An Innovation Agenda for a Low-Carbon Future

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  - Trade and globalization
  - Life sciences, agricultural biotech, and energy
- Formulates and promotes policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress
- World's top think tank for science and technology policy, according to the University of Pennsylvania's authoritative *Global Go To Think Tank* Index

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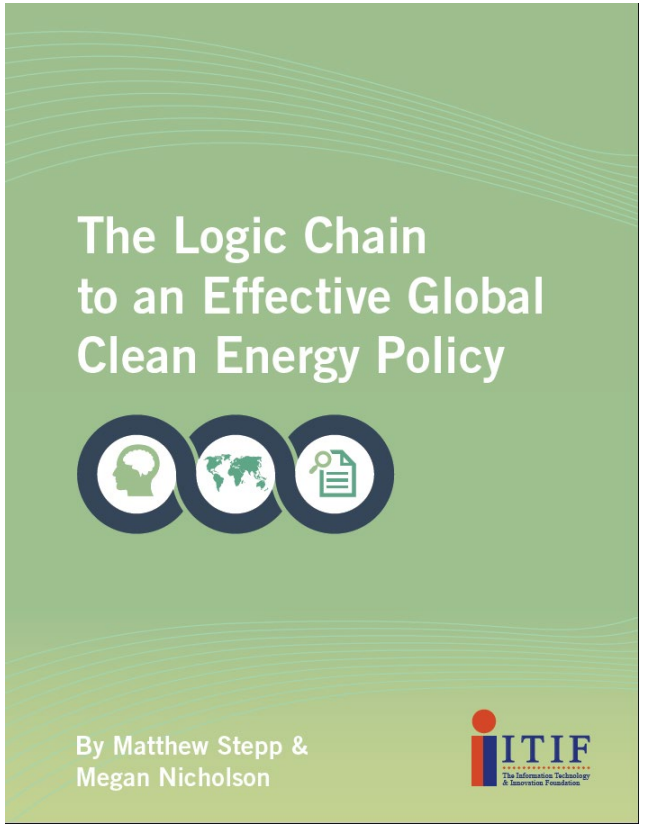
Why the U.S. Needs a Clean Energy Innovation Policy

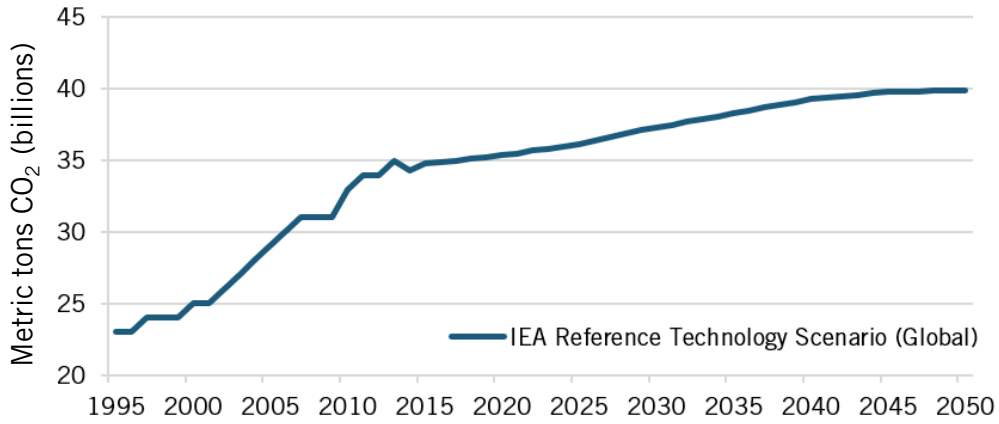
Logic-Chain

- Climate change is a global problem.
- The world needs to reduce carbon pollution to zero before 2100.
- Clean energy needs to be cheaper and better for global adoption.
- This requires smart innovation policy.



Without Innovation, Emissions Increase

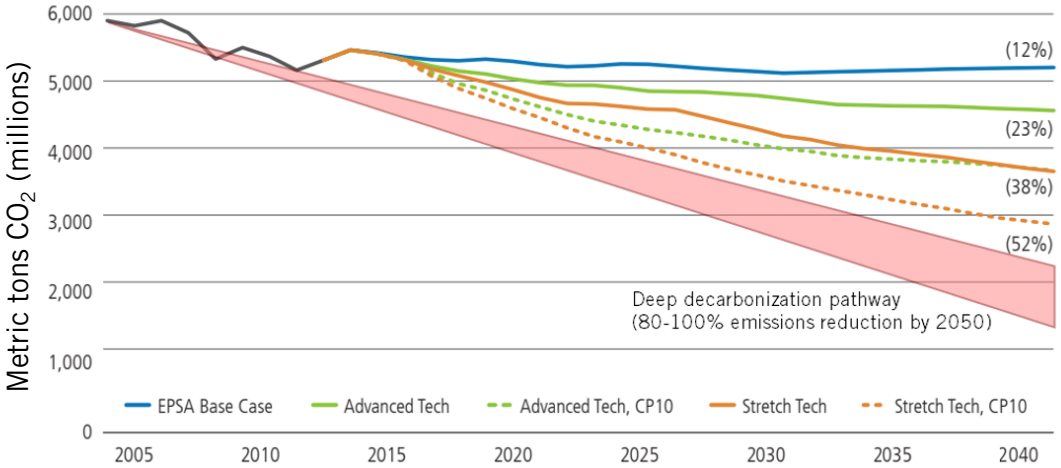
Figure 5. Projections of Global and Domestic Carbon Emissions Under a Reference Technology Scenario.[36]



Global emissions are projected to increase through 2050.

