Unlocking Deep Decarbonization: An Innovation Impact Assessment

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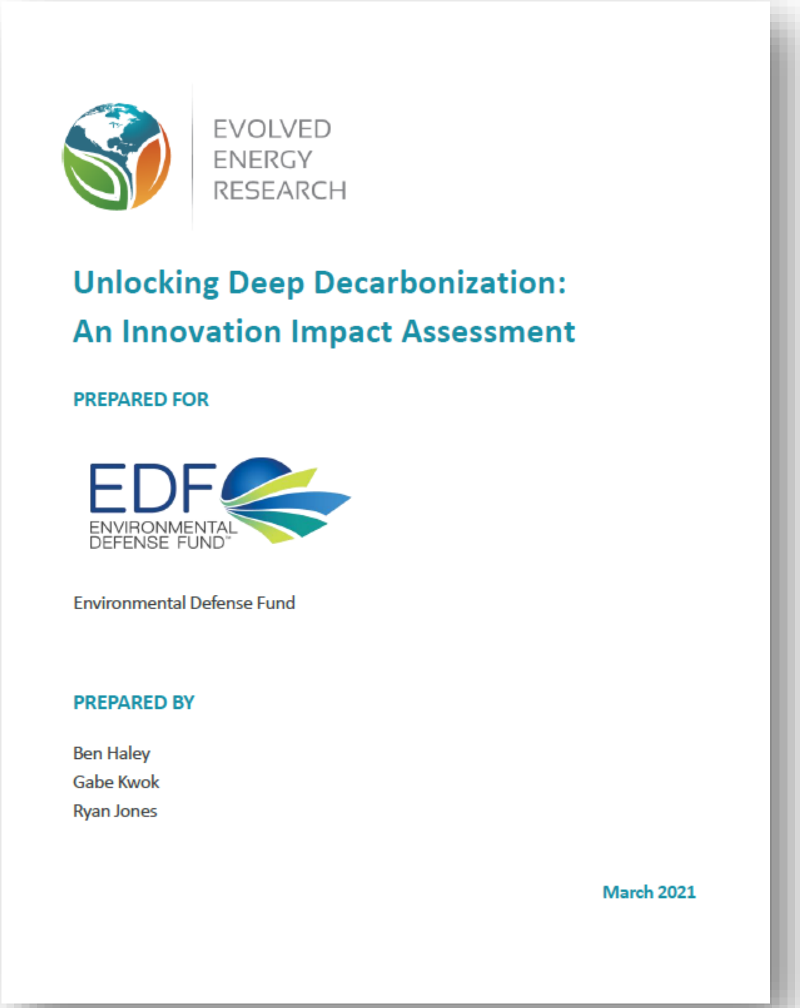
Prepared for: EDF ENVIRONMENTAL DEFENSE FUND

Prepared by: Evolved Energy Research

March 2021

About this presentation

- We assisted the Environmental Defense Fund (EDF) by developing an analytical framework for assessing and prioritizing research and development (R&D) funding to support economy-wide deep decarbonization
- This presentation summarizes our approach, key findings and factors to consider for innovation decision-making
  - Our March 2021 technical report “Unlocking Deep Decarbonization: An Innovation Impact Assessment”, is available at www.evolved.energy
- This work was conducted with support from the Bernard and Anne Spitzer Charitable Trust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Environmental Defense Fund

PREPARED BY

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Background

Motivation

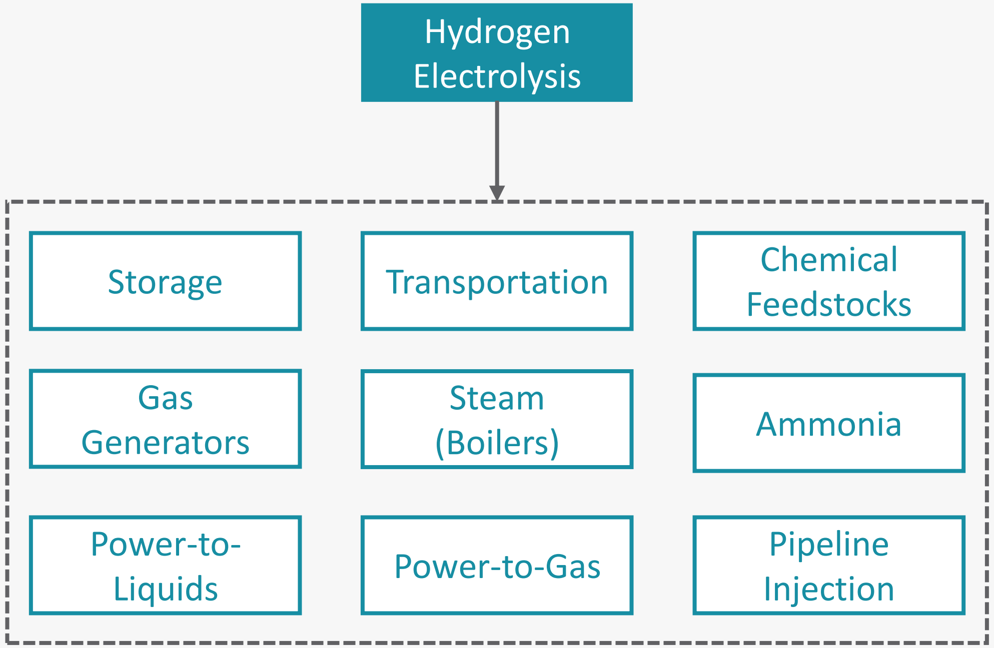
- Achieving net-zero greenhouse gas emissions requires a shift to low-carbon technologies throughout the U.S. energy system
- However, many of the technologies under consideration are not yet at significant commercial scale
- This suggests that R&D has a critical role to play in enabling the technologies that are necessary to realize deep emissions reductions

Question posed: how should federal decision-makers prioritize innovation efforts to best contribute to climate goals?

