

# Challenges in Modeling Rate vs. Mass Pathways for CPP Compliance

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**MPCA Clean Power Plan Stakeholder  
Technical Meeting**  
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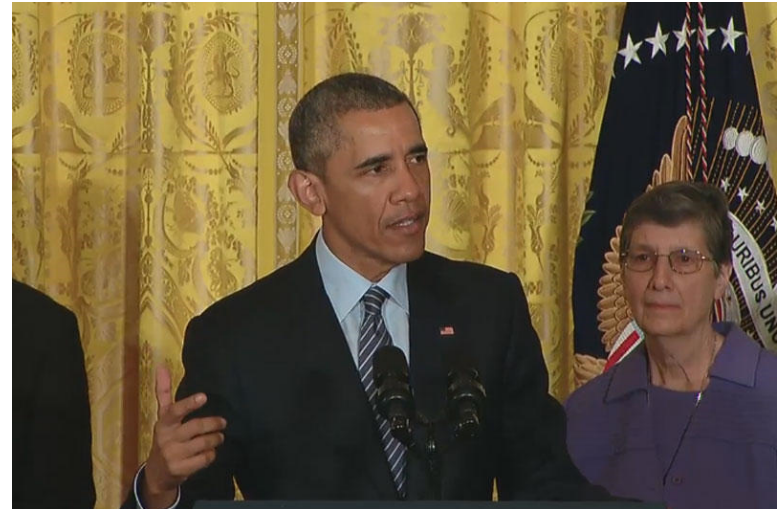
# How Did We Get Here?



Courtesy of Nathan Richardson – Resources for the Future

# Clean Air Act (CAA) Final Rules

- September 20, 2013 – Clean Air Act (CAA) 111(b) proposed rule issued – Applies to new, modified and reconstructed generating units
- June 2, 2014 – Clean Air Act (CAA) 111(d) proposed rule issued – Applies to existing sources (aka “**Clean Power Plan**”)
  - Over 4.3 million comments



**August 3, 2015 – Final Rules issued: CAA 111(b) and 111(d), and Federal Implementation Plan for 111(d)**

# How Did We Get Here?

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## Litigation Update:

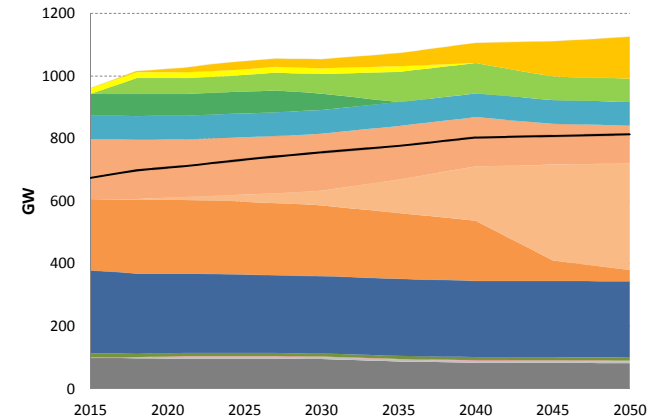
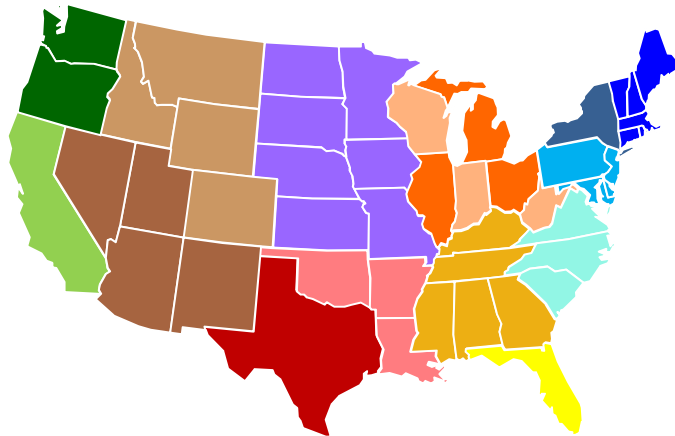
- Immediately following formal release of the CPP multiple states and other stakeholders filed suit in DC District Court to block its implementation (with other states and stakeholders joining the case to support the CPP)
- Oral arguments starting the trial scheduled for June 2, 2016
- On February 9th the Supreme Court “stayed” the CPP pending the final outcome of the ongoing litigation
- This means that the initial requirements of the CPP are delayed for at least two years. Impact on the survival of the rule and final schedule are uncertain

