



# **Legal Pathways to Deep Decarbonization in the United States**

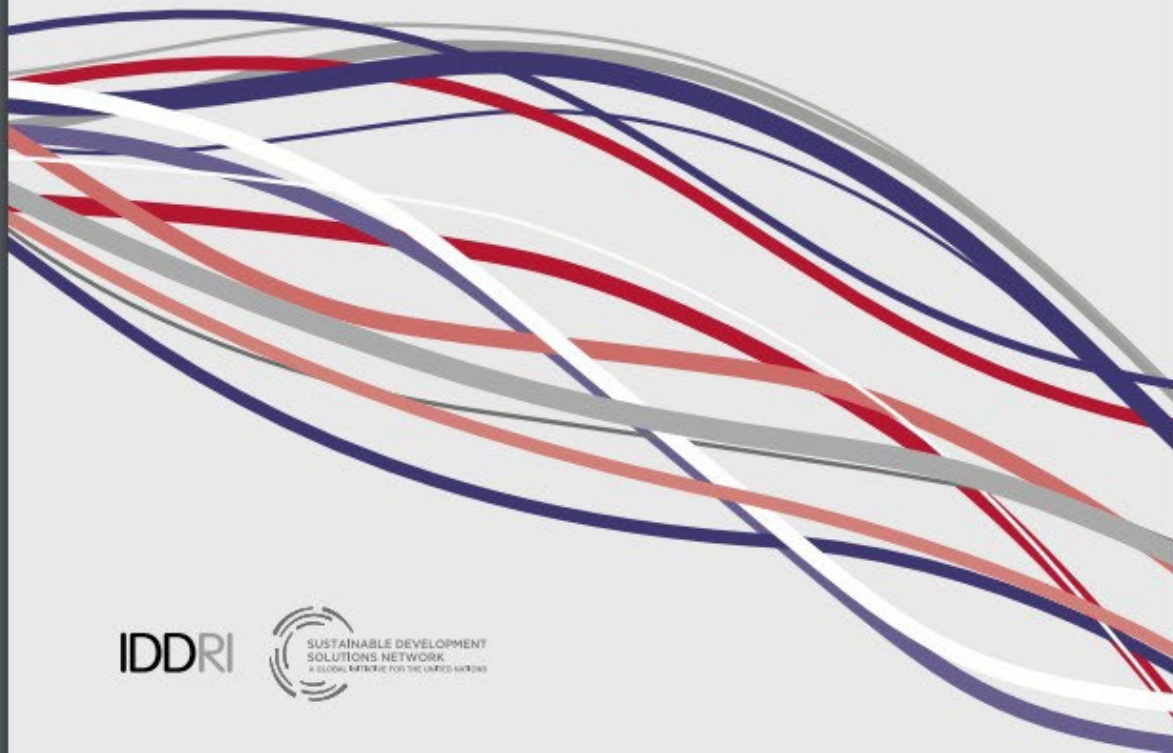
**Michael B. Gerrard**

Andrew Sabin Professor of Professional Practice  
Director, Sabin Center for Climate Change Law  
Columbia Law School

**John C. Dernbach**

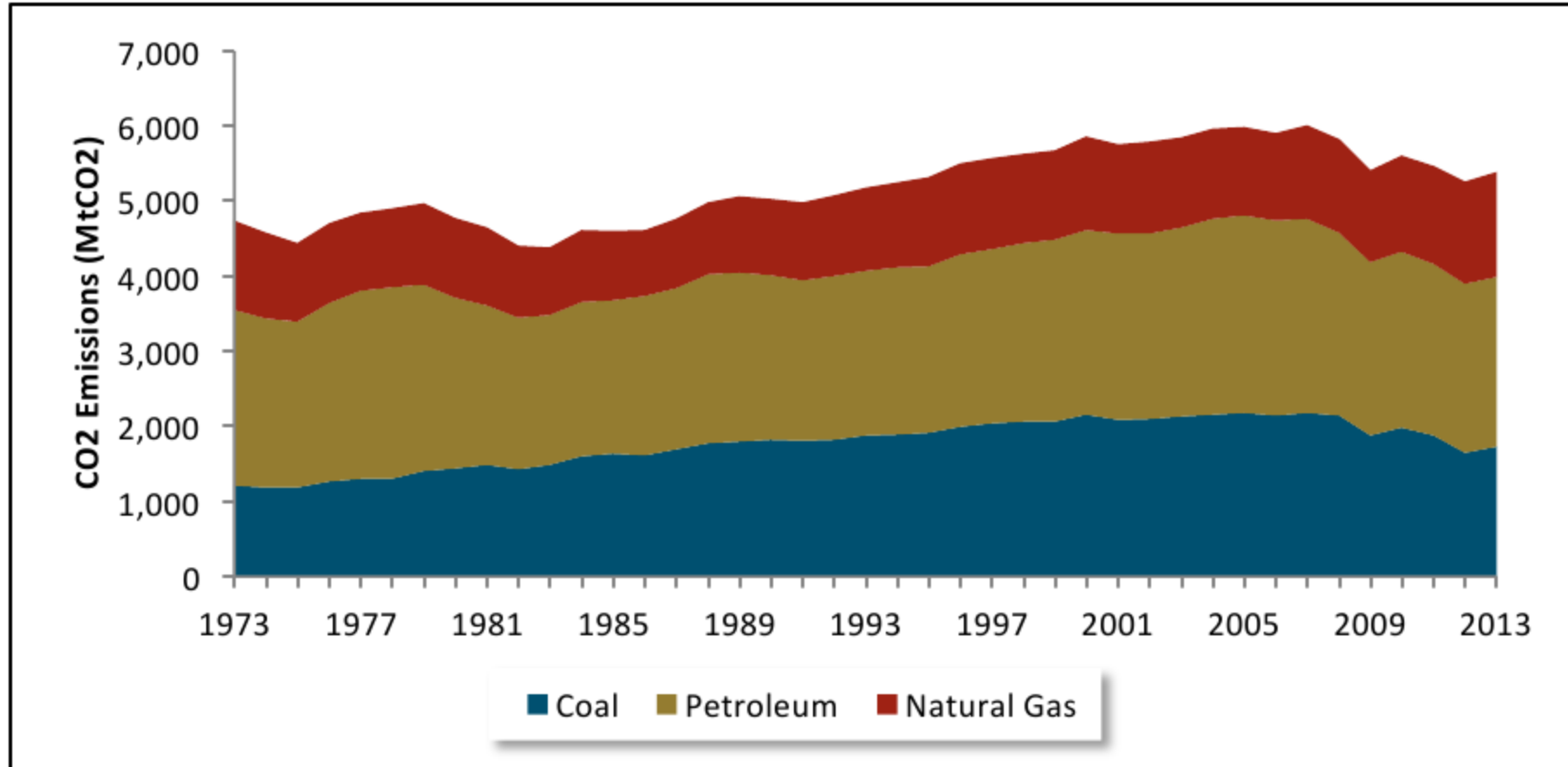
Commonwealth Professor of Environmental Law and Sustainability  
Director, Environmental Law and Sustainability Center  
Widener University Commonwealth Law School

*pathways to*  
**deep decarbonization**  
*in the United States*



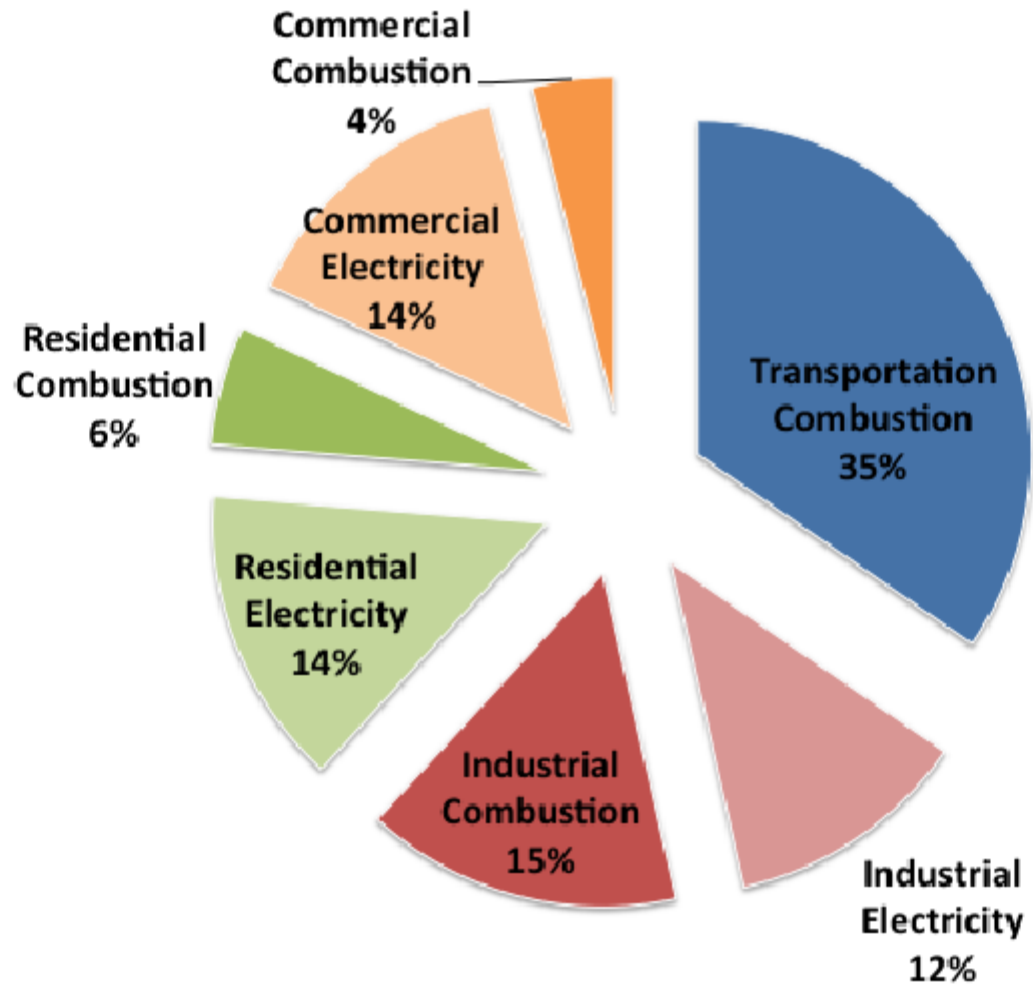
Gas is a higher % now and coal is lower.

