



SCHOOL OF  
PUBLIC POLICY  
CENTER FOR GLOBAL  
SUSTAINABILITY

**Center for Global Sustainability**  
**Analytics for Ambition | Collective Action**

# The Outlines of Deep Decarbonization

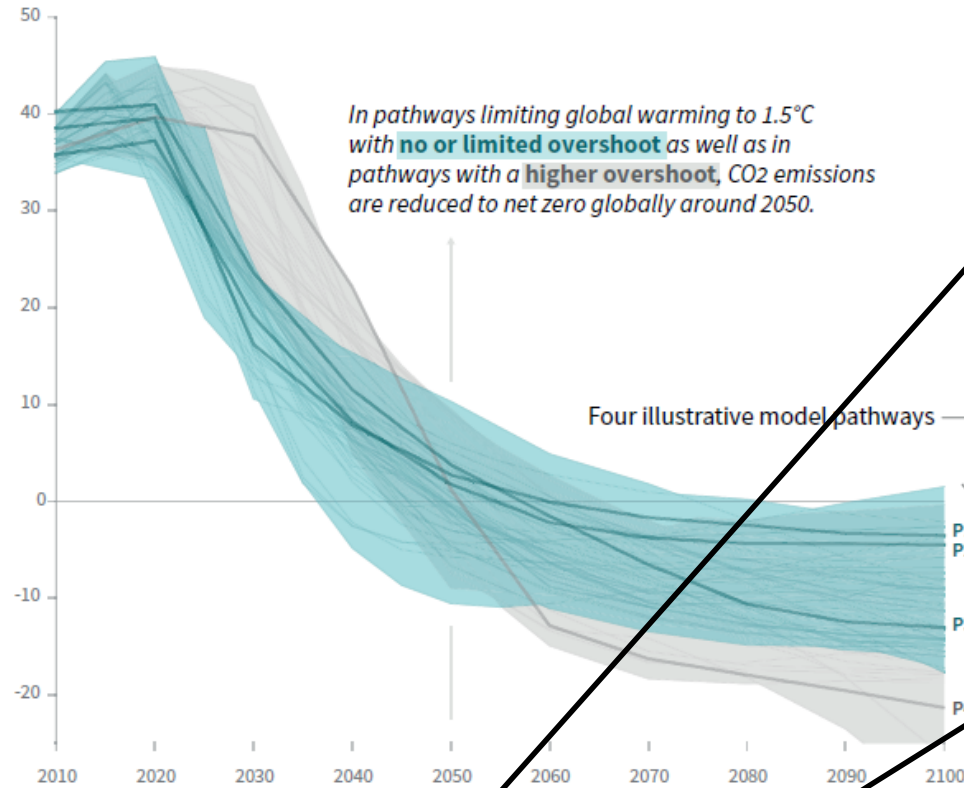
Leon Clarke  
July 22, 2019



# Limiting temperature change to 2C or 1.5C requires rapid emissions reductions

Global total net CO<sub>2</sub> emissions

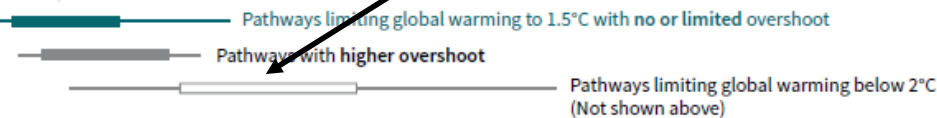
Billion tonnes of CO<sub>2</sub>/yr



**1.5°C Pathways: Carbon neutrality around 2050**

**2.0°C Pathways: Carbon neutrality around 2070**

Timing of net zero CO<sub>2</sub>  
Line widths depict the 5-95th percentile and the 25-75th percentile of scenarios



Source: IPCC, 2018, *Global Warming of 1.5°C*



SCHOOL OF PUBLIC POLICY  
CENTER FOR GLOBAL SUSTAINABILITY

# Many studies have explored deep decarbonization in the U.S.



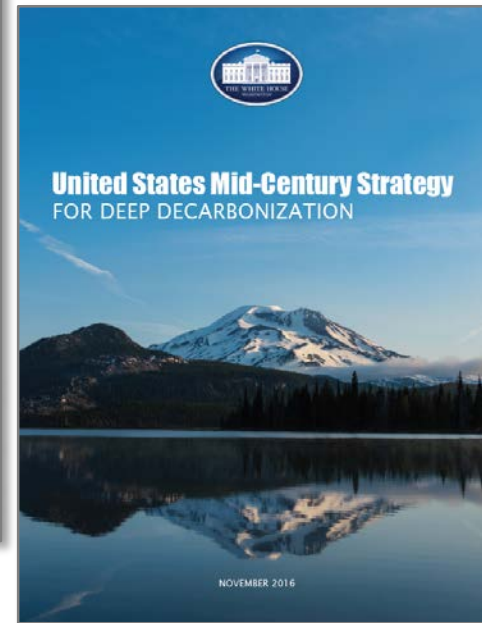
Energy Modeling Forum 22 (2009)



