When Climate and Energy Collide

Planning for a Carbon Neutral Future as the Climate Changes

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Aspen Global Change Institute

Energy+Environmental Economics

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We are already experiencing the impacts of climate change

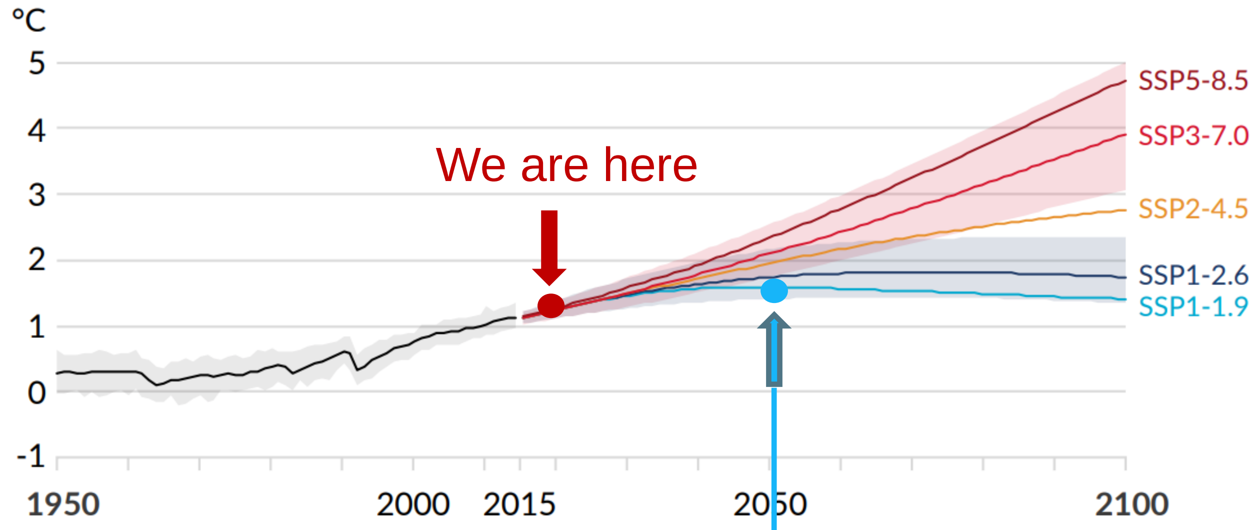

Major Storms
Wildfires
Rising Sea Levels
Rising Heat/ Heatwaves
Drought
Land Subsidence
Overlapping Disasters Expose Harsh Climate Reality: The U.S. Is Not Ready
Blackouts in US Northwest due to heat wave, deaths reported
'This is code red.' Biden visits areas of New York and New Jersey hit hard by Ida.
Wildfires explode again in the West, fanned by turbulent winds
Elevated fire danger in large part of West as California's Dixie and Caldor blazes rapidly expand
Extreme weather is pummeling the Midwest, and farmers are in deep trouble
Climate Change Is Central to California's Wildfires
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?