Innovation has implications for the wider energy system

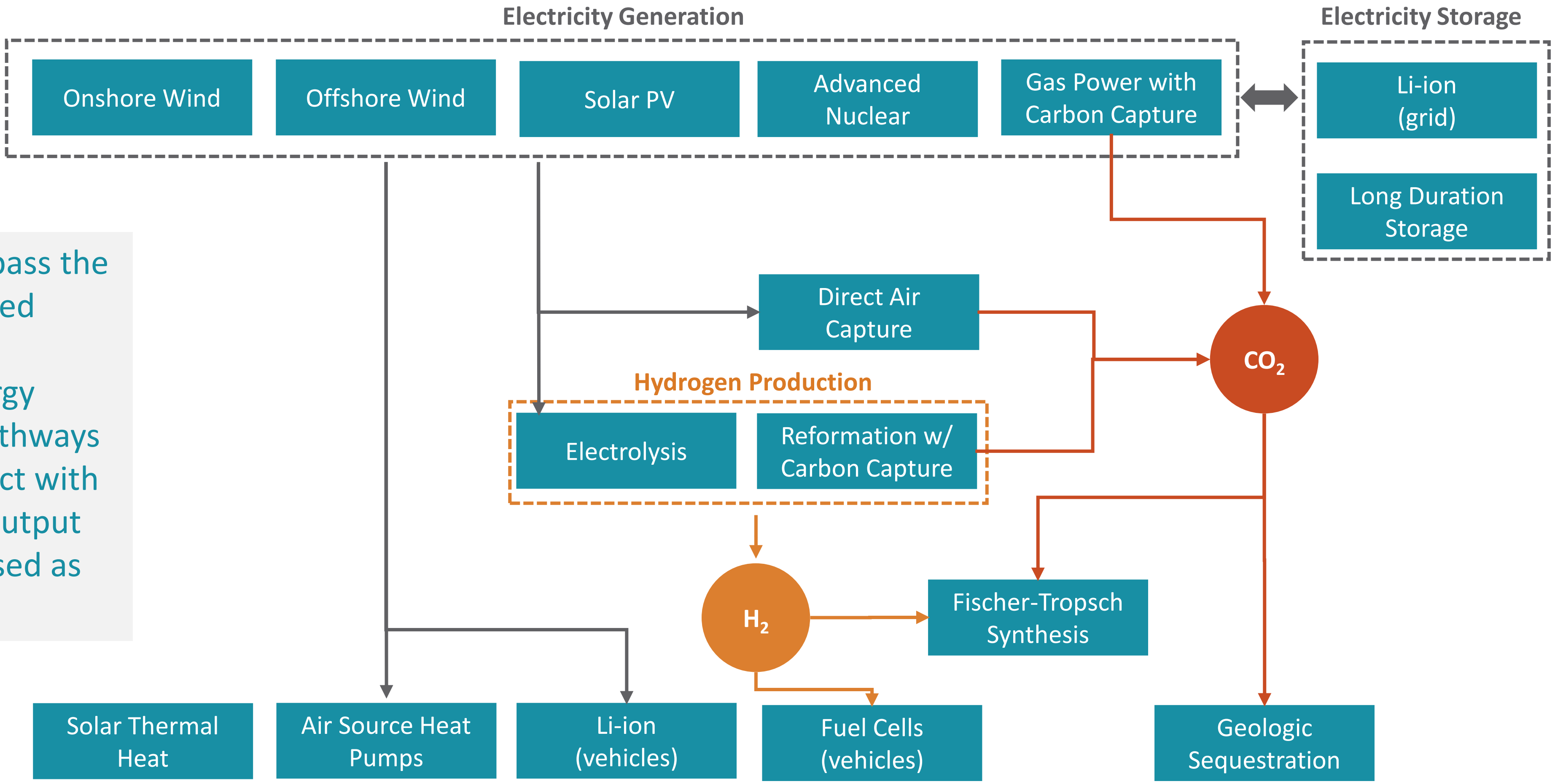
- Technologies in one sector cannot be evaluated without considering technologies in other sectors
- Our approach addresses this challenge by considering the whole U.S. energy system in a holistic manner and assessing all technologies within the same least-cost optimization
- **Study scope**
  - Evaluated fifteen technology areas;
  - Identified three innovation trajectories for each; and
  - Determined their deployment under two levels of climate policy ambition

Example: multiple sectors and technologies of the energy system can utilize electrolytic hydrogen for decarbonization



Technology areas

- Technology areas encompass the spectrum of a decarbonized energy system
- Focus was placed on energy supply and conversion pathways
- Many technologies interact with one another, where the output from one technology is used as an input in another



