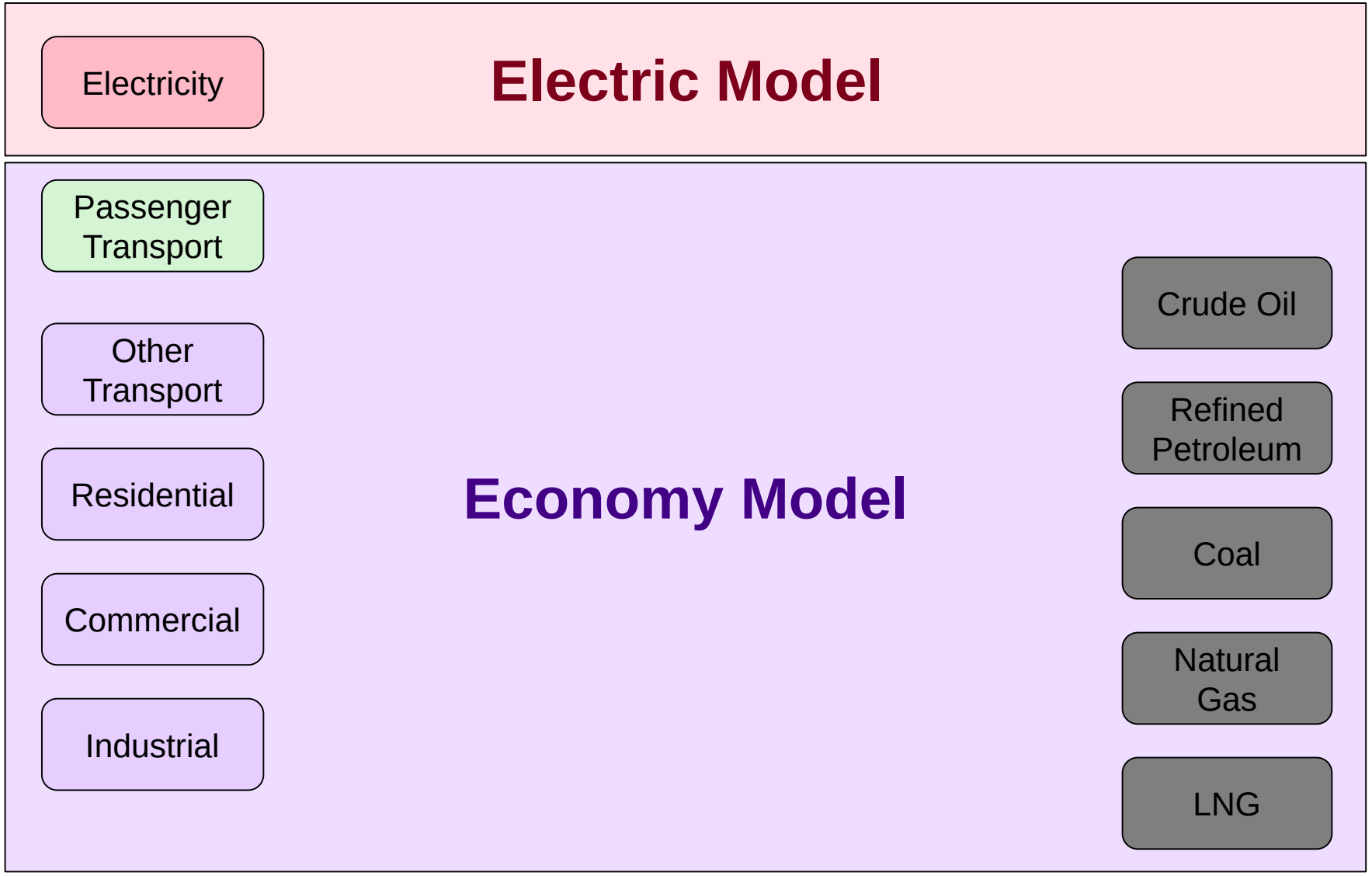
State-Level Modeling of Clean Power Plan Compliance Pathways with EPRI's US-REGEN Model

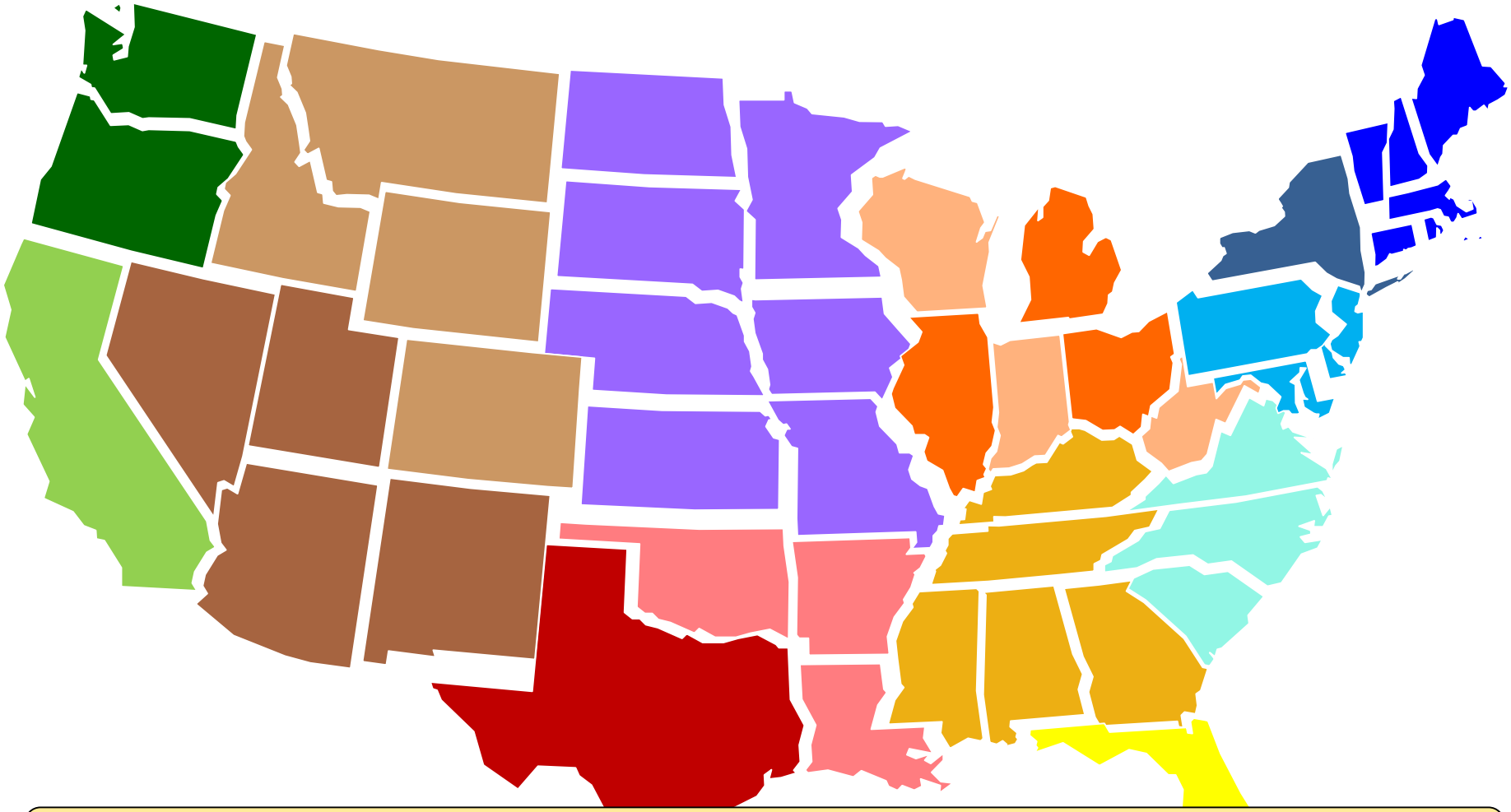
Vic Niemeyer
Senior Technical Executive
Electric Power Research Institute

RFF-EPRI Seminar on Modeling the Clean Power Plan
February 11, 2016

US-REGEN: A Full Energy-Economy Model



CPP Analyses Based on 48-State Electric Model



All lower 48 states represented separately. Economy model not used.

