# Modeling Climate Impacts and Vulnerabilities of the Future Electric System for Planning and Resiliency

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**National Academy of Sciences Workshop**
"Making Climate Assessments Work"
Washington, D.C
August 15, 2018

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# EPRI: Born in a Blackout

The Electric Power Research Institute (EPRI) was founded in 1972 as an independent, non-profit organization for public interest energy and environmental research

*New York City, The Great Northeast Blackout, 1965*

- Annual research budget of $400M
- 450+ participants in more than 35 countries
- EPRI membership represents approximately 90% of the electricity in the United States



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# Modeling for Climate & Electric System Planning – 3 Considerations

## 1. Electric company system planning needs and motivations vary

- Motivation to explore climate risks ranges from resiliency threats to shareholder resolutions
- Much heterogeneity, e.g., regional differences, regulatory environment, market structure
- Integrated resource planning is increasingly complex – evolution of end-use devices and services, power markets, DERs, clean energy policies, variable renewables, fuel supply

## 2. Climate is one of several factors driving change in electric sector

> **For most economic sectors, the impact of climate change will be small relative to the impacts of other drivers (*medium evidence, high agreement*).** Changes in population, age, income, technology, relative prices, lifestyle, regulation, governance, and many other aspects of socioeconomic development will have an impact on the supply and demand of economic goods and services that is large relative to the impact of climate change.
>
> – Key Message #1 IPCC AR5 WG2 Ch 10 Key Economic Sectors and Services

## 3. Planning for what? Incremental change vs. extremes & variability (temporal and spatial)

- Means vs tails, intra-annual vs inter-annual variability, chronic vs acute events
- Assessment methodologies differ – deterministic vs stochastic approaches
- Extremes matter for adaptation planning: max (min) temp drives peak cooling (heating) demand, max storm surge drives extent of coastal protection, etc.


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# These remarks draw on two EPRI research initiatives

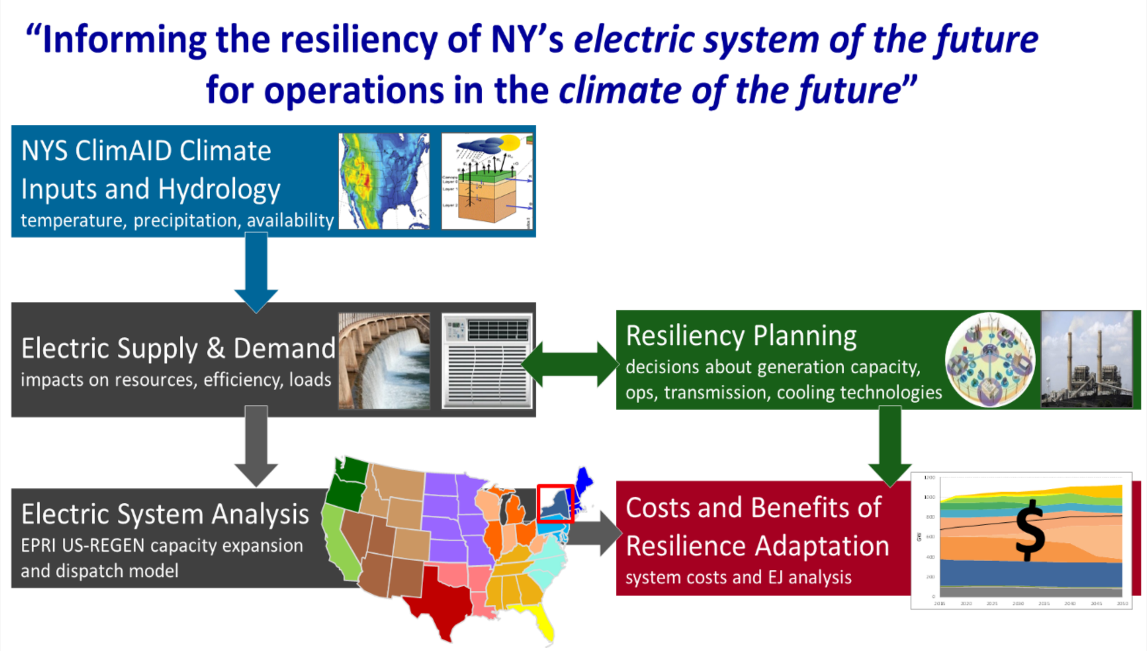
***with REGEN team Geoff Blanford, John Bistline, David Young and other EPRI collaborators***