Analytical framework

Technology and Policy Dimensions

Technology trajectory

- No Progress
- Baseline
- Breakthrough

Breakthrough perspective

- Single technology
- All technologies

Carbon policy ambition

- Modest
- Aggressive

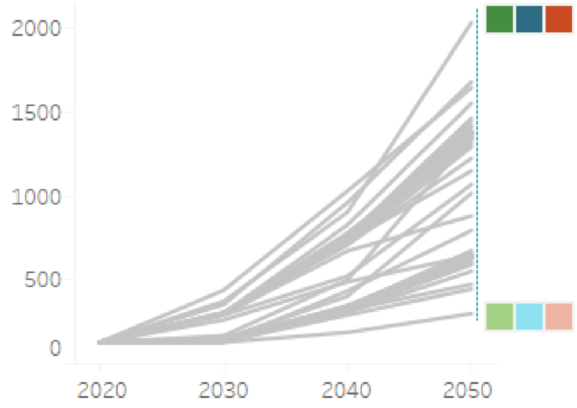
Energy System Modeling

ENERGY PATHWAYS

RIO

Technology Outcomes

Deployment



Technology interactions

Emissions impacts

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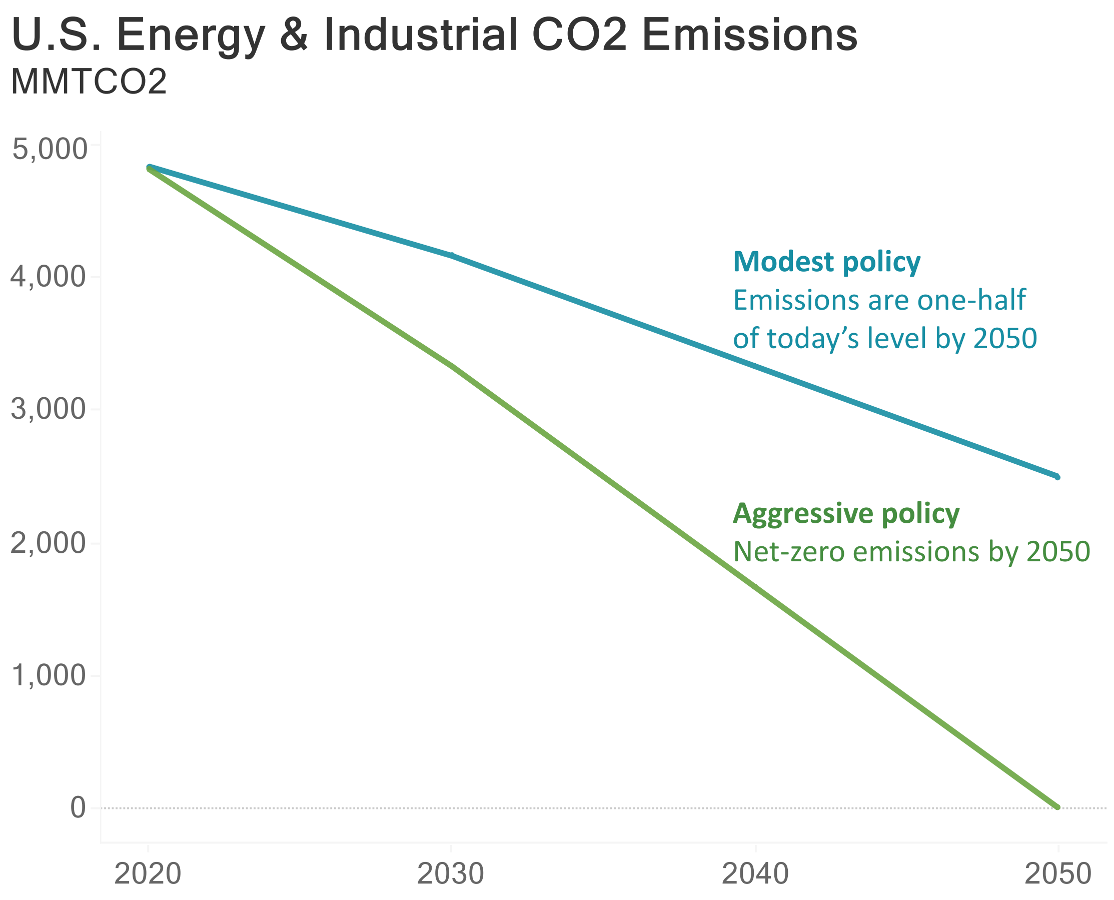
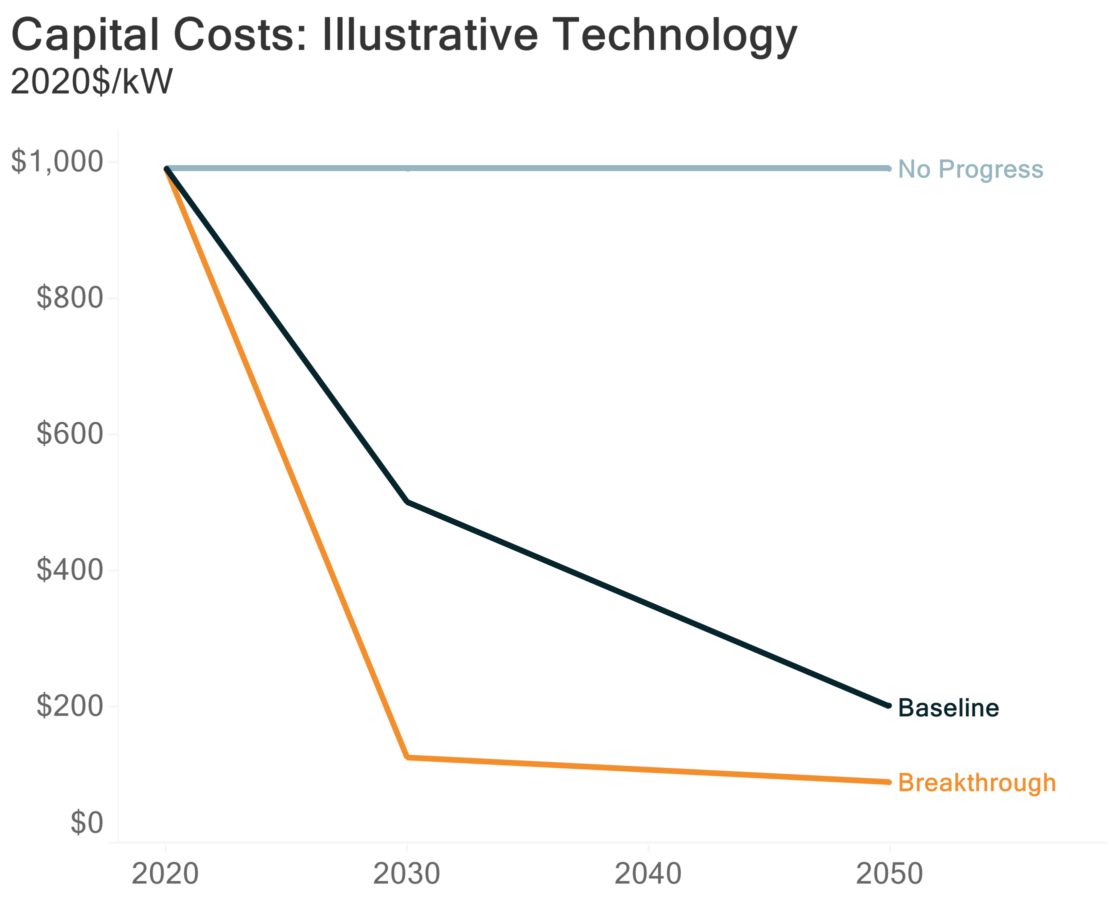
Carbon policy and technology dimensions