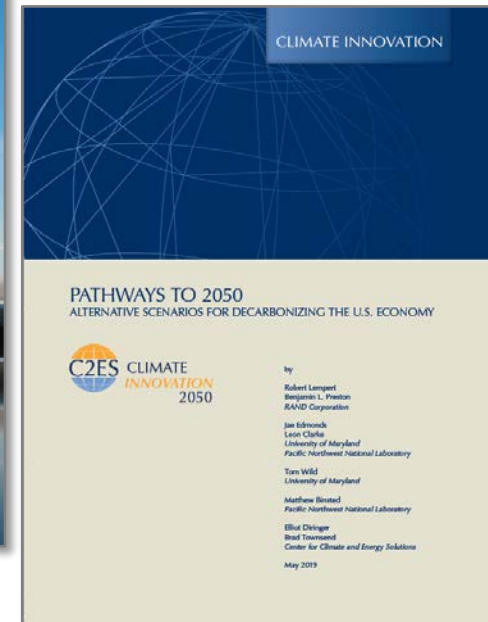
Energy Modeling Forum 24 (2014)



Deep Decarbonization Pathways Project (2014)

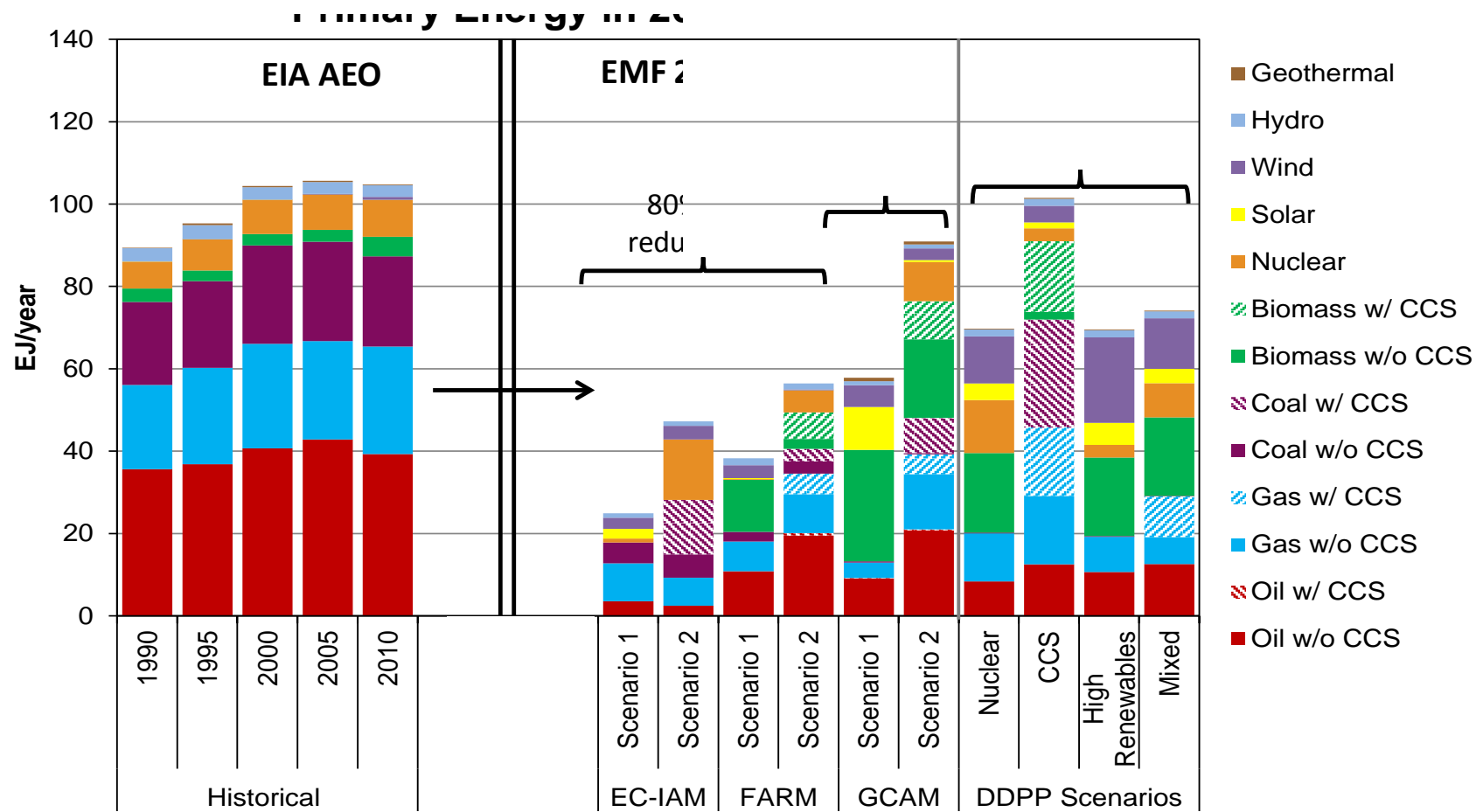


U.S. Mid-Century Strategy (2016)



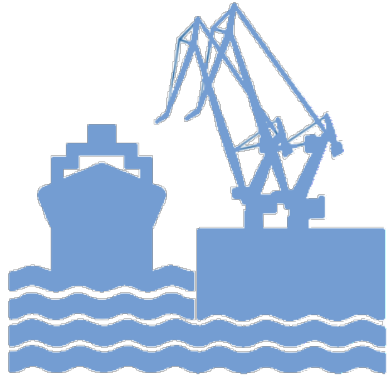
Climate Innovation 2050 (2019)

# Many energy system pathways are possible



# There are multiple societal pathways to deep decarbonization

## A Competitive Climate



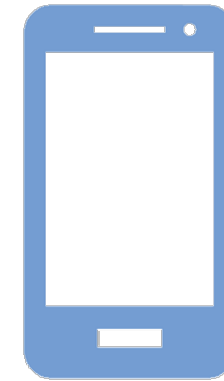
Strong international pressure in the form of carbon tariffs and growing recognition of the competitive benefits of low-carbon innovation lead to a strong, early U.S. federal response, including an economy-wide price on carbon.