## EPRI Clean Power Plan Analysis

- Started over three years ago, before there was a Clean Power Plan, thanks to member foresight
- One year spent reconstructing the US-REGEN model to better capture CPP nuances
- Now working with over 30 utilities in EPRI Program 103 to study CPP insights and national outcomes
- Working with another 20 utilities in 8 states to help understand the implications of the CPP for a given state
- Part of the Stanford Energy Modeling Forum – an inter-model comparison exercise to compare models of the CPP

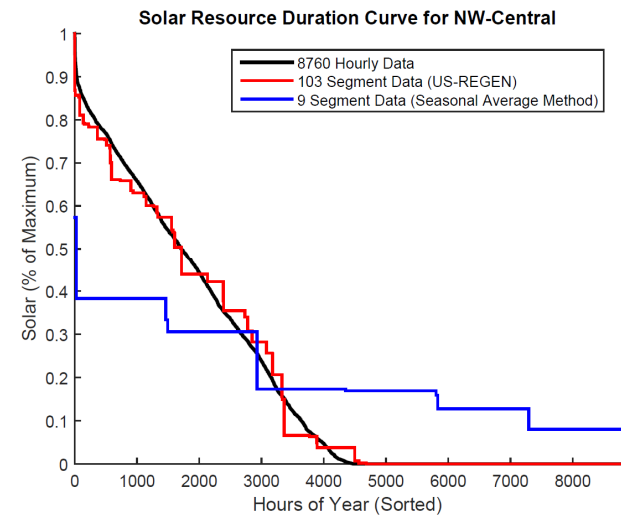
# US-REGEN 48-State Version: EPRI's In-House Electric Sector Model for CPP Modeling

Capacity Expansion Economic Model, Long Horizon to 2050



State-Level Resolution for Policy and Regulation Analysis

Innovative Algorithm to Capture Wind, Solar, & Load Correlations in a Long-Horizon Model