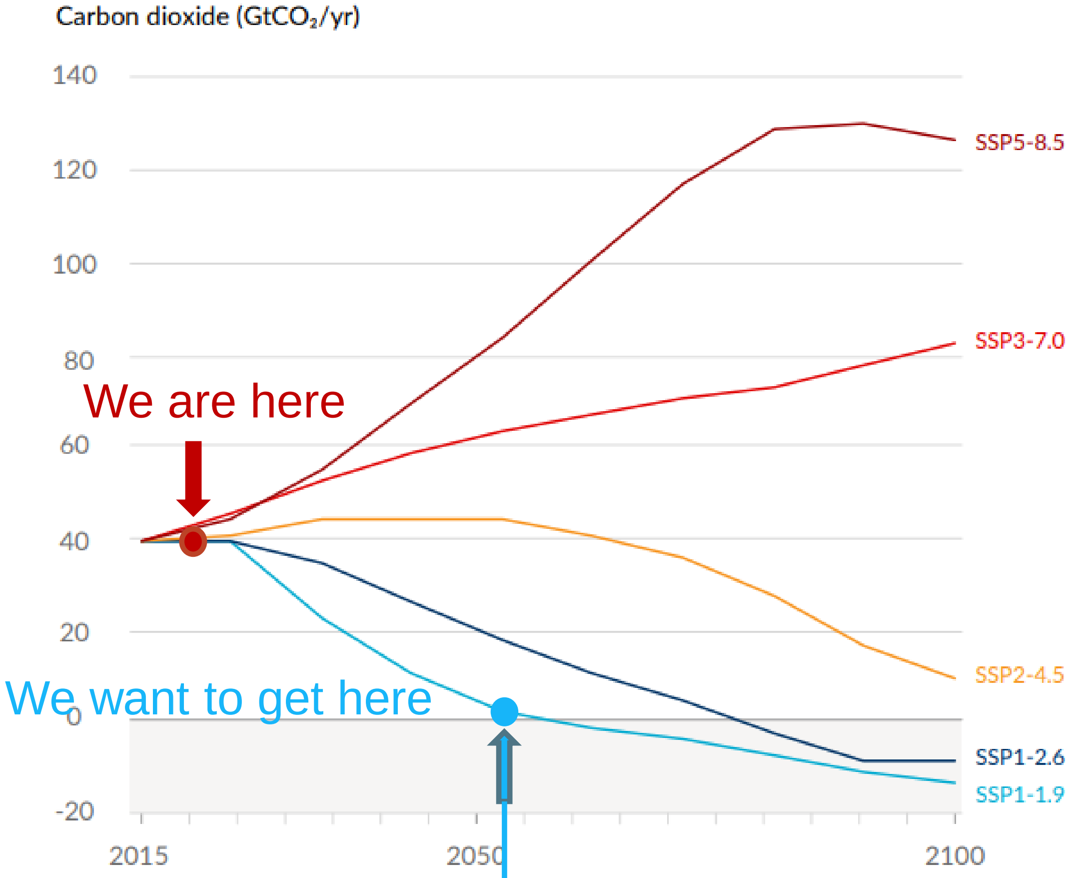
Reducing impacts of climate change requires rapid progress towards carbon neutrality by mid-century

“Climate Change 2021” IPCC Report

a) Global surface temperature change relative to 1850-1900



b) Global Annual Carbon Dioxide Emissions



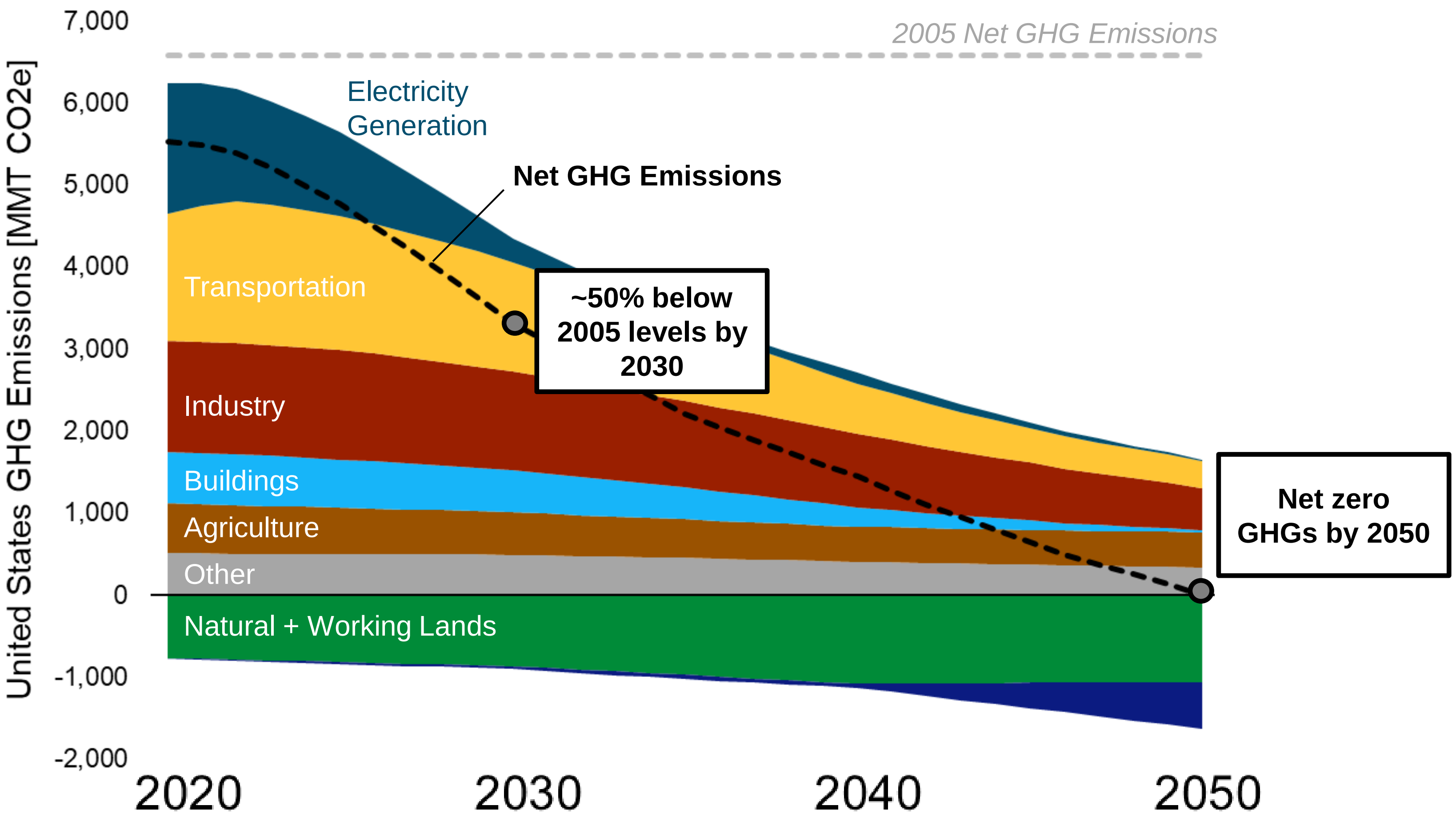
Achieving net zero GHGs by 2050 is our best chance of staying within a 1.5°C warming future