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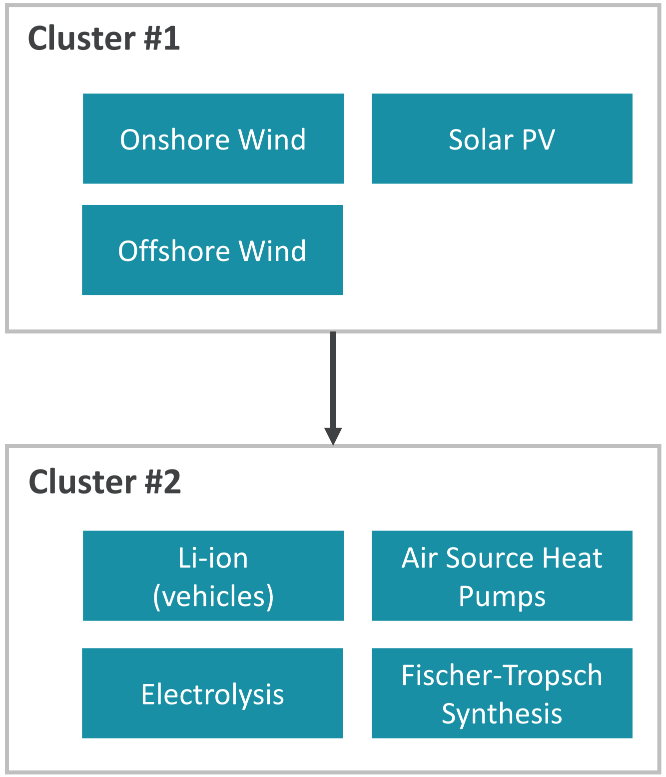
Key findings

High-priority technology areas fall into two clusters

- **Cluster #1: Renewables**
  - Continued cost and performance improvements for wind and solar accelerate electric sector emissions reductions and enable deployment of zero-emissions technologies in other sectors
  - R&D should not be deprioritized because of progress that has already occurred and prior "cost-parity" milestones
  - In a low-carbon economy, a large portion of energy services are ultimately provided by renewable electricity, which means that even modest cost reductions have large impacts on total costs
- **Cluster #2: Electric End-use and Conversion Technologies**
  - Renewables are highly complementary to technologies where electricity is a large cost input and are essential for economy-wide decarbonization

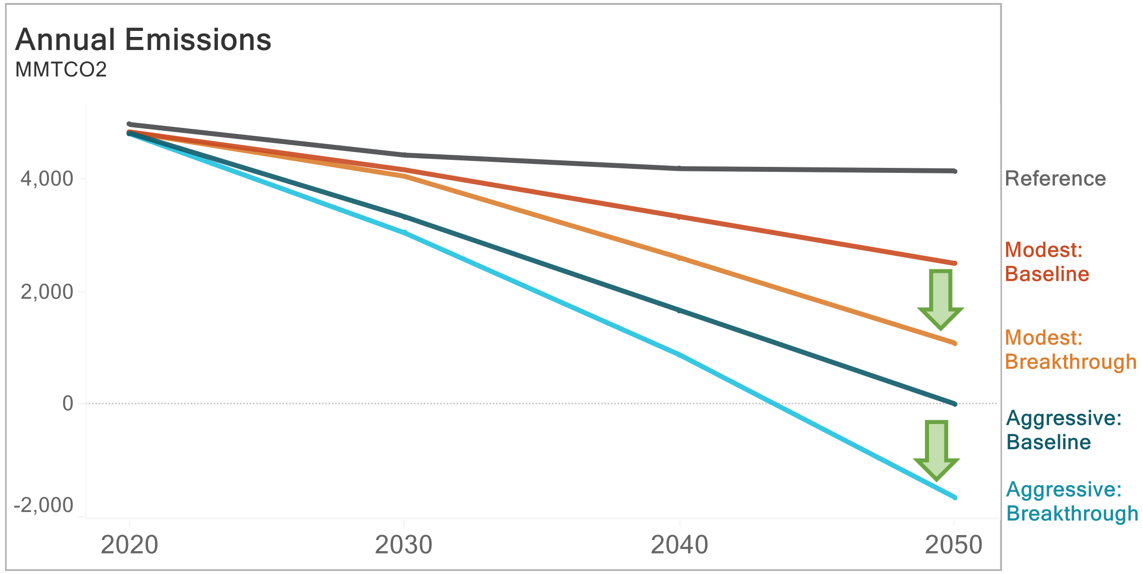


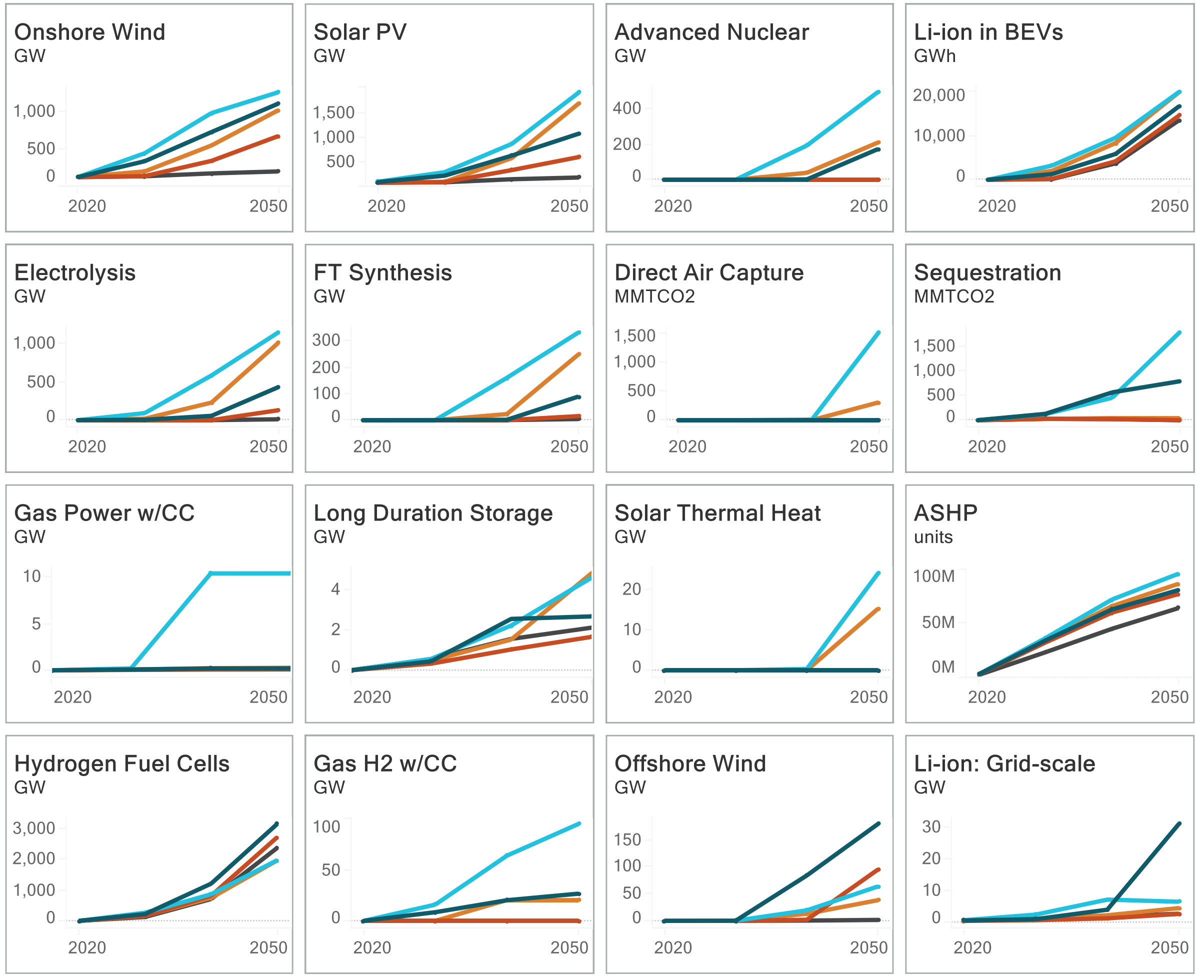
Circumstances matter for prioritizing other technology areas

