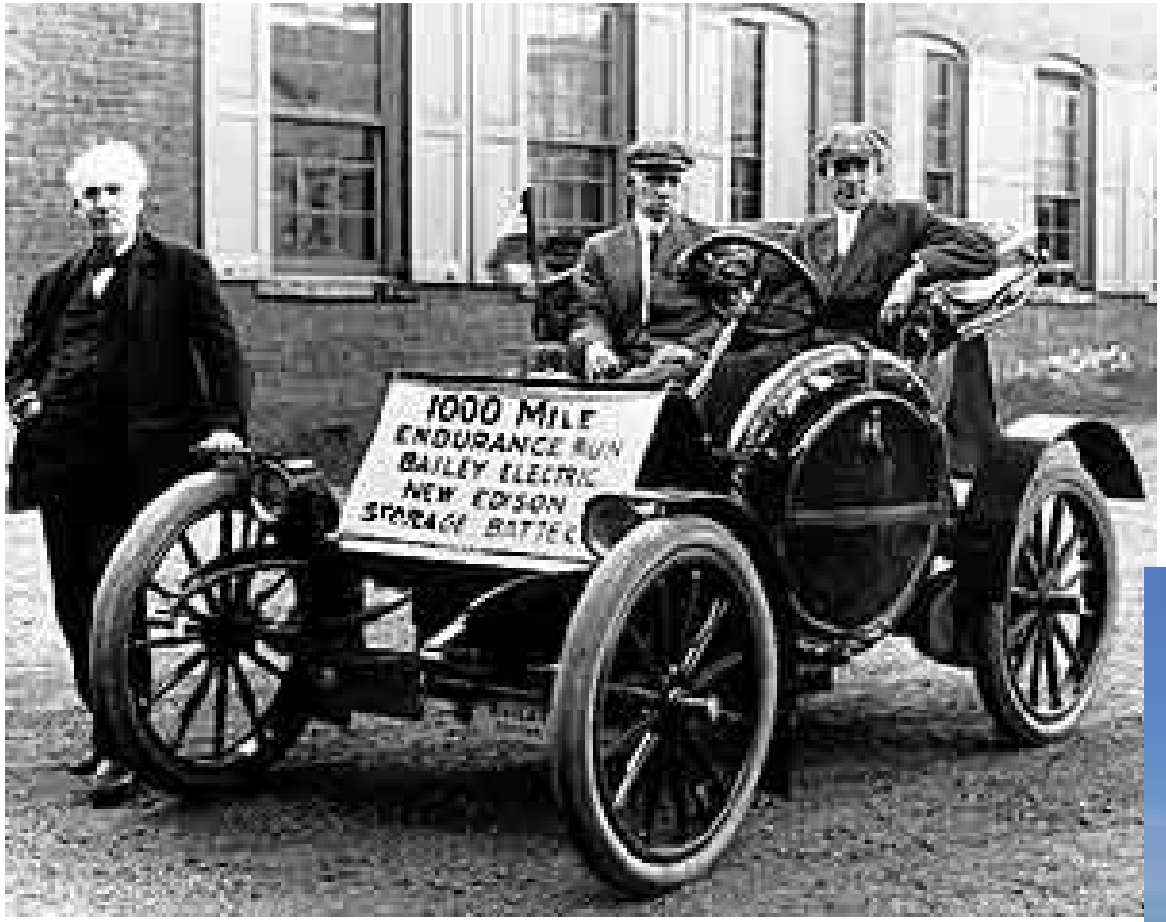


Costs of Energy Efficiency and Productivity Measures Vary

- 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.


