RESOURCES
for the FUTURE

Decarbonization & Electrification

Challenges and Opportunities for System Reliability

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PJM

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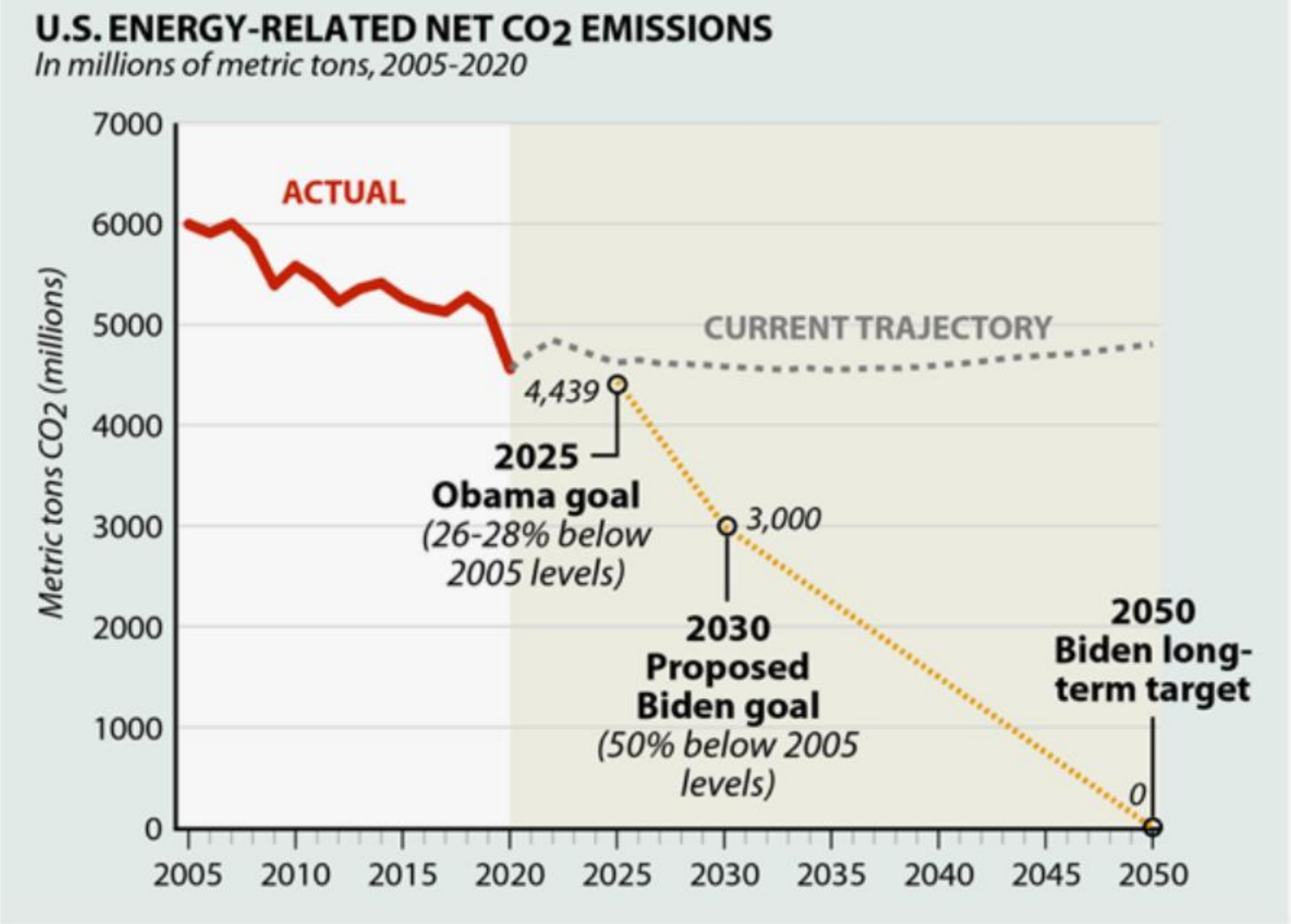
National Decarbonization Goals