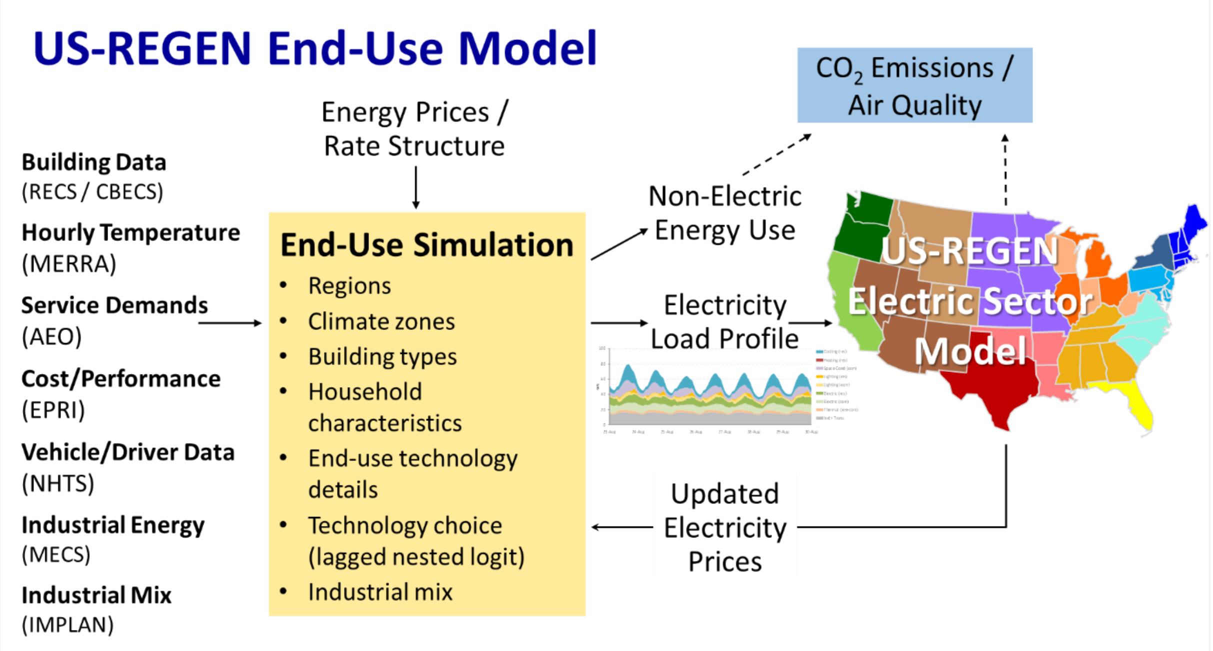
1) EPRI-NYSERDA project "Climate Change Vulnerabilities of and Adaptation Strategies for New York's Future Electric System"

- Assess climate impacts on NY bulk power system
- Supply and demand-side impacts
- Results ETA early 2019

2) US-REGEN End-Use Model

- Backbone of EPRI's National Electrification Assessment (April 2018)
- Structural detail underpins end-use projections with synchronized hourly loads, renewable profiles, and prices across REGEN supply and demand models



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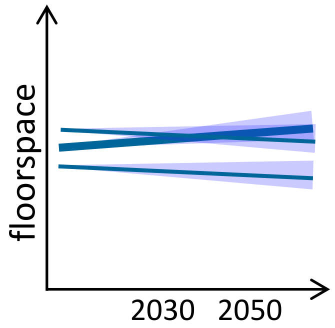
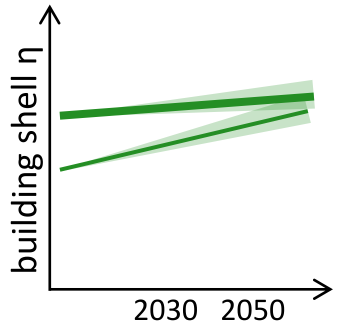
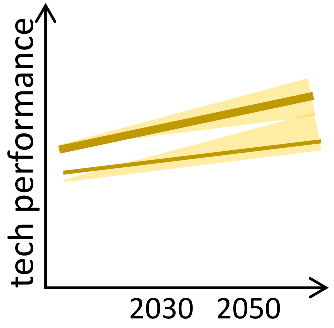
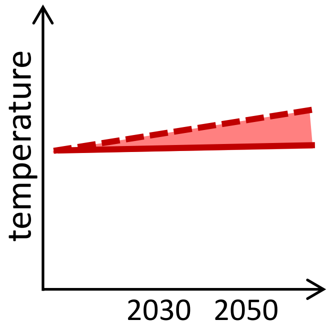
# Bottom-up building simulation projects hourly energy requirement based on socioeconomic & technological factors and observed temperature

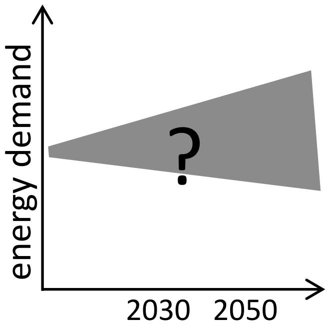
## buildings/technologies – performance – climate → energy consumption



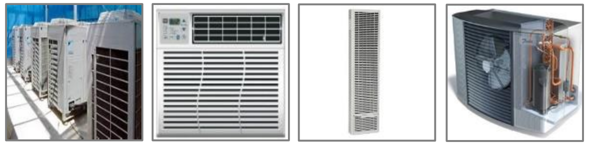



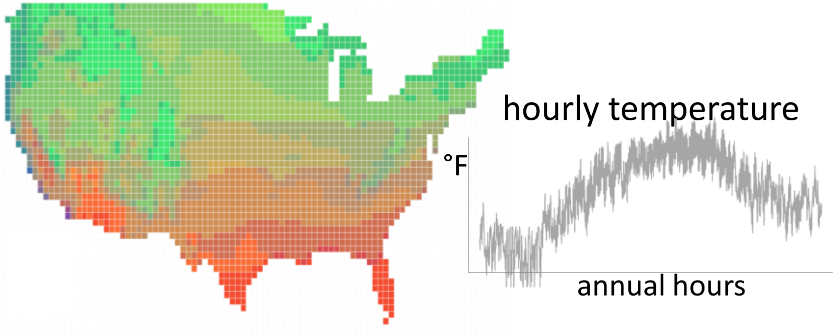

$$\text{sq ft} \times \frac{\text{BTU}}{\text{sq ft} \cdot {}^\circ\text{F}} \times {}^\circ\text{F} = \text{BTU}$$