Technology area	Circumstances
Geologic sequestration	• Aggressive (net-zero) policy ambition is necessary, but is extremely impactful under that policy constraint • Competition for captured carbon between storage and utilization, depending on progress in other technology areas
Direct air capture	• Aggressive (net-zero) policy ambition is necessary • Deployment is contingent on breakthroughs for multiple technologies (e.g., solar PV and electrolysis)
Advanced nuclear	• A major breakthrough from today's costs is needed for the technology to play a major role in the long-run • Analysis indicates that if a breakthrough is not achieved, there are ample substitute technologies available • The question of whether that breakthrough can be achieved at reasonable cost is an open question
Gas power with carbon capture	• Deployment is contingent on a breakthrough and competing technologies maintaining baseline trajectories • Limited to regions with relatively poor onshore wind resource quality
Long-duration storage	• Even with a breakthrough, the technology faces competition from other technologies outside of the electric sector (e.g., electrolysis and electric boilers) for renewable curtailment • Very high levels of wind and solar penetration are achieved regardless of long-duration storage deployment due to the coupling of the electricity and fuels sectors and availability of gas-fired power plants to address over- and under-generation periods, respectively
Lithium-ion (grid-scale)	• Deployment is more significant for vehicle applications and the technology competes for renewable curtailment in the electric sector • Demonstrates complementarity with solar PV technology progress
Fuel cells (vehicles)	• Deployment is contingent on a breakthrough and competing technologies maintaining baseline trajectories • Upside depends on lithium-ion batteries not progressing beyond today's costs
Gas reformation with carbon capture	• Deployment is contingent on a breakthrough and competing technologies maintaining baseline trajectories • Cumulative emissions increase with deployment, since blue hydrogen displaces technologies with more advantageous emissions benefits
Solar thermal heat	• Breakthrough is required, but market share is still limited • Shows no interactions with other technology areas

R&D accelerates emissions reductions

- A universal breakthrough enabled by R&D accelerates deployment of key technology areas and drives forward emissions reductions
- Faster uptake in technologies across the synthetic fuel supply chain and electric end-use equipment, while other areas see modest growth or declines from competition





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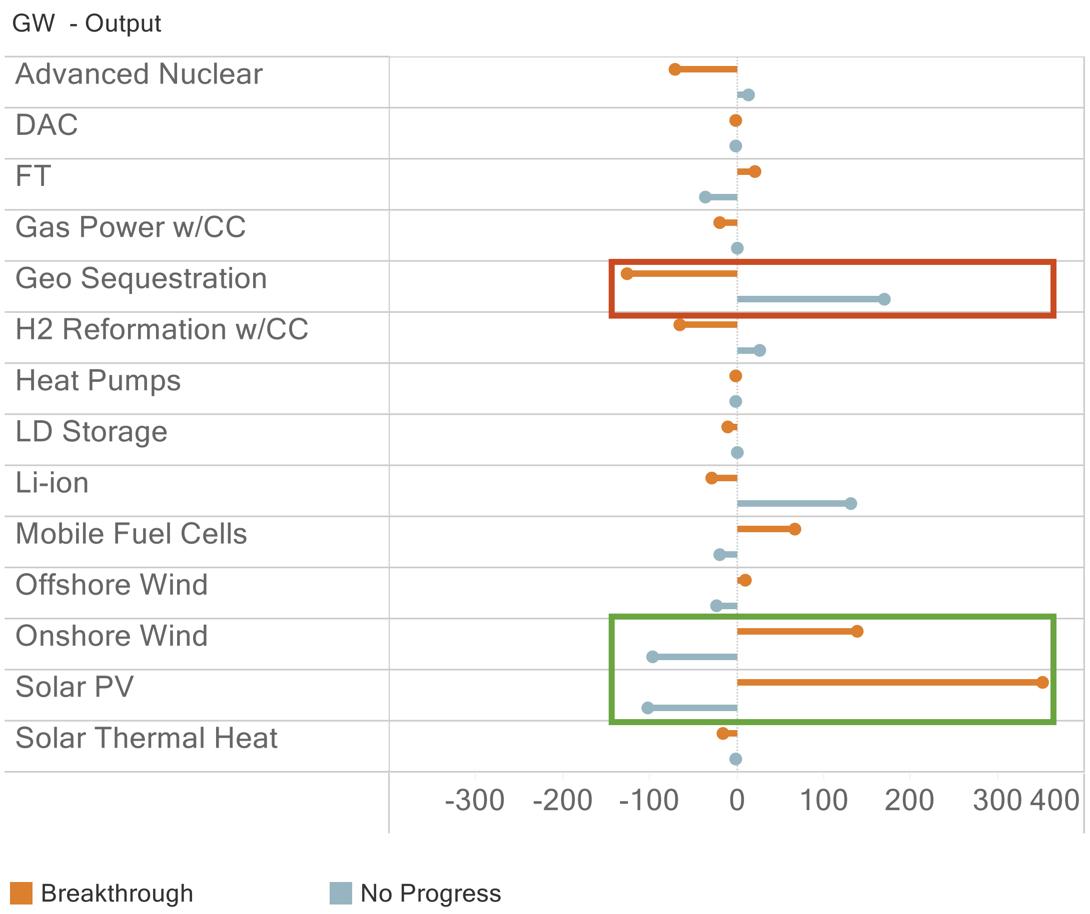
Energy system-wide analysis demonstrates significant technology interactions