1000 MILE
ENDURANCE RUN
BAILEY ELECTRIC
NEW EDISON


TESLA
TESLA
TESLA
Electric vehicle recharging point only
At any time

BEV are becoming cost competitive (Lutsey 2019)

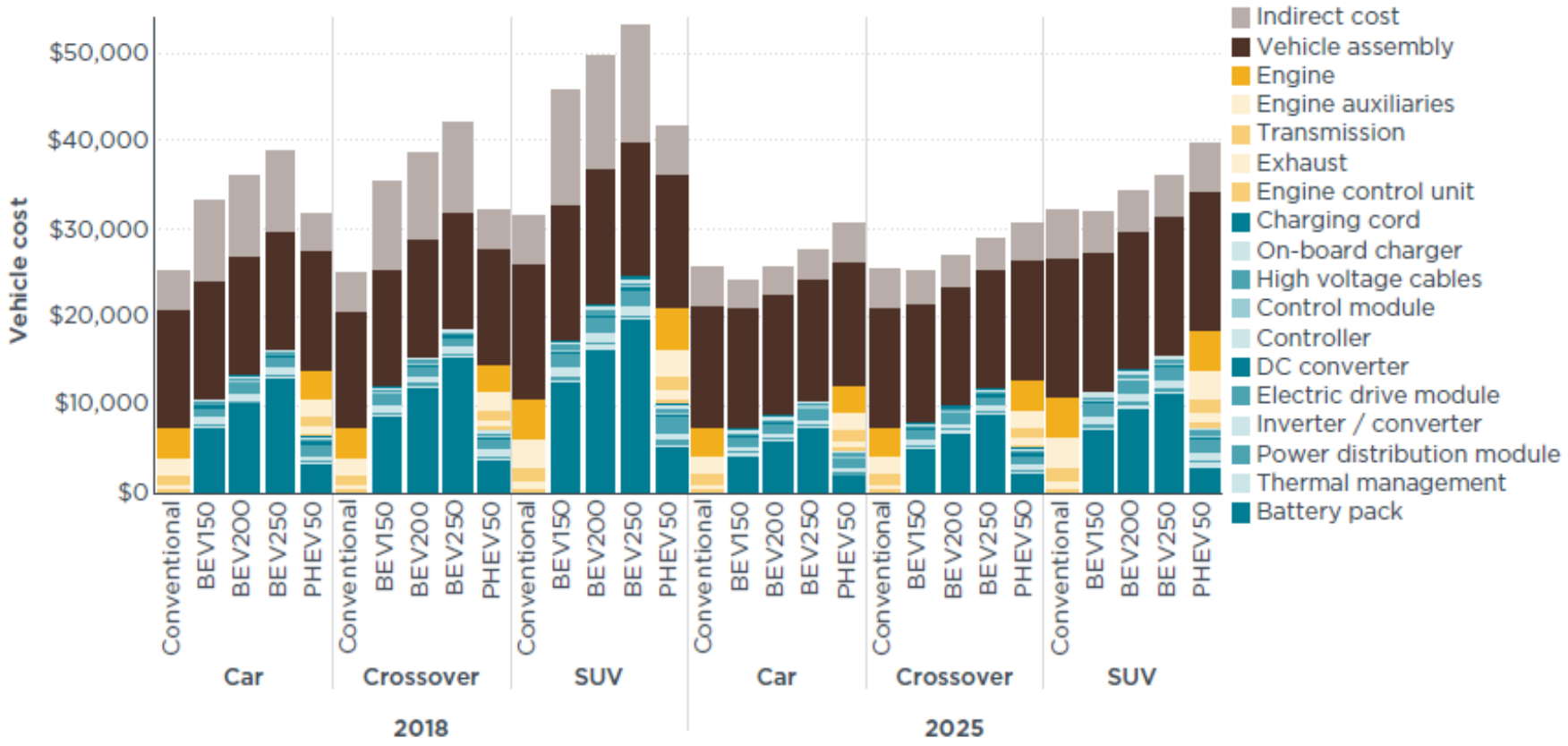
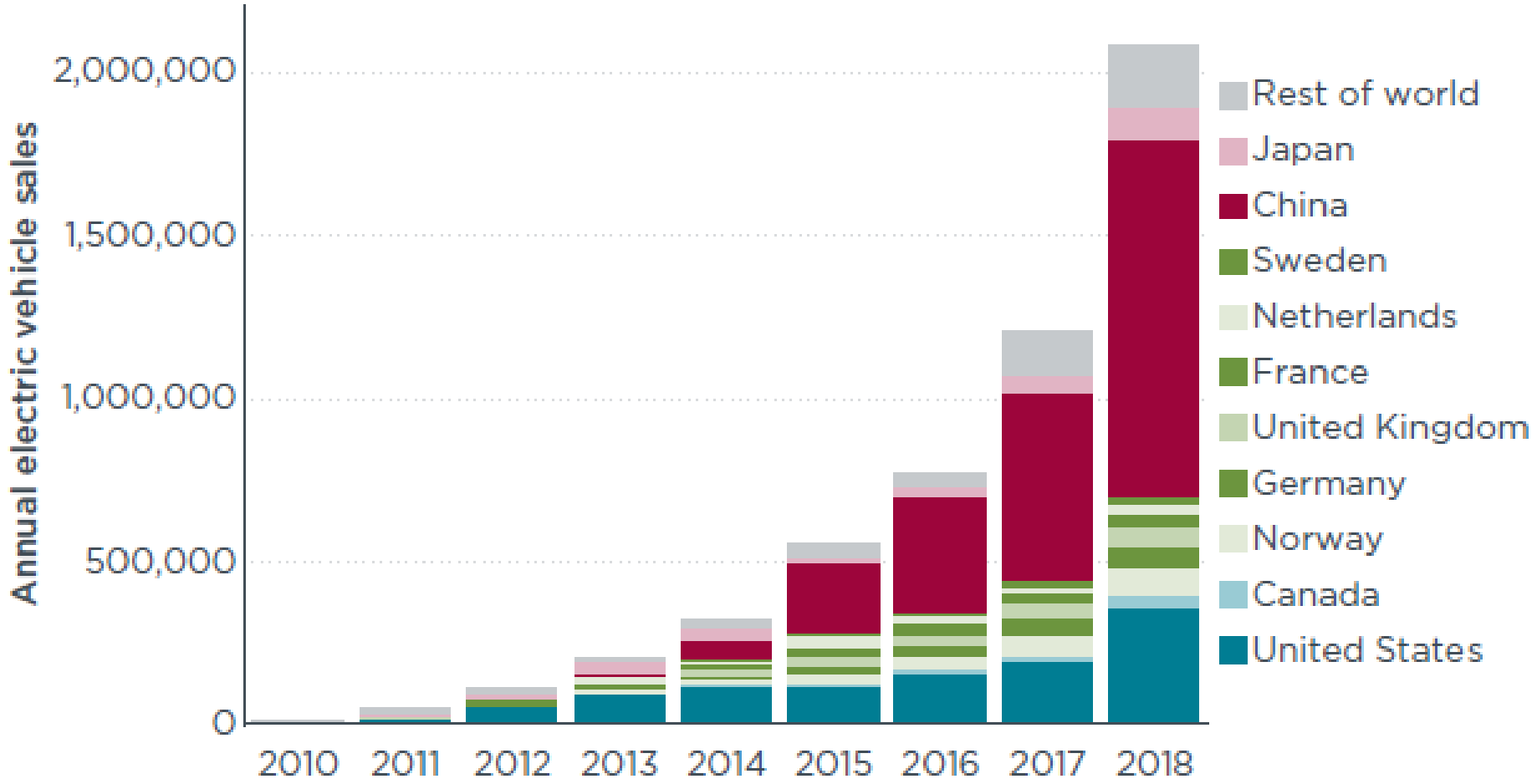