- Location, climate zone
- Building type, vintage, size
- Household characteristics
- Industrial mix

Space conditioning technology detail



central AC window furnace heatpump




gridded temperature from NASA MERRA2 Reanalysis Dataset



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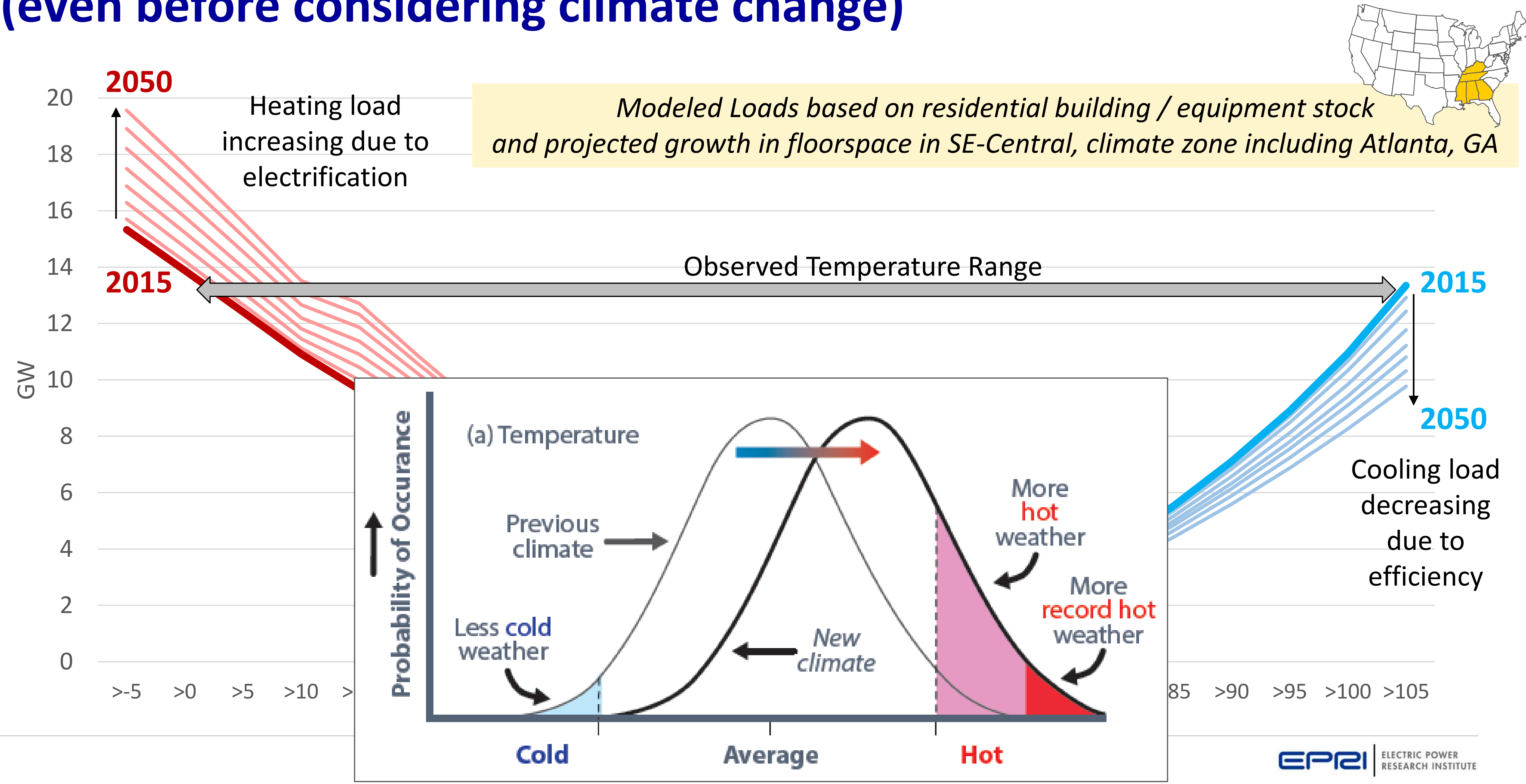
# Electrification and efficiency drive evolution of electricity demand (even before considering climate change)