Source: IPCC, 2021: Summary for Policymakers. In: “Climate Change 2021, The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Plan on Climate Change” From Box SPM.1.1 and Figure SPM.8.

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

Sector	Achieving Net Zero GHGs
Electricity Generation	Coal retirements, renewable generation, new transmission, energy storage
Transportation	100% electric sales of light duty vehicles by 2035, tax incentives and standards to encourage electrification
Industry	Energy efficiency, targeted electrification and hydrogen fuel substitution, carbon capture and storage (CCS), reduction in High Global Warming Potential Gases
Buildings	Energy efficiency, building codes, electric heat pumps replace most gas use
Agriculture	Soil carbon management, methane management
Other (Natural gas & oil systems, waste, coal mine methane)	Reduction in fugitive emissions from oil and gas sector & coal mine methane
Natural and Working Lands	Reforestation, agroforestry, wildfire management measures
Negative Emissions Technologies	Incentives and policies for negative emissions technologies (e.g. bioenergy with CCS for hydrogen production, direct air capture of CO_2)

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 CO_2 sinks, land management
- Direct air capture of CO_2
- Reduce methane, F-gases, N_2O

How does climate change impact our decarbonization strategies?

Climate Impacts and Adaption Needs

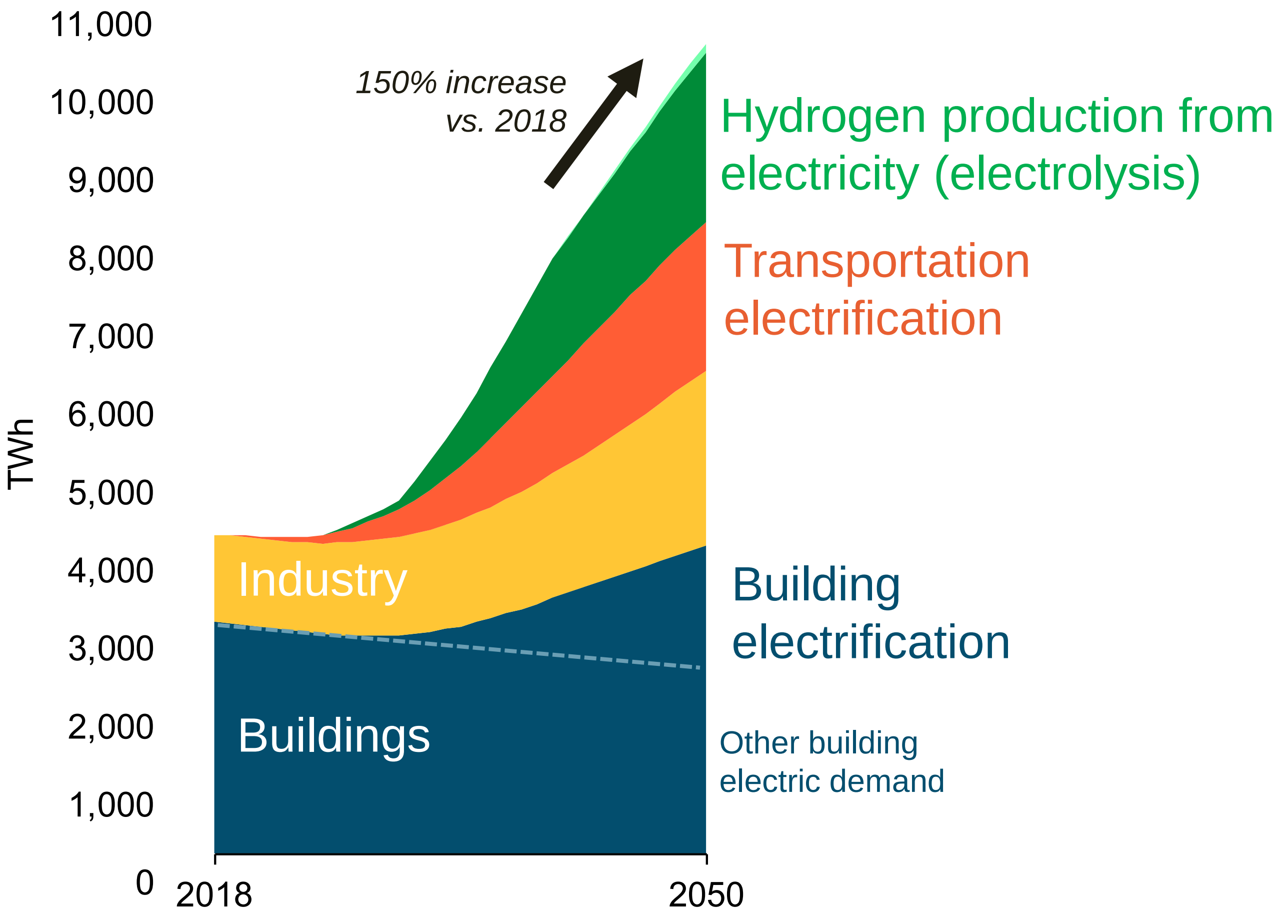
	Climate Impacts & Adaptation Needs
Electricity Generation	Electric reliability risks: flooding, storms, wildfire, heat. Degraded equipment performance, lower hydro generation, changing generation & electric load patterns
Transportation	Infrastructure & public safety risks, supply chain disruptions for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

How does electric sector plan for decarbonization?

How can climate science better inform electric sector planning?

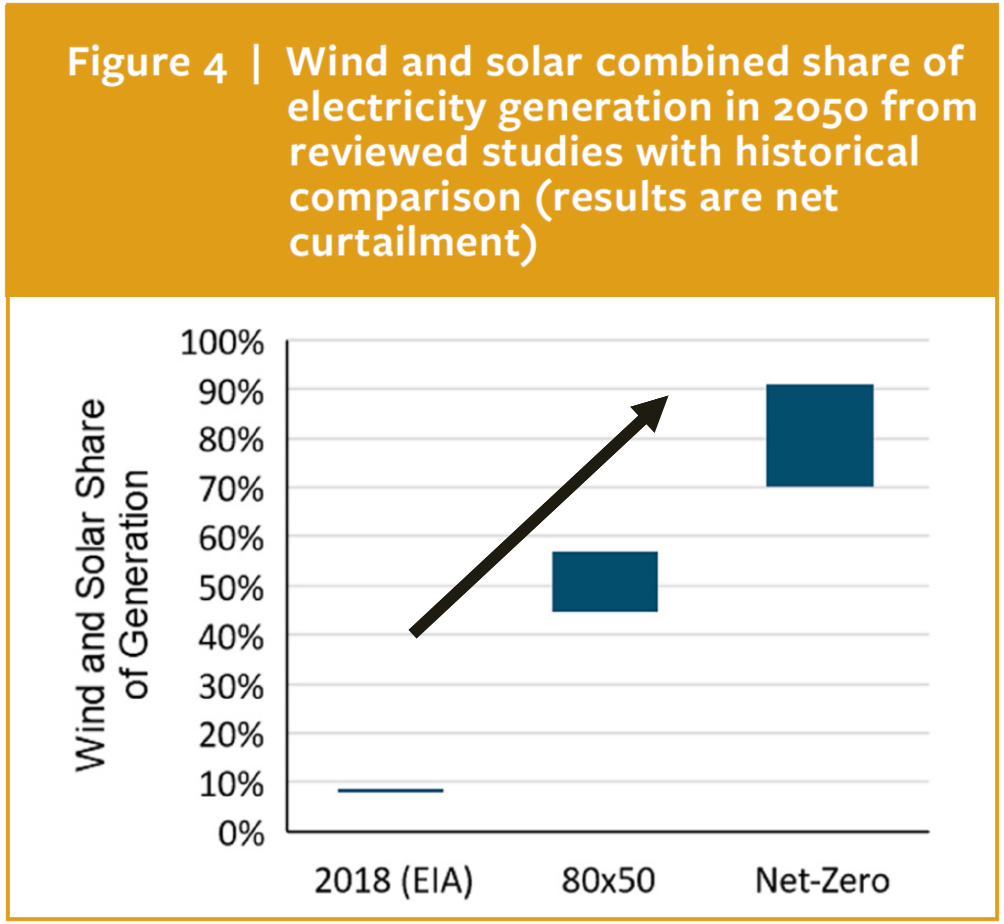
Electricity sector is pivotal to reducing GHGs