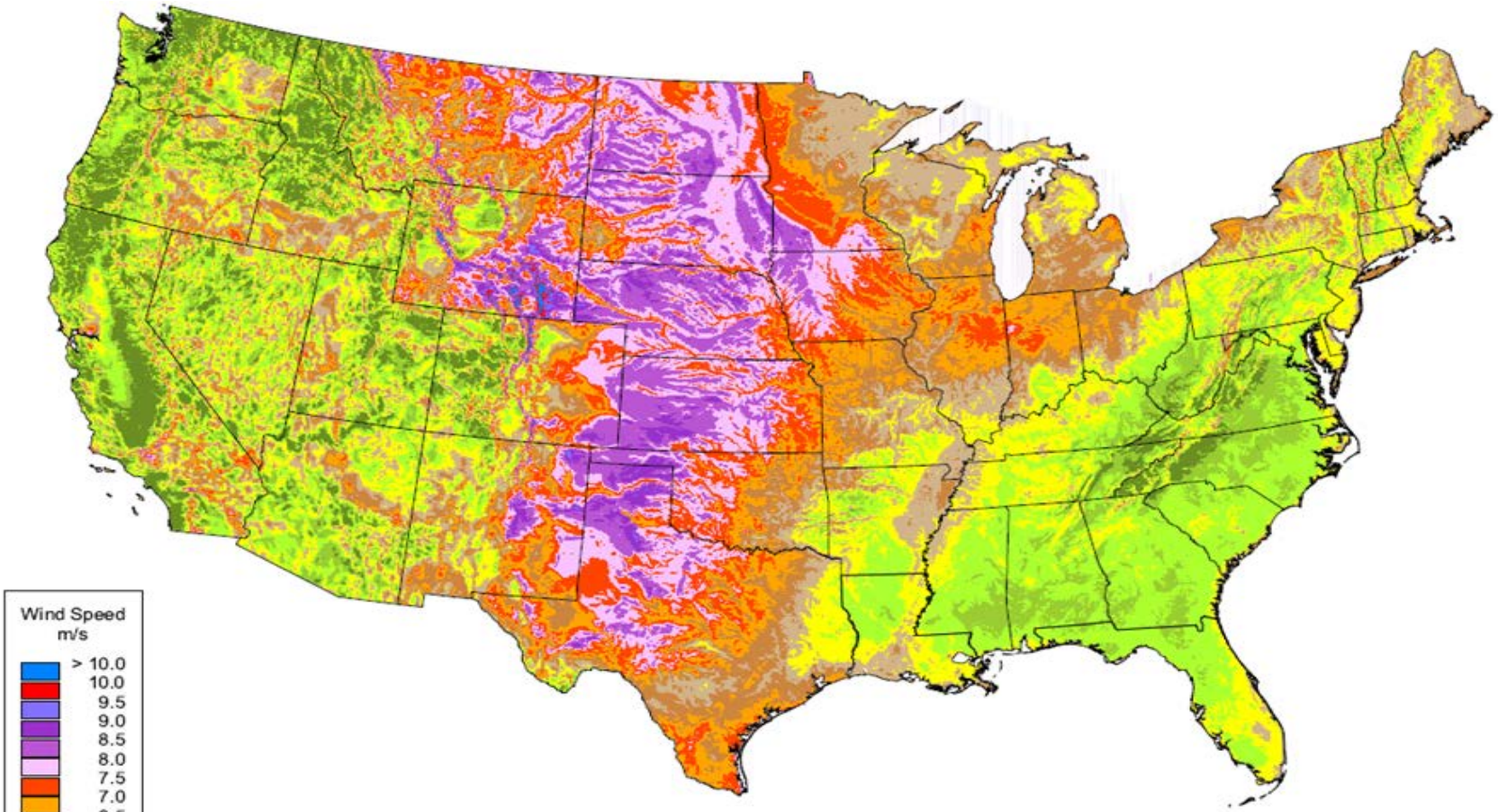
Electric Model: Key Features

- Endogenously builds/retrofits/retires capacity in each model time period according to the economics
  - Coal (+ retrofit to gas, biomass, CCS, co-firing, heatrate improvements), Gas NGCCs, Gas Combustion Turbines, Nuclear, Hydro, Geothermal, Wind (Onshore, Offshore), Solar (CSP, PV, Rooftop PV), Diesel/Oil, Coal/Gas with CCS, new biomass
- Endogenously builds inter-state transmission if needed and economic
- We select representative hours to capture load-wind-solar correlations across the year
  - i.e. US-REGEN knows when load is high and there's no wind!
- Based on a dataset of every unit in the country
  - Last updated July 2015

Renewable Resource Data

- Wind resource data from AWS Truepower
  - Based on 2010 meteorology
- Solar resource data from AWS Truepower
  - Separate resource for central station PV/CSP versus rooftop solar
  - Based on 2010 meteorology
- Geothermal resource data based on NREL (2009) estimates for the Western states
  - New potential additions of ~40GW by 2050 (8GW in CA)
  - Assume capacity factor improves from 50% to 80% due to technical progress

Location of Wind Resource by State



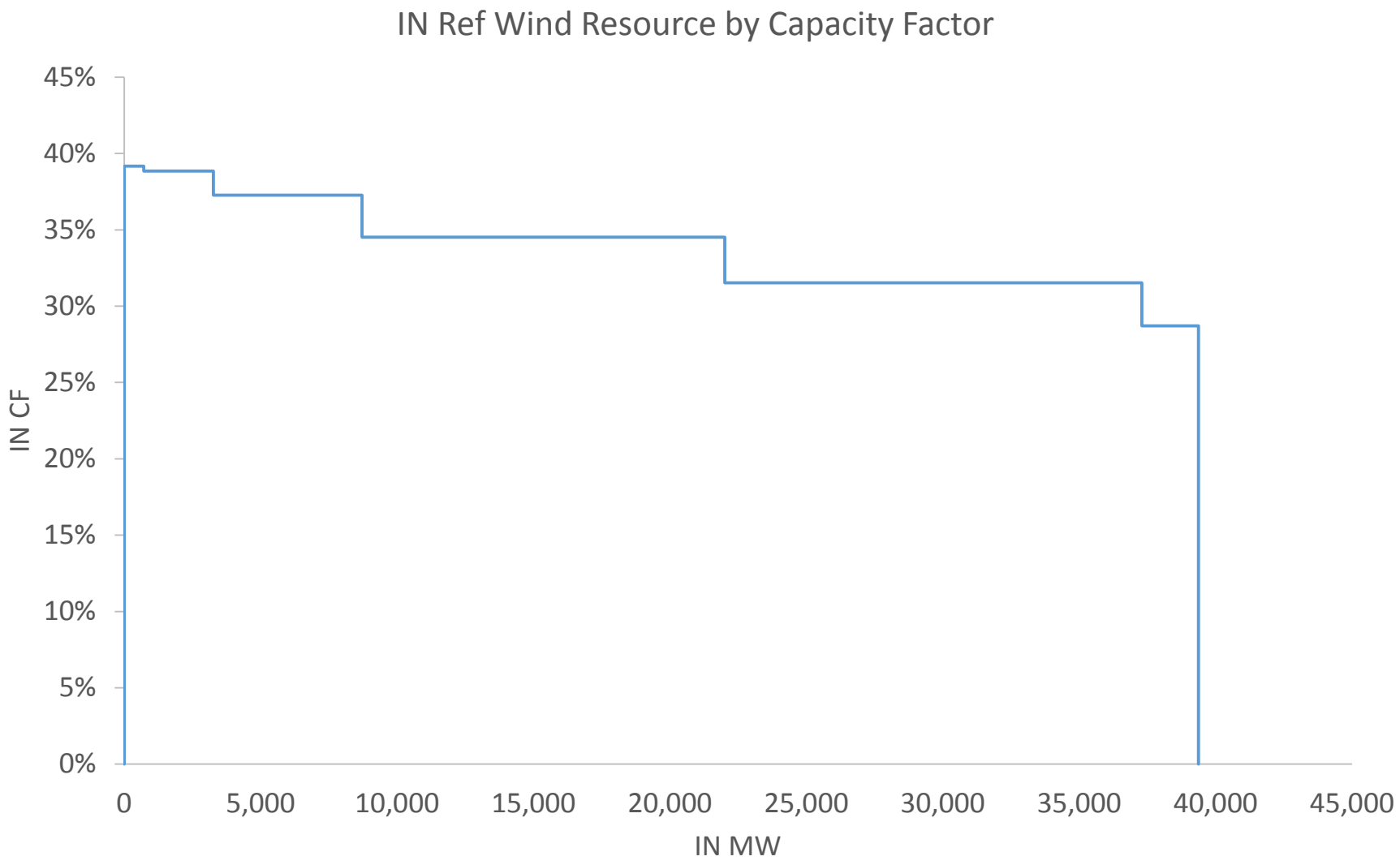
Source: Wind resource estimates developed by AWS Truewind, LLC for windNavigator®. Web: http://navigator.awstruewind.com | www.awstruewind.com. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.