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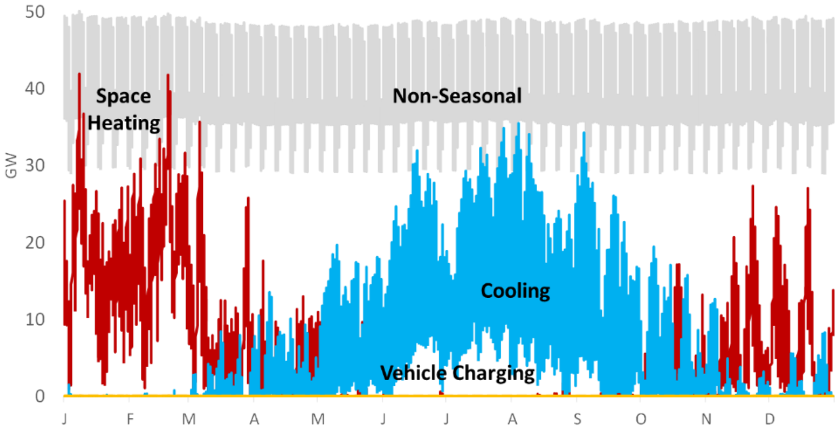
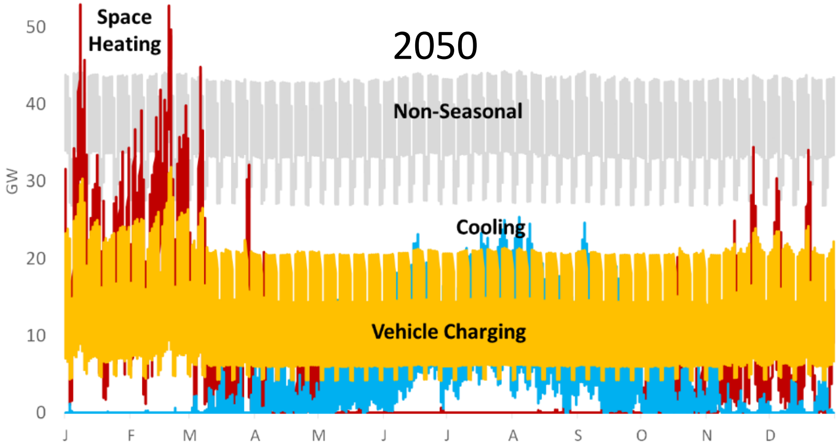
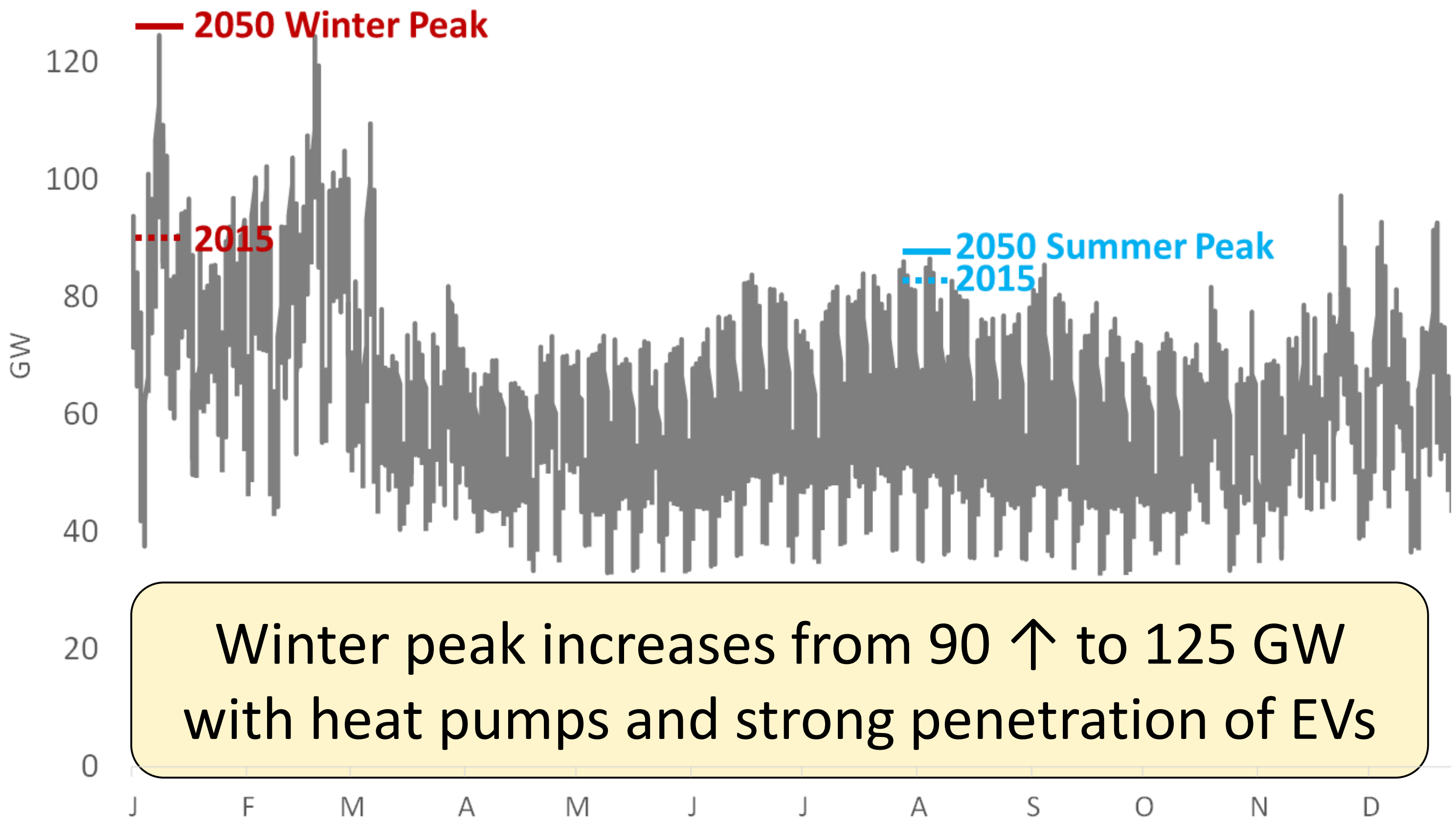
# Major load shape changes are projected in reference case (no warming): How will this impact regional supply mix/grid assets?