- Includes Paris commitments
- Includes future cost reductions for renewables, other clean energy

Figure 6. U.S. energy CO_2 emissions under different technology and policy scenarios



U.S. emissions are projected to level off under a reference technology scenario.

- DOE energy RD&D programs can reduce emissions.
- Substantial gaps remain.

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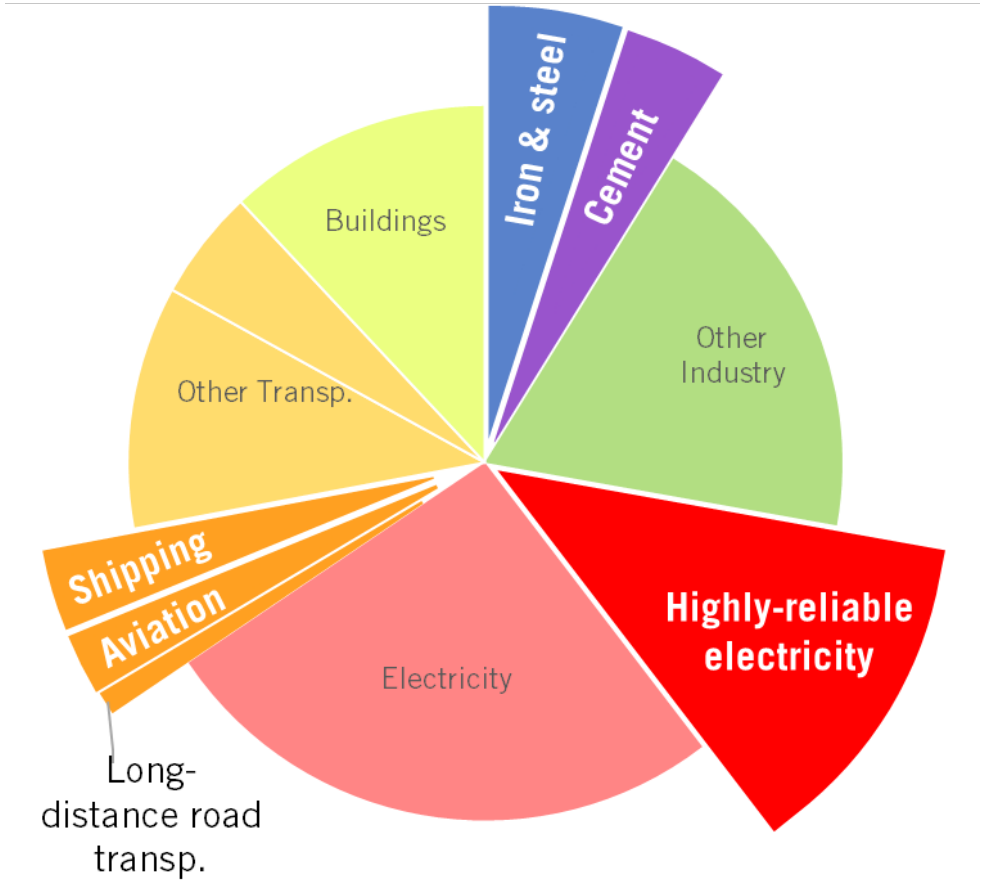
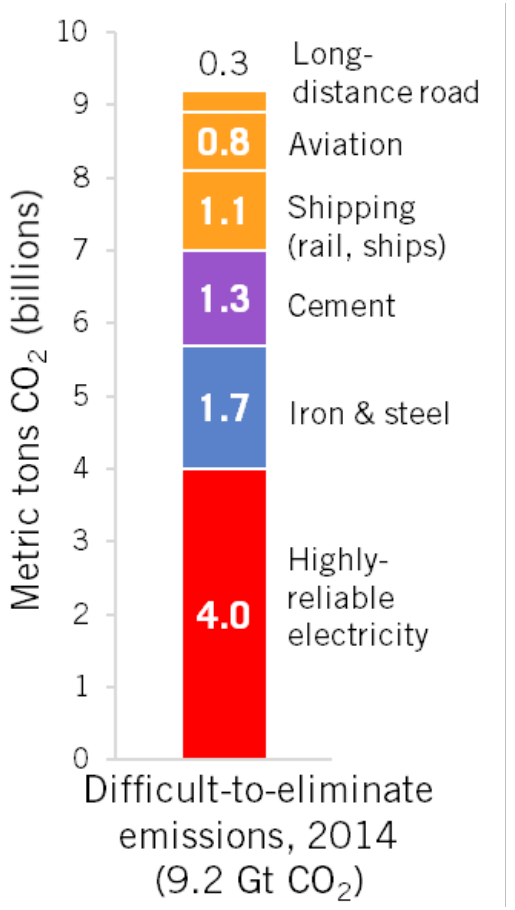
Harder-to-Eliminate Emissions