AWS Truewind

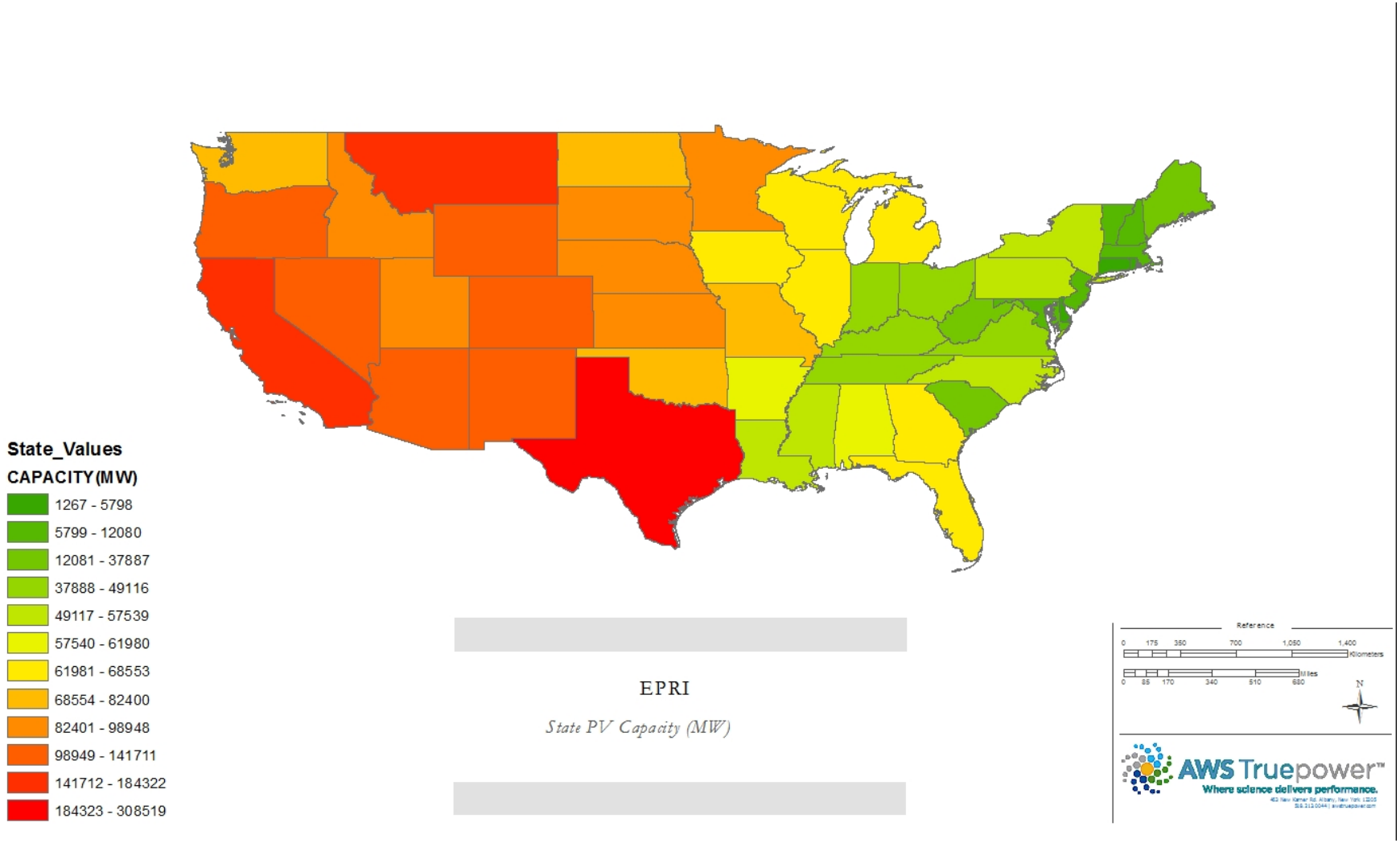
NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Sample Wind Resource for 80/100m Hub Heights



Location of Central PV Resource by State

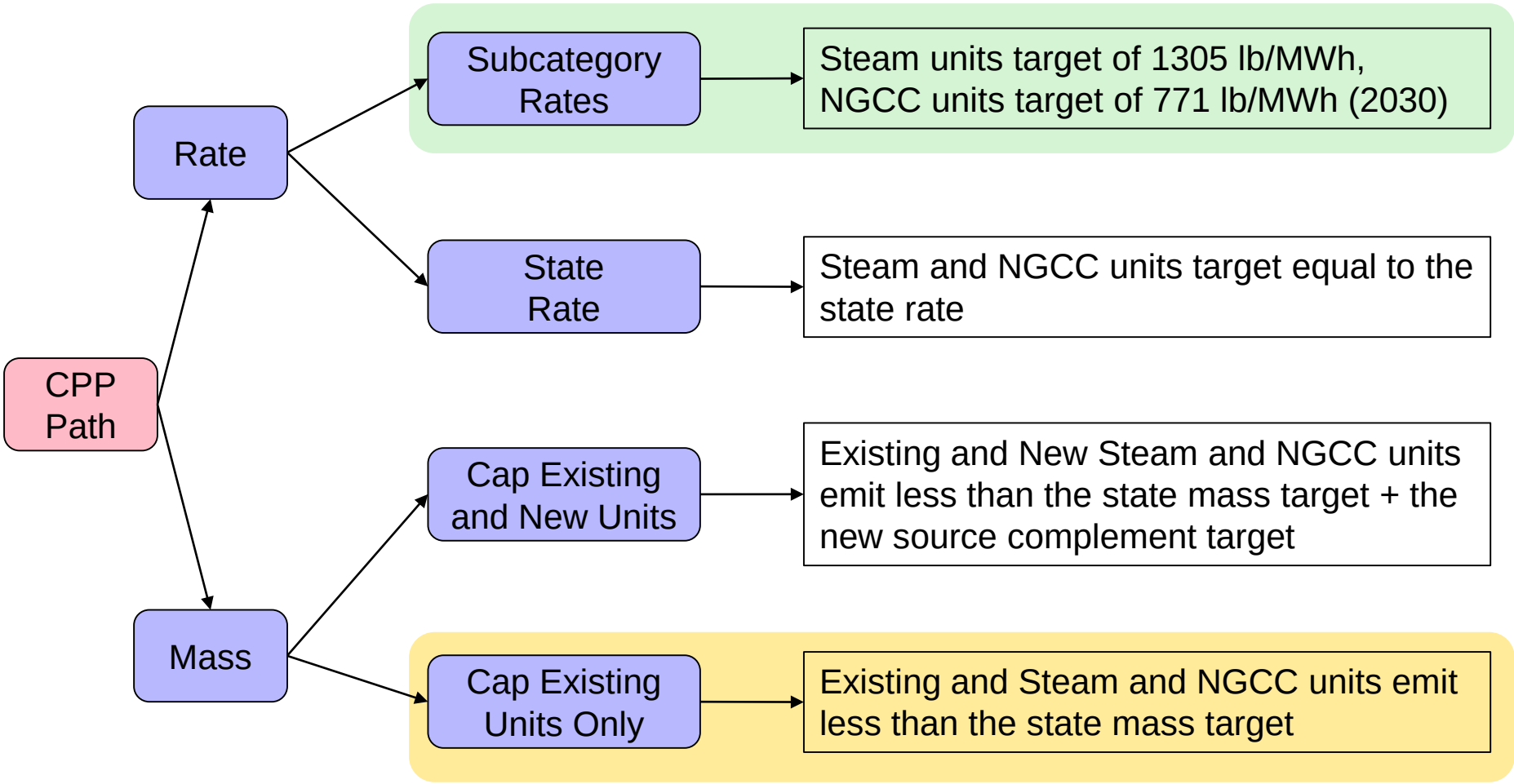


* Assumes the use of up to 1% of each state's available land

US-REGEN vs IPM

- US-REGEN and IPM are both based on the same modeling paradigm
  - Full information, inter-temporal optimization
- Compared to IPM, US-REGEN
  - Uses 48 state-based regions vs IPM's 60+ regions across state lines
  - Aggregates units more, but uses ~ 6 times as many representative hours to capture renewable intermittency better
  - Uses model years 2015, 2018, 2021, 2024, 2027, 2030, 2035, 2040, 2045, 2050; IPM uses 2016, 2018, 2020, 2025, 2030, 2040, 2050
- All models of this type have the same computational limitations; modelers must make tradeoffs as to what elements are important to represent the policy at hand