SE-Central Load Profiles by End-Use




SE-Central 2050 Aggregate Load Profile




Winter peak increases from 90 ↑ to 125 GW with heat pumps and strong penetration of EVs



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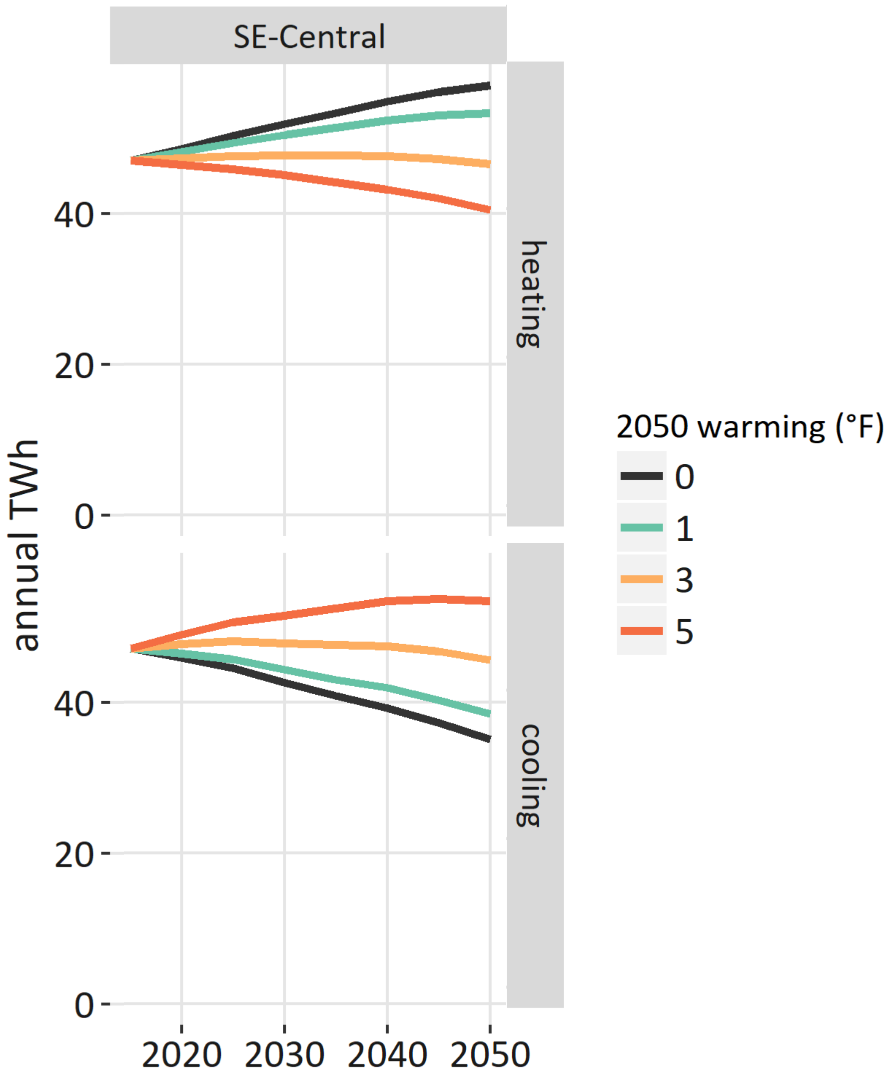
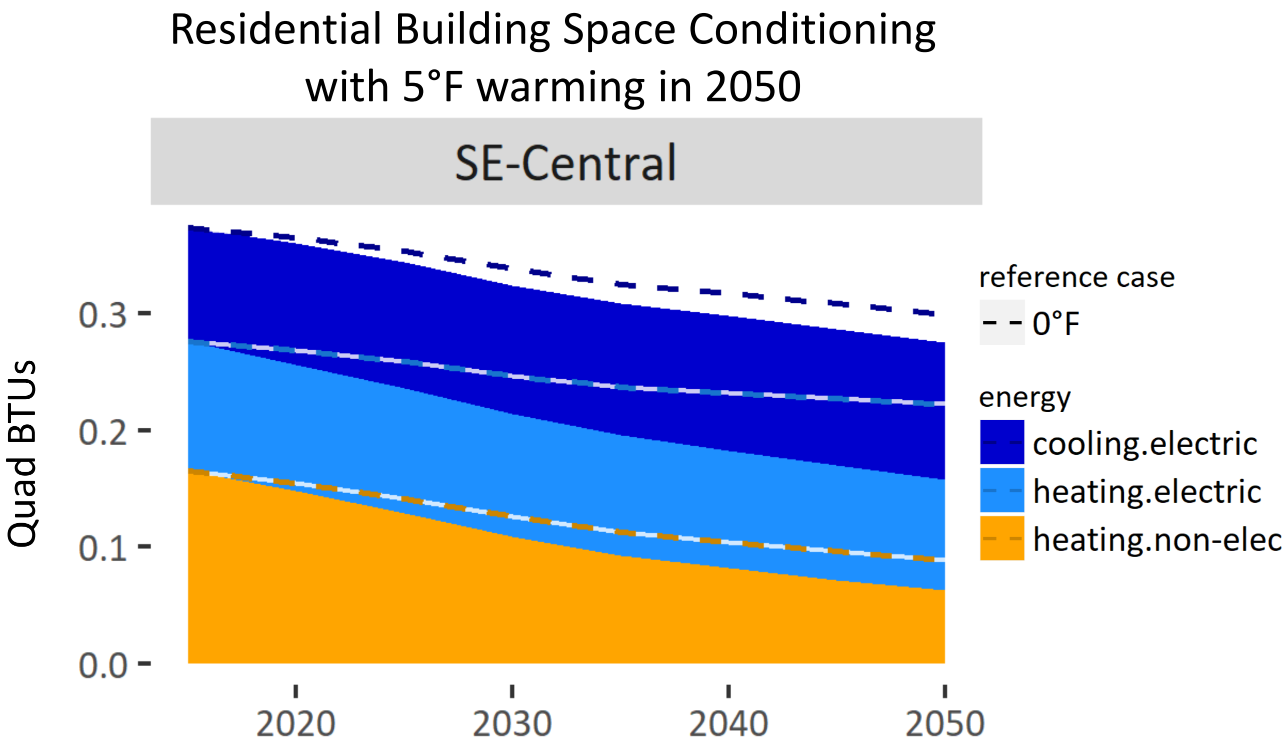
# 5°F warming drives 50% increase in residential cooling demand, while heating final energy drops by 25% → space conditioning declines overall