## Electric Model: Key Features

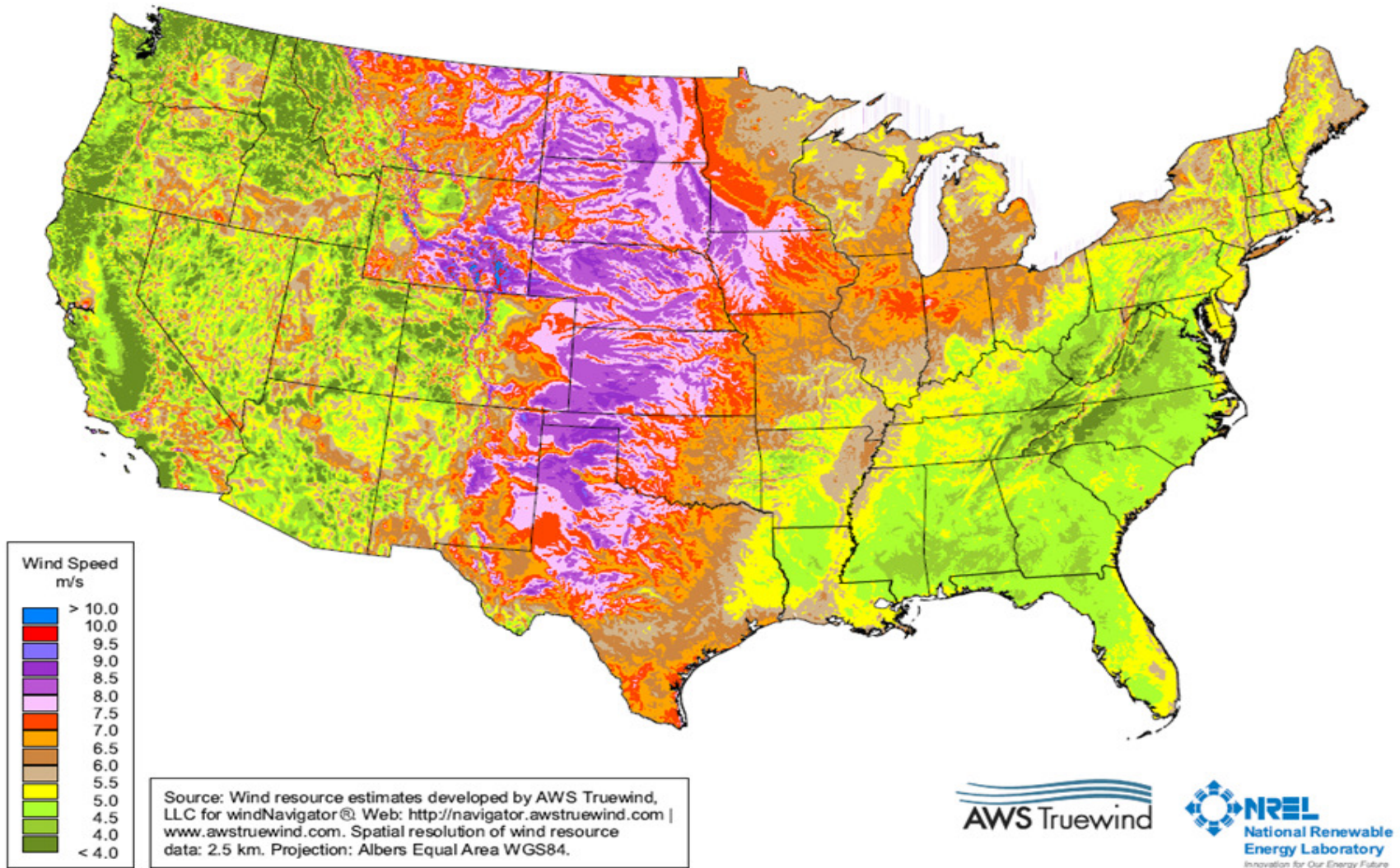
- Endogenously builds/retrofits/retires capacity in each model time period according to the economics
  - Coal (+ retrofit to gas, biomass, CCS, co-firing, heatrate improvements), Gas NGCCs, Gas Combustion Turbines, Nuclear, Hydro, Geothermal, Wind (Onshore, Offshore), Solar (CSP, PV, Rooftop PV), Diesel/Oil, 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 November 2015