Figure 2. U.S. CO<sub>2</sub> Emissions from Fossil Fuel Combustion by Fuel Source, 1973–2013



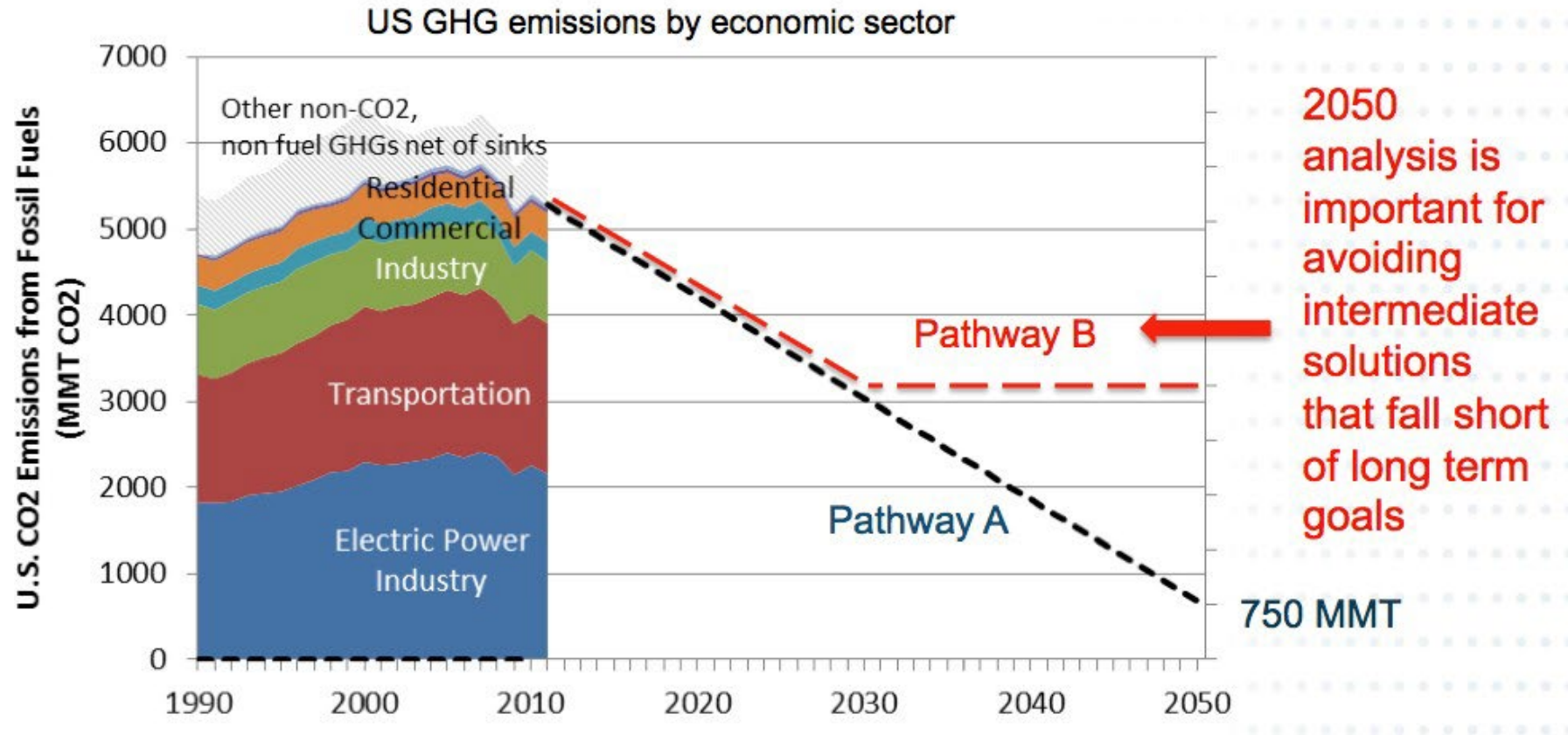
Source: EIA , March, 2014 Monthly Energy Review

Figure 3. U.S. CO<sub>2</sub> Emissions from Fossil Fuel Combustion, with Electricity Emissions Allocated to End Use, 2012



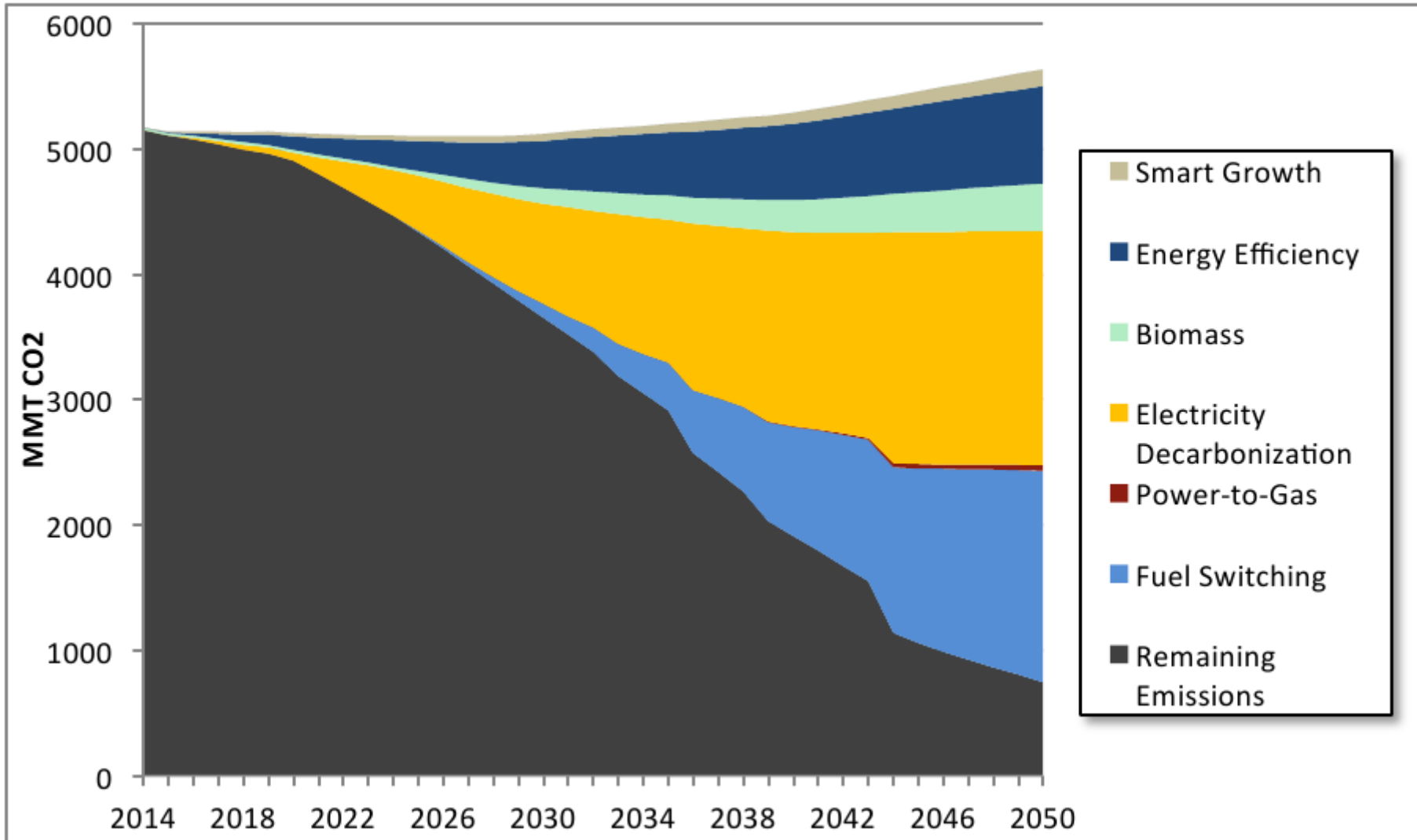
Source: U.S. EPA 2014

# Avoiding emissions dead ends



Todd Stern: "It's all about the transformation."

Figure 10. Decarbonization Wedges for the U.S., Mixed Case



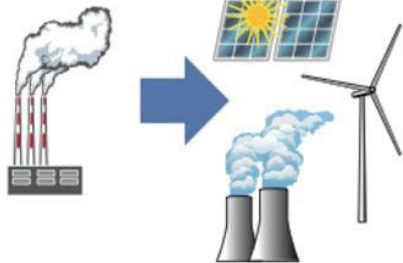
# Three Pillars of Deep Decarbonization

Strategy

Energy Efficiency



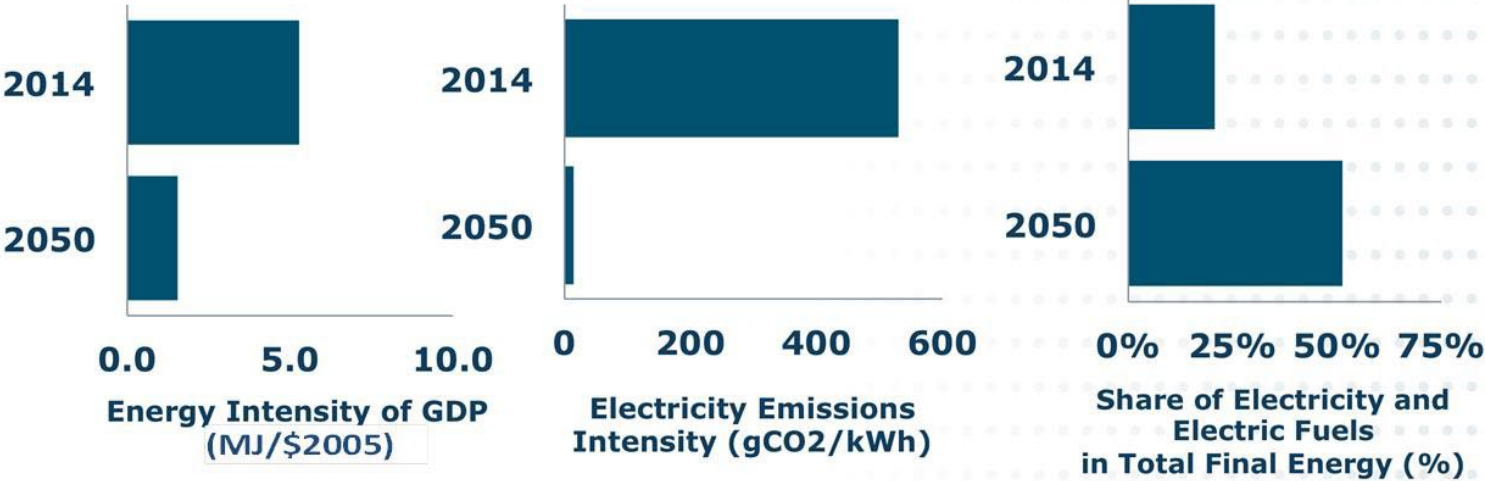
Decarbonization of Electricity



End Use Fuel Switching to Electric Sources



Key Metric of Transformation



Pathways to Deep Decarbonization in the United States, Mixed case results

**Table 6. Key Decarbonization Measures by Sector and Decarbonization Strategy**

Strategy and Sector	Measures
<b>Energy Efficiency Strategies</b>	
<b>Residential and commercial energy efficiency</b>	<ul style="list-style-type: none"> <li>• Highly efficient building shell required for all new buildings</li> <li>• New buildings require electric heat pump HVAC and water heating</li> <li>• Existing buildings retrofitted to electric HVAC and water heating</li> <li>• Near universal LED lighting in new and existing buildings</li> </ul>
<b>Industrial energy efficiency</b>	<ul style="list-style-type: none"> <li>• Improved process design and material efficiency</li> <li>• Improved motor efficiency</li> <li>• Improved capture and re-use of waste heat</li> <li>• Industry specific measures, such as direct reduction in iron and steel</li> </ul>
<b>Transportation energy efficiency</b>	<ul style="list-style-type: none"> <li>• Improved internal combustion engine efficiency</li> <li>• Electric drive trains for both battery and fuel cell vehicles (LDVs)</li> <li>• Materials improvement and weight reduction in both LDVs and freight</li> </ul>



## Energy Supply Decarbonization Strategies

### Electricity supply decarbonization

- Different low-carbon generation mixes with carbon intensity  $<50 \text{ gCO}_2/\text{kWh}$  that include renewable, nuclear, and CCS generation

### Electricity balancing

- Flexible demand assumed for EV charging and thermal building loads
- Flexible intermediate energy production for hydrogen and power-to-gas processes to take advantage of renewable overgeneration
- Hourly/daily storage and regulation from pumped hydro
- Natural gas w/CCS

### Pipeline gas supply decarbonization

- Synthetic natural gas from gasified biomass and anaerobic digestion
- Hydrogen and SNG produced with wind/solar over-generation provides smaller but potentially important additional source of pipeline gas

### Liquid fuels decarbonization

- Diesel and jet-fuel replacement biofuels
- Centralized hydrogen production through electrolysis
- Centralized hydrogen production through natural gas reformation w/CCS

## Fuel Switching Strategies

### Petroleum

- LDVs to hydrogen or electricity
- HDVs to LNG, CNG, or hydrogen
- Industrial sector petroleum uses electrified where possible, with the remainder switched to pipeline gas