- Evaluating all technology areas simultaneously highlights complementarity and competitiveness
- **Example**: electrolysis
  - Geologic sequestration is a competitor: electrolysis deployment decreases when sequestration has a breakthrough
  - Onshore wind and solar complement electrolysis: deployment increases when either technologies have a breakthrough

Change in electrolysis deployment relative to Baseline when another technology area realizes a Breakthrough or No Progress
(Aggressive Policy, 2050)



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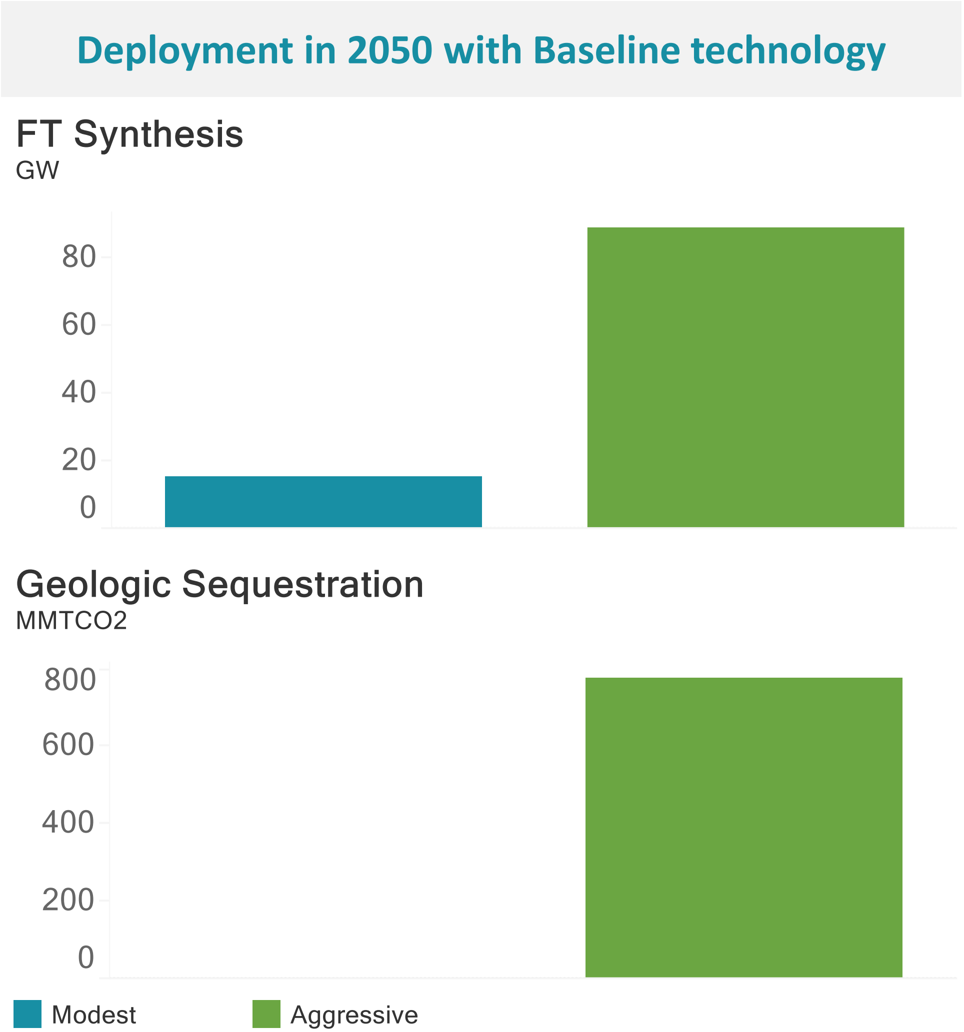
Factors to consider for innovation decision-making

Carbon policy ambition has implications for how breakthroughs permeate

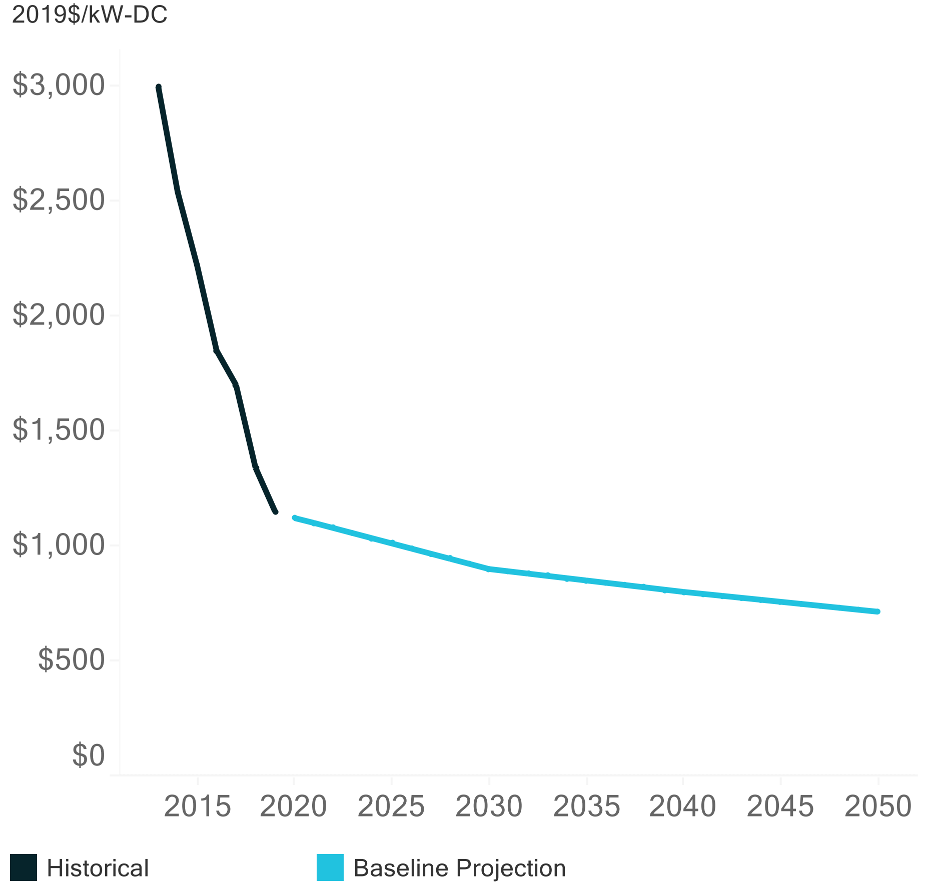
- Establishing the relevant decarbonization policy context is the starting point to evaluating and prioritizing R&D
- Relevant price and deployment potentials for many of the technologies investigated in this study are reflective of society's value of reducing emissions
- **Example**: Fischer-Tropsch (FT) synthesis and geologic sequestration deployment in 2050 is robust with an aggressive policy, but minimal under modest policy
  - The benefits of R&D are only likely to be realized for these technologies with aggressive policy support