1. **Electricity**
2. **Transportation**
3. **Industrial sector**





Source: Davis, et al., *Science* (2018) 1419.

Challenge: Highly-Reliable "Firm" Low-Carbon Electricity

Emissions reductions have been "low-hanging fruit."

There are limits to emissions reductions that can be achieved from natural gas and variable renewables.

Cost is an issue for systems with high reliance on variable renewables.

Need: Zero-carbon "firm" electricity that can be dispatched as needed

Scale: 4.0 Gt CO_2 per year

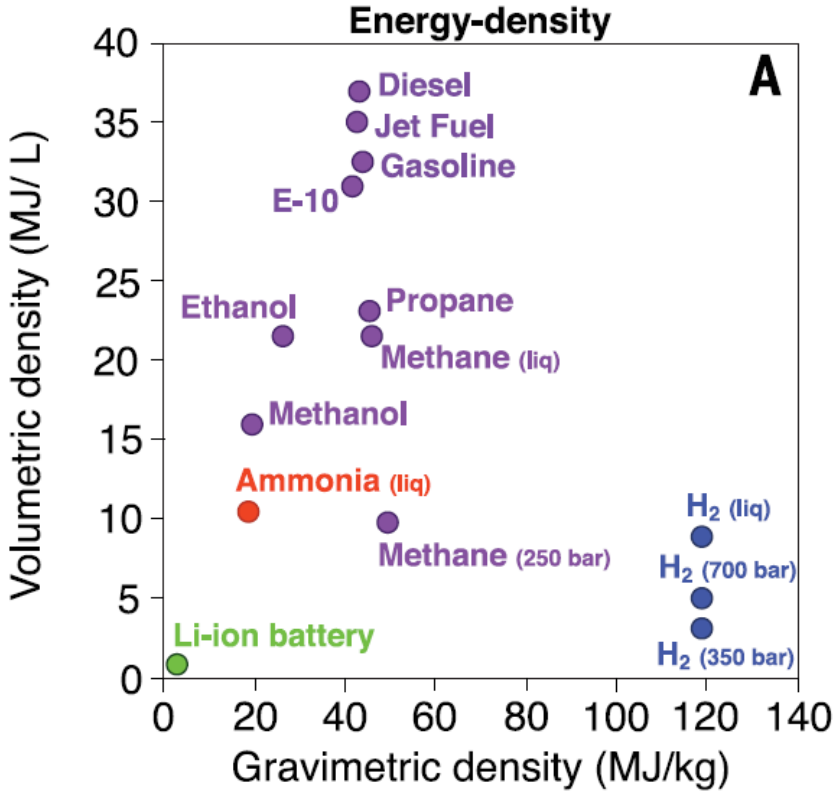
Challenge: Harder-to-Electrify Transportation

Electrification of light-duty vehicles, in combination with decarbonized electricity, can enable deep emissions reductions if battery prices come down.

Batteries are unlikely to achieve the energy density requirements of aviation, shipping, and long-distance road transport.

Need: Energy-dense carbon-neutral fuels

Scale: 2.2 Gt CO_2 per year



Volumetric and gravimetric energy density of transportation fuels.
Davis et al., *Science* (2018).

Challenge: Harder-to-Electrify Industrial Sources

Process emissions cannot be eliminated by switching to carbon-free energy.

High-temperature heat (>750°F) is provided by on-site fossil fuel combustion and is not easily electrified.

Need: clean heat, abatement of process emissions

Scale: 3.0 Gt CO_2 per year

Challenge: Atmospheric Carbon Dioxide Removal (CDR)