## Climate Federalism



Responding to economic opportunities and intensifying climate-related disasters, a growing number of U.S. states implement ambitious climate policies, leading to calls from business for a more harmonized national response.

## Low-Carbon Lifestyles

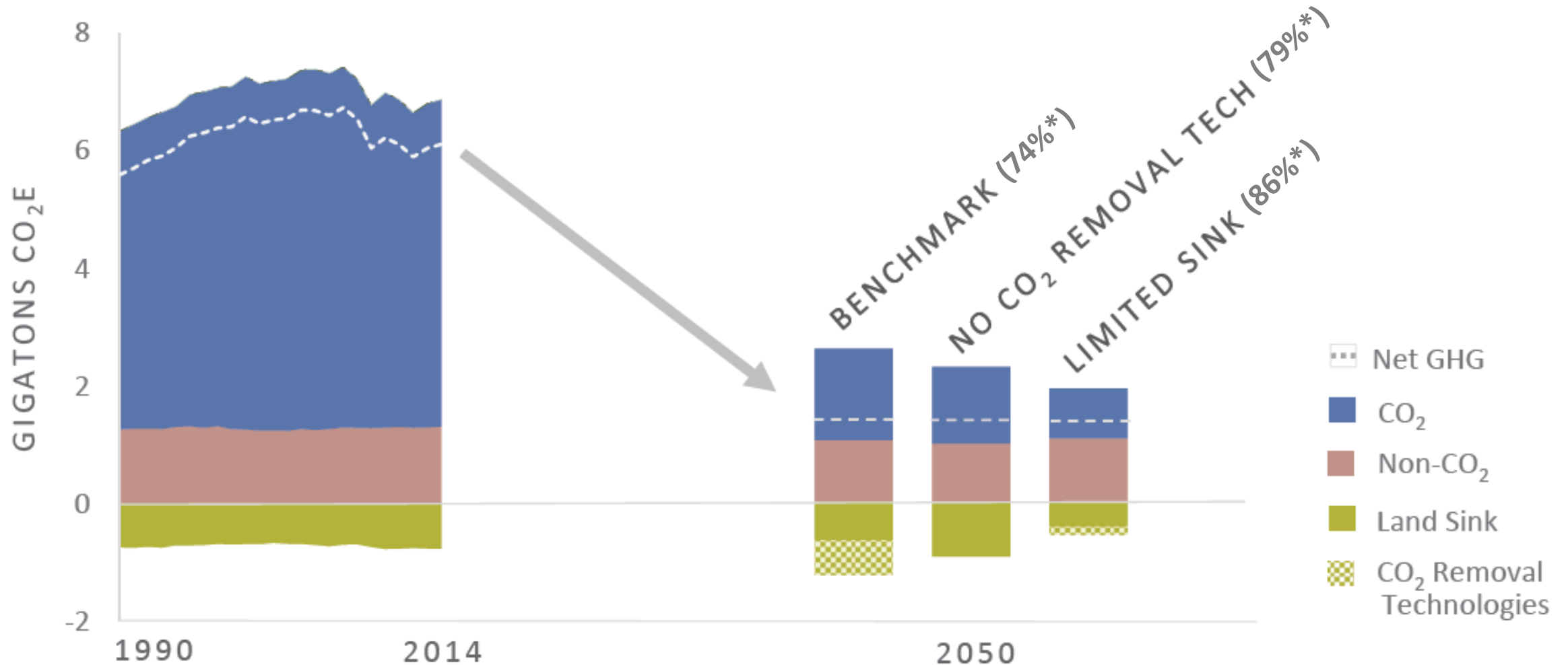


Increased urbanization, generational shifts, and technological breakthroughs lead to strong market demand for low-carbon consumption products and services, along with the emergence of innovative low-carbon business models.

**Every scenario requires broad societal support and involves actors across the economy (e.g., governments, businesses, consumers)**