### Coal

- No coal without CCS used in power generation or industry by 2050
- Industrial sector coal uses switched to pipeline gas and electricity

### Natural gas

- Low carbon energy sources replace most natural gas for power generation; non-CCS gas retained for balancing in some cases
- Switch from gas to electricity in most residential and commercial energy use, including majority of space and water heating and cooking

# Multiple Feasible Technology Pathways Exist

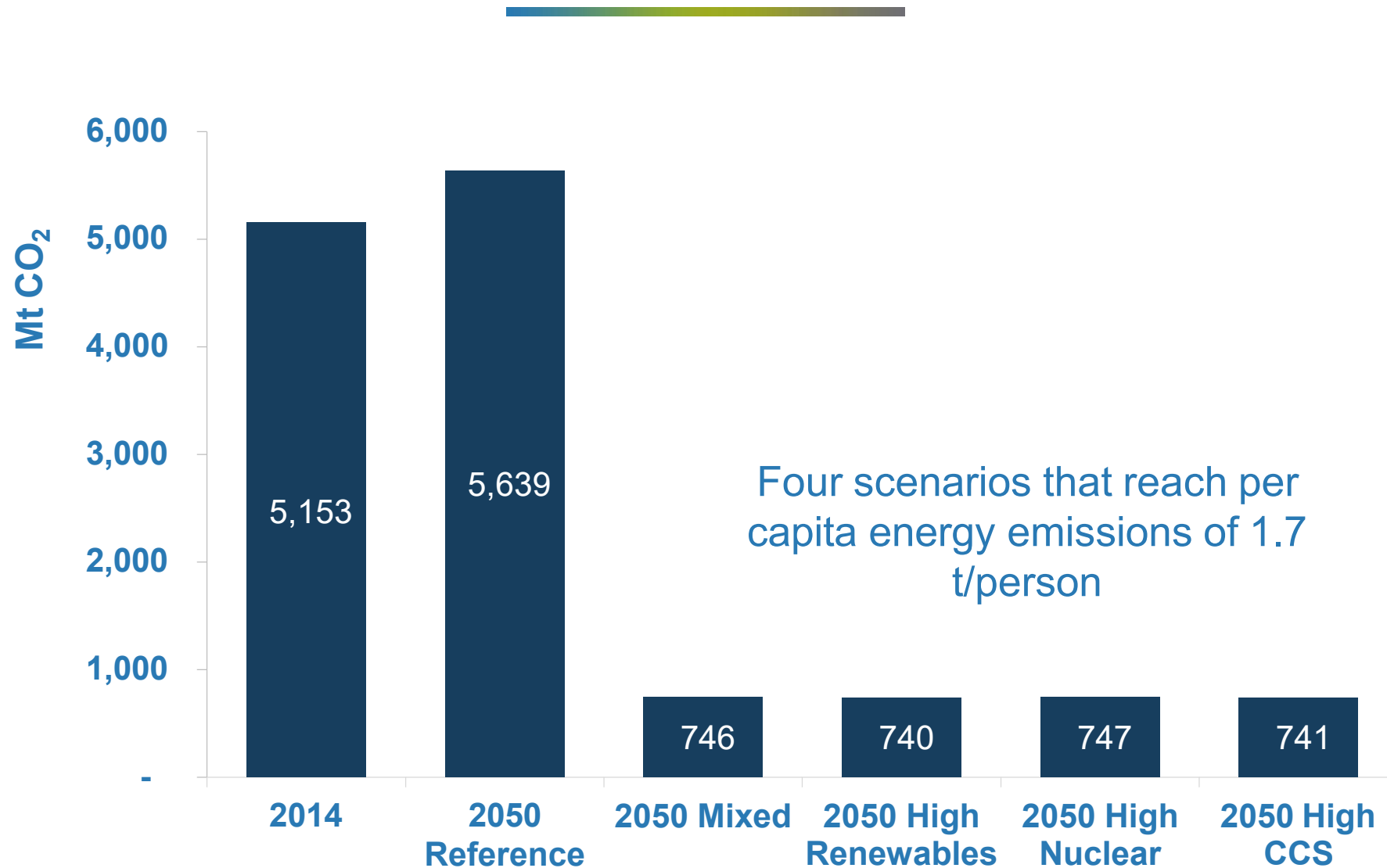


Figure 39. Mixed Case Regional Per Capita CO<sub>2</sub> Emissions Intensity (Tonnes CO<sub>2</sub> Per Person)

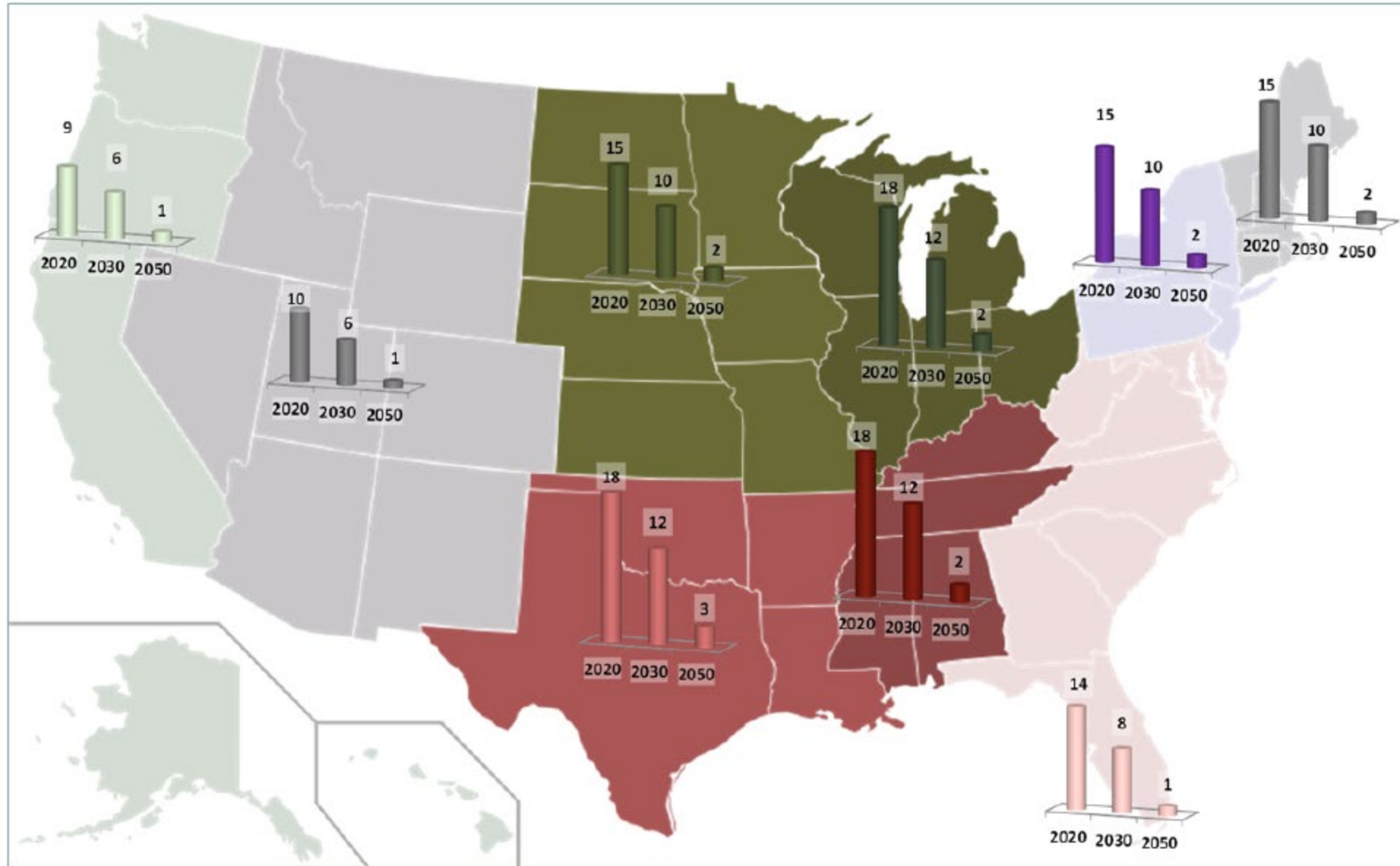


Figure 11. Indicative Metrics for the Three Main Decarbonization Strategies, Mixed Case Compared to 2014