Figure 3. Vehicle technology costs for conventional and electric vehicles in 2018 and 2025 for cars, crossovers, and SUVs.

Electric vehicles sales are increasing (2% 2018)



Fleet turnover is slow

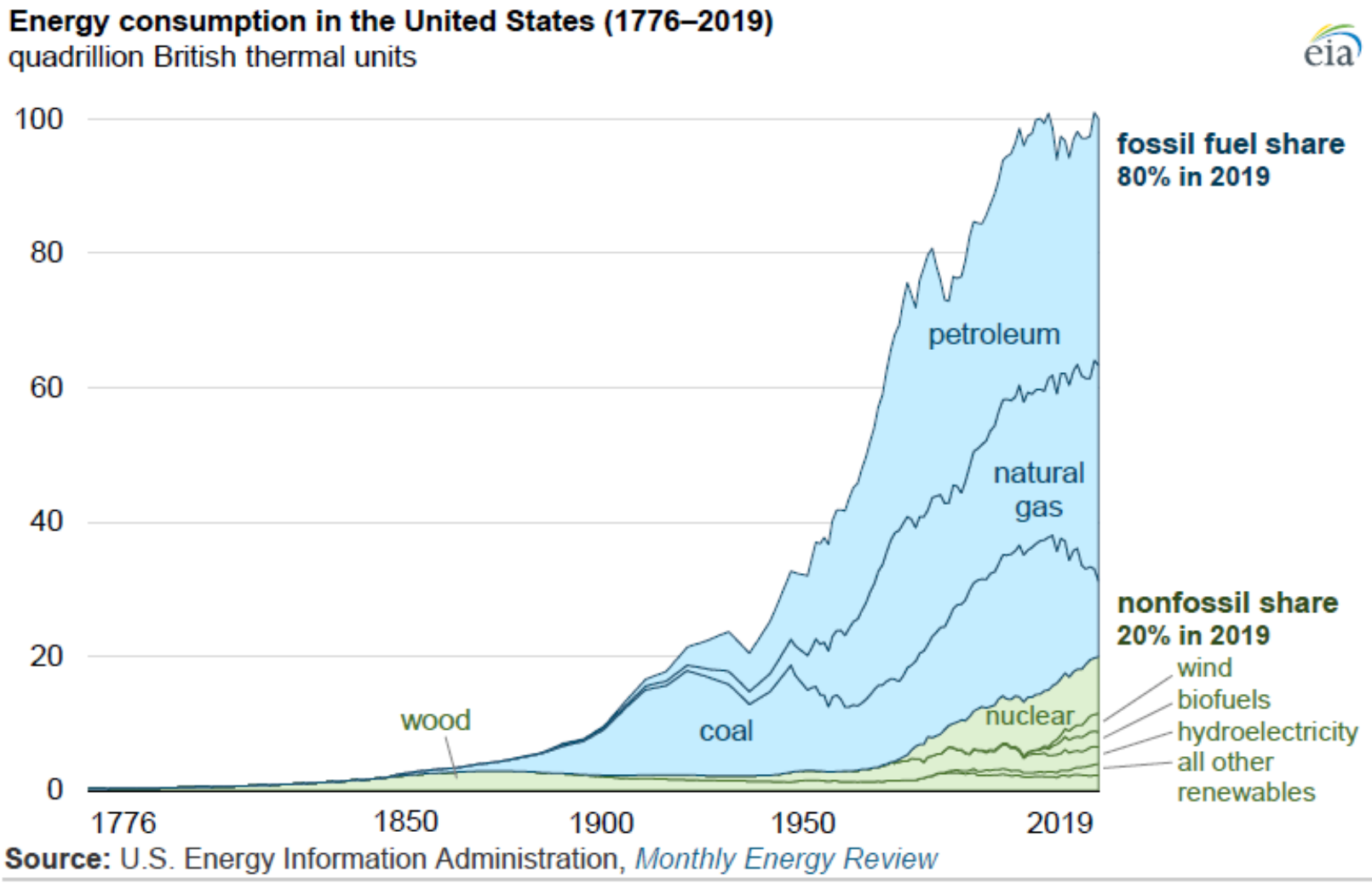
- Average age of light duty vehicle in US is 12 years.
- Complete fleet turnover requires ~20 years without premature scrappage.
- For cost effective achievement of our 2050 goal, we need a large fraction of battery electric vehicles or fuel cell vehicles being sold by 2030.