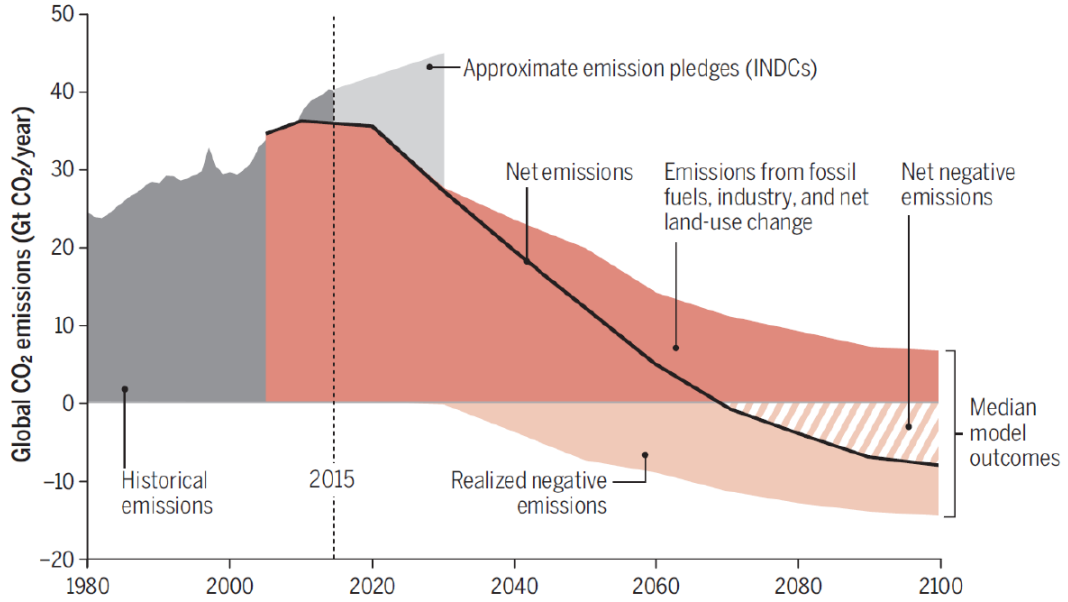
The world may not be able to reduce carbon pollution fast enough or at sufficient scale.

All pathways that limit warming to 2.7°F (1.5°C) require CDR.

Need: direct air capture, mineral carbonation, other CDR technologies

Scale: 100-1,000 Gt CO_2 by 2100

Figure 14: Carbon dioxide removal (CDR) technologies are likely essential to achieving deep decarbonized systems[174]



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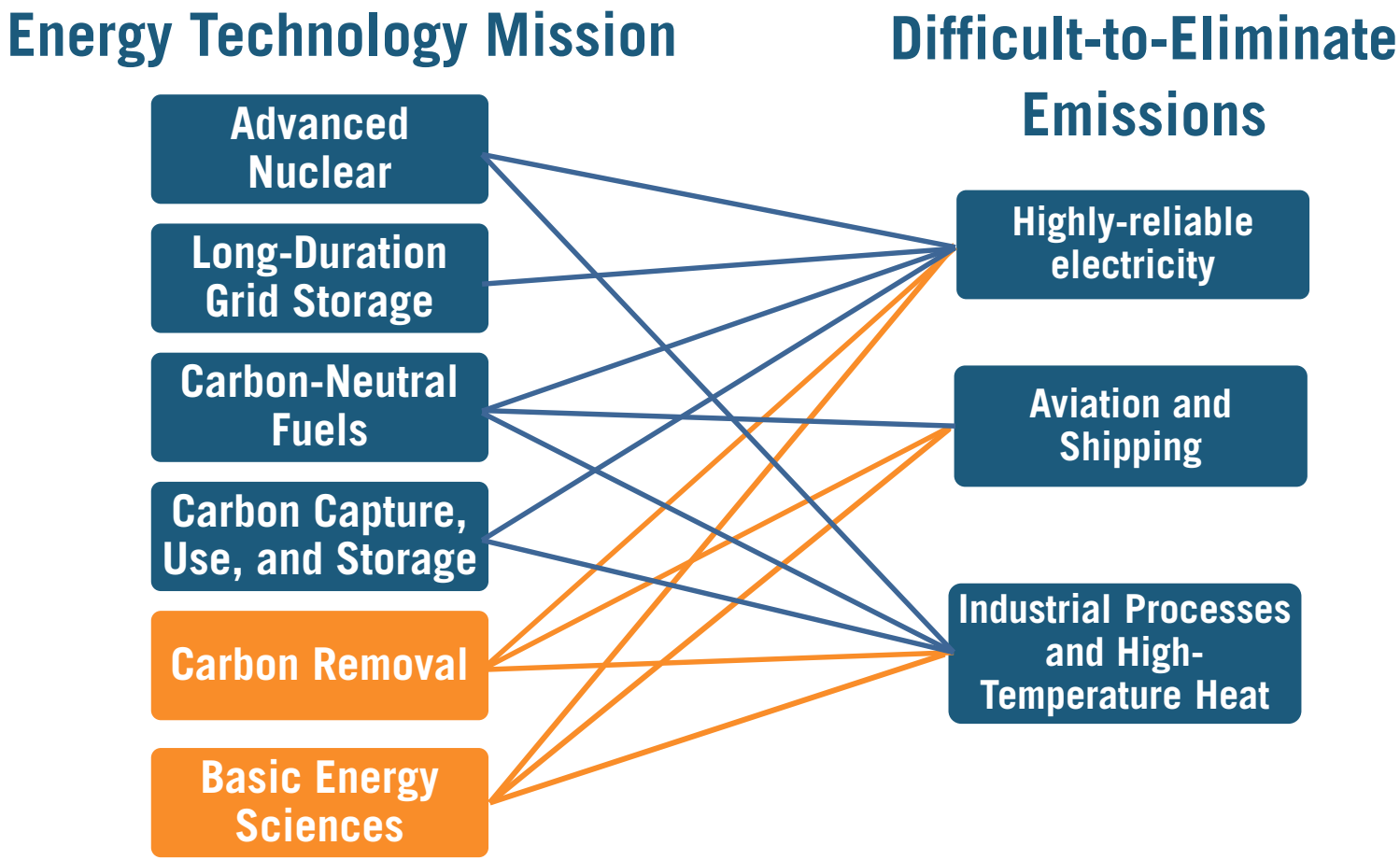
An Innovation Agenda for Difficult-to-Eliminate Emissions