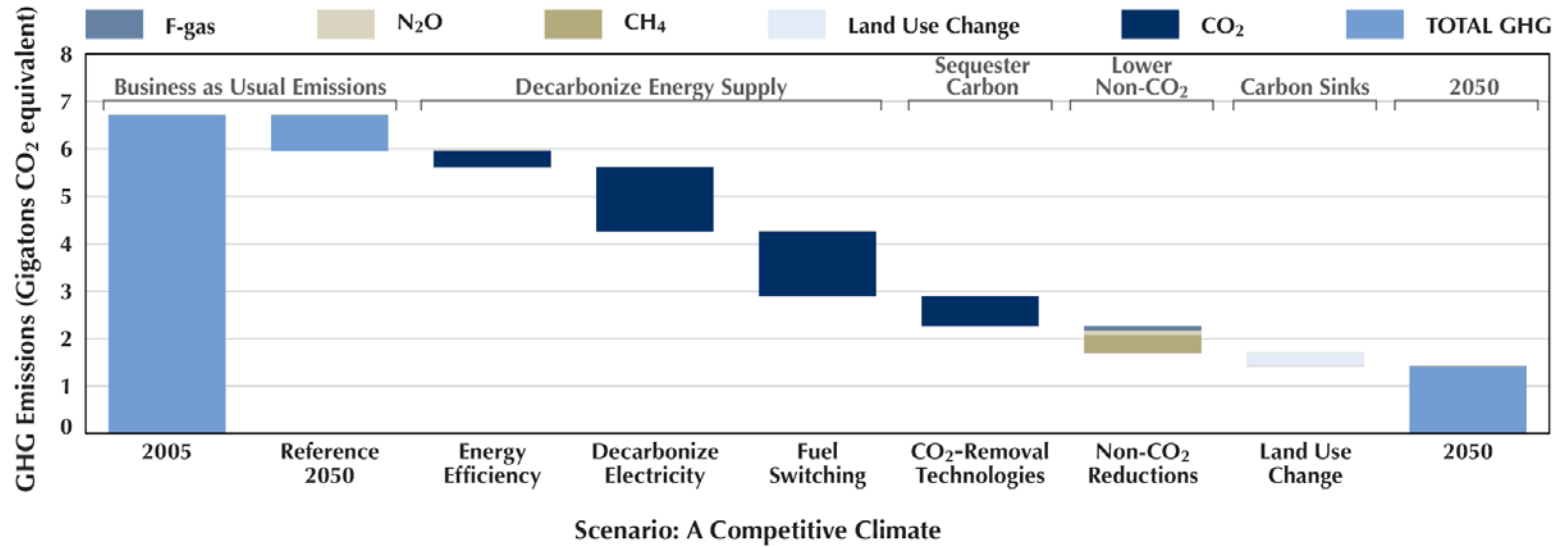
# Energy emissions in context



Source: United States Mid-Century Strategy (2016)

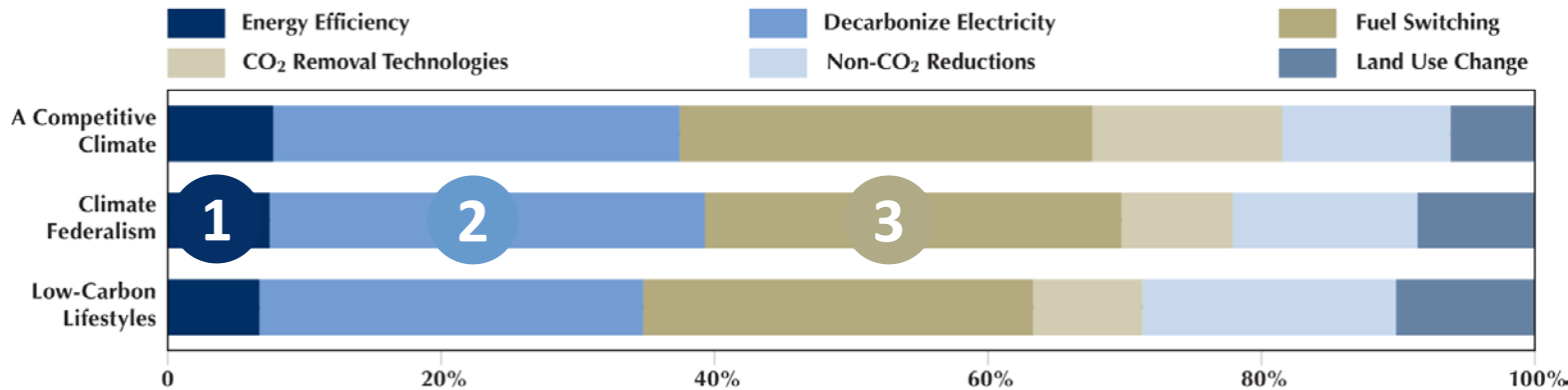
\* (Percent reduction in direct fossil combustion relative to 2005. Does not account for CDR from energy )

