When Climate and Energy Collide

Planning for a Carbon Neutral Future as the Climate Changes

September 14, 2021
Aspen Global Change Institute
We are already experiencing the impacts of climate change
Overlapping Disasters Expose Harsh Climate Reality: The U.S. Is Not Ready

Blackouts in US Northwest due to heat wave, deaths reported

Wildfires explode again in the West, fanned by turbulent winds

Climate Change Is Central to California’s Wildfires

‘This is code red.’ Biden visits areas of New York and New Jersey hit hard by Ida.

Extreme weather is pummeling the Midwest, and farmers are in deep trouble

Hurricane Ida power outages, misery persist 9 days later

The damage in Florida from rising sea levels already is here

Almost 70% of ERCOT customers lost power during winter storm, study finds
What do we need to do to slow the impacts of climate change?
Reducing impacts of climate change requires rapid progress towards carbon neutrality by mid-century. Achieving net zero GHGs by 2050 is our best chance of staying within a 1.5°C warming future.

What would it take for the U.S. to achieve net zero greenhouse gas (GHG) emissions by mid-century?
Achieving Net Zero by Mid-Century Requires Reductions in all Sectors

U.S. Greenhouse Gas Emissions, A Net Zero Scenario

Notes:
- Source: E3 PATHWAYS analysis conducted for World Resources Institute (forthcoming)
- "Industry" includes energy consumption and industrial process emissions; "Other" includes natural gas and oil systems, waste management, and coal mining
- Emissions accounting on 100-yr AR5 basis using EPA methodology
## Net Zero GHG Reduction Strategies

<table>
<thead>
<tr>
<th>Category</th>
<th>Achieving Net Zero GHGs</th>
</tr>
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<tbody>
<tr>
<td>Electricity Generation</td>
<td>Coal retirements, renewable generation, new transmission, energy storage</td>
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<tr>
<td>Transportation</td>
<td>100% electric sales of light duty vehicles by 2035, tax incentives and standards to encourage electrification</td>
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<tr>
<td>Industry</td>
<td>Energy efficiency, targeted electrification and hydrogen fuel substitution, carbon capture and storage (CCS), reduction in High Global Warming Potential Gases</td>
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<tr>
<td>Buildings</td>
<td>Energy efficiency, building codes, electric heat pumps replace most gas use</td>
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<tr>
<td>Agriculture</td>
<td>Soil carbon management, methane management</td>
</tr>
<tr>
<td>Other (Natural gas &amp; oil systems, waste, coal mine methane)</td>
<td>Reduction in fugitive emissions from oil and gas sector &amp; coal mine methane</td>
</tr>
<tr>
<td>Natural and Working Lands</td>
<td>Reforestation, agroforestry, wildfire management measures</td>
</tr>
<tr>
<td>Negative Emissions Technologies</td>
<td>Incentives and policies for negative emissions technologies (e.g. bioenergy with CCS for hydrogen production, direct air capture of CO₂)</td>
</tr>
</tbody>
</table>
Five “Pillars” of GHG reductions

- **Energy efficiency & conservation**
  - Industrial efficiency
  - Fuel economy & smart growth
  - Building efficiency & conservation

- **Electrification**
  - Industrial electrification
  - Building electrification
  - Vehicle and freight electrification

- **Low Carbon Electricity**
  - Nuclear
  - Generation w/ carbon capture & storage
  - Renewables, storage and hydroelectric

- **Low Carbon Fuels**
  - Biofuels
  - Carbon-neutral synthetic fuels
  - Hydrogen

- **Sequester carbon & reduce non-combustion GHGs**
  - Soil CO₂ sinks, land management
  - Direct air capture of CO₂
  - Reduce methane, F-gases, N₂O
How does climate change impact our decarbonization strategies?
## Climate Impacts and Adaptation Needs

<table>
<thead>
<tr>
<th>Sector</th>
<th>Climate Impacts &amp; Adaptation Needs</th>
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</thead>
<tbody>
<tr>
<td><strong>Electricity Generation</strong></td>
<td>Electric reliability risks: flooding, storms, wildfire, heat. Degraded equipment performance, lower hydro generation, changing generation &amp; electric load patterns</td>
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<tr>
<td><strong>Transportation</strong></td>
<td>Infrastructure &amp; public safety risks, supply chain disruptions for fuels</td>
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<tr>
<td><strong>Industry</strong></td>
<td>Infrastructure risks, outage risks, supply chain disruptions</td>
</tr>
<tr>
<td><strong>Buildings</strong></td>
<td>Resiliency from storms, wildfires, heat waves, higher air conditioning demands</td>
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<tr>
<td><strong>Agriculture</strong></td>
<td>Drought, extreme weather &amp; wildfires affect agricultural productivity</td>
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<tr>
<td>Other (Natural gas &amp; oil systems, waste, coal mine methane)</td>
<td>Infrastructure risks, outage risks, supply chain disruptions can impact electric gen.</td>
</tr>
<tr>
<td><strong>Natural and Working Lands</strong></td>
<td>Drought, desertification, wildfires, changing ecosystems &amp; habitats</td>
</tr>
<tr>
<td><strong>Negative Emissions Technologies</strong></td>
<td>Infrastructure risks, outage risks</td>
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</table>
How does electric sector plan for decarbonization?