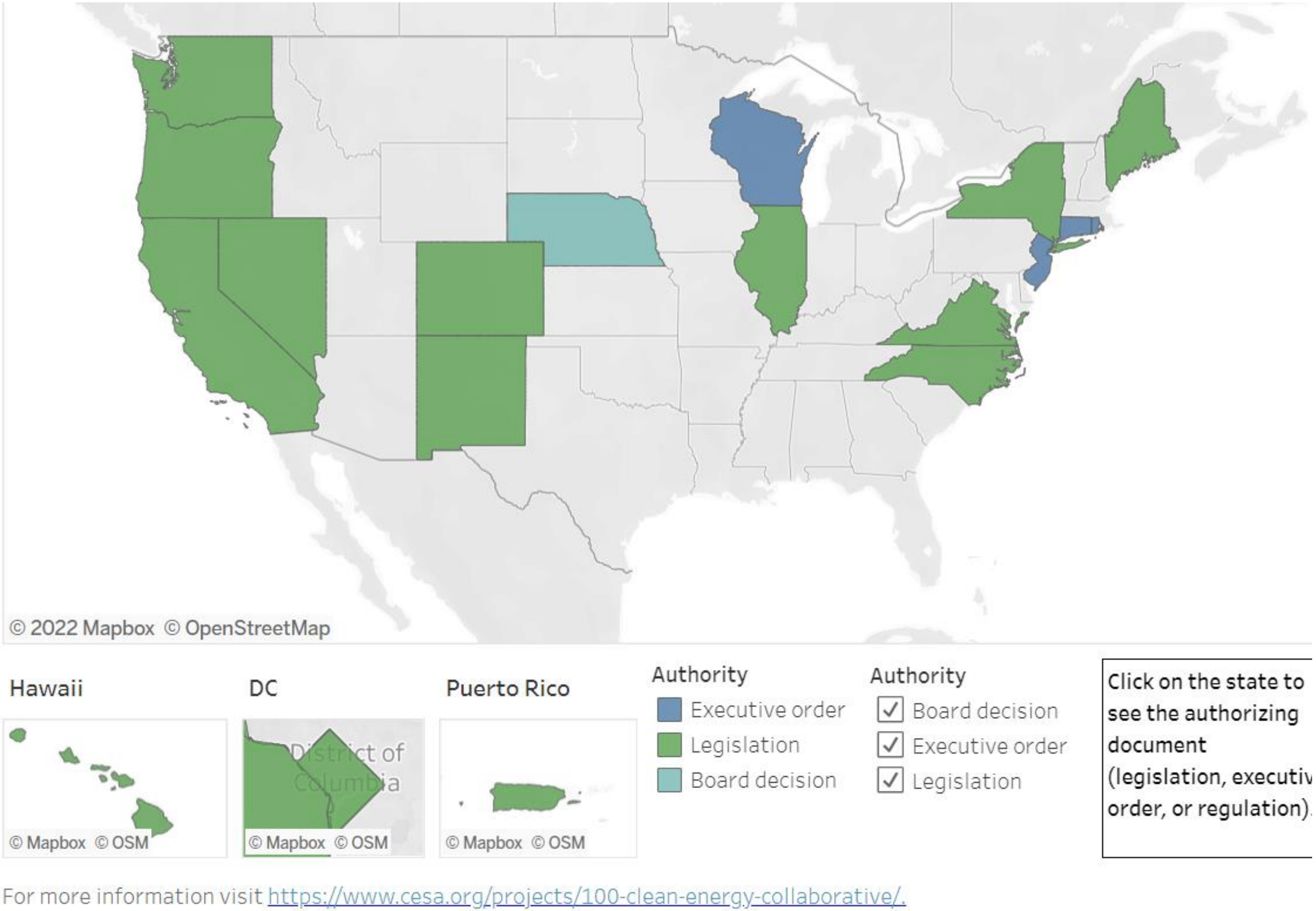


SOURCES: U.S. Energy Information Administration; ICN research PAUL HORN / Inside Climate News

State Climate Action Plans

Source: C2ES

Map of 100% Clean Electricity States



Authority

🟦 Executive order
🟩 Legislation
■ Board decision

Authority

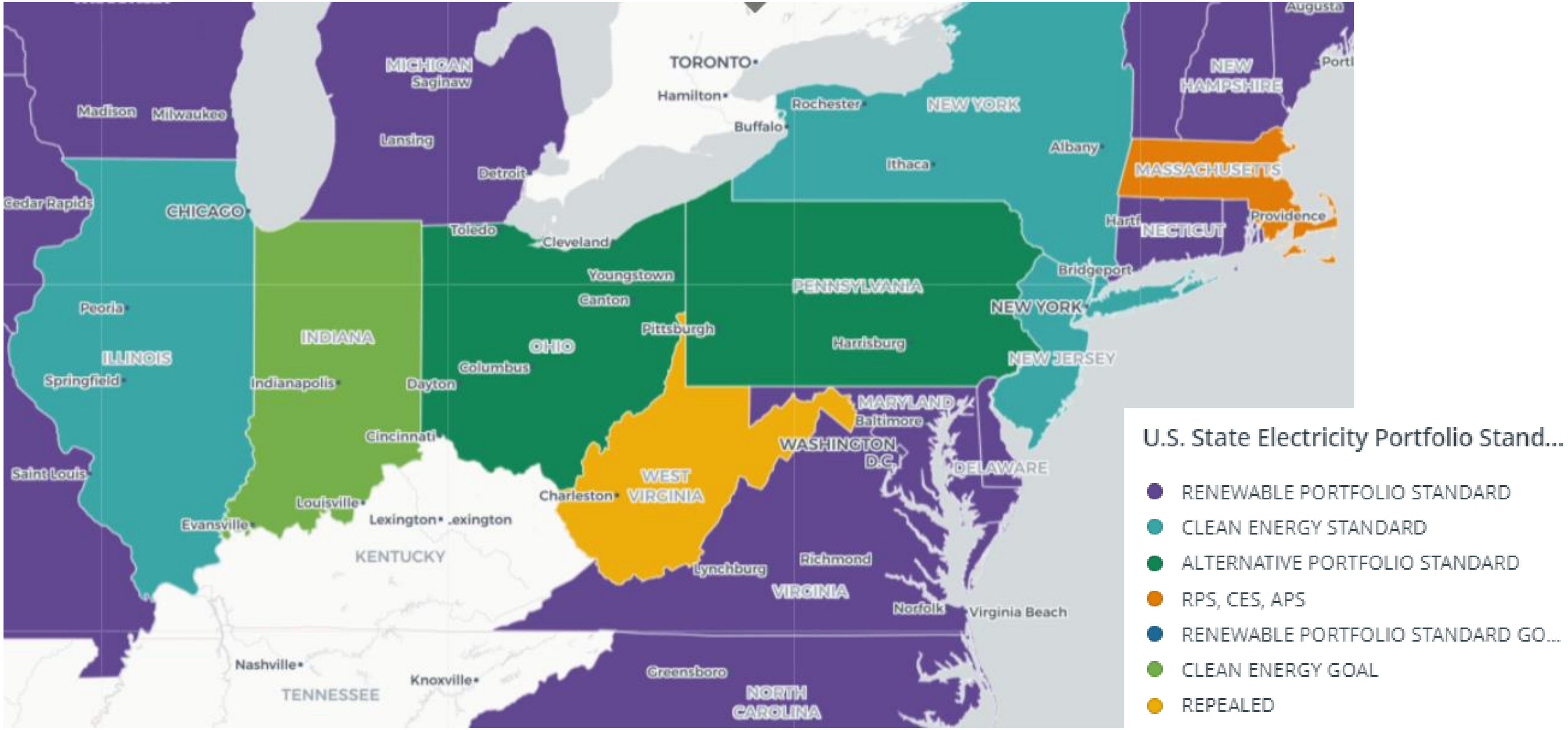
☑ Board decision
☑ Executive order
☑ Legislation