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



Source: E3 PATHWAYS analysis, 2021 (forthcoming)

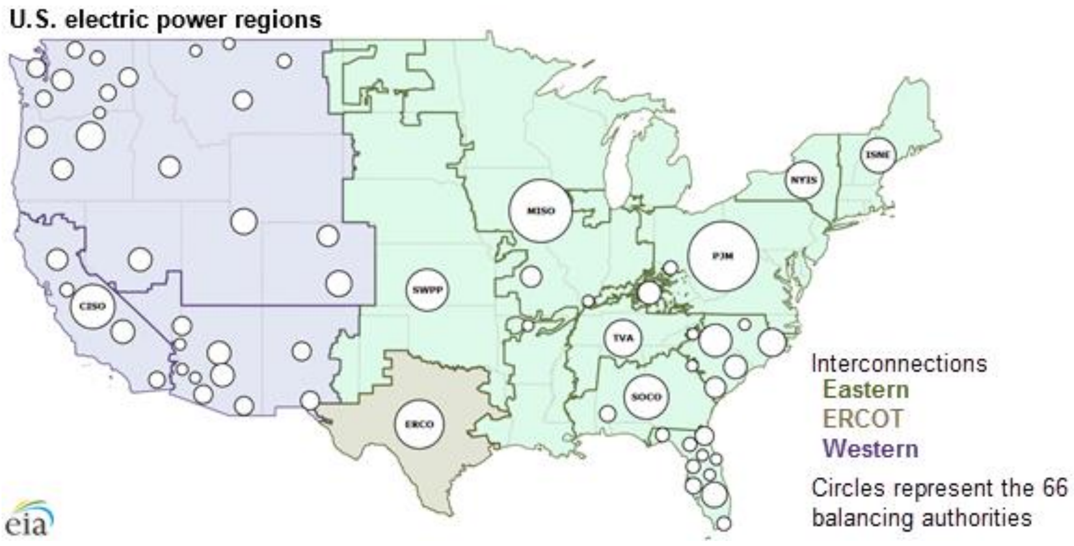
U.S. Wind and Solar Share of Generation under a Net-Zero Scenario



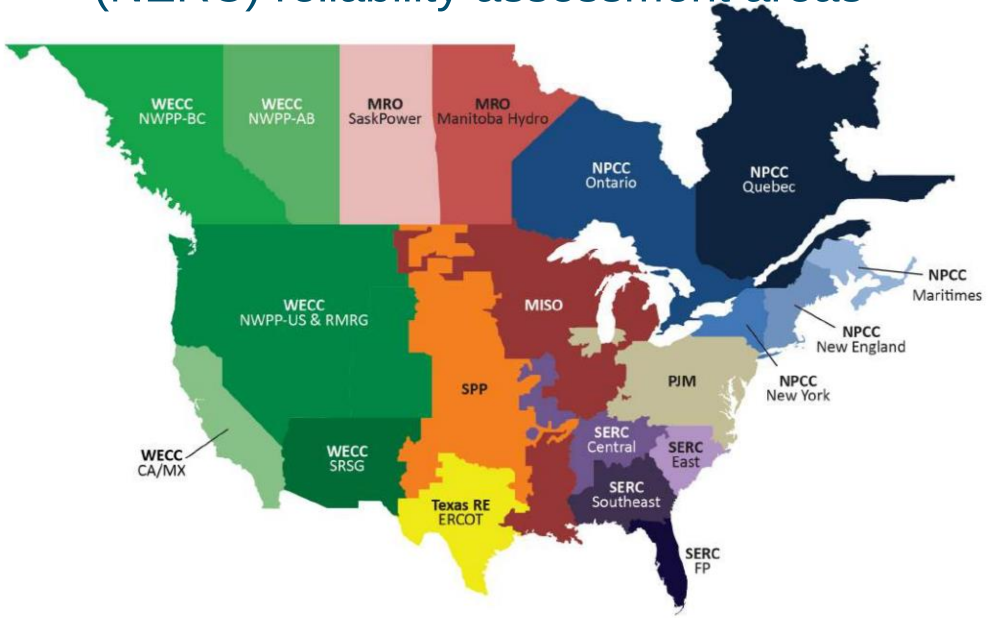
Source: "Getting to Net Zero U.S. Report", California Climate Change Institute (CCCI) and E3, 2021