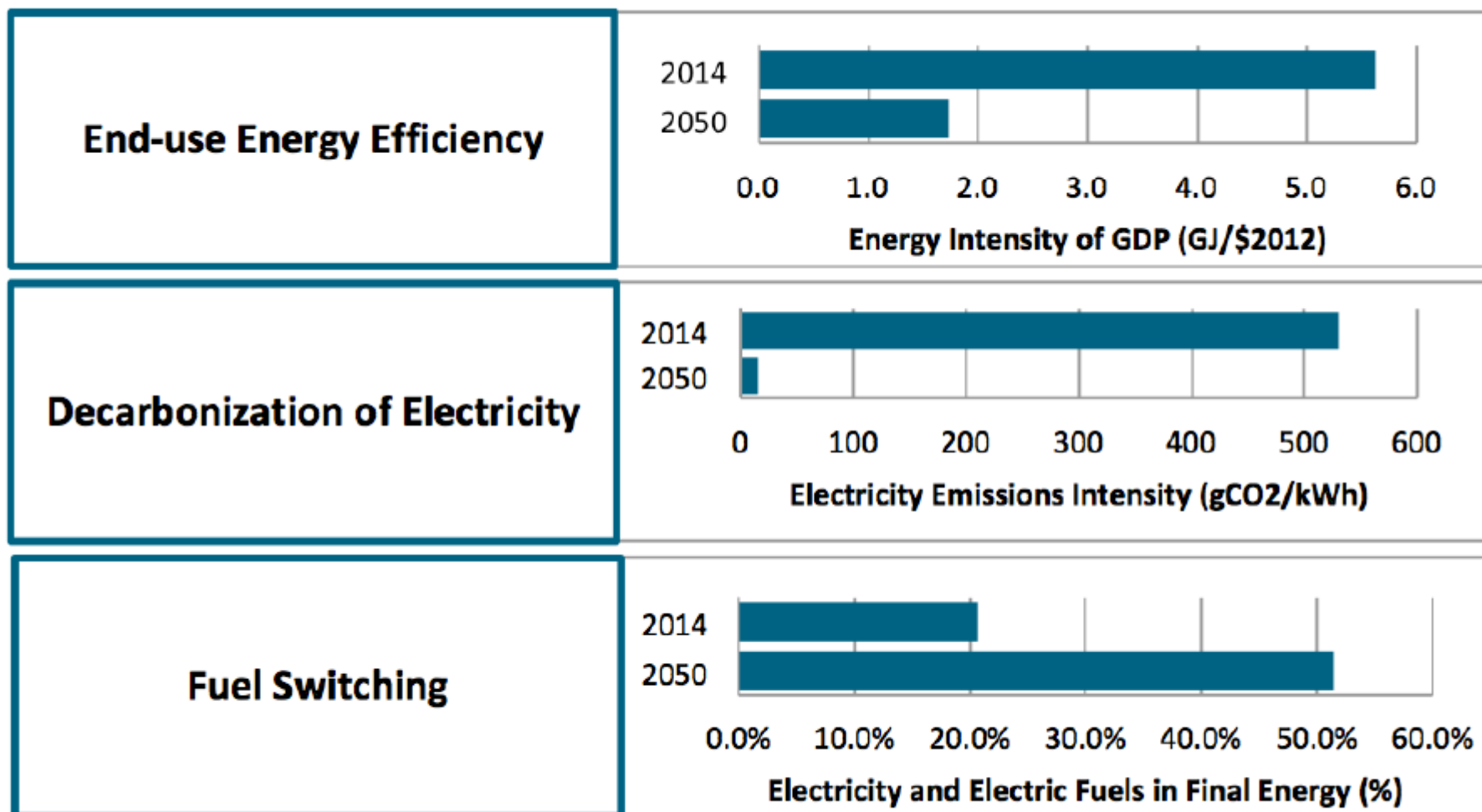
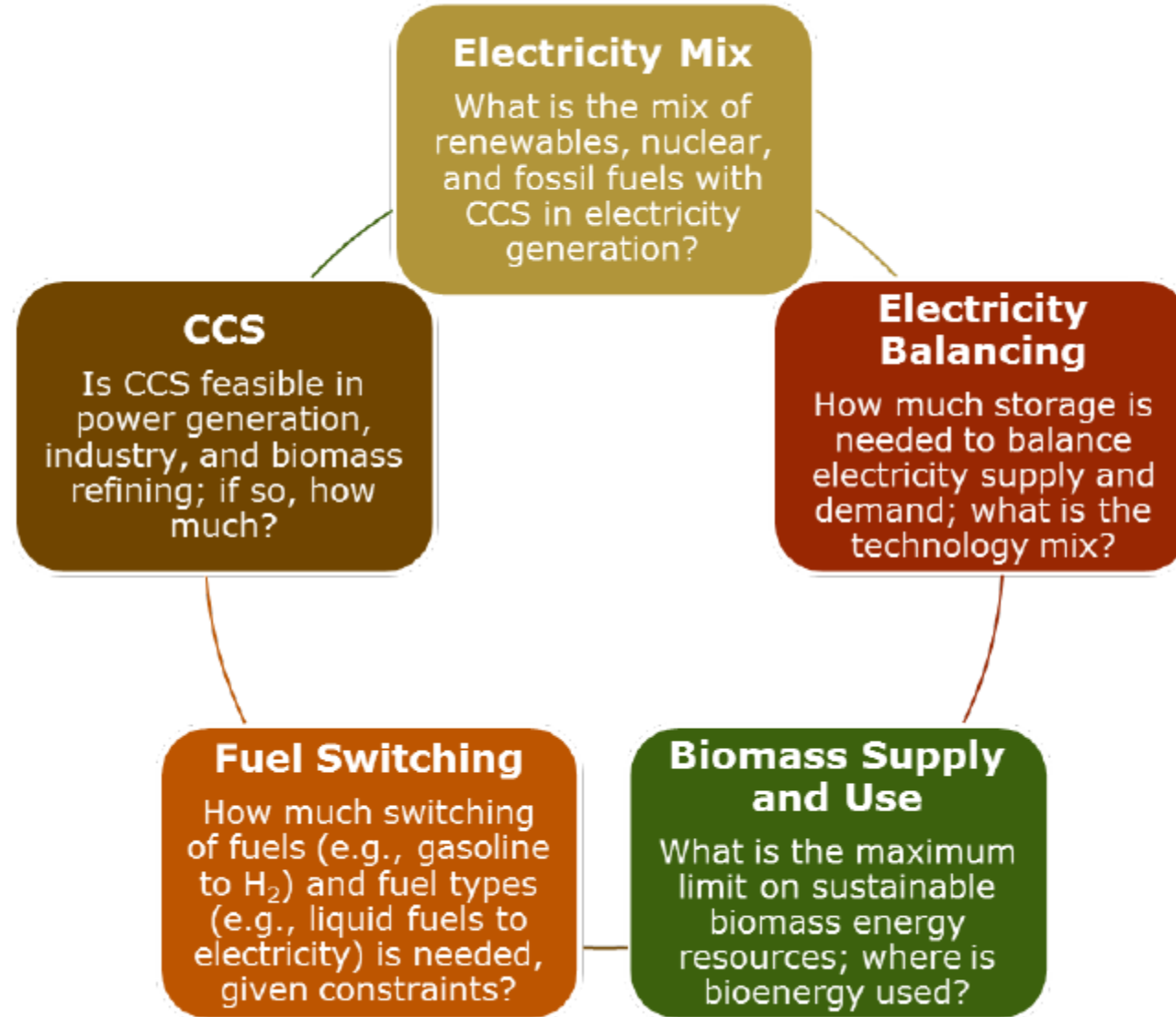


Figure 6. Pathways Determinants: Critical Elements that Determine the Features of a Low Carbon Energy System

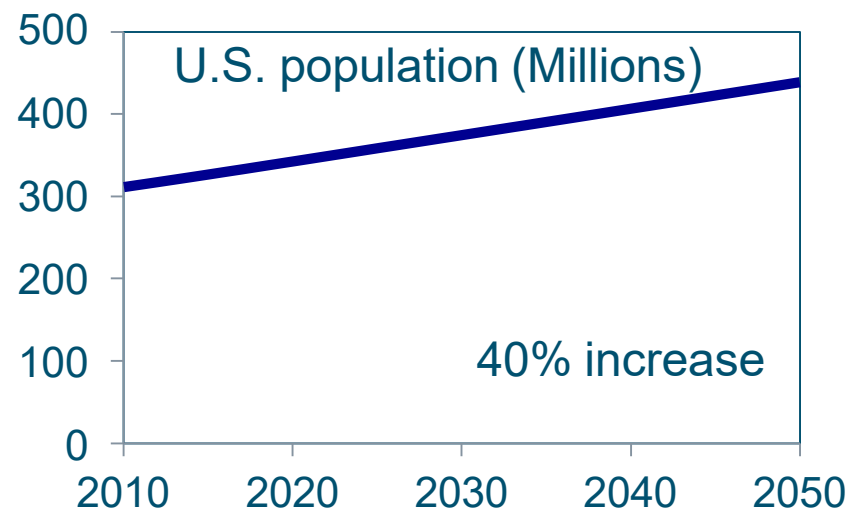
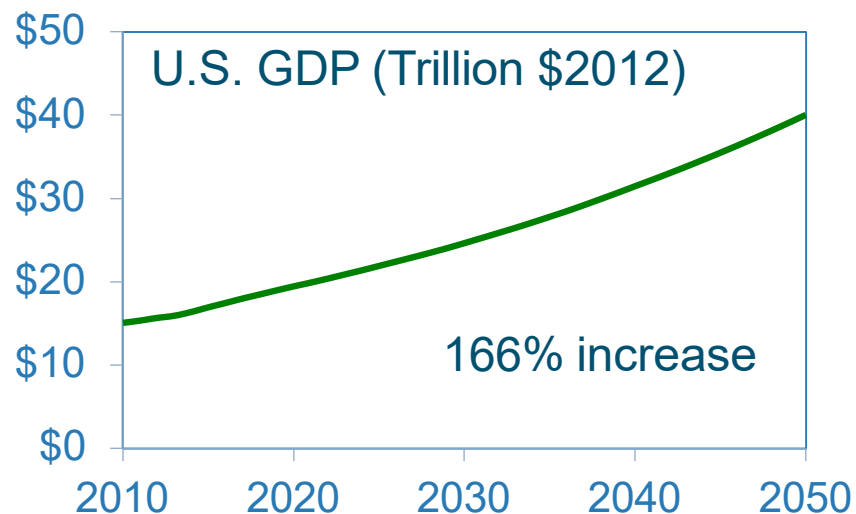


# 80% Reduction Goal by 2050 is Technically Feasible and Would Cost Only 1% of US GDP

- Almost complete decarbonization of electricity by 2050
- Double electricity generation through massive program of renewables construction
- More than double the efficiency with which energy is used
- Switching most end uses that require liquid fuels to electricity, especially passenger cars and space heating and cooling
- Requires deployment of roughly 300 million alternative fuel vehicles by 2050

# Scenario Design Constraints

- Infrastructure inertia
- Electric reliability
- Same energy services as EIA forecast
- Technology is commercial or near-commercial
- Environmental limits (biomass, hydro)

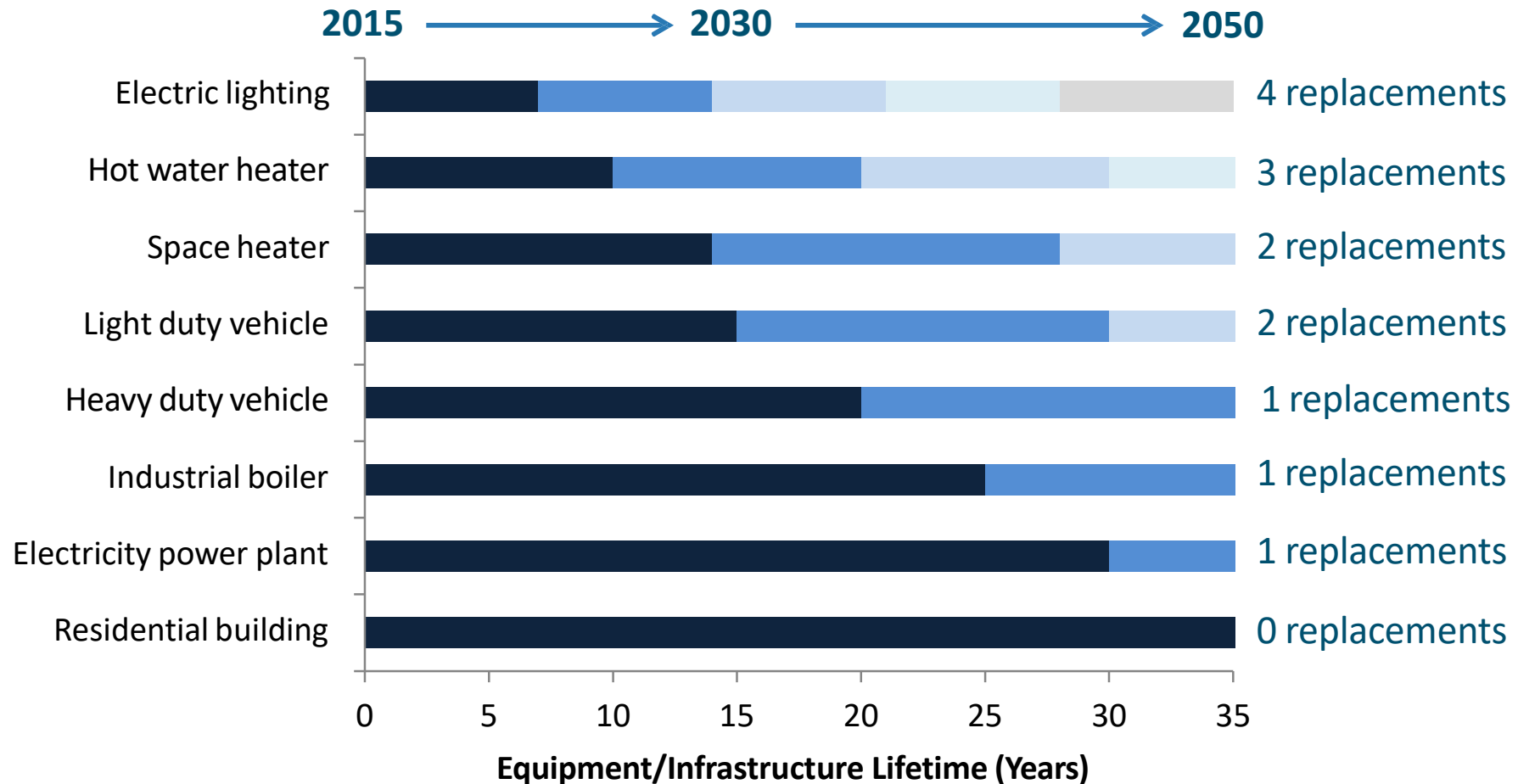


U.S. National Energy Modeling System and 2013 Annual Energy Outlook reference case



# Early Retirement Not Required... But Timely Replacement Is

- A car purchased today, is likely to be replaced at most 2 times before 2050.  
A residential building constructed today, is likely to still be standing in 2050.