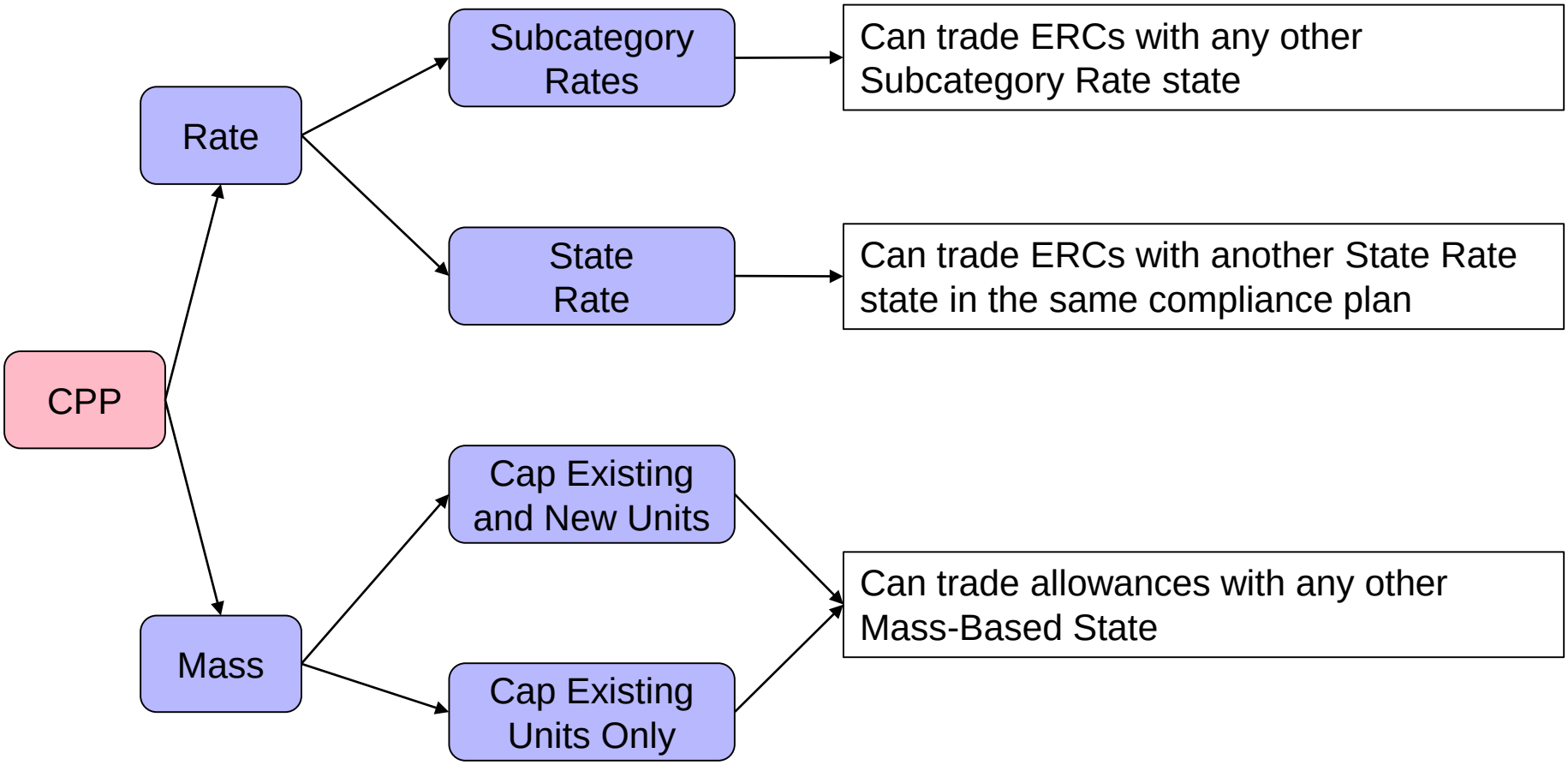
US-REGEN Models Four Main Compliance Pathways



Specific Features for Modeling the Clean Power Plan

- Detailed representation of ERC sources by type
  - Zero, Fossil, Gas-Shift
- Inclusion of output-based set-asides for Existing Mass path
- Endogenous energy efficiency
  - US-REGEN can endogenously build energy efficiency (that counts towards CPP compliance)
  - Current using EPA CPP proposal costs, could revisit
- Detailed renewable representation
  - US-REGEN was built from scratch to give a very detailed representation of wind and solar, and their intermittency
- Other options for coal
  - Co-firing, conversion to biomass or gas, CCS retrofits

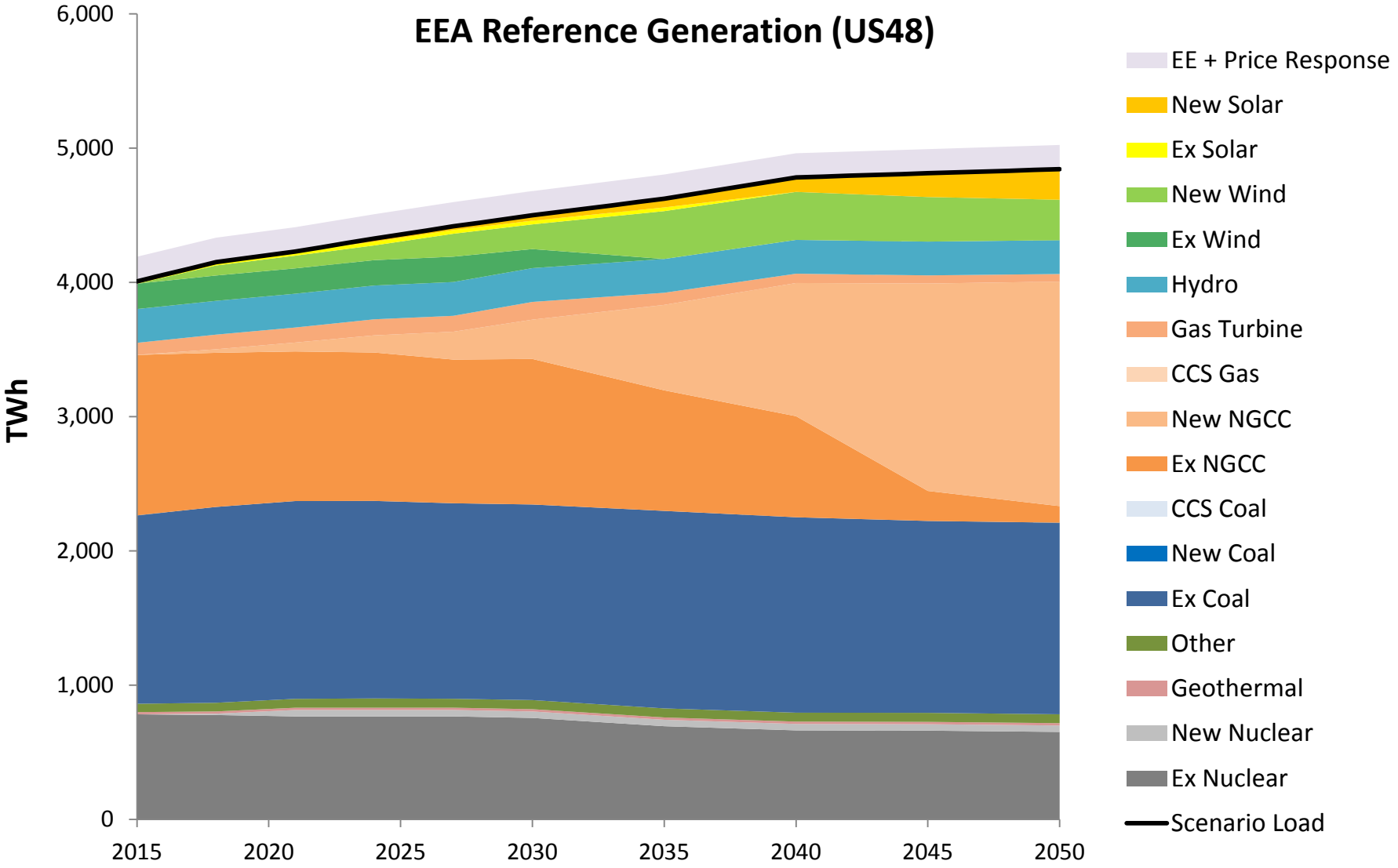
Compliance Pathway Determines Trading Partners



Caveats for Following Model Results

- All analyses preliminary
  - CPP highly complex, still testing our modeling
- Models are highly aggregated simulations but not reality
- No constraints on gas delivery
- Not forecasting
- Choices for states intended to show consequences of alternative pathways in a heterogeneous world, not speaking to what pathways states may choose
- Many uncertainties not explored here
  - Cost of EE and RE
  - Possible future additional CO2 policy/regulation
  - Ability to deploy added transmission