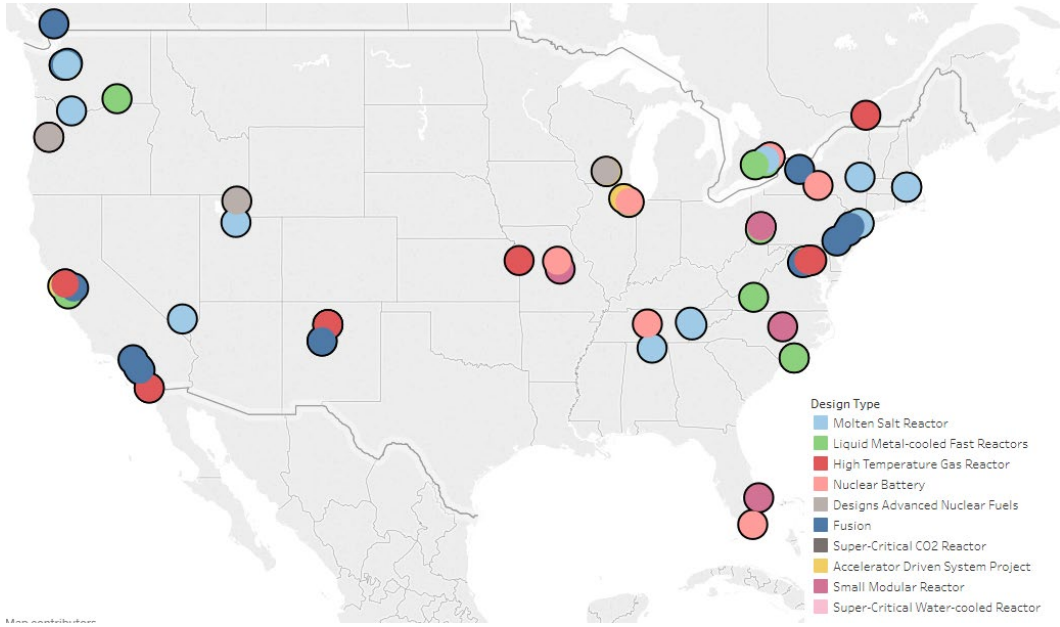


A Technology Mission for Advanced Nuclear Energy

Problem: rising cost of new nuclear due to site-specific design & construction

Recommendations

- Refocus DOE on small modular reactors and advanced reactor concepts.
- Unlock private-sector innovation (e.g., VTR, HA-LEU).
- Expand research into non-electricity applications.



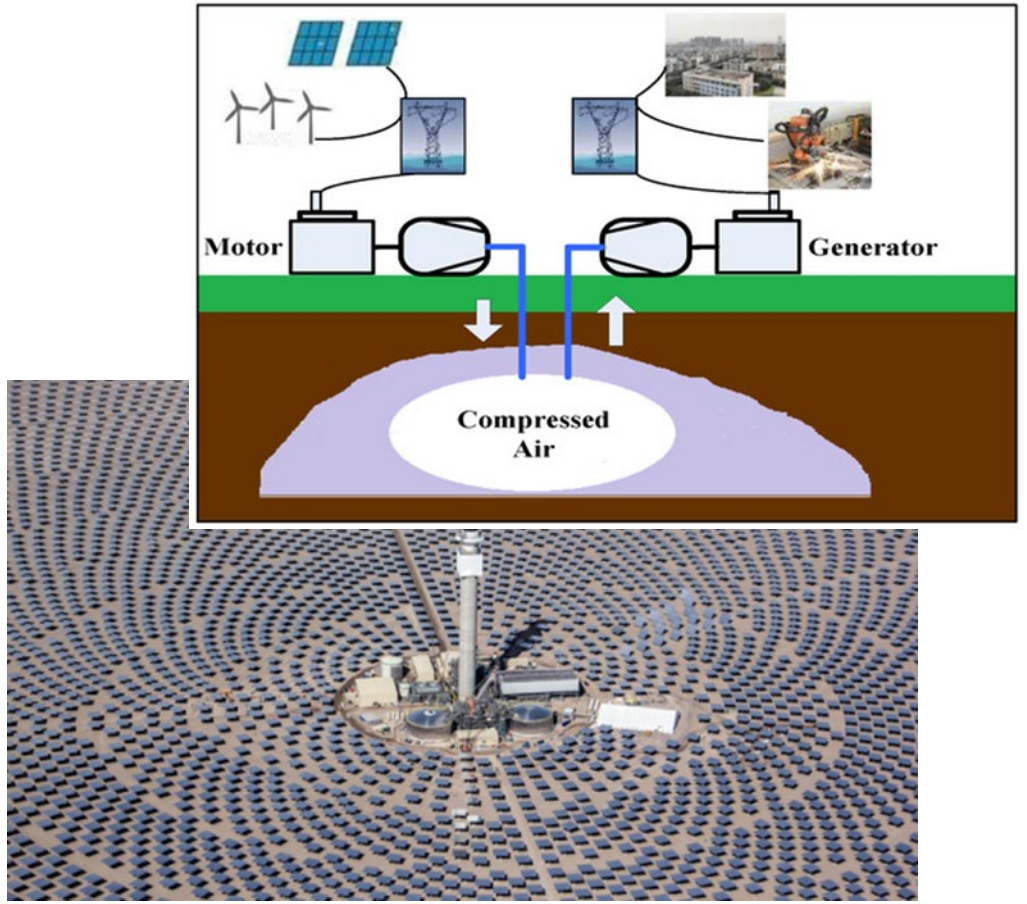
Advanced Nuclear Industry
Source: Third Way (2018).