3. Decarbonize Power Generation

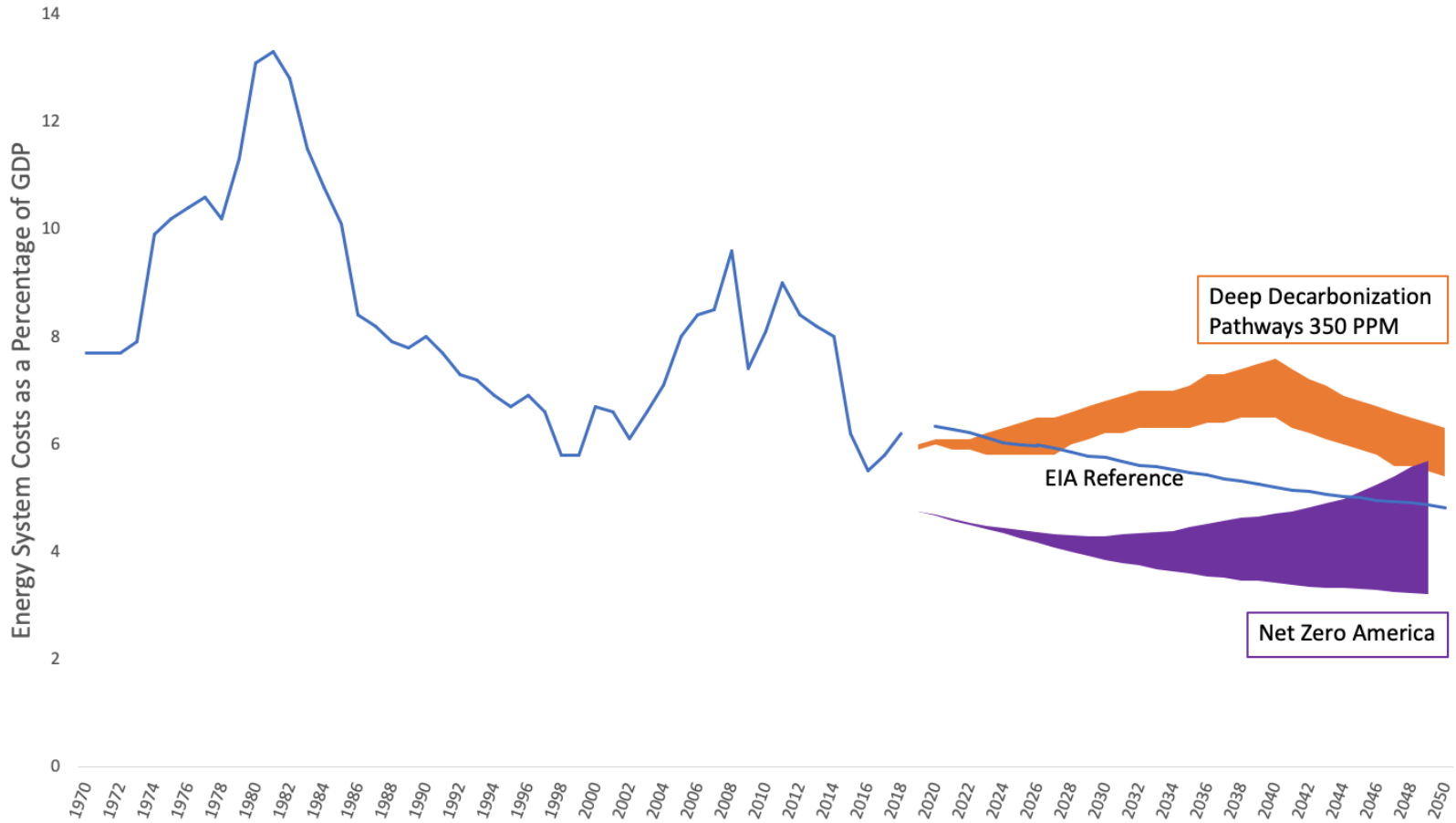
- Increase renewable power generation share dramatically (e.g. solar, geothermal and wind).
- Insure stable supply of power (e.g. battery or pump storage).
- Preserve nuclear generation
- Manage the transition of coal fired power plants to carbon capture and sequestration.