Click on the state to see the authorizing document (legislation, executiv order, or regulation).

For more information visit https://www.cesa.org/projects/100-clean-energy-collaborative/.

Source: Clean Energy States Alliance

State Electricity Sector Policies



Source: C2ES

Why Electrification?

- There are several pathways to decarbonization, including leveraging hydrogen and biofuels to replace fossil fuels.
- Electricity is generally considered the most cost-effective alternative to fossil fuels in most applications
  - The electric grid has decarbonized and will get cleaner over time
  - Technologies that use electricity as a fuel source result in lower carbon dioxide emissions on average than those that use fossil fuels directly.
  - Some electric technologies are more **fuel efficient** relative to fossil technologies and therefore use less energy to perform the same task

Electrification and Decarbonization

- Most decarbonization scenarios prominently feature electrification
- Princeton's Net Zero America decarbonization pathways analysis found that electrification uptake by consumers must be rapid across all states to achieve net zero by 2050
- EPRI projects that in a variety of decarbonization scenarios, electrification will lead to a cumulative load growth of 24–52% by 2050 over 2015 load

Barriers to Widespread Electrification

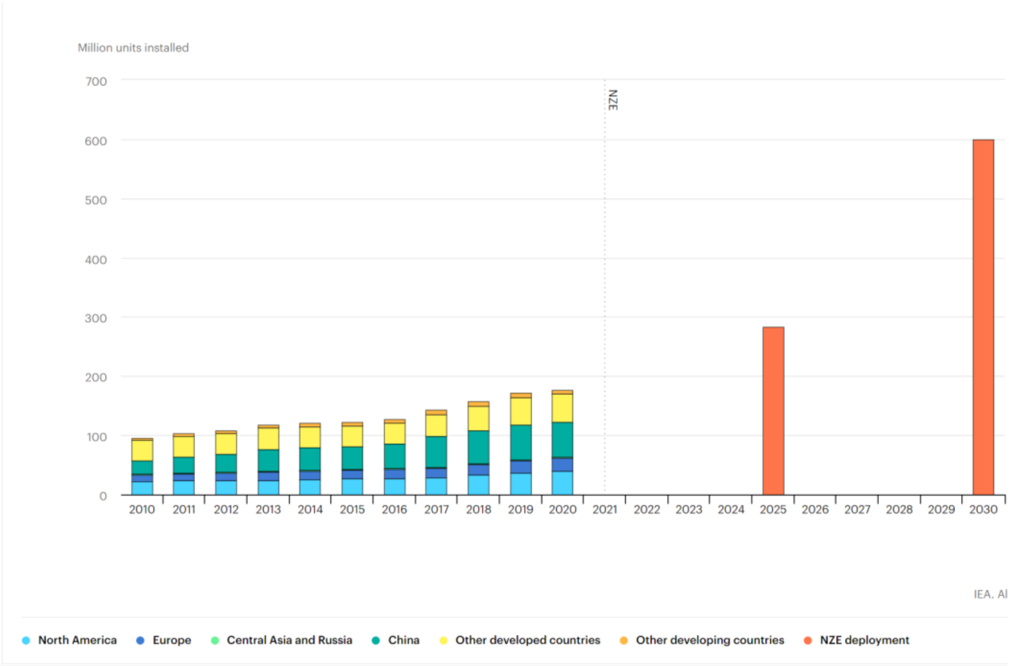
- Transportation
  - High upfront costs for vehicles and associated equipment (home chargers, etc.)
  - Lack of publicly available charging infrastructure
  - Range anxiety
  - Uncertainty about performance
- Buildings
  - Technologies can be expensive upfront (example: heat pumps)
  - Electric heaters and water heaters can be more expensive to operate relative to fossil-fueled counterparts
  - Existing investments in natural gas infrastructure required to deliver gas to homes, buildings