## Renewable Resource Data

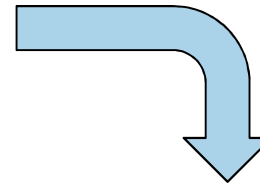
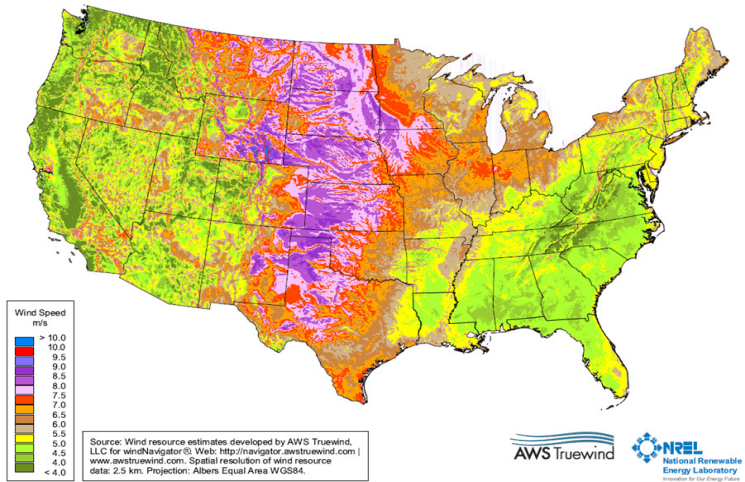
- Wind resource data from AWS Truepower
  - Based on 2010 meteorology
- Solar resource data from AWS Truepower
  - Separate resource for central station PV/CSP versus rooftop solar
  - Based on 2010 meteorology
- Geothermal resource data based on NREL (2009) estimates for the Western states
  - New potential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