A Technology Mission for Long-Duration Grid Storage

Problem: variability of renewable generation, especially seasonal

Recommendations

- Set high-profile goals ("StorageShot"); support a diverse technology portfolio.
- Lead a new international challenge within Mission Innovation.
- Create demonstration pathways with DOE, DOD, states & private sector.

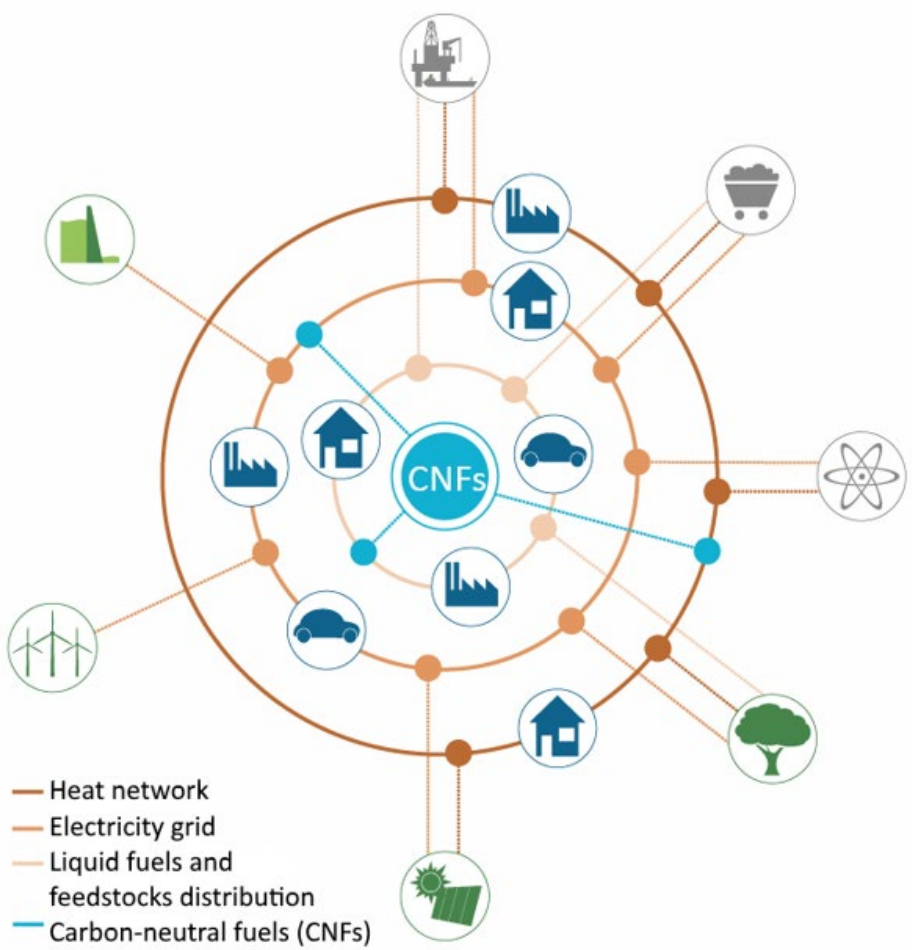


A Technology Mission for Carbon-Neutral Fuels

Problem: fuels as energy-dense and easily transportable as petroleum

Recommendations

- Expand research into production of CNFs (ammonia, hydrogen, synthetic fuels).
- Expand research in applications of CNFs in harder-to-decarbonize transportation and industrial sectors.