# Key Elements of Decarbonization



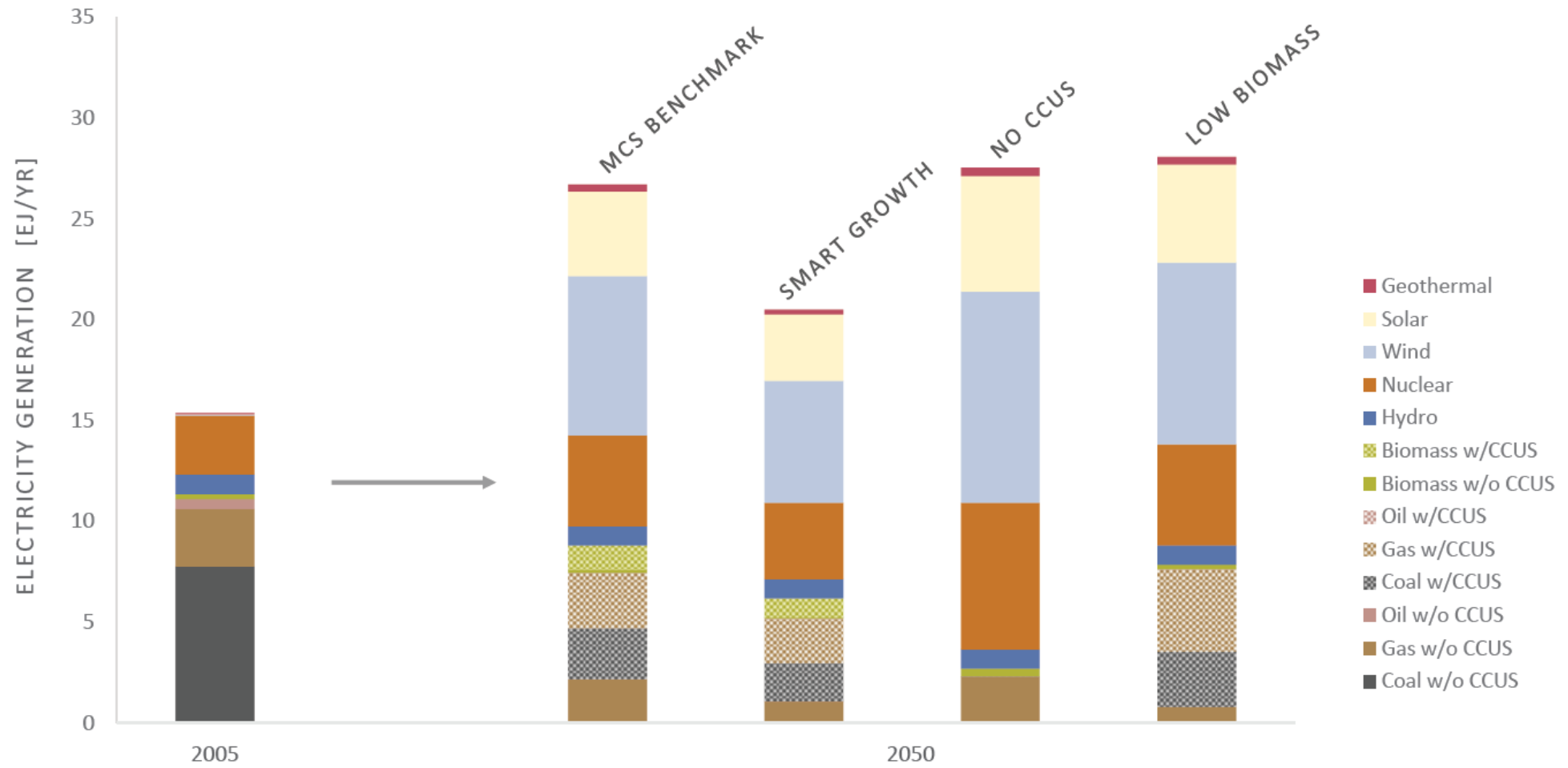
## Three pillars of energy sector decarbonization

- 1 Energy Efficiency
- 2 Decarbonize electricity
- 3 Fuel switching





# Electricity in the MCS Benchmark



*Only 8% of electricity comes from freely-emitting fossil energy; no freely-emitting coal in the benchmark scenario*

*Source: United States Mid-Century Strategy (2016)*

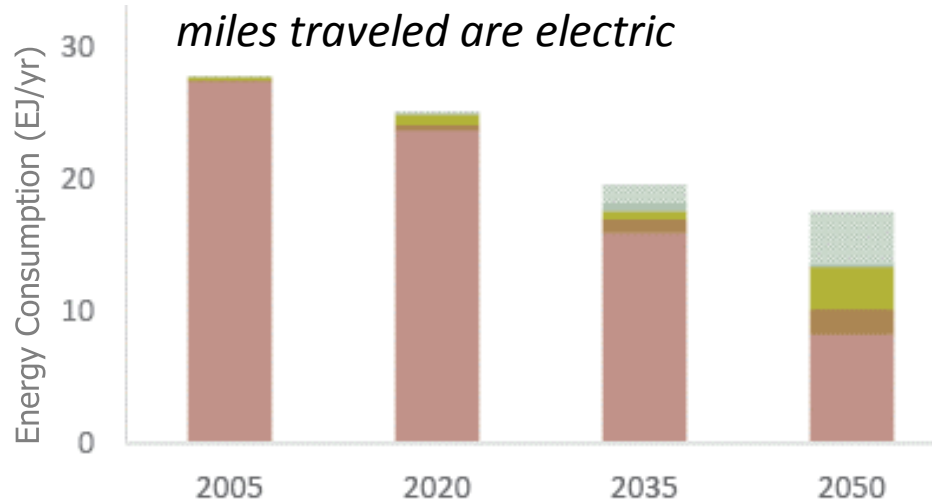




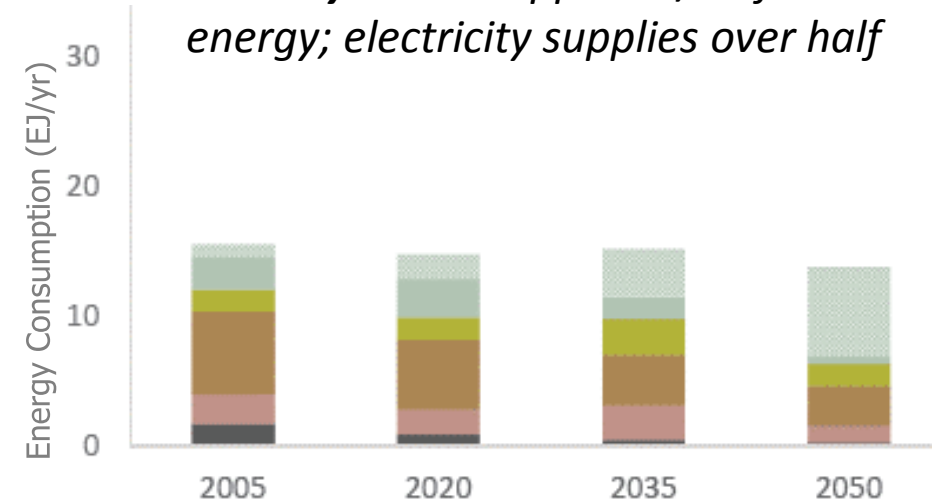
# The transformation will extend across sectors