How can climate science better inform electric sector planning?
Electricity sector is pivotal to reducing GHGs

U.S. Electricity Demand under a Net Zero GHG Scenario

- Industry
- Building electrification
- Other building electric demand
- Transportation electrification
- Hydrogen production from electricity (electrolysis)

150% increase vs. 2018

U.S. Wind and Solar Share of Generation under a Net-Zero Scenario

Figure 4 | Wind and solar combined share of electricity generation in 2050 from reviewed studies with historical comparison (results are net curtailment)

Source: E3 PATHWAYS analysis, 2021 (forthcoming)

Source: “Getting to Net Zero U.S. Report”, California Climate Change Institute (CCCI) and E3, 2021
Electric planning is done by electric utilities, balancing authorities and reliability assessment areas.

Counties served by U.S. utilities, by type of ownership (2017)

U.S. Transmission Interconnections and Balancing Authorities

North American Electric Reliability Corporation (NERC) reliability assessment areas

Circles represent the 66 balancing authorities.
Electric resource planning must adapt to new challenges

Yesterday’s Planning Paradigm
- Reliability driven by summer (or winter) peak demand

Today’s Planning Paradigm
- Understanding chronological system dispatch becomes necessary to evaluate investments & integration challenges for wind, solar, and batteries

Tomorrow’s Planning Paradigm
- Increasing investment & operational uncertainty requires greater spatial & temporal granularity to capture system conditions & value streams for new technologies like long duration storage
- Reliability driven by “dark doldrums” when renewables are unavailable to serve demand for extended periods
Challenges include capturing the full range of potential electric demands

+ Neural network regression techniques rely on extensive records of historical weather data to simulate loads
+ Developing “weather-matched” datasets for hourly load and renewable resources is challenging, even before accounting for climate change impacts

**Emerging challenge:**
capturing climate change impacts on magnitude and frequency of extreme weather events

Most extreme peaks can be 5-10% higher than typical peak loads today, not reflecting future climate impacts

Simulated Hourly Load, 1979-2018 (MW)

*Median (“1-in-2”) peak demand*
Planning-grade simulated wind & solar profiles do not yet reflect future impacts of climate change

+ NREL’s Wind Integration National Dataset (WIND) and Solar Integration National Dataset (SIND) Toolkits provide best publicly available resource for variable renewable profiles

**NREL Wind Prospector**
- 126,000 sites
- 5-min temporal resolution
- 2007-2013 historical period

**NREL Solar Prospector**
- 120,000 sites
- 1-min temporal resolution
- 2007-2013 historical period
We typically model thermal units based on seasonal/monthly capacity ratings – but we should aspire to improve upon this:

- Standards used to report “net summer capacity” may not be uniform across all generators
- Net summer capacity may not reflect most extreme conditions

At 115°F, plant output is roughly 20% lower than design rating
How to incorporate more climate data into electric sector reliability planning?

Improving on the status quo

- Properly characterize & capture joint probability of load and renewables for today's climate
- Adjust for historical climate change impacts on loads
- Characterize uncertainty and incorporate future climate change impacts on loads
- Incorporate climate change impacts on infrastructure (i.e. generator outages, hydropower, renewable generation availability correlated with weather & load)
Electricity sector must balance multiple priorities

- **Reducing GHGs**
  - Investments needed in zero-carbon generation and energy storage
  - Higher electricity demand from electrification
  - Changing patterns of hourly and seasonal generation from renewable generation

- **Adapting to climate change**
  - Investments needed in infrastructure due to flooding, storms, wildfires, heat, drought
  - Higher electricity demand from increased air conditioning needs & heat waves
  - Changing patterns of hourly and seasonal electricity demand from changing weather

Goals for Electric Sector Planning

- Safe
- Reliable & Resilient
- Equitable & Affordable
The electric sector is pivotal to achieving greenhouse gas reductions in every sector.

The electric sector is also at the front-lines of climate impacts.

Electric reliability is essential for human health and – considering climate impacts and decarbonization – is a key planning challenge.

Research funding could prioritize methods to plan jointly for climate risks, adaptation and mitigation.

Combining climate mitigation and climate adaptation may make each more cost-effective, when considered together.
Thank you!