Electric planning is done by electric utilities, balancing authorities and reliability assessment areas

U.S. Transmission Interconnections and Balancing Authorities



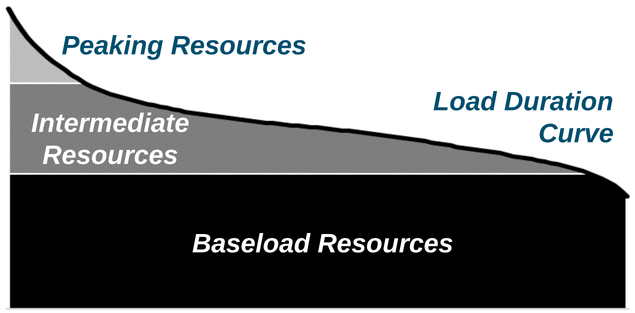
North American Electric Reliability Corporation (NERC) reliability assessment areas



Electric resource planning must adapt to new challenges

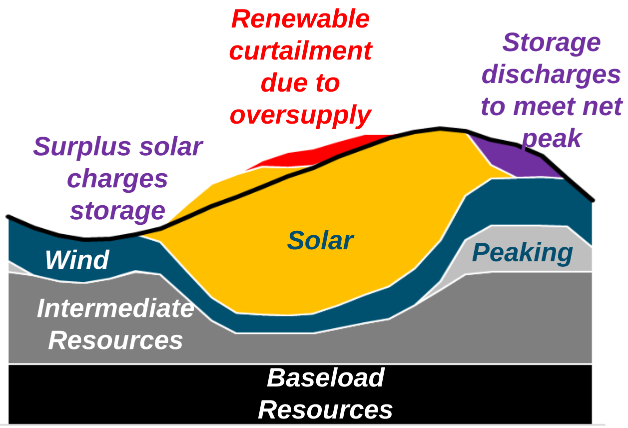
Yesterday's Planning Paradigm

+ Reliability driven by summer (or winter) **peak demand**



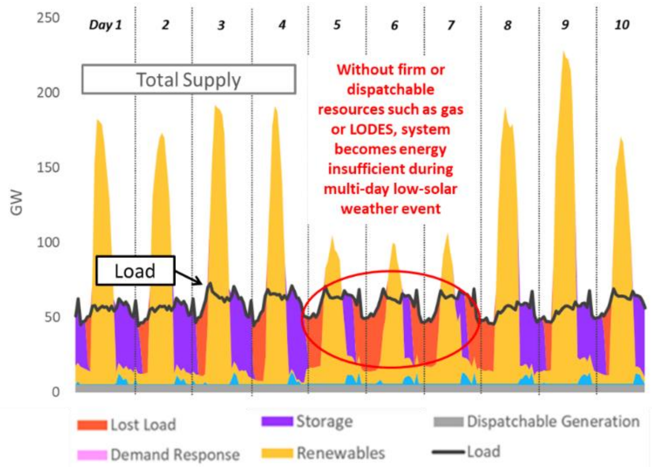
Today's Planning Paradigm

+ Understanding **chronological system dispatch** becomes necessary to evaluate investments & integration challenges for wind, solar, and batteries