EEA Reference Case + 111(b)

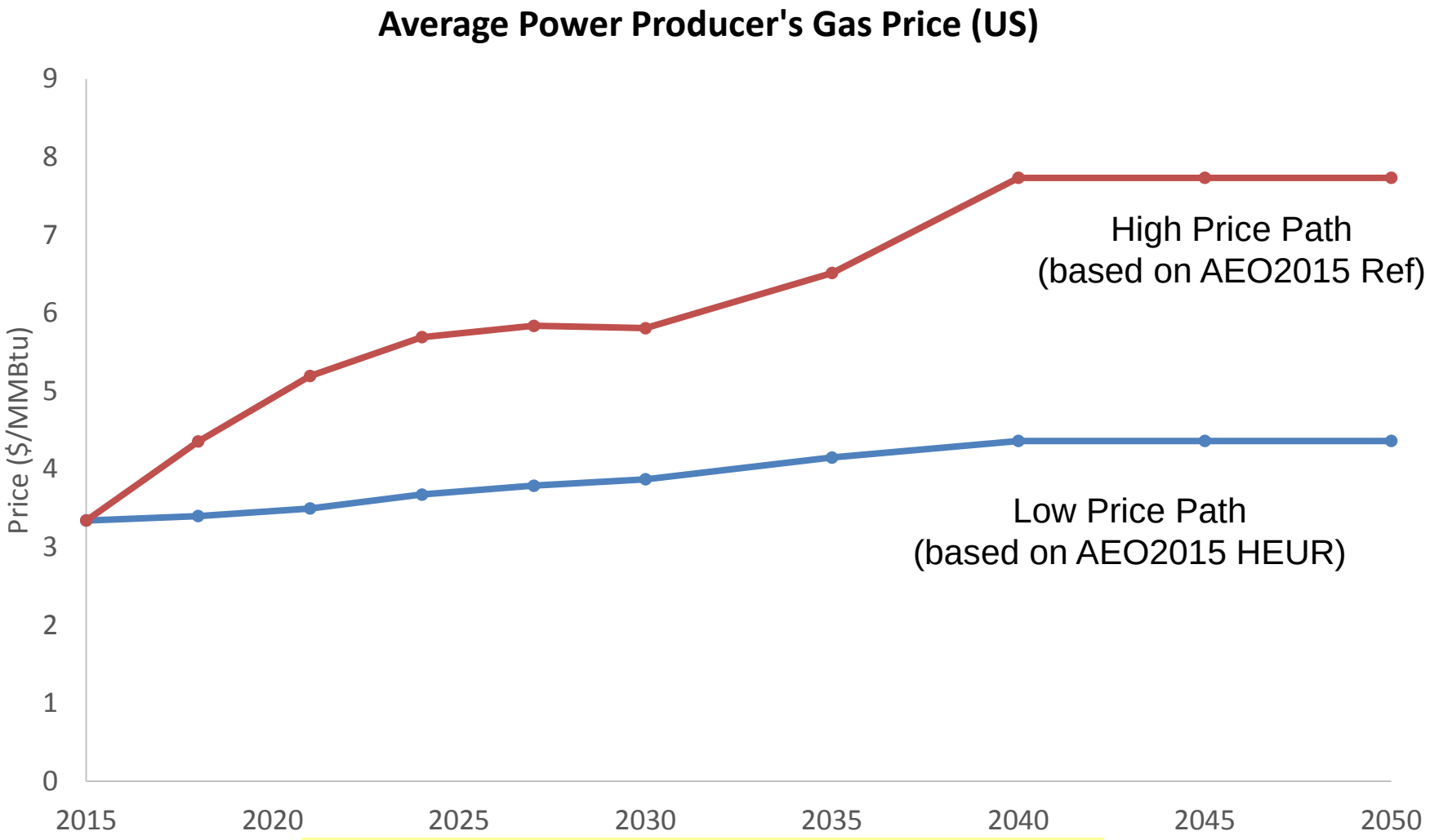


EPRI ELECTRIC POWER RESEARCH INSTITUTE

Island Results

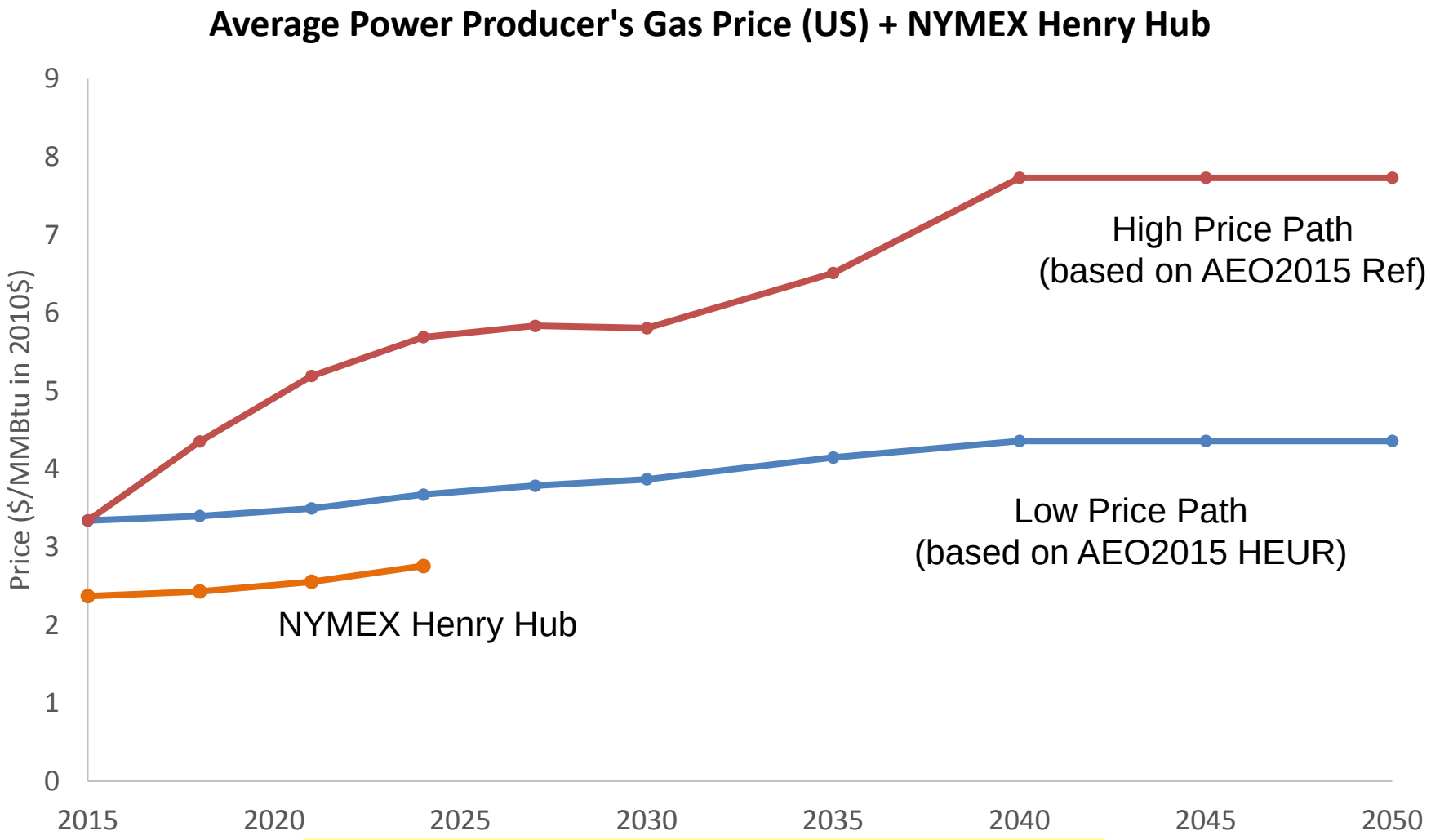
Each state must comply relying solely on resources within its own boundary; power trading limited to that in reference case

Natural Gas Price Uncertainty Represented with EIA's Annual Energy Outlook 2015 "High" and "Low" Paths