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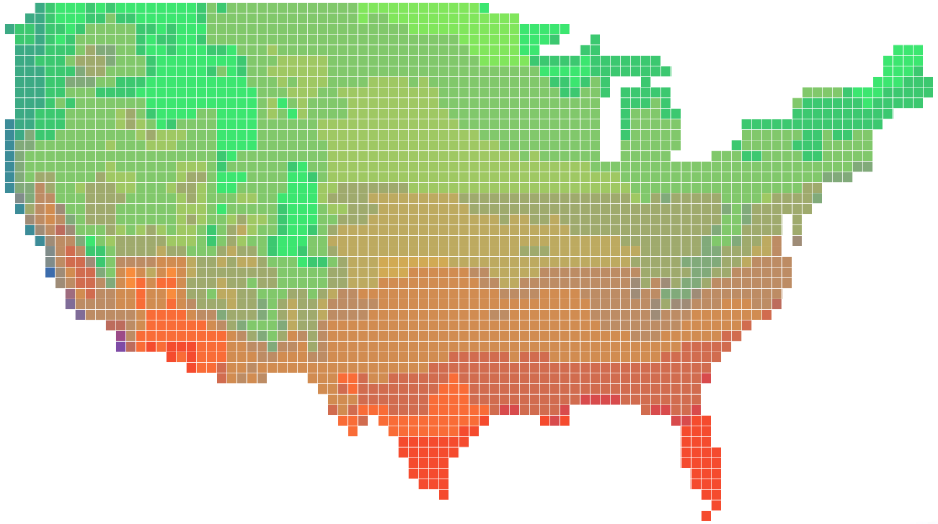
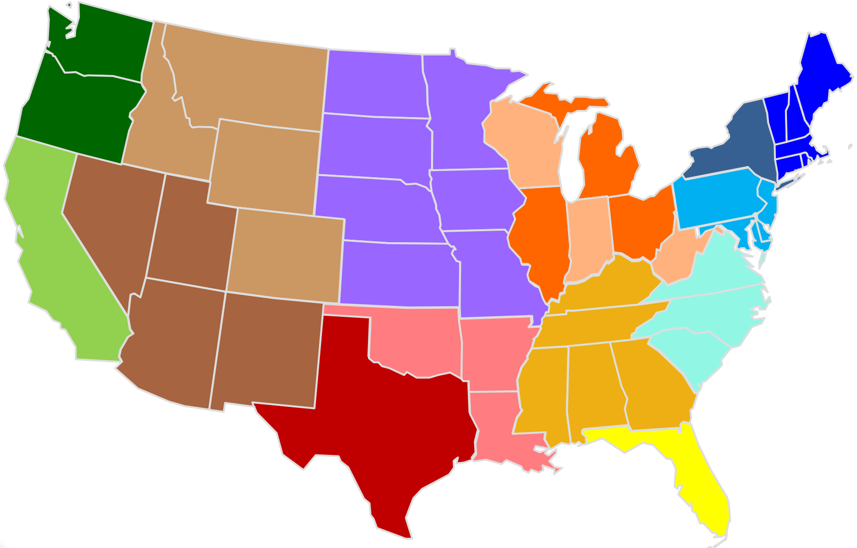
# Integrated Assessment and Energy-Economy Models like REGEN develop strategic insights around energy and environmental issues