Sustained technological progress must not be taken for granted

- Our baseline trajectories assume cost and performance improvements from sustained R&D funding and deployment
- However, there is no guarantee this will materialize under business-as-usual conditions
- **Example**: solar PV costs have fallen significantly during the past decade and continued cost reductions depend on further R&D investments

Utility-Scale Solar PV Capital Costs

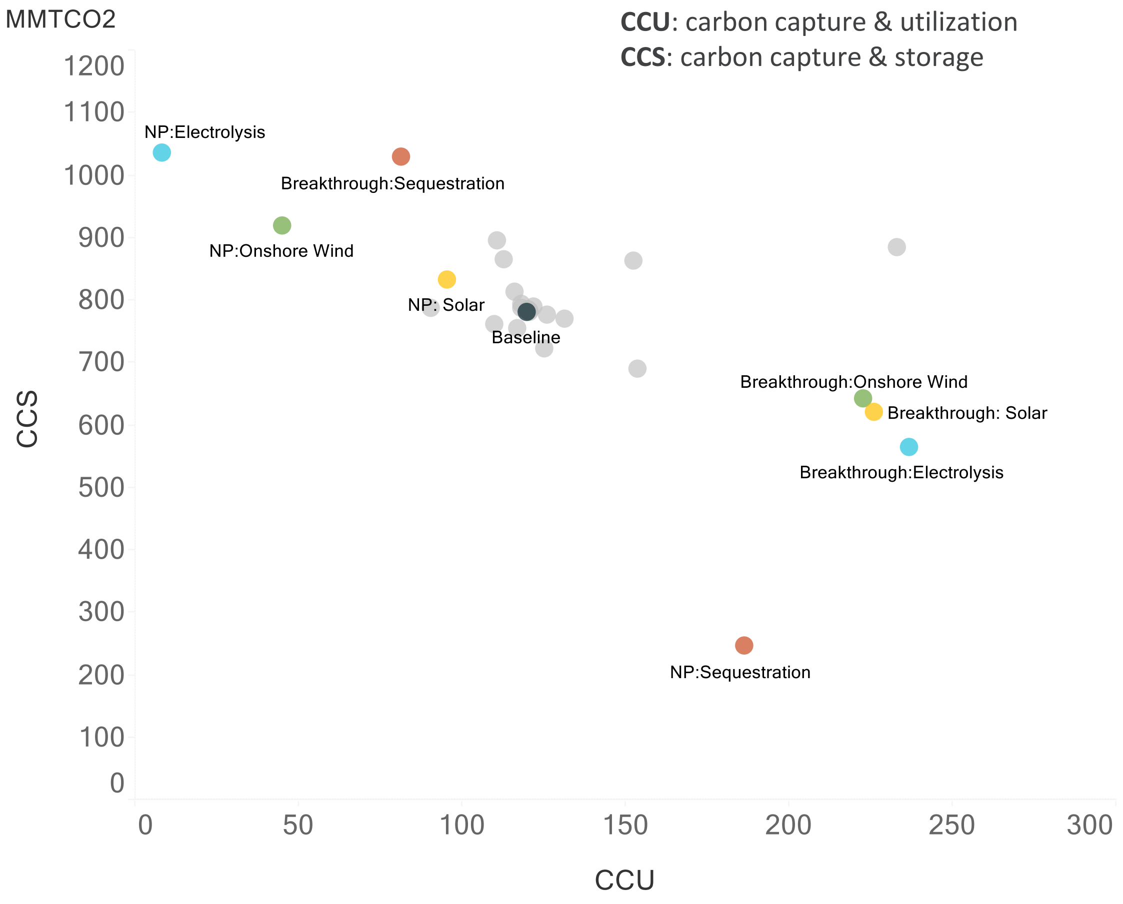


Notes: historical is the median project cost by installation year from Berkeley Lab. Baseline projection is from NREL's Annual Technology Baseline.

Innovation policy should take a systems approach

- The most impactful R&D efforts will coordinate clusters of technologies and consider energy system-wide interactions
  – Our analysis reveals how changes in one technology area can strongly influence another
- **Example**: CCUS (carbon management) is affected by trajectories for multiple technology areas
  – Breakthroughs in electrolysis and renewable technologies increase the attractiveness of utilization (CCU), while no progress increases storage (CCS) economics