ENERGY

US Non Fossil Share of Energy is 20% in 2019

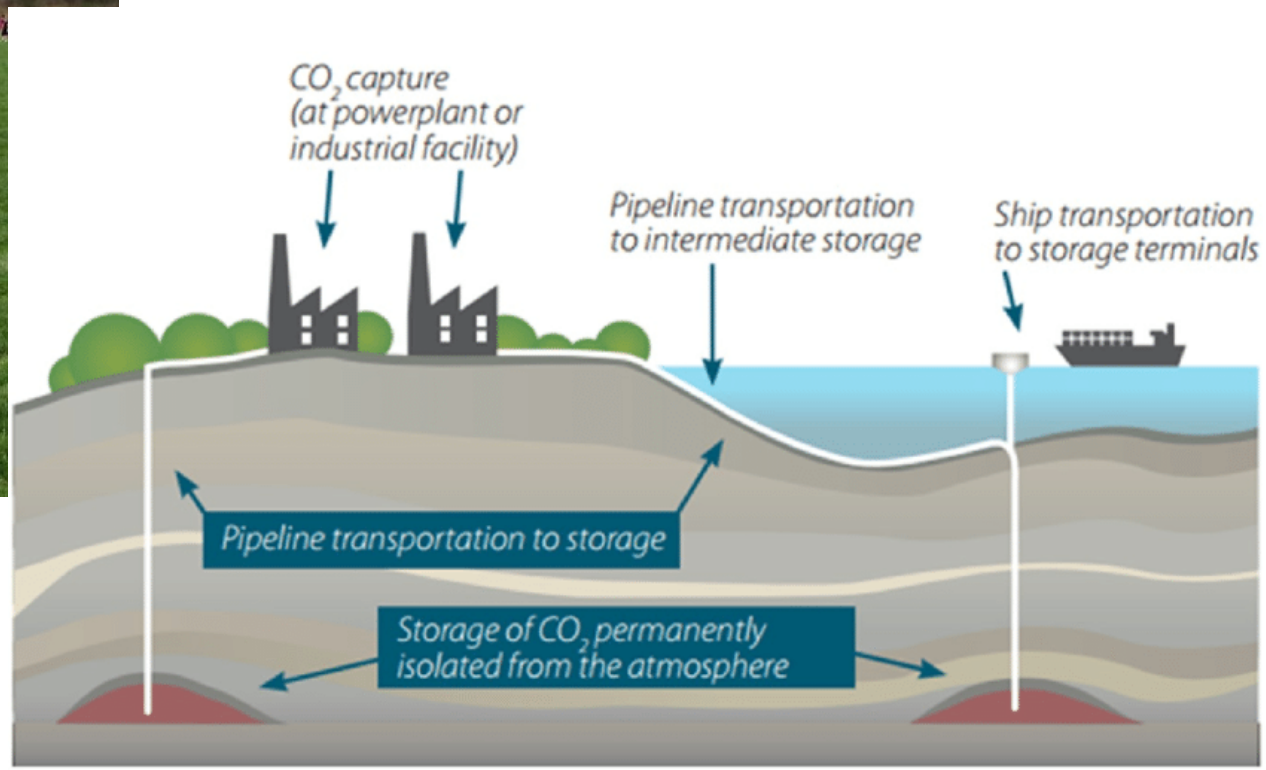


Studies suggest power decarbonization is affordable



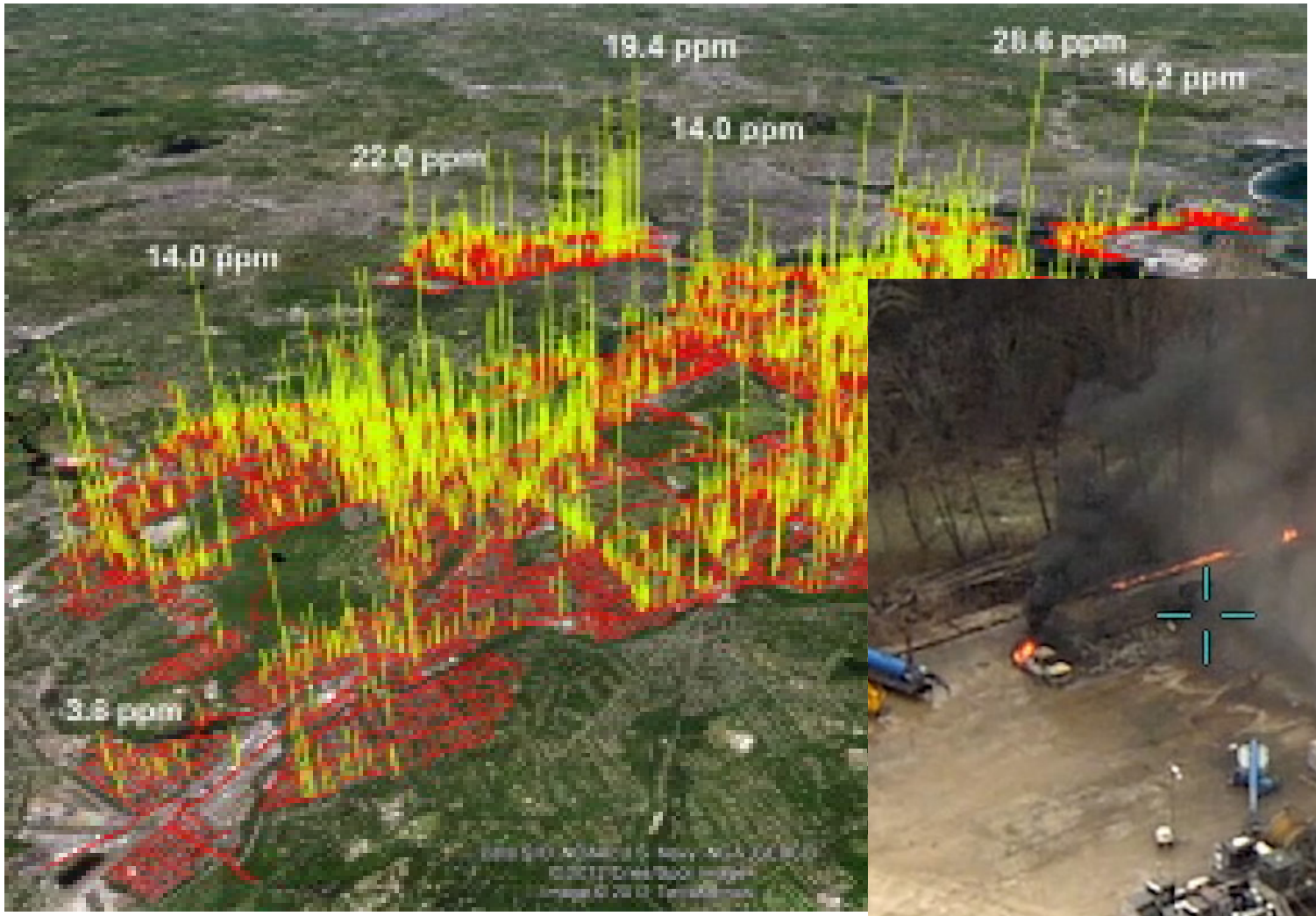
4. Build Critical Infrastructure

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


CO_2 capture
(at powerplant or
industrial facility)
Pipeline transportation
to intermediate storage
Ship transportation
to storage terminals
Pipeline transportation to storage
Storage of CO_2 permanently
isolated from the atmosphere