Source: U.S. Energy Information Administration's Annual Energy Outlook for 2015

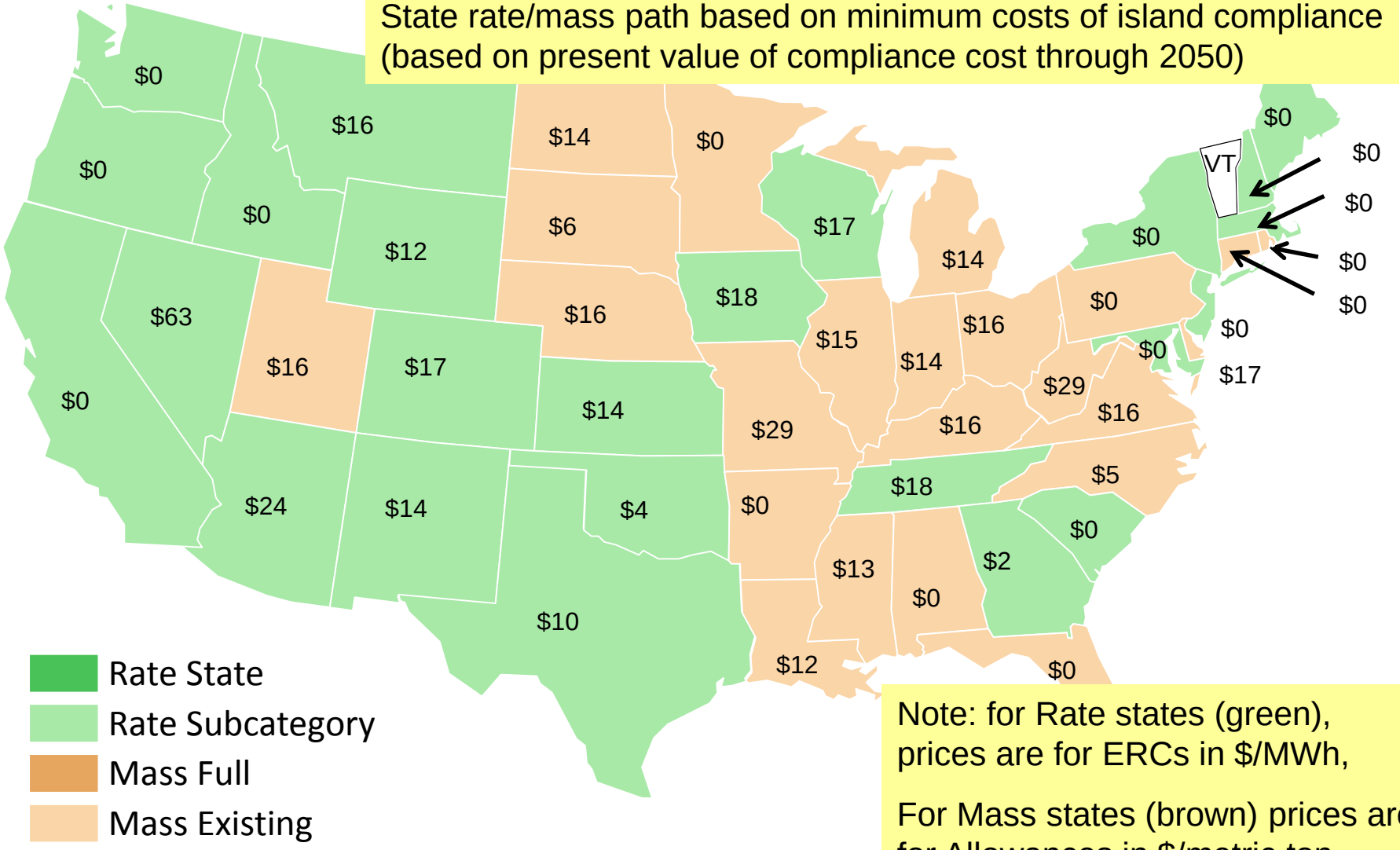
Natural Gas Price Uncertainty Represented with EIA's Annual Energy Outlook 2015 "High" and "Low" Paths



Source: U.S. Energy Information Administration's Annual Energy Outlook for 2015

Emission Rate Credit (ERC)/Allowance Prices for 2030 with Full Island Compliance (Low gas price path)

State rate/mass path based on minimum costs of island compliance (based on present value of compliance cost through 2050)

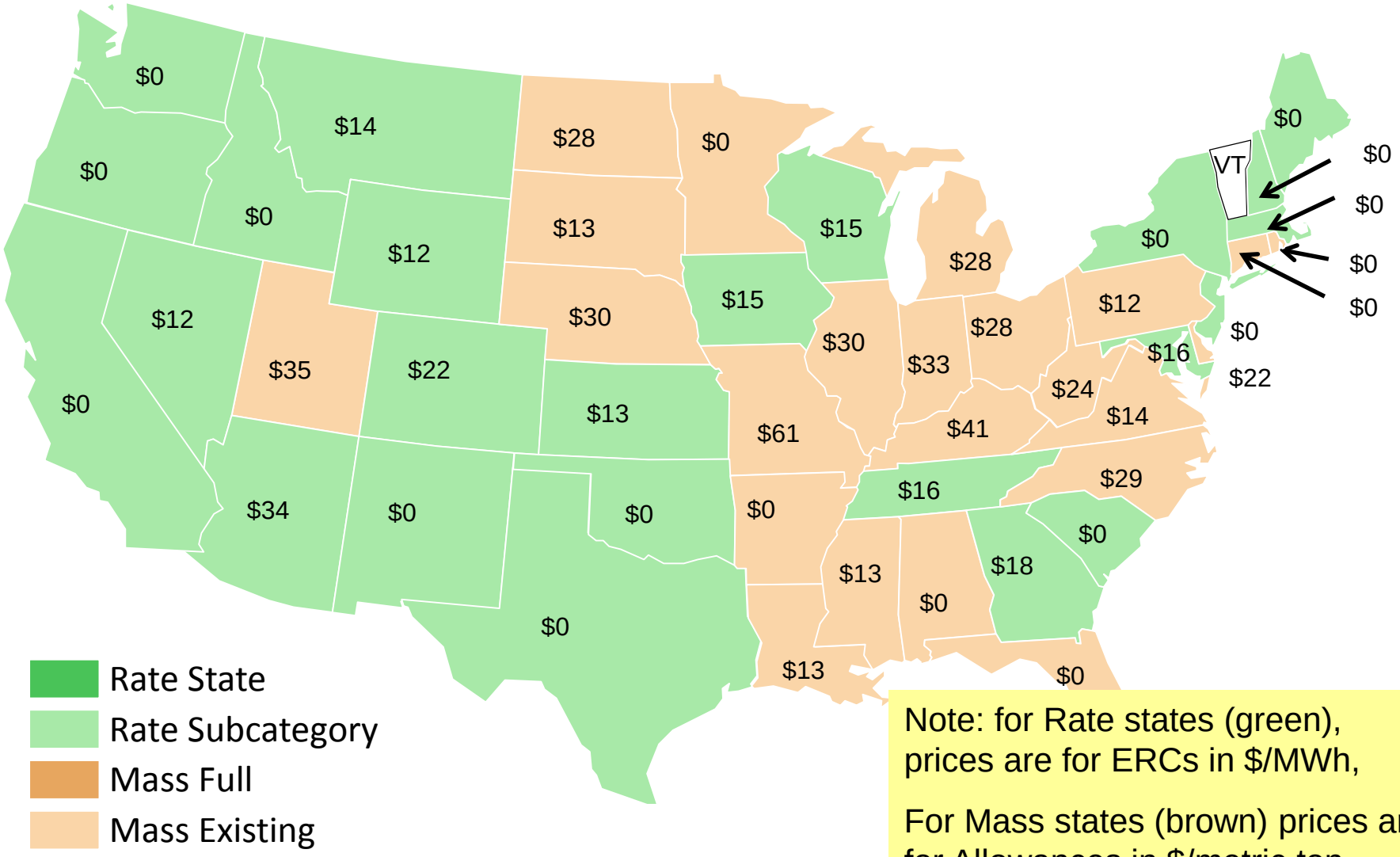


Note: for Rate states (green), prices are for ERCs in $/MWh,

For Mass states (brown) prices are for Allowances in $/metric ton

EPRI ELECTRIC POWER RESEARCH INSTITUTE

ERC/Allowance Prices for 2030 with Full Island Compliance (High gas price path)