Tomorrow's Planning Paradigm

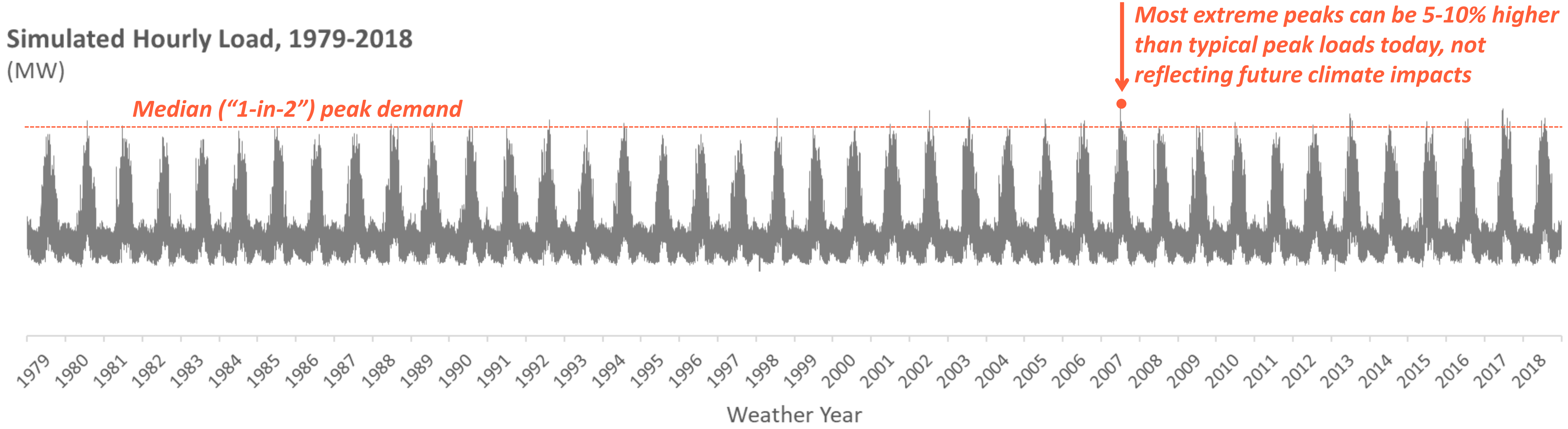
+ Increasing investment & operational uncertainty requires greater **spatial & temporal granularity** to capture system conditions & value streams for new technologies like long duration storage
+ Reliability driven by **"dark doldrums"** when renewables are unavailable to serve demand for extended periods



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

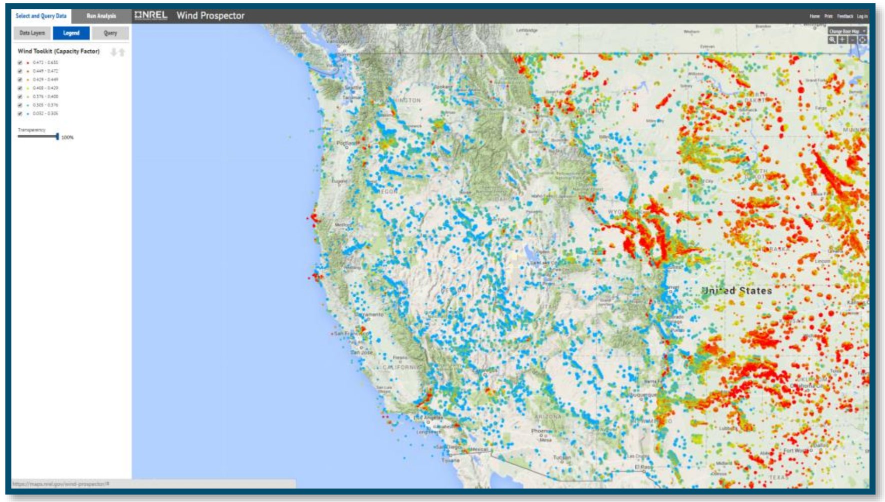
Emerging challenge:
capturing climate change impacts on magnitude and frequency of extreme weather events



Planning-grade simulated wind & solar profiles do not yet reflect future impacts of climate change

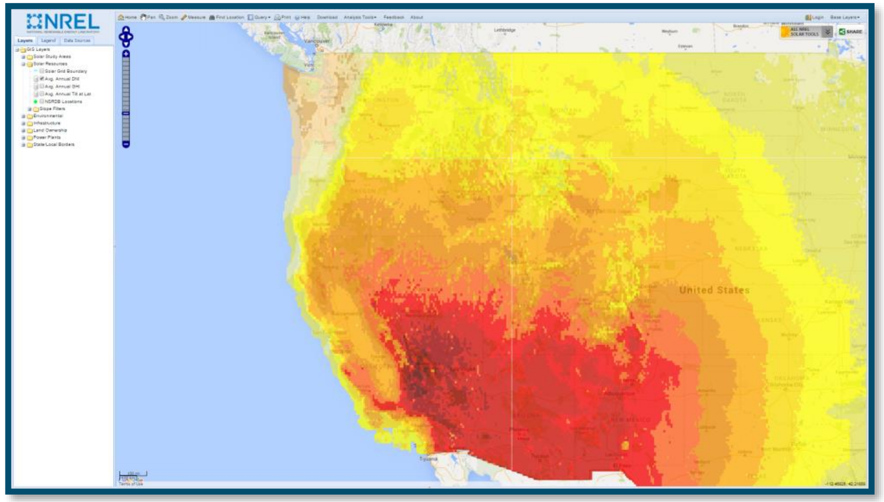
+ **NREL's Wind Integration National Dataset (WIND) and Solar Integration National Dataset (SIND) Toolkits provide best publicly available resource for variable renewable profiles**