Primary energy use declines by over 20 percent between 2005 and 2050

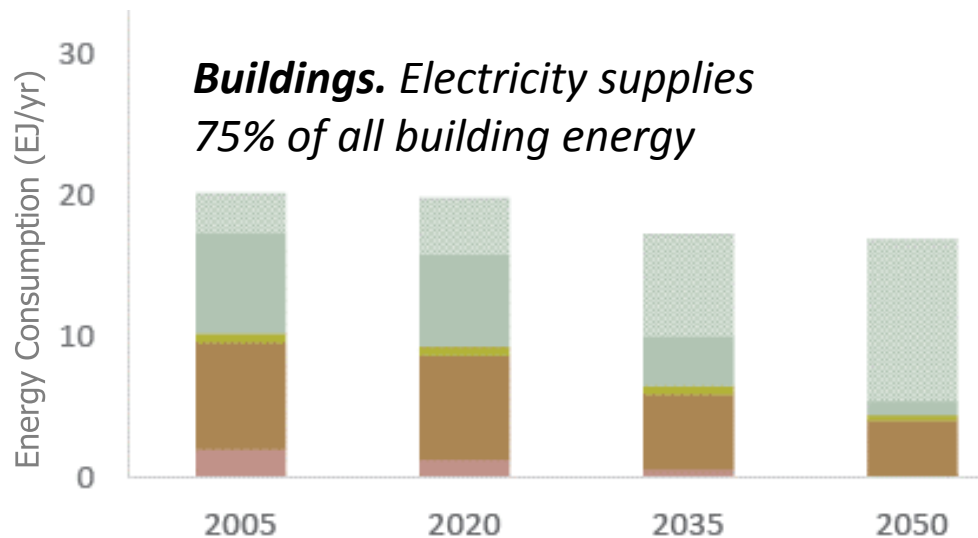
**Transport.** 60% of all light duty miles traveled are electric