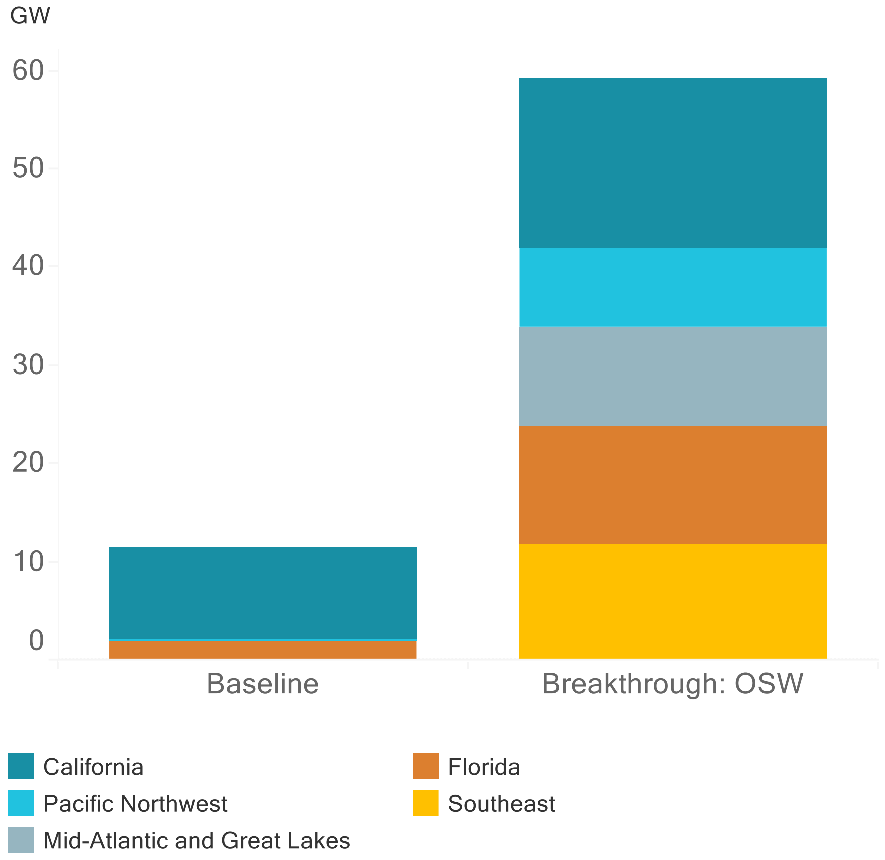
Carbon Capture Utilization and Storage (CCUS)
(Aggressive Policy, 2050)



Competitive landscapes matter for innovation

- Innovation enabled by R&D may lead some technologies that are not competitive in certain regions and under certain circumstances to become more broadly competitive
- **Example**: a breakthrough in offshore wind technology alone can expand deployment of lower-quality resources (deeper water depths; further distance to landfall; lower wind speeds) to regions such as the West Coast, Gulf Coast and Great Lakes
  - Higher-quality resources are more robustly deployed in regions such as New England

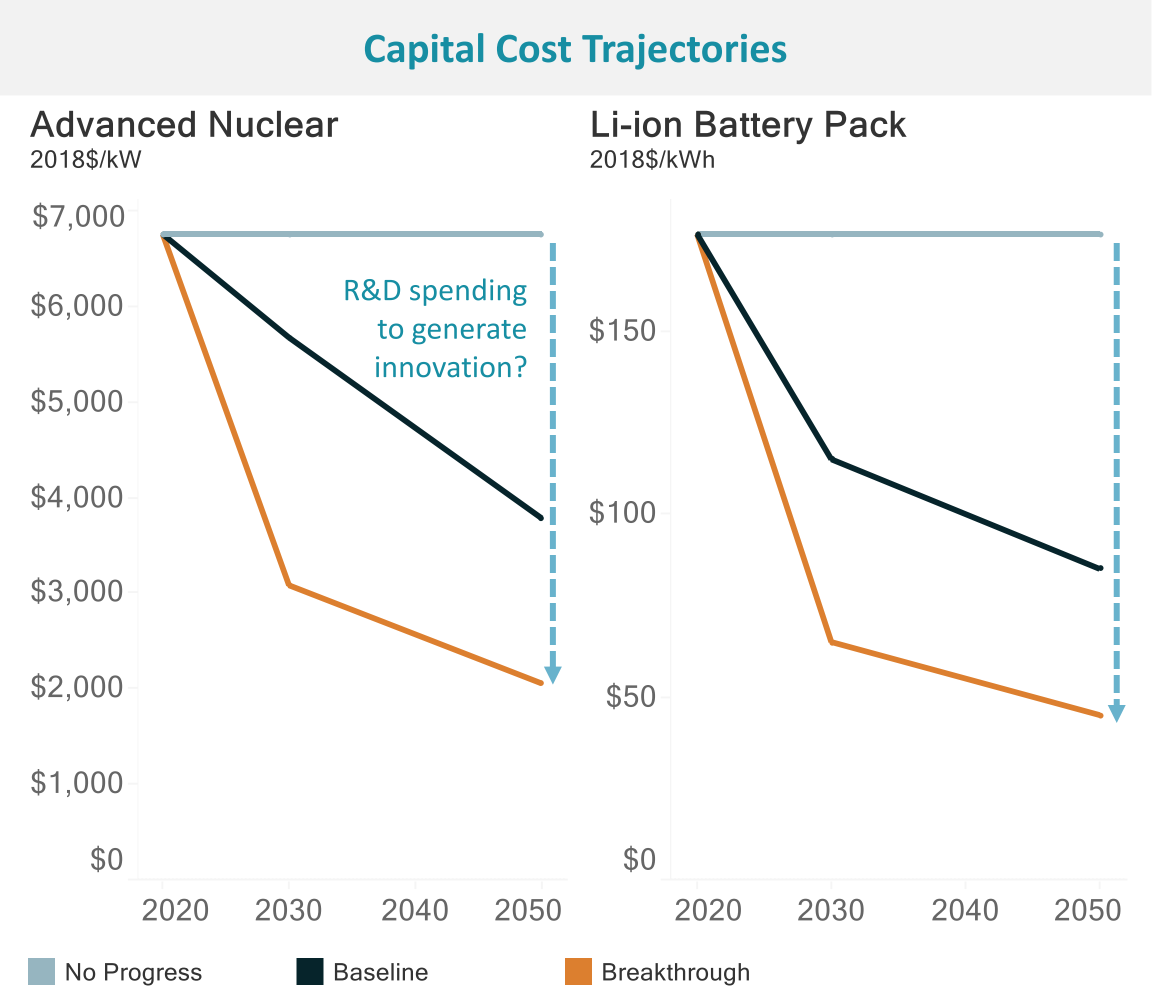
Offshore Wind: Lower-Quality Resource Groups
(Aggressive Policy, 2050)



Includes the following NREL techno-resource groups (TRG): fixed-bottom TRG5 and floating TRG12-15

The value of R&D should be compared against its cost

- Our analysis assessed the value of R&D in terms of impacts on deployment and emissions, but the cost (R&D expenditures) to realize technology progress from today must be considered
- **Example**: the R&D expenditures to realize advanced nuclear capital costs of $2,000/kW may be significantly higher than those to reduce lithium-ion battery pack costs to $50/kWh



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Non-economic factors can have large implications but are not easily modeled

- An innovation strategy that targets costs alone is unlikely to maximize deployment
- Market barriers, consumer demand and enabling policies, among other considerations, all play significant roles in determining deployment
- Impacts from R&D can also extend to global energy markets

Thank You

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