# Key Findings on Legal Pathways

- Legal tools are available to decarbonize U.S.
  - Available, but necessarily politically acceptable
- More than 1,500 specific recommendations for federal, state, local and private action
- Wide variety of types of tools; some are regulatory, but most are not
- These tools would create economic, social, environmental, and security benefits in addition to reducing GHG emissions

# Twelve types of legal tools

- Additional regulation
- Reduction or removal of legal barriers
- Market-leveraging approaches
- Removal of incentives for fossil fuel use
- Tradable permits or allowances
- Information/persuasion
- Facilities and operations
- Infrastructure development
- Research and development
- Insurance
- Property rights
- Social equity

# Legal Pathways

## Energy efficiency, conservation, fuel switching

- Light duty vehicles
- Heavy duty vehicles and freight
- Transportation demand and mode shifting
- Aviation
- Shipping
- Lighting, appliances and other equipment
- Old buildings
- New buildings
- Industrial sector

# Legal Pathways

## Electricity decarbonization

- Utility-scale renewables
- Distributed renewables
- Transmission, distribution and storage
- Nuclear
- Hydropower
- Phasing out fossil fuels in electricity sector

# Legal Pathways

## Fuel decarbonization

- Production and delivery of low-carbon gaseous fuels
  - Hydrogen?
- Production and delivery of bioenergy fuels
  - Fuel from biomass or algae production

# Legal Pathways

## Carbon capture and negative emissions

- Carbon capture, sequestration, utilization
- Direct air capture
- Agriculture
- Forestry

# Legal Pathways

## Non-CO2 climate pollutants

- Black carbon
- Methane
- Fluorinated gases
- Nitrous oxide



# Carbon pricing alone will not solve everything

Local opposition (e.g. Cape Wind)

Hard-to-measure emissions (e.g. natural gas leakage)

Principal-agent problem (e.g. builders don't pay occupants' energy bills)

Sectors with low price elasticity (e.g. some HFC uses)

Sectors with long lead times (e.g. passenger autos, commercial vehicles, housing)

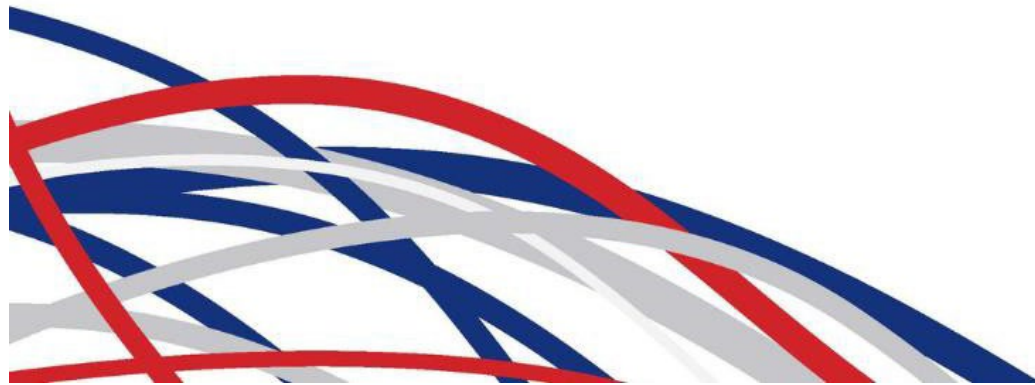
Public infrastructure construction

TRANSPORTATION:  
LIGHT-DUTY VEHICLES

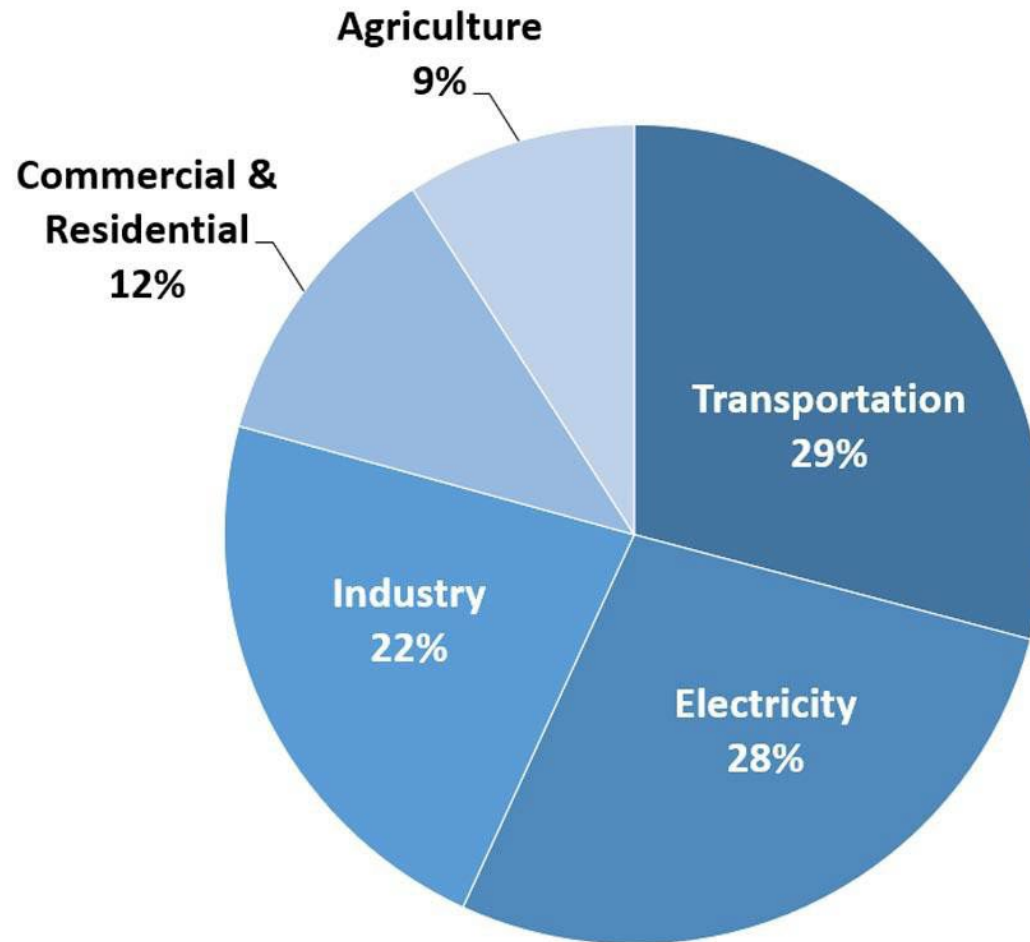
Professor Amy L. Stein  
University of Florida  
Levin College of Law

**LEGAL  
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DEEP DECARBONIZATION  
IN THE UNITED STATES**

**MICHAEL B. GERRARD AND JOHN C. DERNBACH,**  
EDITORS

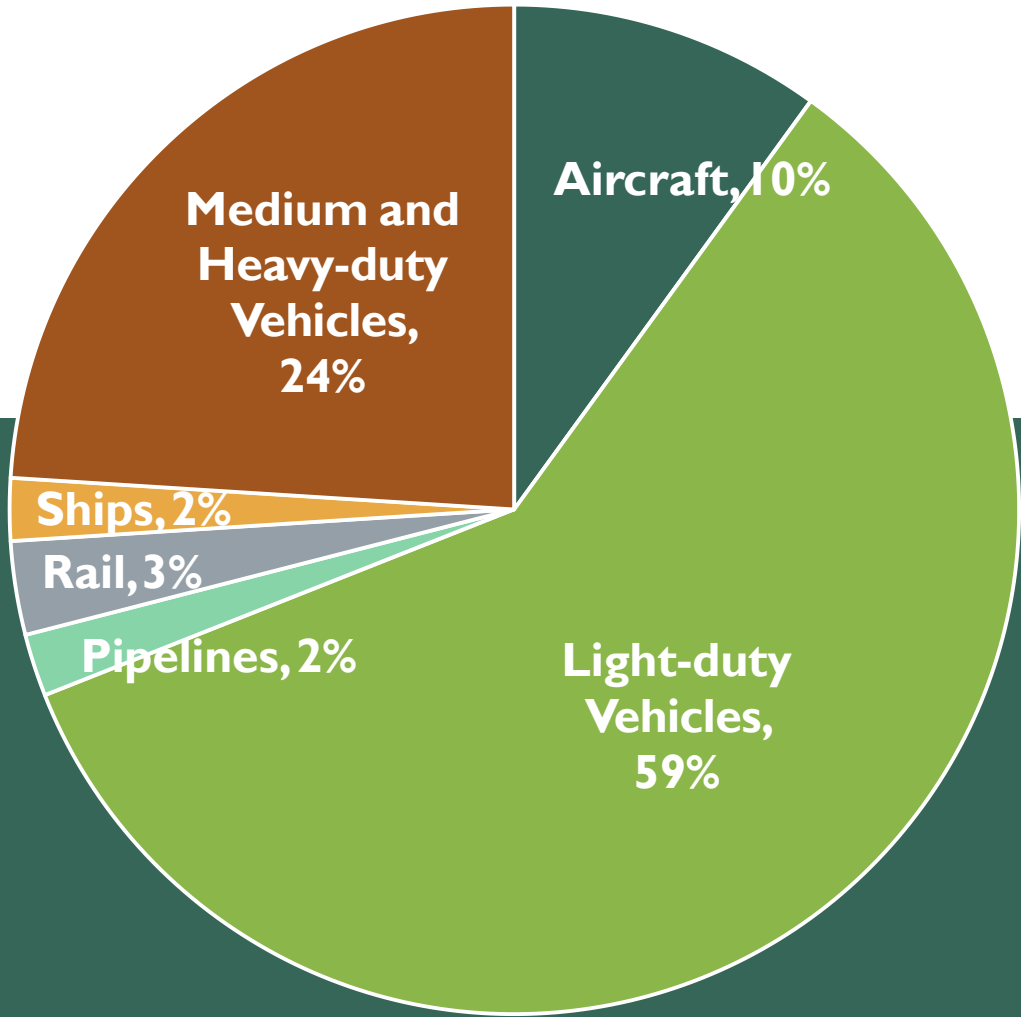


## Total U.S. Greenhouse Gas Emissions by Economic Sector in 2017



THE  
TRANSPORTATION  
SECTOR IS THE  
LARGEST  
CONTRIBUTOR OF  
GHG EMISSIONS

TRANSPORTATION GHG EMISSIONS



LIGHTDUTYVEHICLESARE  
THE LARGEST SOURCE OF  
TRANSPORTATION GHG  
EMISSIONS

U.S. Environmental Protection Agency (2019). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017

# DDPP GOALS

Reduce greenhouse gases by at least 80% from 1990 levels by 2050

- DDPP Transportation Goal #1:
  - Increase fuel economy standards in excess of 100 mpg