**Industry.** Fossil supplies 1/3 of total energy; electricity supplies over half



**Buildings.** Electricity supplies 75% of all building energy

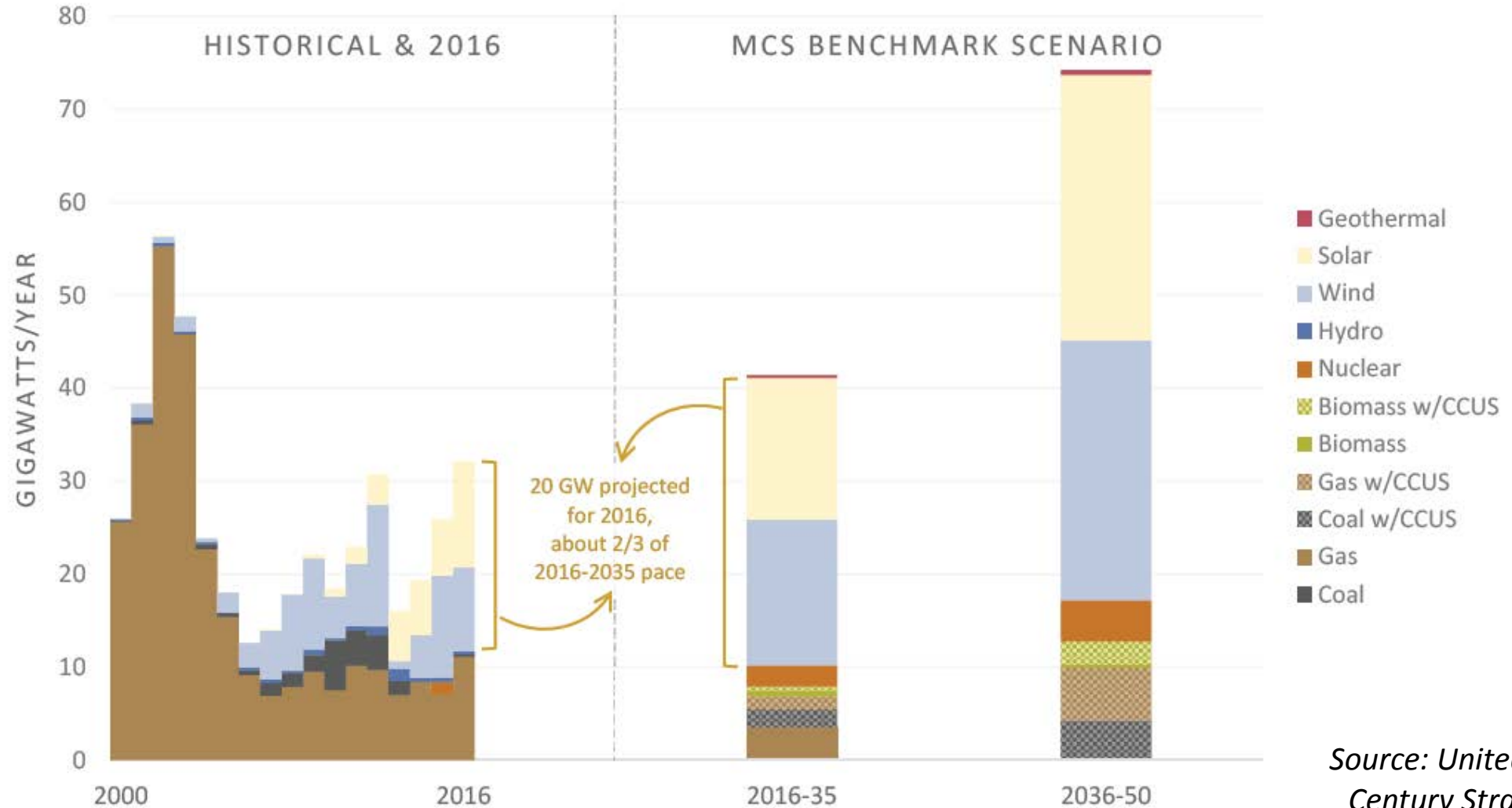


Source: United States Mid-Century Strategy (2016)



# Investment patterns need to evolve

## Average Annual Capacity Additions



Source: United States Mid-Century Strategy (2016)



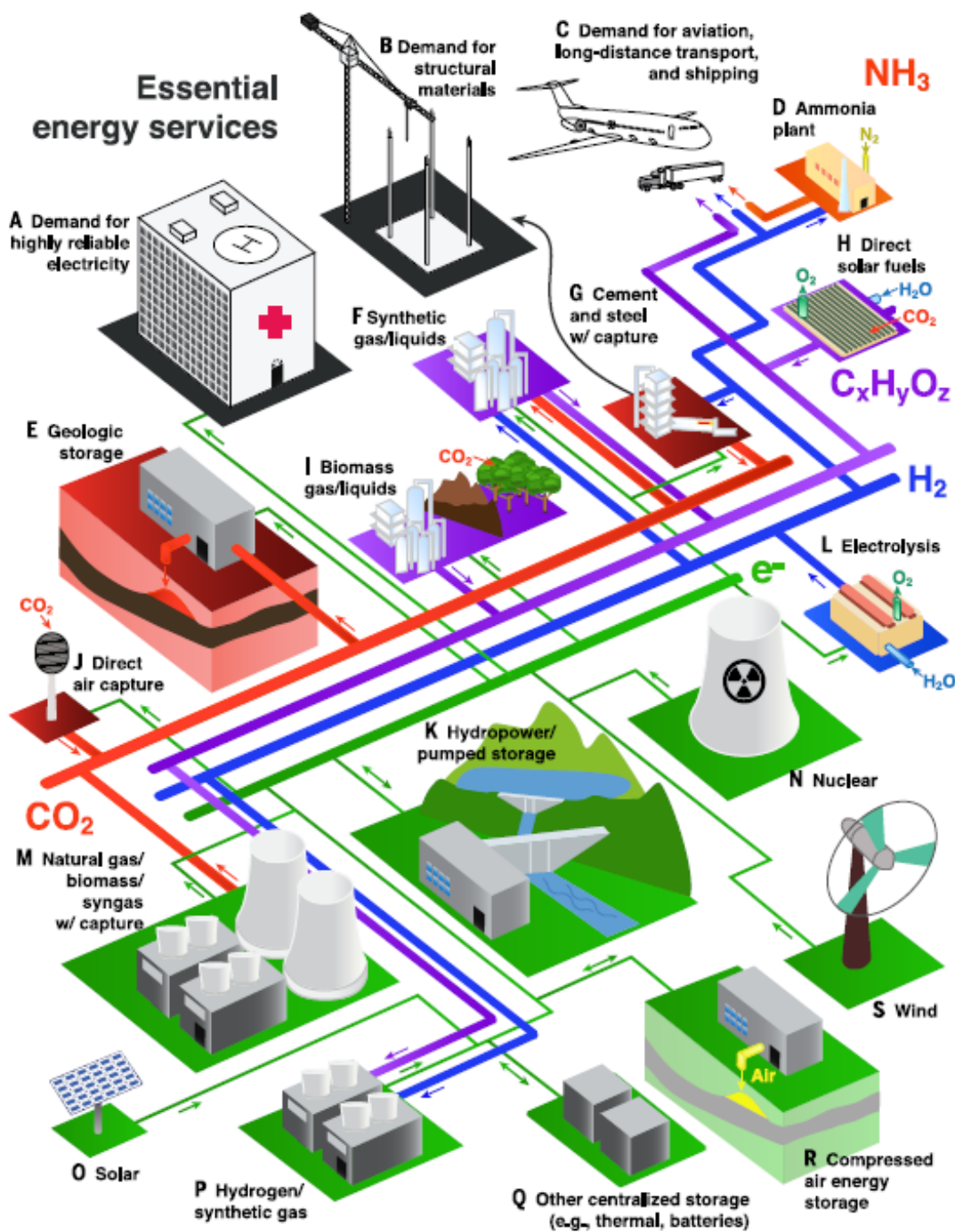
# What do we know and not know?