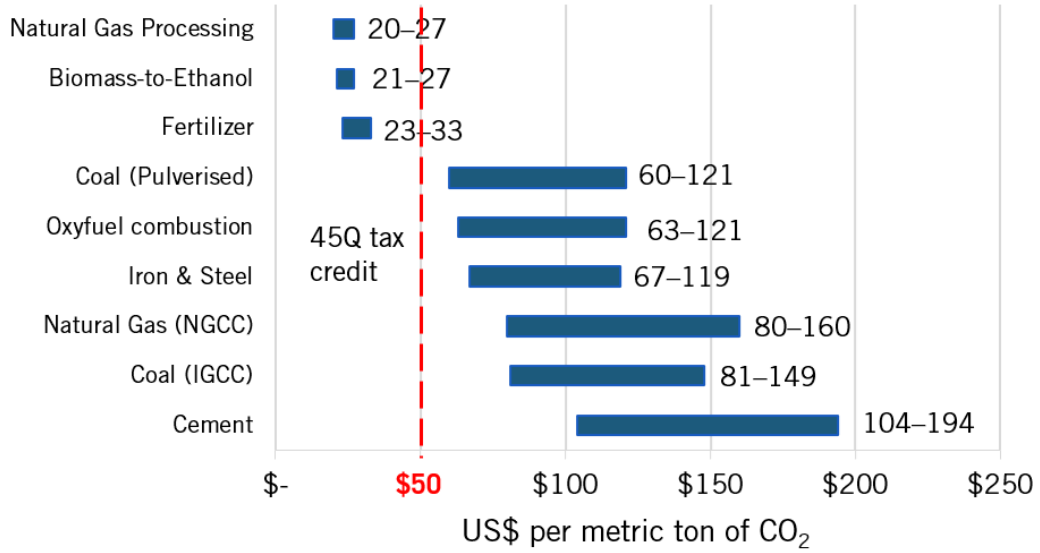
A Technology Mission for CCUS

Problem: industrial processes (cement & steel), unabated emissions from low-cost fossil fuels

Recommendations

- Expand capture research to other sources beyond coal.
- Create demonstration and commercialization pathways.
- Increase R&D into carbon utilization and storage.

Figure 11. Costs of capture, compression, and transportation from different sources[108]



Source: EFI, "Advancing Large-Scale Carbon Management," (2018).

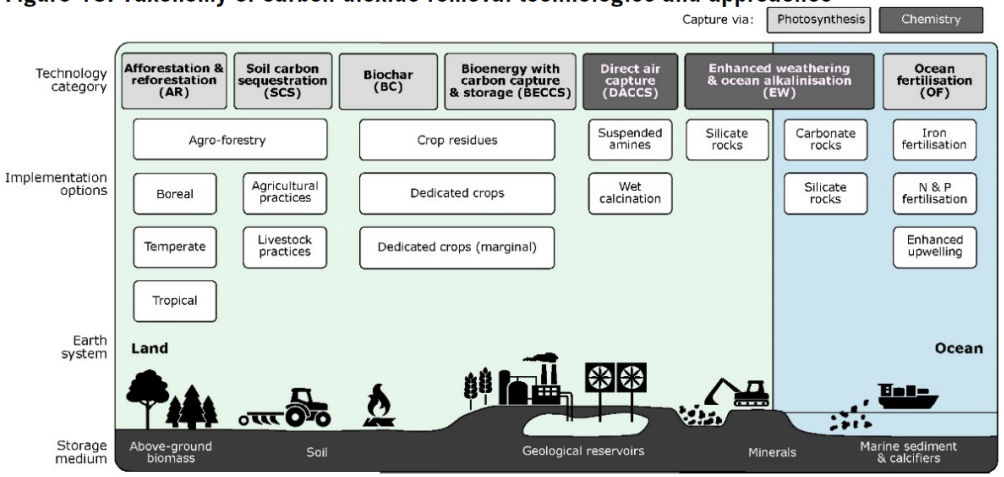
A Technology Mission for Atmospheric Carbon Dioxide Removal

Problem: risk that rapid emissions reductions do not materialize

Recommendations

- Establish new R&D programs across a diverse portfolio of CDR approaches.
- Prioritize pilot-scale demonstrations of direct air capture and mineral carbonation.
- Coordinate inter-agency programs across DOE, USDA, NSF, DOI, USGS.