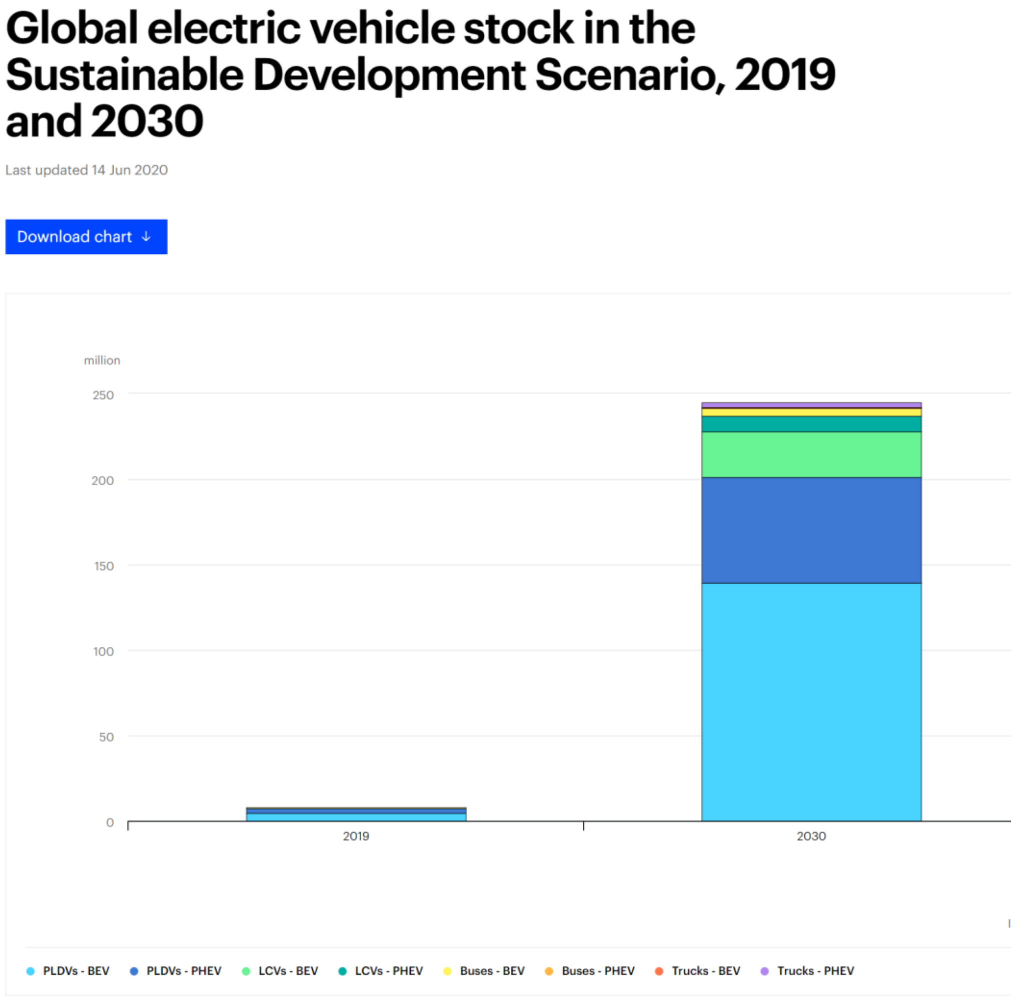
Policies Encouraging Electrification

- Low Carbon Fuel Standards (CA)
  - Electric vehicles considered low carbon intensity fuel
- ZEV Mandates (CA, NY, CO, VT, WA, OR, RI, MA, ME, MD, NJ)
  - require increasing % of ZEV sales by manufacturers
- Economy-wide carbon pricing (OR, CA, WA)
  - Carbon pricing would make operating fossil-fueled technologies (like gasoline cars) relatively more expensive than operating electric technologies
  - Notably, a carbon price in the electricity sector alone could *discourage* electrification by making electricity relatively more expensive
- Building standards and new fossil fuel hook up bans (NY, NJ, CA, WA)
- Infrastructure investments in charging stations for EVs ($7.5 billion authorized in IIJA)

Investment Challenges of Widespread Electrification

Installed heat pump stock by region and global Net Zero Scenario Deployment, 2010 - 2030





Global electric vehicle stock in the Sustainable Development Scenario, 2019 and 2030