*Not so clear*

## Three pillars of energy sector decarbonization

- 1** Energy Efficiency
- 2** Decarbonize electricity  
*Almost all electricity from clean sources by 2050*
- 3** Fuel switching  
*A major evolution toward electricity across end uses*

1. The electricity mix (nuclear, CCUS, renewables)
2. Bioenergy and alternative fuels like hydrogen
3. CCUS and the future of coal and gas
4. Carbon dioxide removal
5. Hard-to-decarbonize sectors (e.g., air transport, structural materials)
6. The industrial sector
7. Growth and evolution in energy services
8. Societal approach to mitigation (e.g., policies, consumer preferences)



# The long-term goal is zero or negative emissions

1. Aviation, long-distance transport, and shipping.
2. Structural materials (iron and steel, cement)

## 3. Load-following electricity

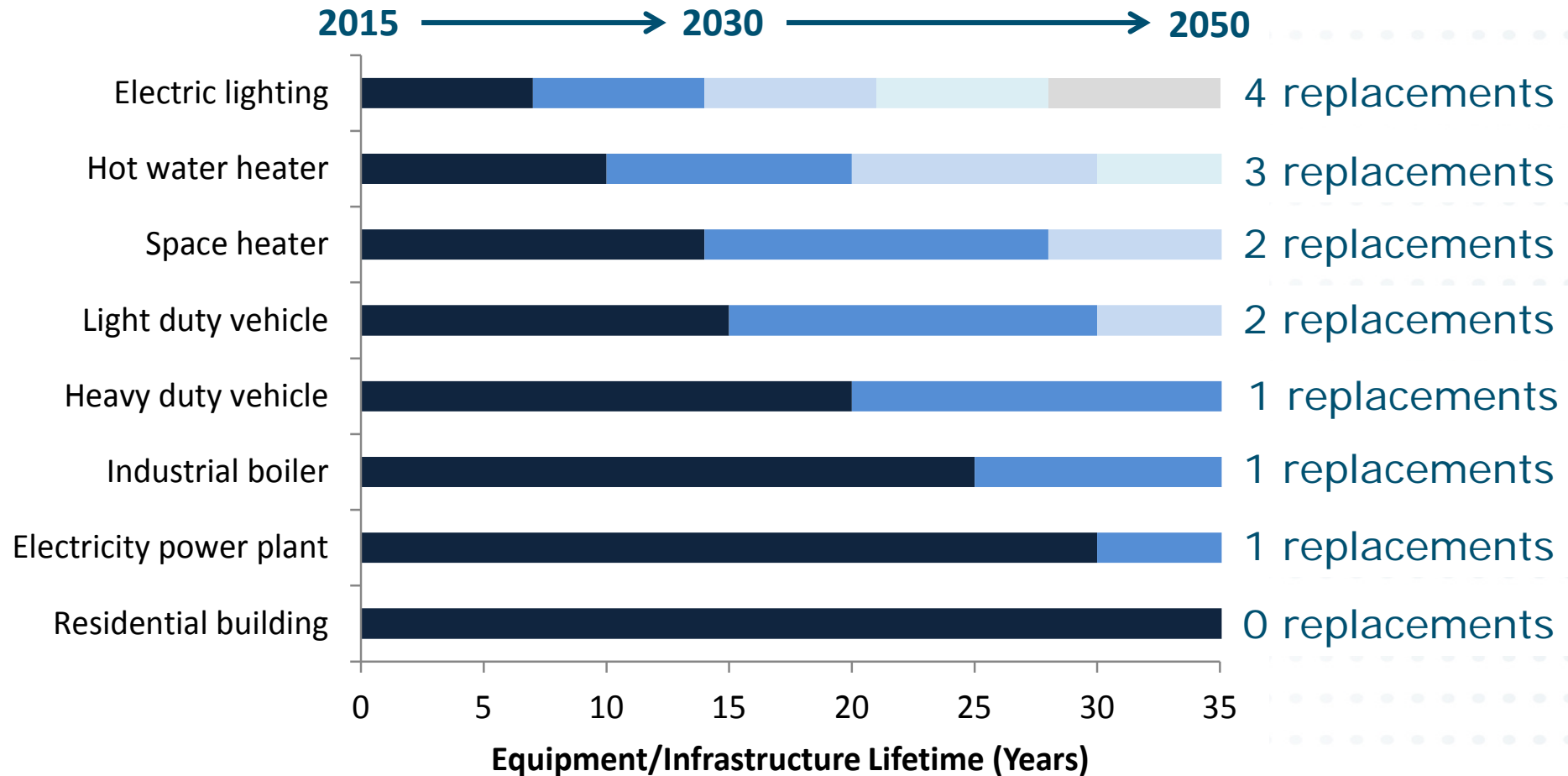
Source: Davis, S. J., Lewis, N. S., Shaner, M., Aggarwal, S., Arent, D., Azevedo, I. L., ... & Clack, C. T. (2018). Net-zero emissions energy systems. *Science*

- Carbon dioxide removal



# Timing for Action is Limited

- + 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.





SCHOOL OF  
**PUBLIC POLICY**  
CENTER FOR GLOBAL  
SUSTAINABILITY

**Center for Global Sustainability**  
**Analytics for Ambition | Collective Action**

Thank You