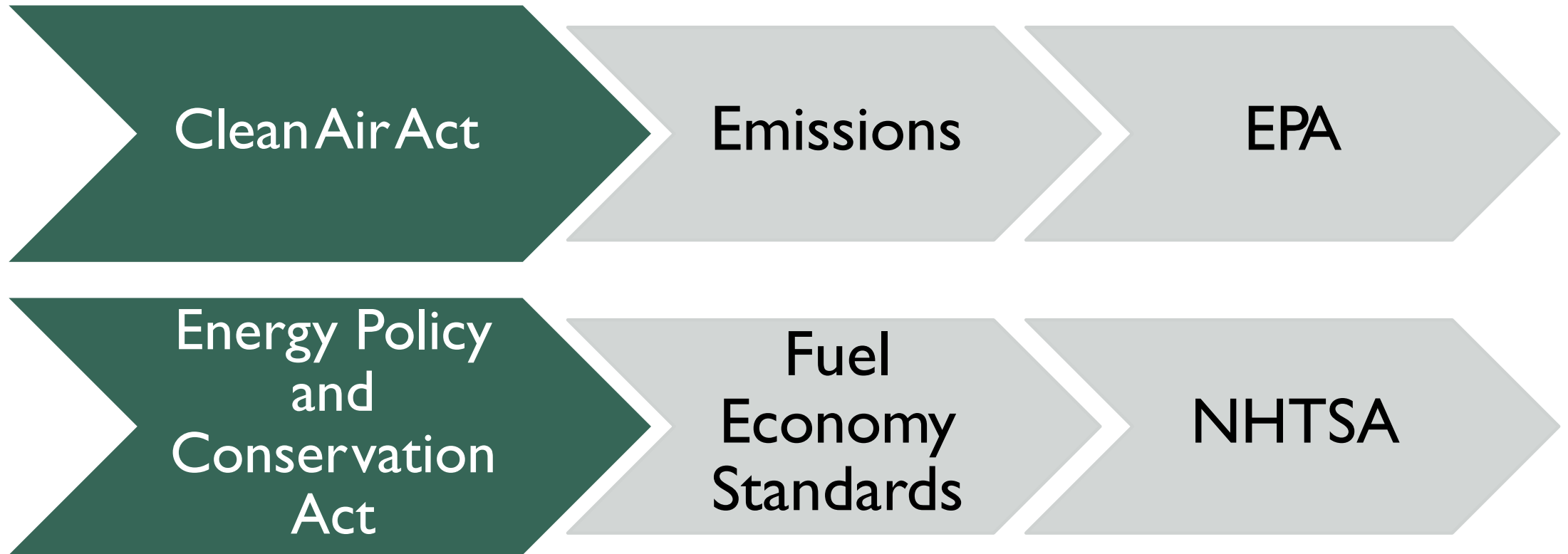
- DDPP Transportation Goal #2:
  - Deploy 300 million alternative fuel vehicles



# GOAL #1

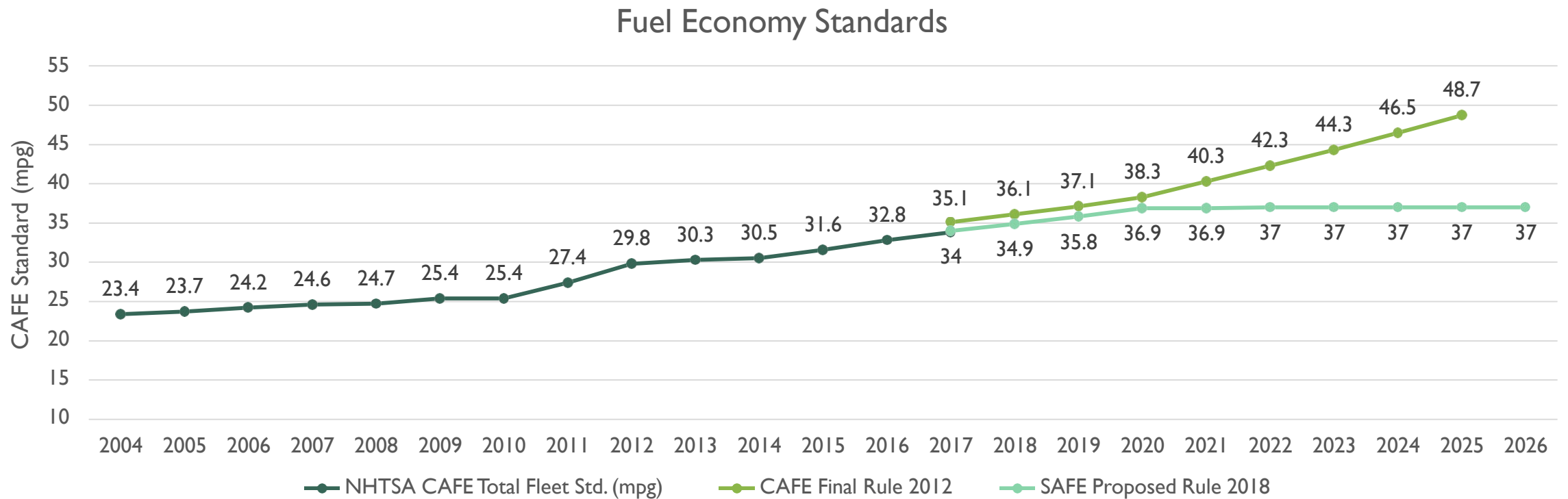
## INCREASE FUEL ECONOMY STANDARDS IN EXCESS OF 100 MPG

**GOAL #1: INCREASE FUEL ECONOMY STANDARDS  
BIFURCATED LEGAL AUTHORITY**



# GOAL #1: INCREASE FUEL ECONOMY STANDARDS

## HISTORIC FUEL ECONOMY STANDARDS



[https://one.nhtsa.gov/cafe\\_pic/CAFE\\_PIC\\_fleet\\_LIVE.html](https://one.nhtsa.gov/cafe_pic/CAFE_PIC_fleet_LIVE.html) (using all MY years, Total Fleet, Fleet Standards)

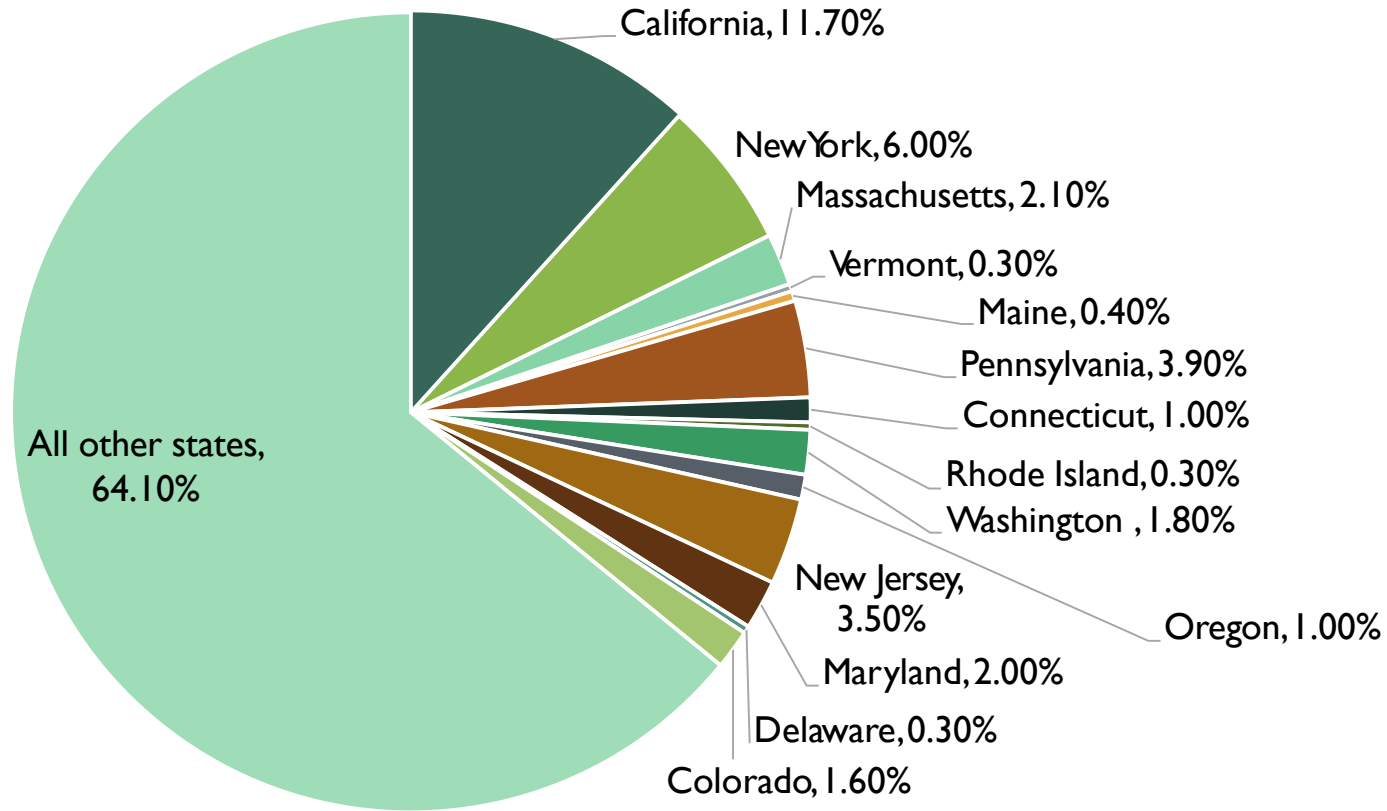
<https://www.govinfo.gov/content/pkg/FR-2012-10-15/pdf/2012-21972.pdf> (CAFE Final Rule 2012)

<https://www.govinfo.gov/content/pkg/FR-2018-08-24/pdf/2018-16820.pdf> (SAFE Proposed Rule 2018)



# GOAL #1: INCREASE FUEL ECONOMY STANDARDS FEDERALISM 101

## ZEV State Shares of U.S. New LDV Sales



**STATES THAT HAVE  
ADOPTED THE CA  
EMISSIONS  
STANDARDS  
REFLECT 46% OF  
NEW LDV SALES**

States that have Adopted California's Vehicle Emissions Standards under Section 177 of the Federal Clean Air Act, CALIFORNIA AIR RESOURCES BOARD (last updated Sept. 27, 2019) <https://ww2.arb.ca.gov/resources/documents/states-have-adopted-californias-vehicle-standards-under-section-177-federal>