5. Non-energy greenhouse gas emissions

- Industrial process improvement (e.g. cement)
- Enhance land and water sequestration of carbon
- Reduce non-CO2 greenhouse gas emissions (e.g. methane and hydrofluorocarbons). Leaking pipelines are an issue here.


19.4 ppm
20.6 ppm
16.2 ppm
14.0 ppm
22.0 ppm
14.0 ppm
3.8 ppm

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.

Consensus emerging from studies

- Net zero emissions has technically feasible pathways
- Transportation electrification is a critical element, but many other actions can contribute such as energy efficiency.
- Battery electric vehicles are currently less costly than fuel cell vehicles but suffer from limited range.
- Despite industry claims, extra costs should not be prohibitive (and likely are less than the social costs of climate change and air emissions). Cost reductions in renewable power generation and batteries have been game changers.

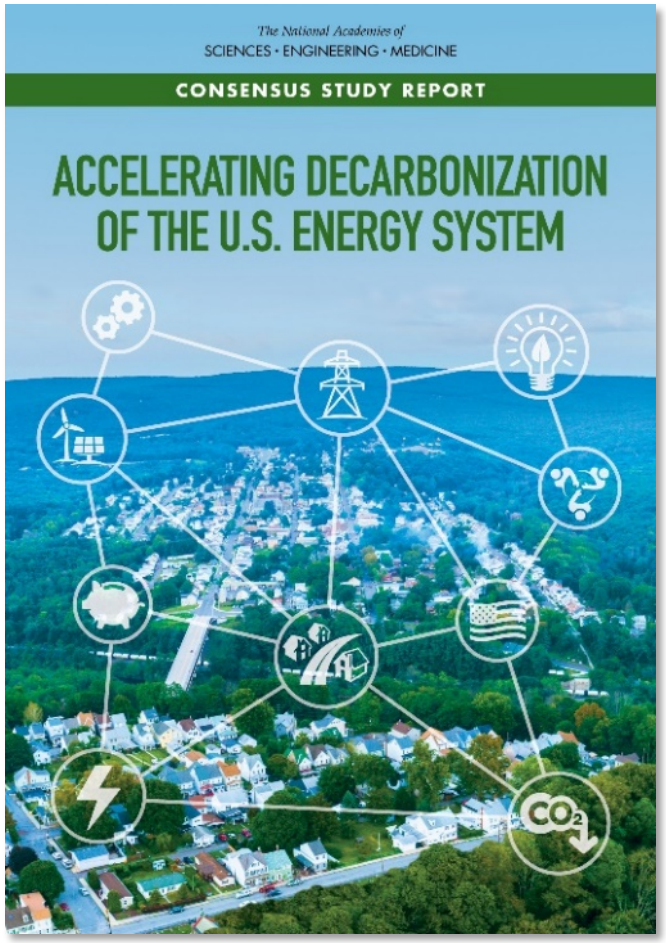
Plans for Second Report

Decisions on topics and structure of second report guided by task statement and informed by committee's discussions.

Topics might include:

- agriculture and forestry carbon sinks
- greater sector-specific detail
- expanded treatment of technologies that will be important in the 2030-2050 time range
- broader range of policy actors (state, local, private sector, non-governmental organizations)
- national security implications
- wider consideration of benefits

Thank you!



Download the report and report resources at nap.edu/decarbonization

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Other public events and briefings are in the works.

- We welcome suggestions for additional briefings, please email decarbonization@nas.edu