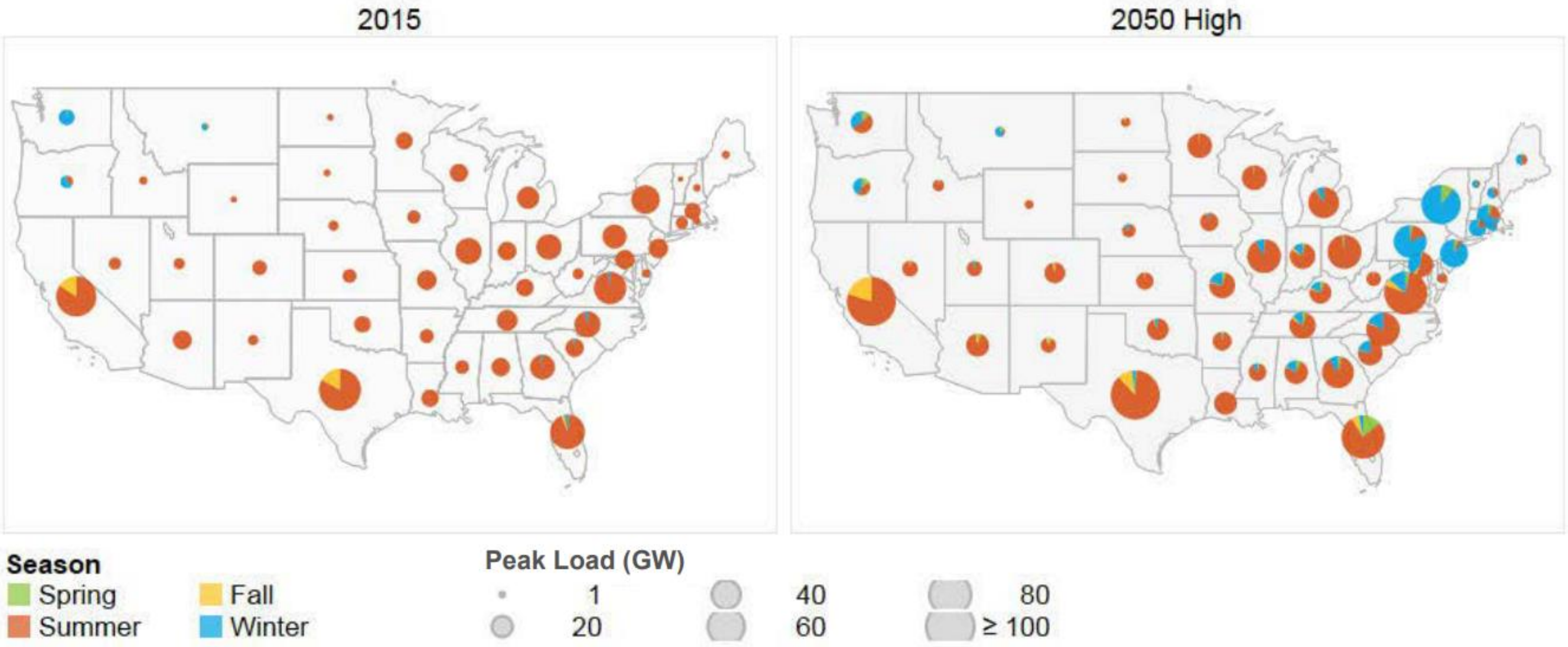
Last updated 14 Jun 2020

Source: IEA NET Zero Scenario and Sustainable Development Scenario

Integration Challenges of Electrification

- Overloading distribution grid (feeders, transformers, etc.), requiring expensive upgrades
    - Warehouses (where delivery vans part) are often co-located
    - Fast chargers pose larger challenges
- Need for more peaking capacity, much of which could be carbon-polluting
    - Studies on electric vehicles specifically show significant increases in peak load under unmanaged charging scenarios at penetrations as low as 30% of total vehicles
- Potential seasonal shifts in system peaks that may not coincide with renewable resource availability

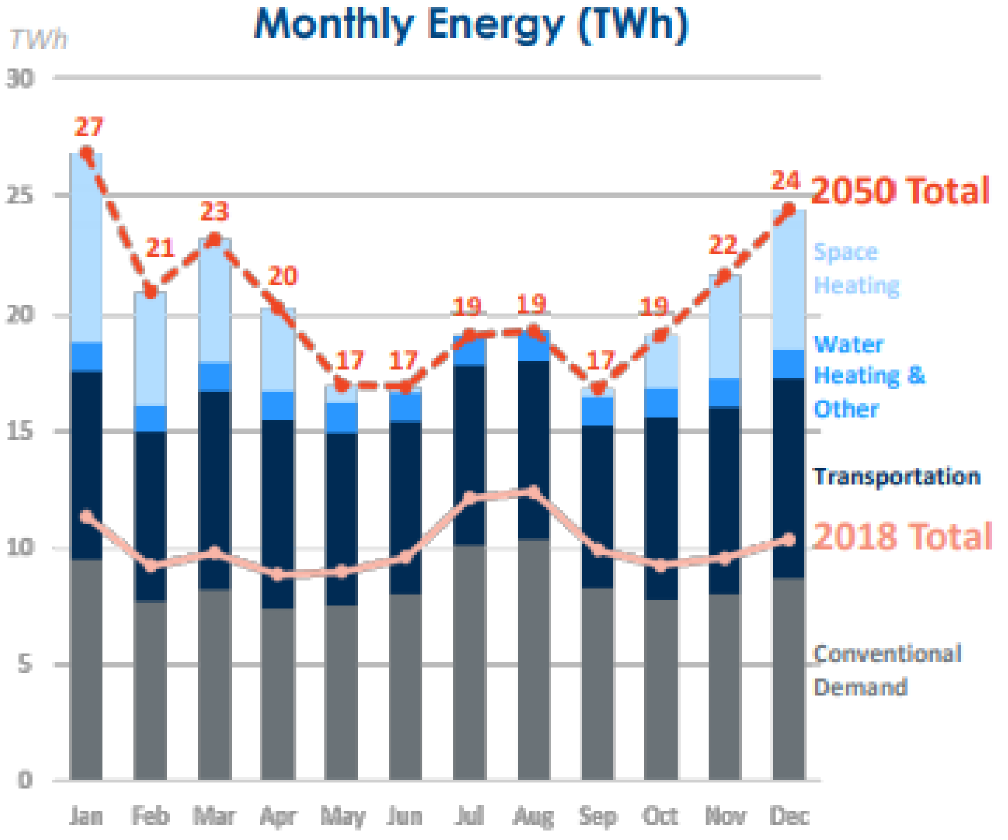
Timing of peak demand will change over time



Note: Summer = June–August, Fall = September – November, Winter = December – February, Spring = March – May