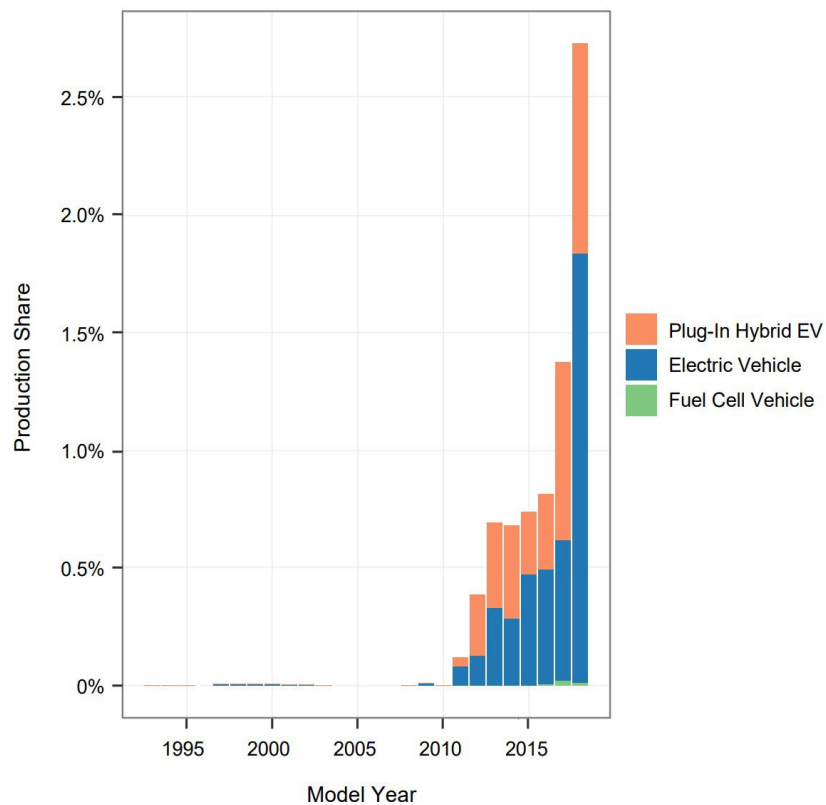


# GOAL #2

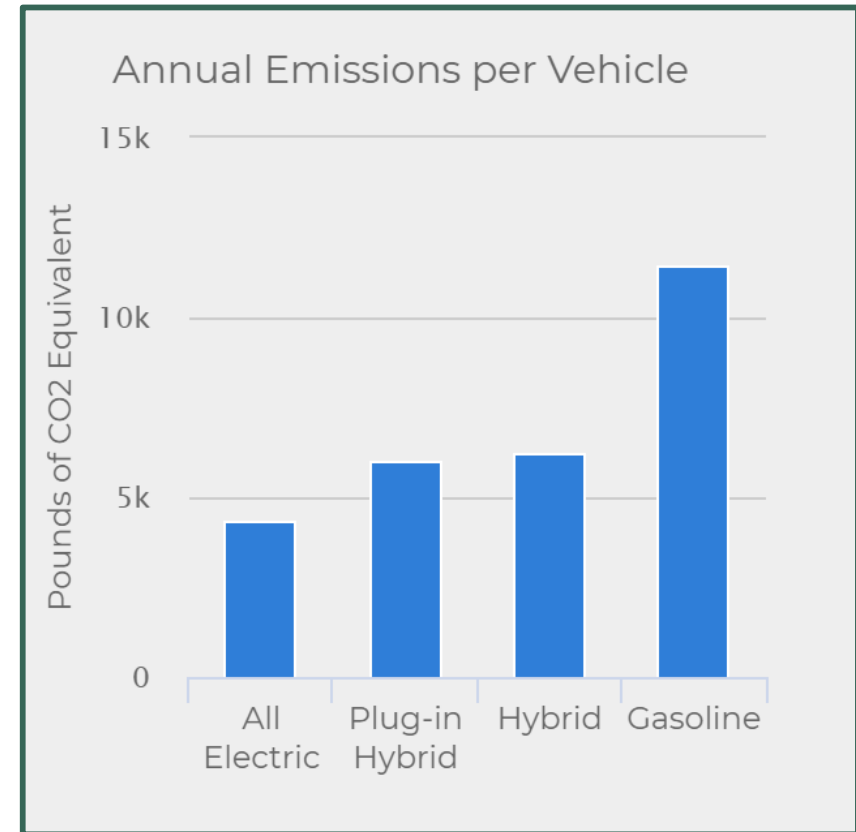
DEPLOY 300 MILLION ALTERNATIVE FUEL VEHICLES

# GOAL #2: DEPLOY 300 MILLION ALTERNATIVE FUEL VEHICLES

Figure 4.13. Production Share of EVs, PHEVs, and FCVs, Model Year 1995-2017<sup>11</sup>

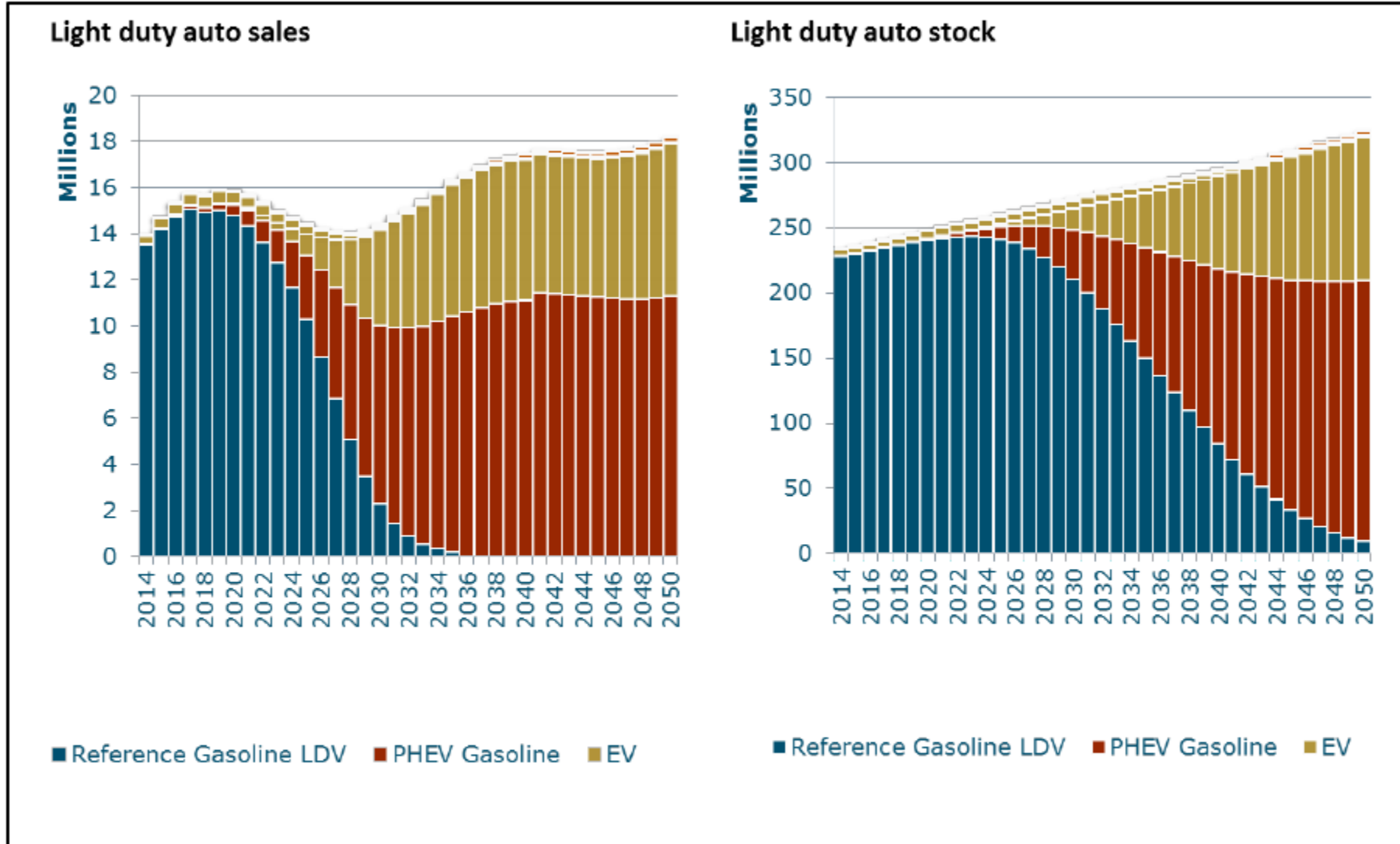


The 2018 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975, EPA (last visited Nov. 21, 2019)  
<https://nepis.epa.gov/Exe/ZyPDF.cgi/PI00W5C2.PDF?Dockkey=PI00W5C2.PDF>



Emissions from Hybrid and Plug-In Electric Vehicles: National Average, U.S. DEPT. OF ENERGY (last visited Nov. 21, 2019)  
[https://afdc.energy.gov/vehicles/electric\\_emissions.html](https://afdc.energy.gov/vehicles/electric_emissions.html)

Figure 5. Stock-rollover Example in PATHWAYS: Light Duty Auto Sales and Stock by Model Year



PHEV - plug-in hybrid electric vehicles

# GOAL #2: DEPLOY 300 MILLION ALTERNATIVE FUEL VEHICLES

## PATHWAY #1: REDUCE COSTS

2020 Ford Fusion:  
\$23,170



2020 Ford Fusion Energi:  
\$34,595

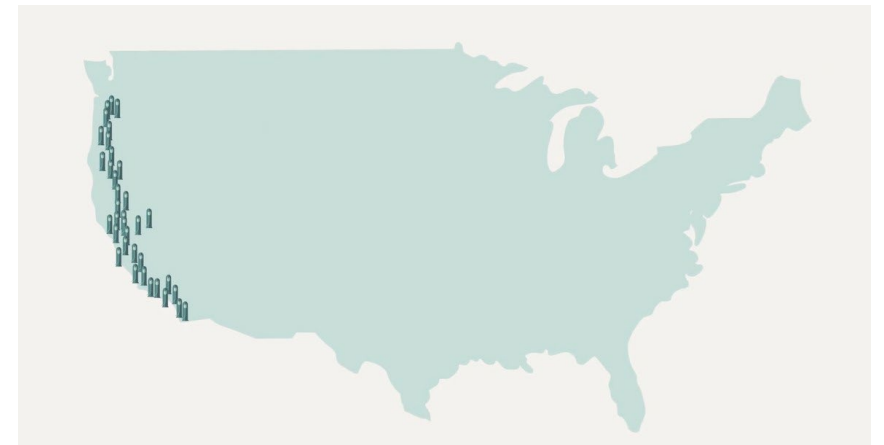


# GOAL #2: DEPLOY 300 MILLION ALTERNATIVE FUEL VEHICLES

## PATHWAY #2: FACILITATE INFRASTRUCTURE DEVELOPMENT

- Workplace Charging
- Home Charging
- Charging Corridors

- *ChargePoint Electric Vehicle Charging Corridors: United States of America*, UNITED NATIONS: CLIMATE CHANGE, <https://unfccc.int/climate-action/momentum-for-change/ict-solutions/chargepoint-electric-vehicle-charging-corridors>



## ACTION ITEMS

- Maintain 54.5 mpg fuel economy standard for 2025 and ramp up by 2050
- View EVs as grid assets (rise in EVs=rise in electricity demand,V2G programs)
- Work with electric utilities to capitalize on charging patterns and rates
- Maximize EV climate impacts through cleaner electricity resources
- Investments (e.g.infrastructure,education,and battery technologies)
- Harness government purchasing power for EVs
- Plan ahead (provide funding for pilot studies on distribution grid pressures from EVs,secure lithium supply,prepare for lithium battery disposal)
- Think creatively (battery recycling, resale markets, Cash for Clunkers-type program, smart city design,autonomous vehicles,EV-Ready building codes,decouple highway revenues from gas taxes)

*Environmental and Energy Study Institute  
Briefing to the House Select Committee on the Climate Crisis*

# **LEGAL PATHWAYS TO DEEP DECARBONIZATION IN U.S. AGRICULTURE**



PETER LEHNER  
MANAGING ATTORNEY



# CLIMATE CHANGE HARMS AGRICULTURE



## EXTREME WEATHER

- Hurricanes and storms increase in frequency and severity
  - Hurricane Maria: \$780M in ag losses
  - CAFO overflows

## PESTS, WEEDS, DISEASES

- More optimal living conditions for pests, parasites and fungi
- Invasive species expand and spread
- Reduced resilience to disease outbreak



## HEAT WAVES AND WILD FIRES

- More frequent and severe
- Lead to yield declines
- Dangerous working conditions

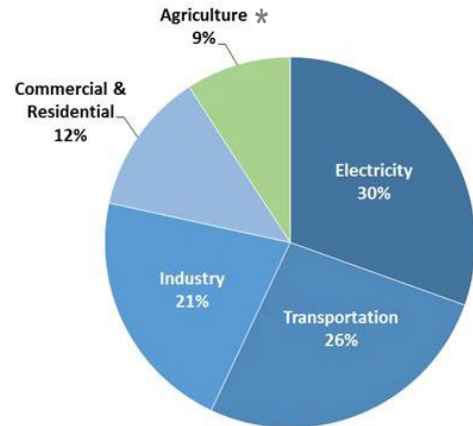


## FLOODS AND DROUGHTS

- Irregular and extreme precipitation events more frequent and severe
- 2016 CA Drought: \$603M in ag losses
- 2019 Midwest floods: 5-10M bushels corn and soy rotted



# INDUSTRIAL AGRICULTURE CONTRIBUTES TO CLIMATE CHANGE



\*Additional food system related emissions are produced across all sectors (e.g. processing, refrigeration, cooking, transport, indirect deforestation abroad)

## NITROUS OXIDE

- Excess fertilizer, animal manure
- ~73 coal-fired power plants



## SOIL CARBON

- Forest and grassland conversion, tillage
  - ~17 coal-fired power plants
- 7.8M+ acres converted to cropland from 2008-2012