Note: for Rate states (green), prices are for ERCs in $/MWh,

For Mass states (brown) prices are for Allowances in $/metric ton

EPRI ELECTRIC POWER RESEARCH INSTITUTE

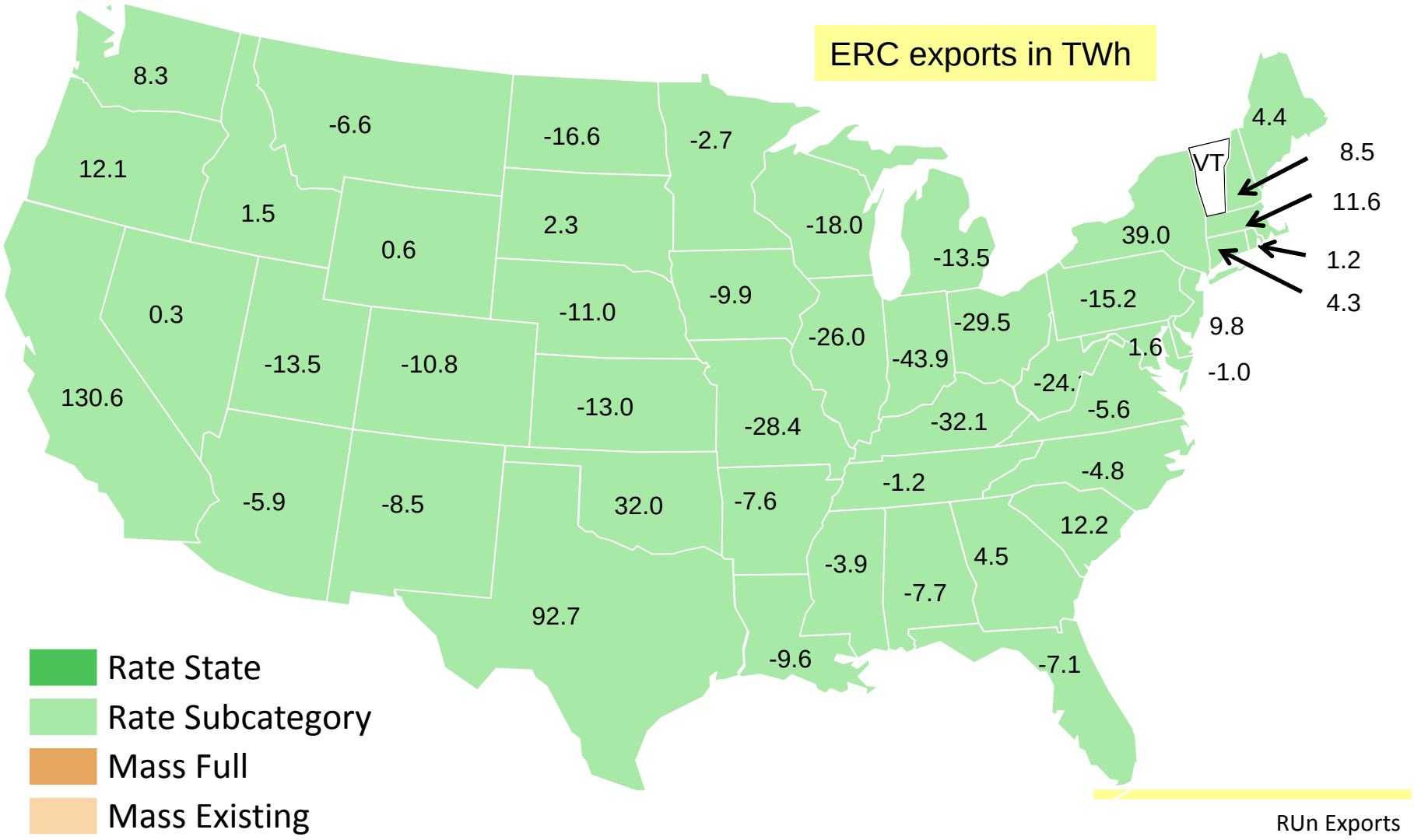
Observations

- Simple economics of rate vs mass:
  - rate compliance achieved with investment in renewables (wind) and energy efficiency, gas redispatch
  - mass compliance achieved with more gas generation
- Zero prices imply states are in compliance in 2030 (though possible need some effort to comply in other time periods)
- Low prices driven by ease of compliance, in turn driven by
  - Low price of natural gas
  - Low incremental cost of wind (in high-wind states)
  - Energy efficiency credits from existing EE programs
  - Announced/expected post 2012 coal retirements
- Many states at/near compliance for both Rate and Mass paths