Electrification in New England

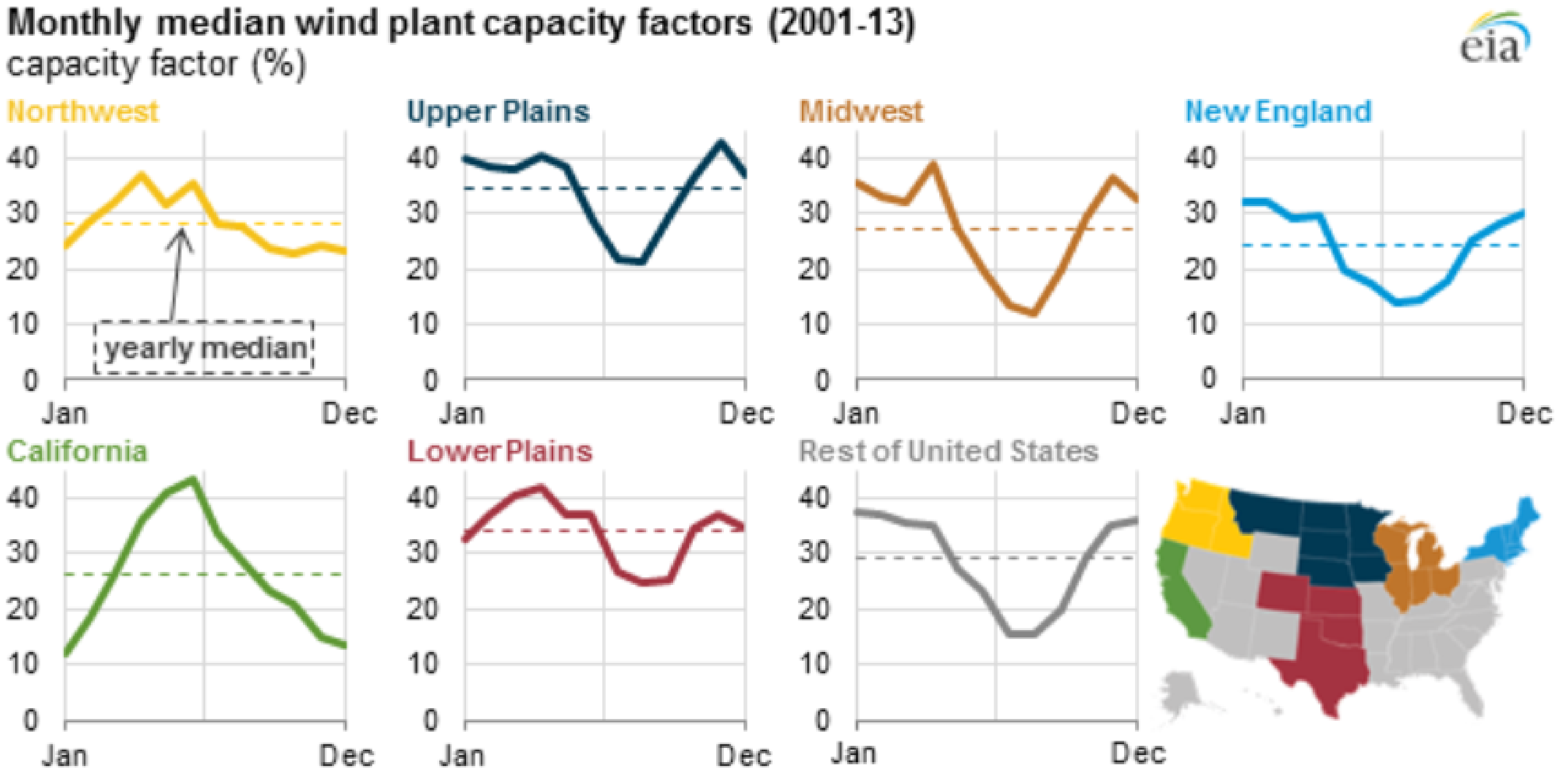
- A recent study finds to electrifying transport and buildings key to NE decarbonization goals.
- As a result, electricity demand will be double what it is today.
- Largely due to increased usage for heating peak demand shifts from summer to winter months.



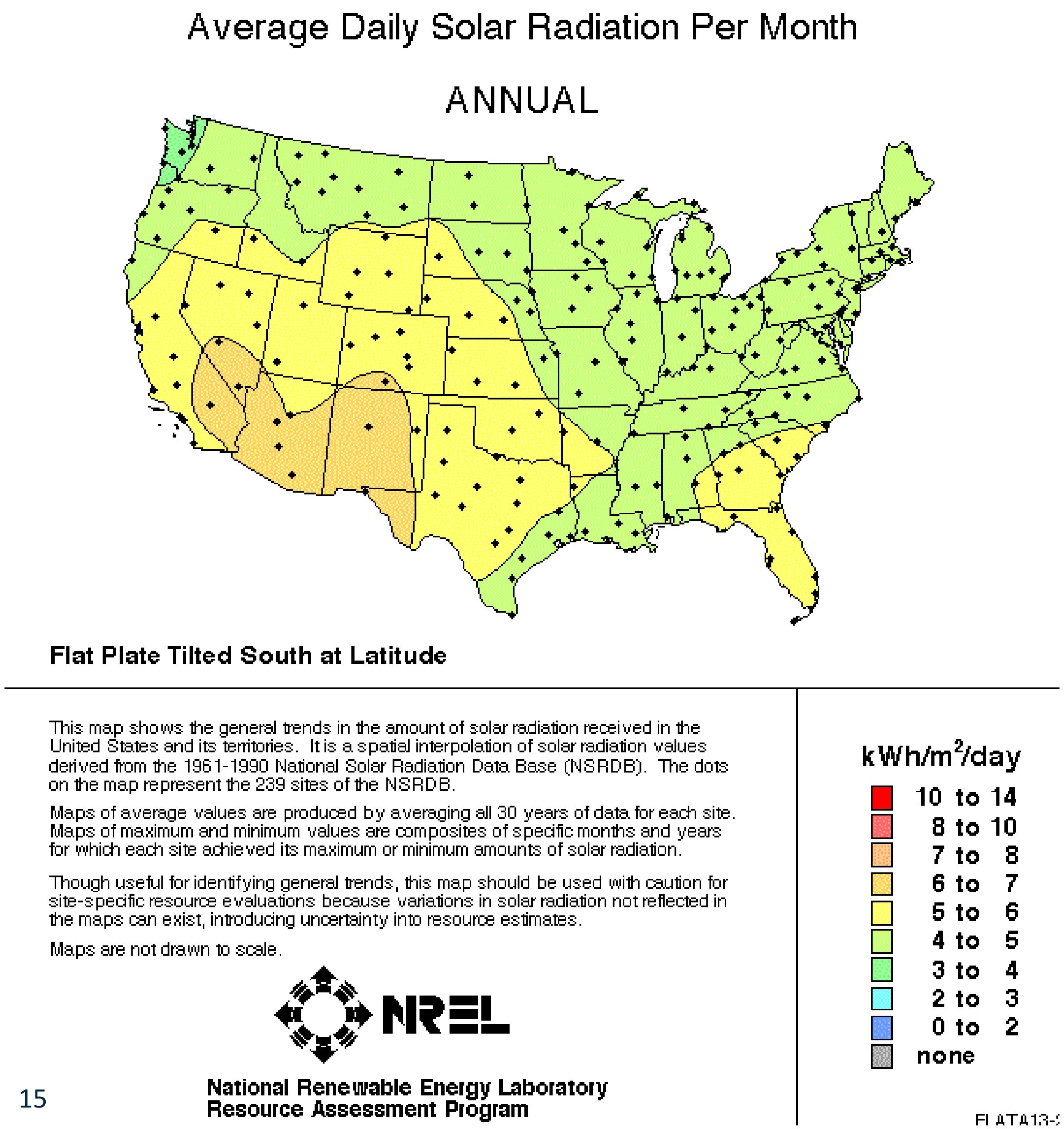
Source: Monthly conventional demand based on ISO-NE 2018 monthly demand pattern. See appen was an average year for heating demand, but had a relatively warm February. Incremental electrif