## METHANE

- Cattle, animal manure
- ~87 coal-fired power plants
- Equal to emissions from entire oil and gas sector



## CARBON DIOXIDE

- Fertilizer manufacture, on-farm energy, food waste in landfills
  - ~12 coal-fired power plants

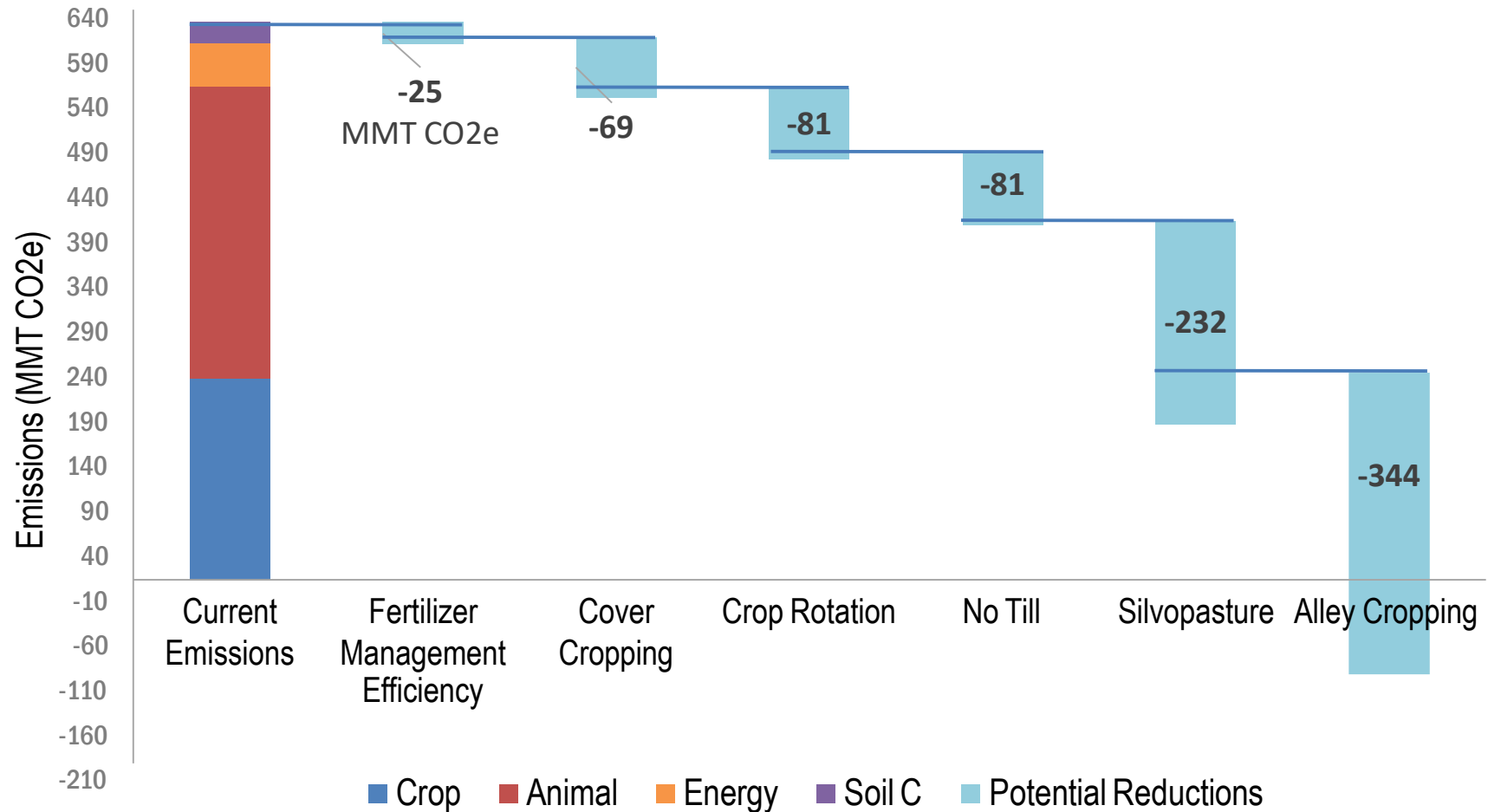
# AGROECOLOGICAL PRACTICES REDUCE CHEMICAL USE, POLLUTION, CLIMATE IMPACTS



Annual crop root mass (left) vs. perennial crop root mass (right).  
*Greater root mass improves drought/flood resilience and nutrient uptake.*

- Chemical-intensive, monoculture systems increase erosion and GHG emissions and are not necessary for high productivity and profitability
- **Organic and agroecological practices can provide ample nutritious food** while reducing fertilizer/pesticide needs and costs
- These proven practices include:
  - Perennial crops (*see image*)
  - Crop rotations (different yearly crops)
  - Cover crops (avoiding winter bare ground)
  - No-till, reduced till; prairie strips
  - Management intensive grazing
  - Agroforestry & silvopasture (trees)
  - Dry manure management
  - Organic fertilizer
  - Riparian buffers, wind breaks

# CARBON-NEUTRAL FUTURE: BETTER PRACTICES CAN REDUCE EMISSIONS



# ALTERNATIVE PRACTICES NEED INCENTIVES TO INCREASE ADOPTION

- Agroecological practices are very effective, but not widely employed
  - **Universal barriers include:** knowledge and capacity, technical and technological support, lack of site- or region-specific information, cultural attitudes, financial risks and opportunity costs...
  - **>85%** of USDA survey participants would NOT adopt structural conservation practices without outside funding

PRACTICE	U.S. ADOPTION RATE
Cover crops	~4% of all cropland acres
No-till	26% of all cropland acres*
Fertilizer management	6% of corn and 24% of cotton acreage meet all 4 criteria for good nitrogen management**
Certified organic	<1% of all US farms

\*Less than a third of “no-till farms” are truly no-till.

\*\*No fall application, optimal rate, some N after planting, incorporated below soil surface

# STATUTORY CHANGES NECESSARY FOR CARBON NEUTRAL AGRICULTURE

- **The Farm Bill**
  - Expand and better target **conservation programs** to practices with climate change mitigation and resilience potential and away from practices with negative impacts
  - Increase funding for **R&D** into climate-friendly practices, education, & outreach
  - Reform **crop insurance and commodity payments** to avoid barriers to climate-friendly practices and create additional incentives
- **Energy policy and laws**
  - Fix **renewable fuel standard** to reduce conversion of native grasslands to cropland
  - Encourage **on-farm renewable energy** and energy efficiency
- **Pollution and land management statutes**
  - Eliminate barriers and create incentives for management intensive grazing
  - Increase information sharing and data availability
  - Prioritize climate beneficial practices in other water and air quality programs (e.g. nonpoint source)

# POLICIES TO ACCELERATE SHIFT TO CLIMATE-FRIENDLY PRACTICES (1): EXPAND & FOCUS EDUCATION, OUTREACH & RESEARCH



*NOFA-NY field day at  
Poughkeepsie Farm Project (2018)*

- Knowledge, information and capacity is major barrier for all practices
- Educational and technical support from:
  - NRCS agents and offices in each county
  - Farmer-to-farmer networks
  - On-farm demonstrations and workshops
- ***But, research and outreach funding half of levels from previous years***
- Moreover, majority of NRCS funds still support conventional agriculture

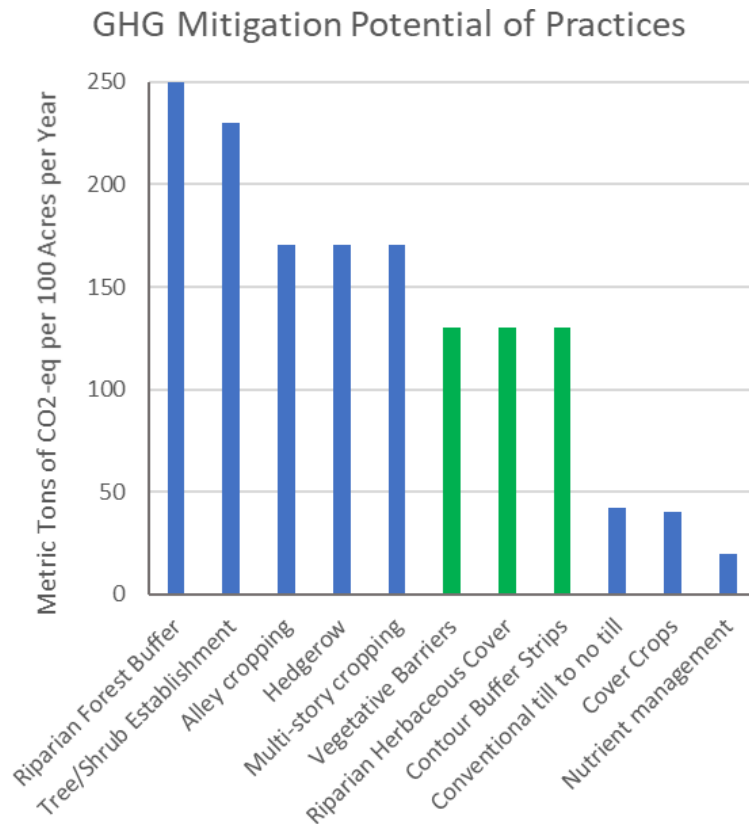
# POLICIES (2): EXPAND AND FOCUS FEDERAL CONSERVATION FINANCING



- **Environmental Quality Incentives Program (EQIP)**
  - Funded projects often counter-productive (NRCS review) or impede broader shift to agroecological practices (irrigation, CAFOs)
  - 2018 Farm Bill allows states to provide 90% cost share to 10 “best practices”
  - Reform criteria to prioritize climate-friendly practices
- **Conservation Stewardship Program (CSP)**
  - 2018 Farm Bill retained program
  - States can direct toward best practices for organic transition



# POLICIES (3): INCENTIVIZE VEGETATED BUFFERS AND EASEMENTS



- **Conservation Reserve Program (CRP)**
  - Program often provides only temporary benefits
  - Accumulated soil carbon is lost when CRP contracts expire and land is put back in production
  - 2018 Farm Bill allows 30-year contracts on pilot basis
  - Focus on land with greatest climate benefits
- Congress and States can expand **Agricultural Conservation Easement Program (ACEP)**

# POLICIES (4): REFORM CROP INSURANCE AND COMMODITY PROGRAMS



- **Crop insurance & commodity programs**
  - Provide **transition crop insurance** for farmers transitioning from conventional to sustainable practices
  - Add to **conservation compliance** required practices and expand to all tilled acreage
  - Remove **barriers** to climate-friendly practices
  - Expand **incentives** for risk-reducing practices
  - Improve **oversight**
- Add environmental practice conditions (e.g. BMPs, buffers, cover crops, etc.) on **agricultural district designations**

# POLICIES (5): OTHER FINANCIAL SUPPORT



- **Market assistance**
  - Assist infrastructure for additional crops to allow longer rotations and perennial crops
  - Help build market for new crops
- **Equipment loans**
  - Aid in covering costs of new equipment necessary to implement practices
  - Ex. No-till seed drills for producers
- **Preferential purchasing/promotion**
  - Give preference in government purchasing to organic or other climate-friendly production
  - Example: **New York Grown and Certified** (70% people said they would buy more; 50% would pay more)

# POLICIES (6): ACCELERATE OTHER GHG REDUCTION



- Increase support and eliminate barriers for other practices that reduce GHG:
  - Improved livestock manure management, including switching from **wet to dry manure storage**
  - New **on-farm technology** (remote sensing, precision agriculture, etc.)
  - New climate resilient **crop and feed varieties** for more efficient growth
- Encourage and incentivize on-farm **renewable energy** and **energy efficiency**
- Reform “aggregate compliance” in **renewable fuel standard** to slow grassland conversion