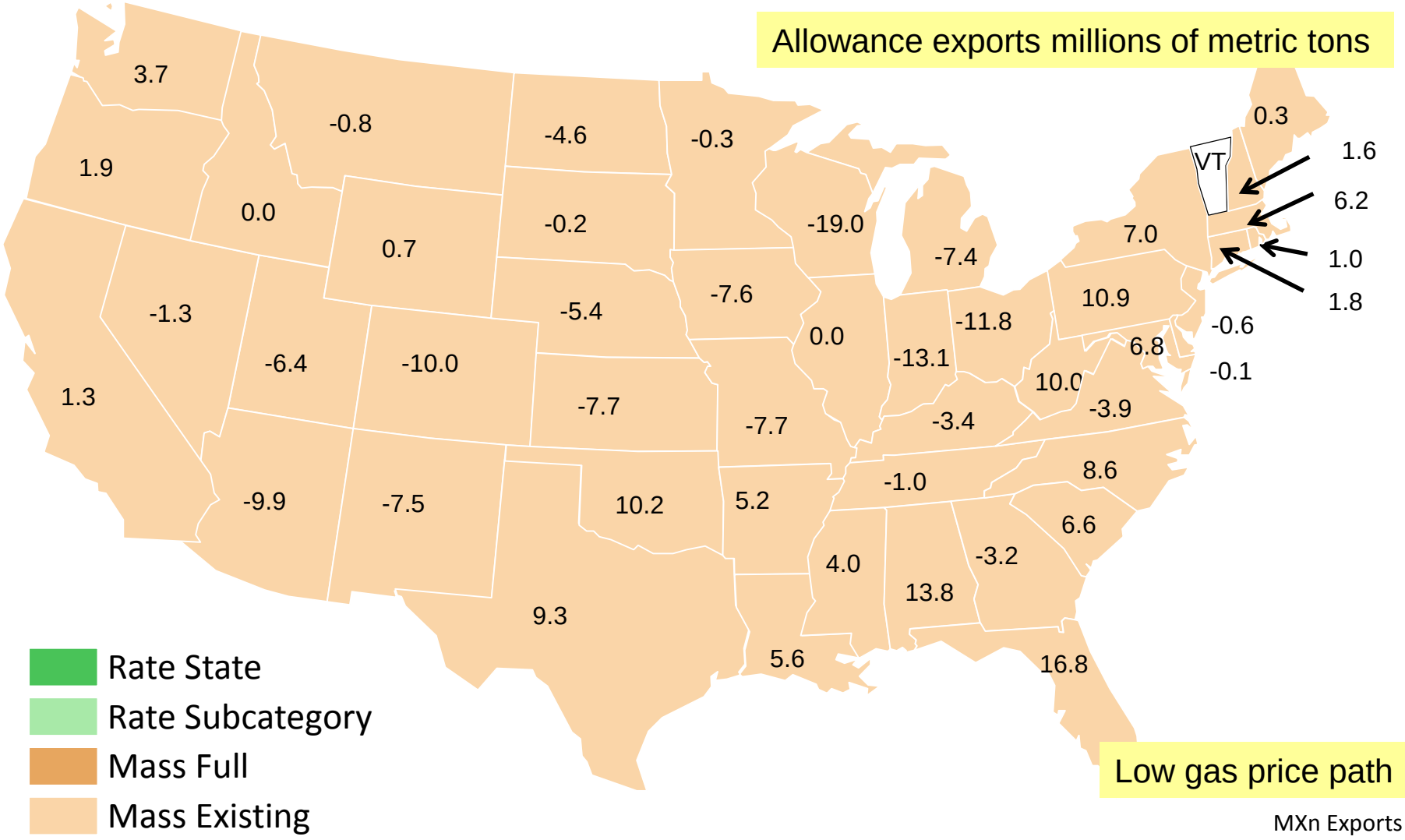
National Uniform-Pathway Results

All states choose the same compliance pathway

2030 Net ERC Exports if All States Choose Sub Category Rate Path and Trade ERCs (ERC price = $10.96/MWh)

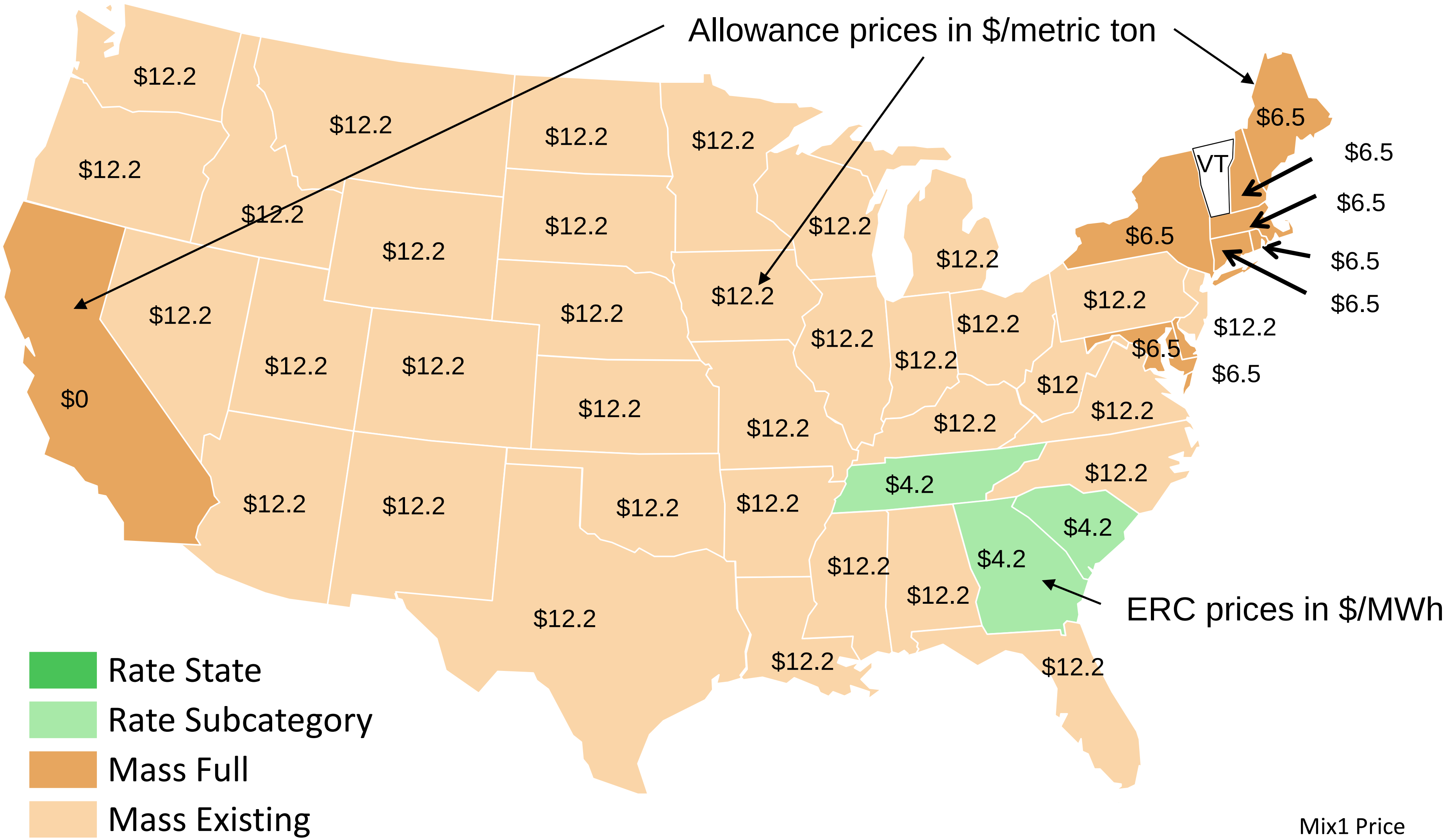


2030 Net Emission Allowance Exports if All States Choose Existing Mass Path (EA price = $12.49/metric ton)



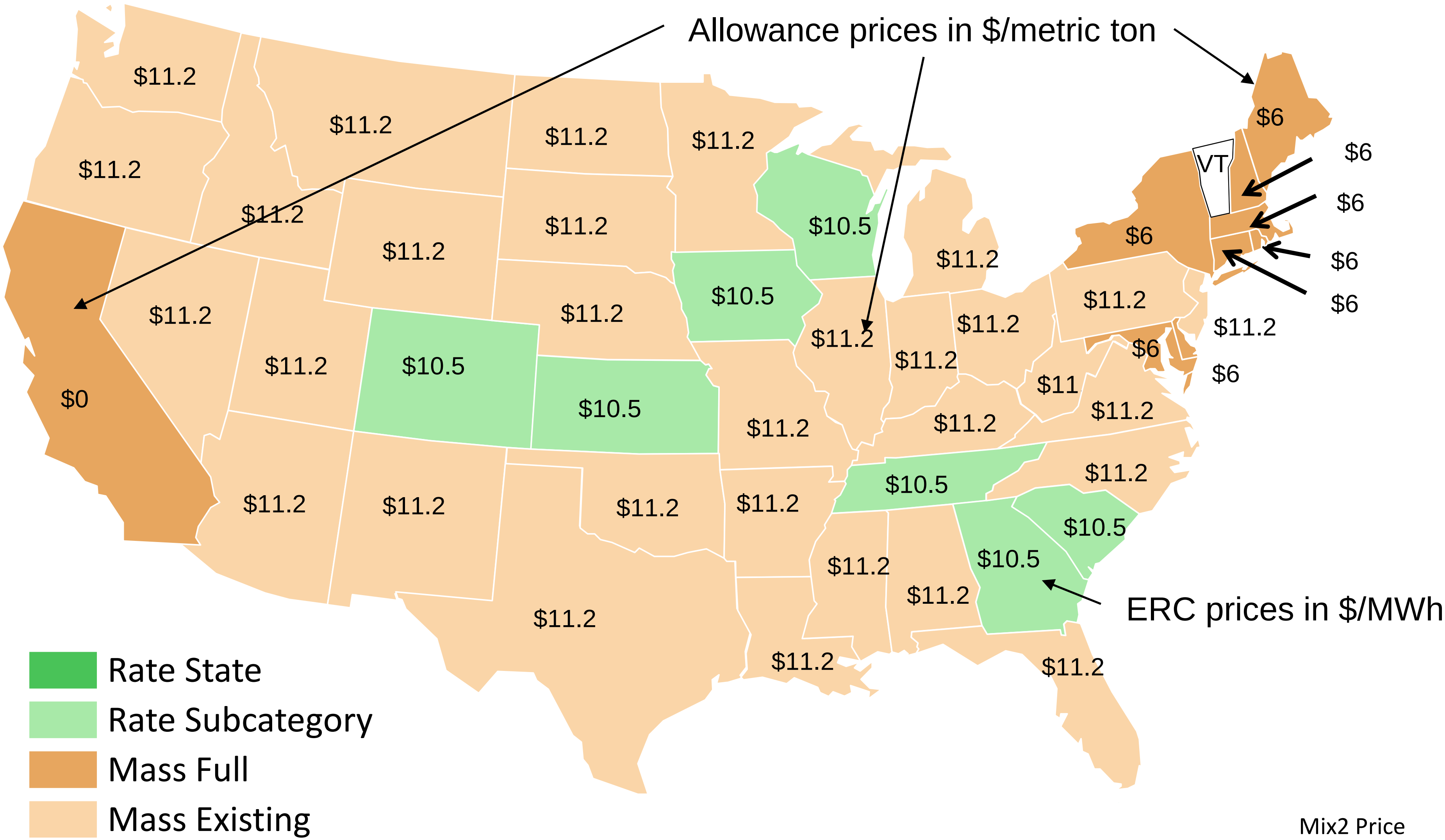
Trading Results Sensitive to National Mix of Pathways

2030 Mix1 ERC/Allowance Pricing with Low Gas Prices



EPRI ELECTRIC POWER RESEARCH INSTITUTE

2030 Mix2 ERC/Allowance Pricing with Low Gas Prices



EPRI ELECTRIC POWER RESEARCH INSTITUTE

Observations

- Mix scenarios are illustrative samples of many possibilities
- Assume national markets for ERCs and Allowances
- ERC price if only new-nuclear states choose Rate is low, but that price may invite other state to “go rate”
- Mix2 shows more realistic set of ERC/Allowance prices
- Many states nominally committed to mass path through existing state polices, e.g., California and RGGI states, would be in compliance with the CPP by choosing rate pathway
- Reasonable variation in future natural gas prices has greater impact on costs than the Clean Power Plan

Strategic Insights

- Key decisions for states are Rate vs. Mass, but also reliance on participation in the market
- Some states appear to have lower costs with Rate, some for Mass, no single universal lowest-cost choice
- Some states may be net beneficiaries of the CPP
- Trading creates value on both sides of the transaction
- The future matters
  - Natural gas prices
  - Renewable and EE costs
  - Market scope and depth
    - Supply/demand for ERCs and Allowances depends on individual state choices for Rate vs. Mass

Together…Shaping the Future of Electricity