(source of graph is Brattle 2019)

Renewable resource capacity also varies over time…



Source: U.S. Energy Information Administration, Forms EIA-860 and EIA-923
Note: Data include facilities with a net summer capacity of 1 MW and above only.



Average Daily Solar Radiation Per Month

ANNUAL

Flat Plate Tilted South at Latitude

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates.

Maps are not drawn to scale.

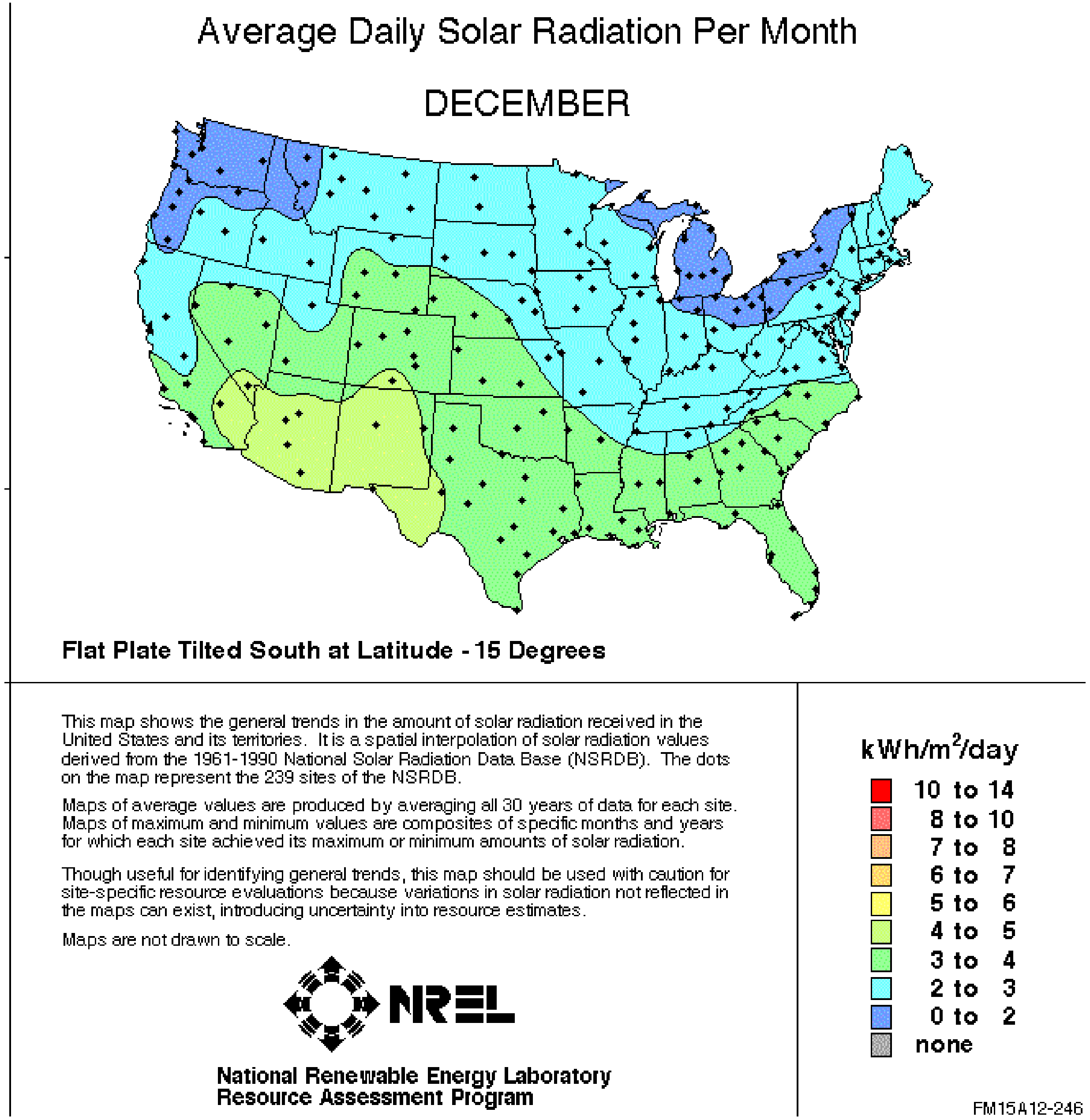
NREL

National Renewable Energy Laboratory
Resource Assessment Program

kWh/m^2/day

- 🟥 10 to 14
- 🟥 8 to 10
- 🟧 7 to 8
- 🟧 6 to 7
- 🟨 5 to 6
- 🟩 4 to 5
- 🟩 3 to 4
- 🟦 2 to 3
- 🟦 0 to 2
- ⬜ none