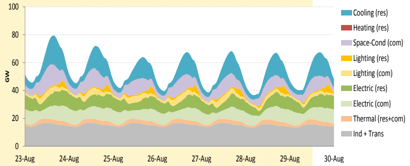
Synchronized

hourly load, renewable profiles, and prices



## Energy End-Use

- Regions
- Building types
- Climate zones
- Hourly temperature
- Household characteristics
- End-use technology details
- Technology choice
- Industrial mix



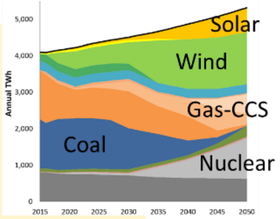

**Model Outputs**:

Economic equilibrium for generation, capacity, and end-use mix

Emissions and environmental outcomes

## Electric Generation

- Investment and dispatch
- Transmission
- Intermittent renewables
- Energy and capacity requirements
- State-level policies and constraints



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# Together…Shaping the Future of Electricity

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# Motivation: Extreme weather and climate resiliency affect the electric system via multiple pathways and at various scales

| | Vulnerability | Driver | Risk |
|---|---|---|---|
| Supply and Distribution | Hydropower | precipitation, snowmelt, runoff | Reduced hydropower resource availability |
| | Thermoelectric units | air temp | Reduced thermal efficiency of power generation |
| | Power plants near water | sea level rise, precipitation | Flood risk in low-lying coastal and riverine areas |
| | Water-cooled units | water temp | Temp of intake and discharge water, cooling efficiency |
| | Wind and solar | wind speed & direction, clouds | Availability / predictability of renewable power |
| | T&D lines | air temp | Line efficiency, sagging lines |
| | Utility assets | extreme weather, storms | Power outages, infrastructure damage |
| Demand | Total consumption | air temp, extreme weather | Changes in HDDs / CDDs<br>Changes in demand shapes and regional patterns |
| | Peak demand | air temp, humidity, extreme weather | Increase in summer peak load, power outages |

Adapted from NYSERDA (2011)

**What is the potential cost of these impacts?**

**What is the benefit of proactive adaptation planning?**



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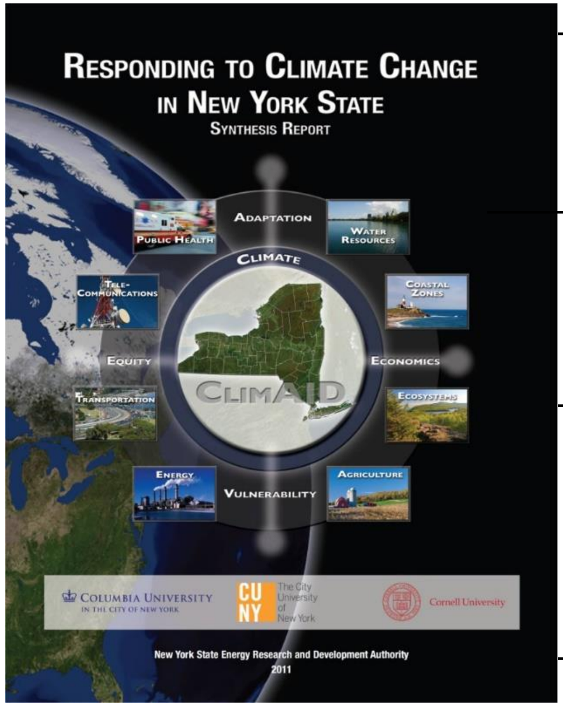
# EPRI-NYSERDA project assesses NYS electricity system performance, vulnerabilities, and adaptation strategies under a future climate

NYSERDA ClimAID Assessment

changes in:

- Air temperature
- Water temperature
- Water availability




www.nyserda.ny.gov/climaid

Thermal cooling technology

Increased cooling / decreased heating demand

Decreased capacity of transmission lines

Decreased efficiency of thermal generators (EPRI SOAPP model)

Changes in seasonal output from hydro generators

Other policy, resource, customer trends and drivers

End-use technology choice

Inter-region transmission additions

Generation capacity addition and dispatch decisions



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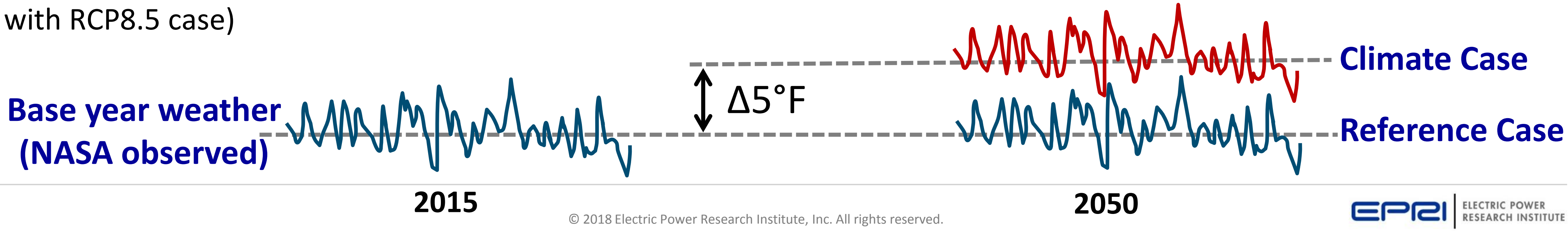
# Climate change is *one of several factors* driving change in electric sector – challenge is to differentiate and quantify the relative impact

