The Outlines of Deep Decarbonization

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

1.5°C Pathways: Carbon neutrality around 2050

2.0°C Pathways: Carbon neutrality around 2070

Source: IPCC, 2018, Global Warming of 1.5°C
Many studies have explored deep decarbonization in the U.S.
Many energy system pathways are possible
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.

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.

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

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

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

Source: United States Mid-Century Strategy (2016)
Investment patterns need to evolve

Average Annual Capacity Additions

HISTORICAL & 2016

MCS BENCHMARK SCENARIO

GIGAWATTS/YEAR

20 GW projected for 2016, about 2/3 of 2016-2035 pace

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**
   - Almost all electricity from clean sources by 2050

2. **Decarbonize electricity**
   - A major evolution toward electricity across end uses

3. **Fuel switching**

### Not so clear

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


- Carbon dioxide removal
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.

- Electric lighting: 4 replacements
- Hot water heater: 3 replacements
- Space heater: 2 replacements
- Light duty vehicle: 2 replacements
- Heavy duty vehicle: 1 replacement
- Industrial boiler: 1 replacement
- Electricity power plant: 1 replacement
- Residential building: 0 replacements
Thank You