FLATA13-



Average Daily Solar Radiation Per Month

DECEMBER

Flat Plate Tilted South at Latitude - 15 Degrees

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

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- 🟦 0 to 2
- ⬜ none

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Electrification and Reliable Energy Services

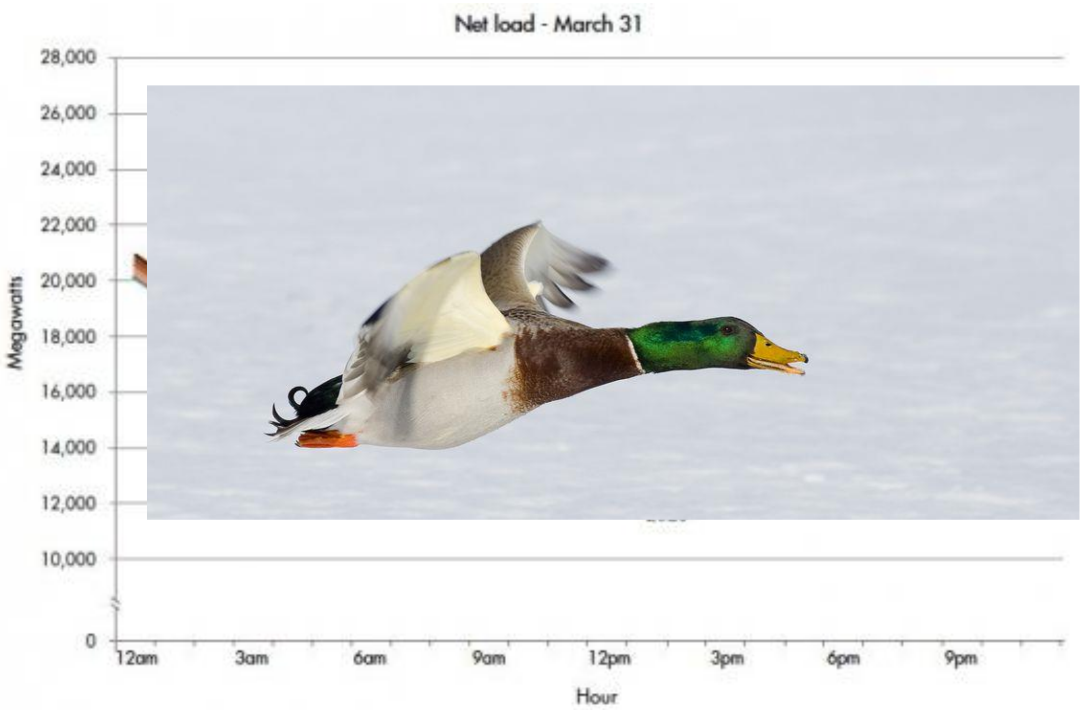
- As the range and share of energy needs met by electricity grows, will demand for reliable and resilient electricity systems increase? Does electrification raise the value of loss load (VOLL)?
- Maybe not because electricity is already ubiquitous
  - Natural gas and even oil furnaces typically need electricity to operate
  - Modern gasoline pumps also require electricity
- Could increase demand for back up generation to keep spaces conditioned
  - Or will electric car battery become the back up system?
- Could flexible technologies help reduce outage risks?

Opportunities in widespread electrification

- Aggregated electrified loads can act as **DERs** and provide grid benefits
- Energy storage
  - Draw power from the grid during times of high supply/low demand
  - EVs can also discharge power back to the grid with vehicle-to-grid technology
- Frequency and voltage control
  - Real time control of car charging or electric water heating

Efficient prices needed in decarbonized grid

- Non-dispatchability of renewables poses challenge
- Can time varying electricity prices help?
  - Provide incentive to consume when electricity is cheap
  - Reduce slope of troublesome ramps
  - Proverbial duck takes flight
- Electricity rates that encourage smart electrification
  - Hasten decarbonization of transport and buildings
  - Newly electrified loads (space conditioning, water heating, EV batteries) have inherent storage characteristics
  - Use pricing incentives/rate design to create virtuous cycle
- California has open proceeding at CEC and policy development at CPUC



Utilities and RTOs can play a role

- Facilitate participation of DERs (FERC 2222)
- Allow compensation for demand reduction in addition to energy generation (FERC 2222)
- Consider new approaches
    - Subscription for energy services in exchange for load control (RFF paper on Energy Service Subscriptions)
    - Role of utilities? (RFF paper by Tim Brennan)
    - Greater role for price responsive demand in retail and wholesale markets.

Concluding Thoughts

- A decarbonizing(ed) grid can help decarbonize buildings and transport through electrification.
- Electrification raises investment challenges for consumers, utilities and infrastructure planners.
- Electrification brings opportunities for more flexible demand.
- Smart electrification and better electric rate design can help support grid decarbonization.

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