NREL Wind Prospector



- 126,000 sites
- 5-min temporal resolution
- 2007-2013 historical period

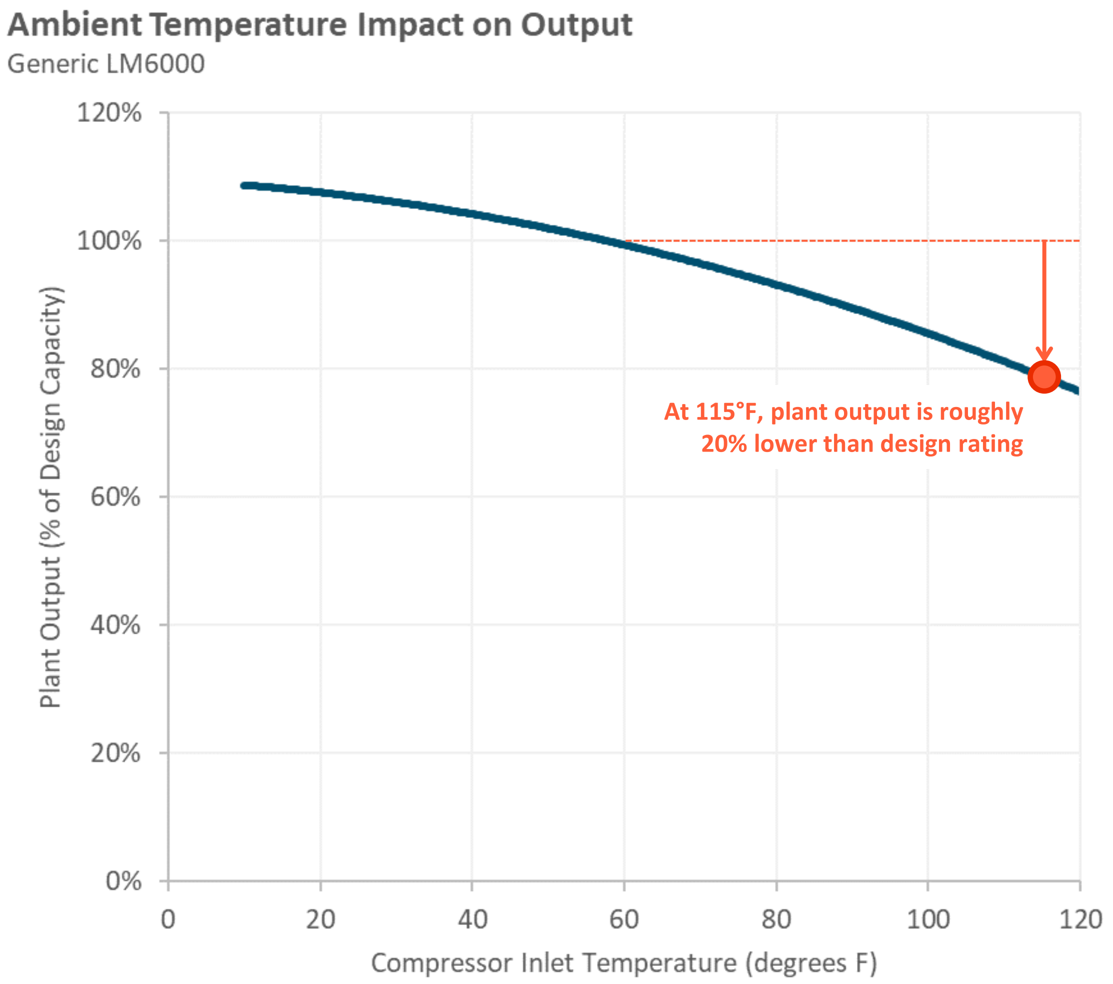
NREL Solar Prospector



- 120,000 sites
- 1-min temporal resolution
- 2007-2013 historical period

Accounting for temperature impacts on plant performance

- **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



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

Goals for Electric Sector Planning

- **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

Concluding Thoughts

- 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

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Thank you!