Figure 15: Taxonomy of carbon dioxide removal technologies and approaches[177]

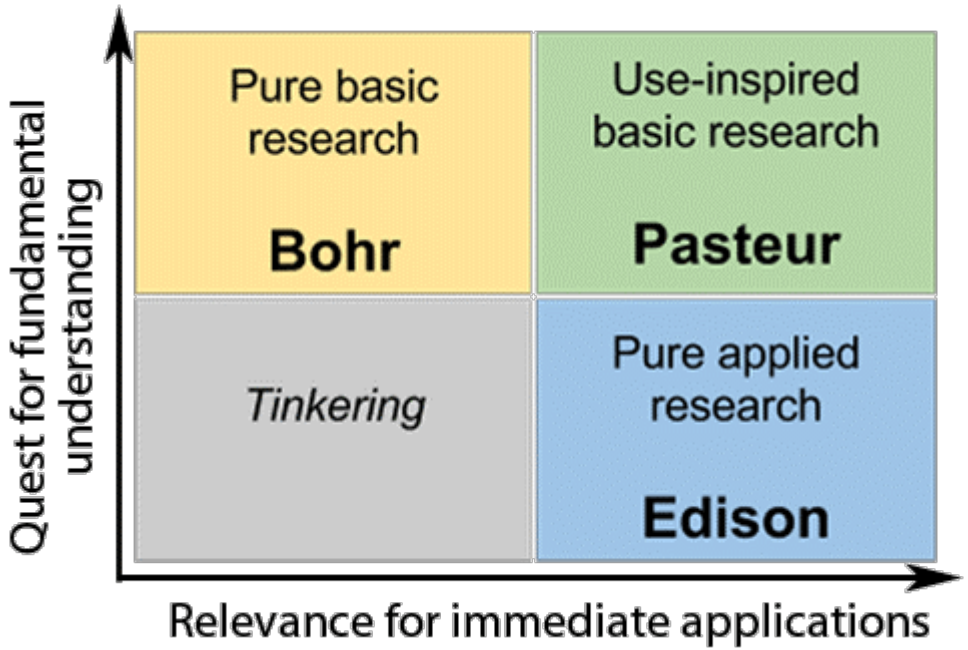


Basic Use-Inspired Research that Supports Clean Energy

Problem: neglect of Pasteur's quadrant

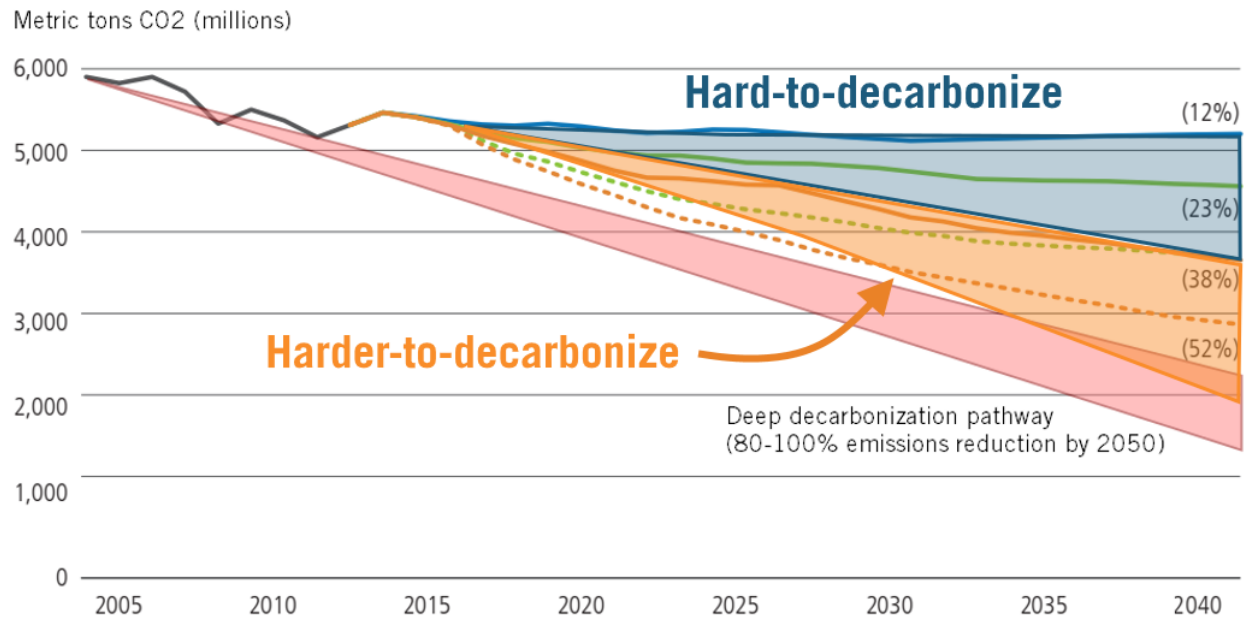
Recommendations

- Double the number of Energy Frontier Research Centers.
- Expand NSF funding for the science underpinning clean technology breakthroughs.
- Develop next-generation user facilities.



Invest in Solutions for Hard- and Harder-to-Decarbonize Sectors

Figure 6. U.S. energy CO_2 emissions under different technology and policy scenarios



- Incorporate new Technology Missions in existing energy programs.
- Increase funding and establish new research programs.
- Reorganize energy RD&D programs.
- Enable greater private-sector innovation.

Thank You!

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