1. Socioeconomic growth
2. Technology change (building and technology efficiency improvements)
3. Infrastructure/capital stock turnover (new vintage additions)
4. Electrification opportunities (e.g., air source heat pump replacing gas furnace)
5. Weather (inter-annual temperature variability – not treated here)
6. Climate (long-term trend in CDDs)

- **Reference Case (no warming)**: non-climatic factors only; assume stationary weather (2050 = 2015)
- **Warming Case (5 °F warming)**: reference plus constant hourly temperature adder, rising linearly to 5 °F in 2050 (in line with RCP8.5 case)





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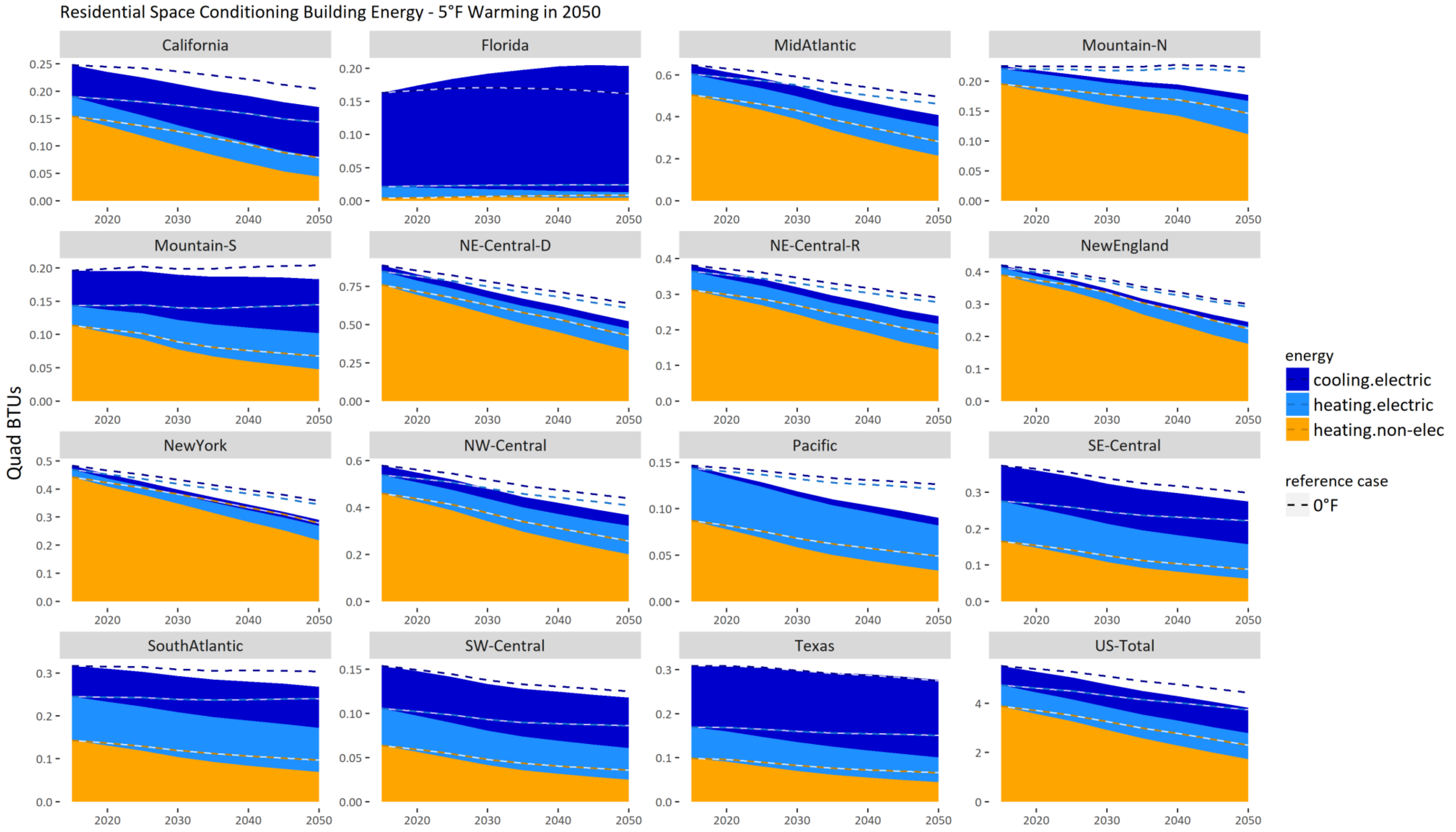




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