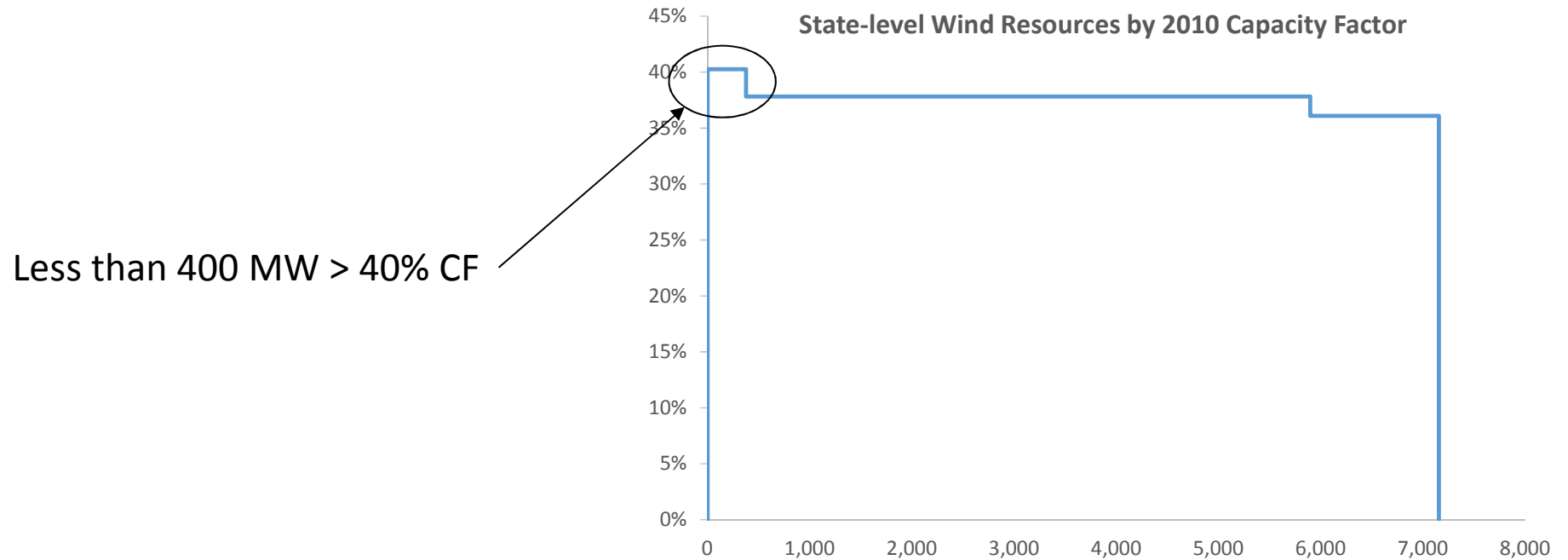
# Location of Wind Resource by State



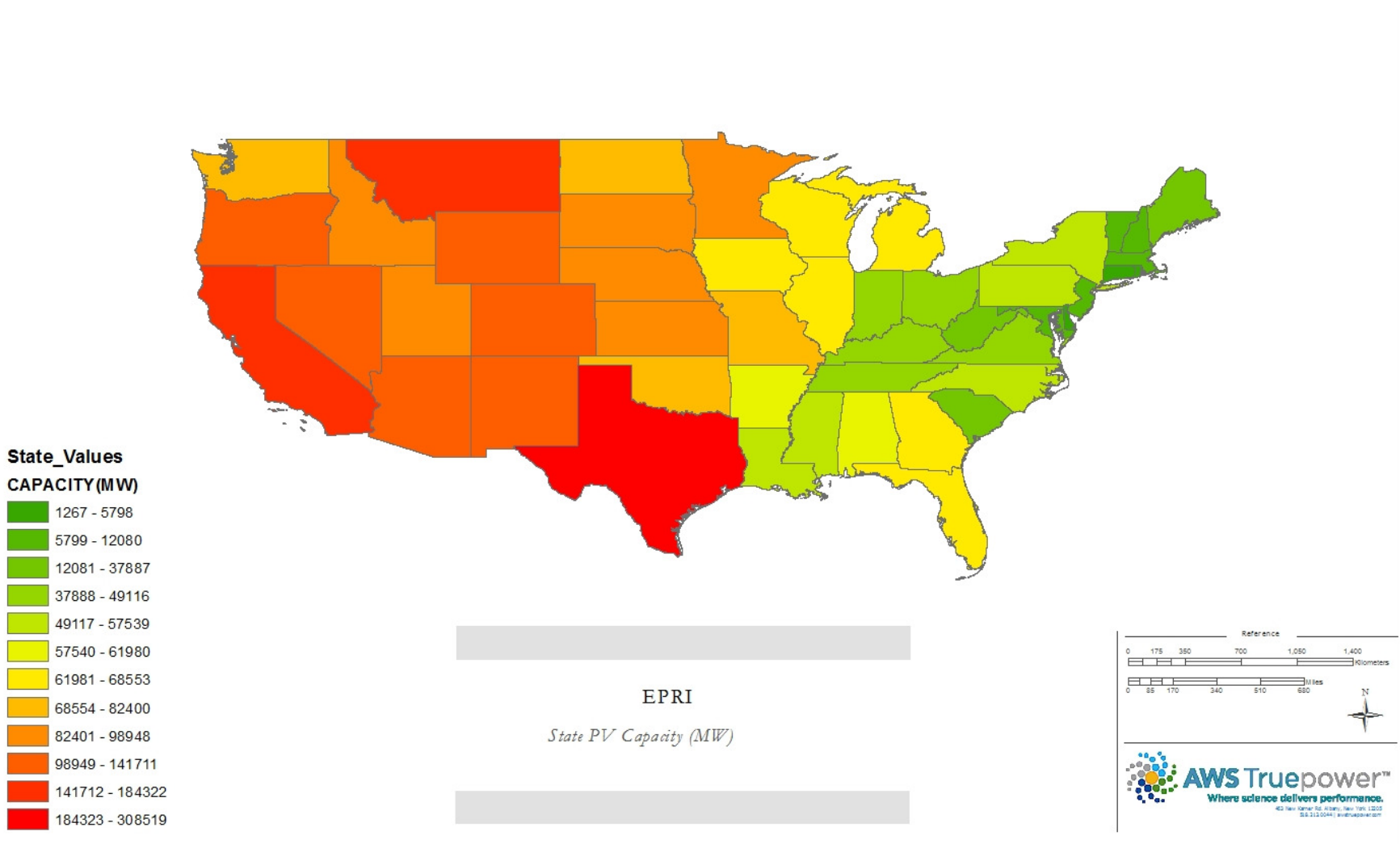
# Location of Wind Resources by State



## State-Level Wind Resource Base



# Location of Central PV Resource by State

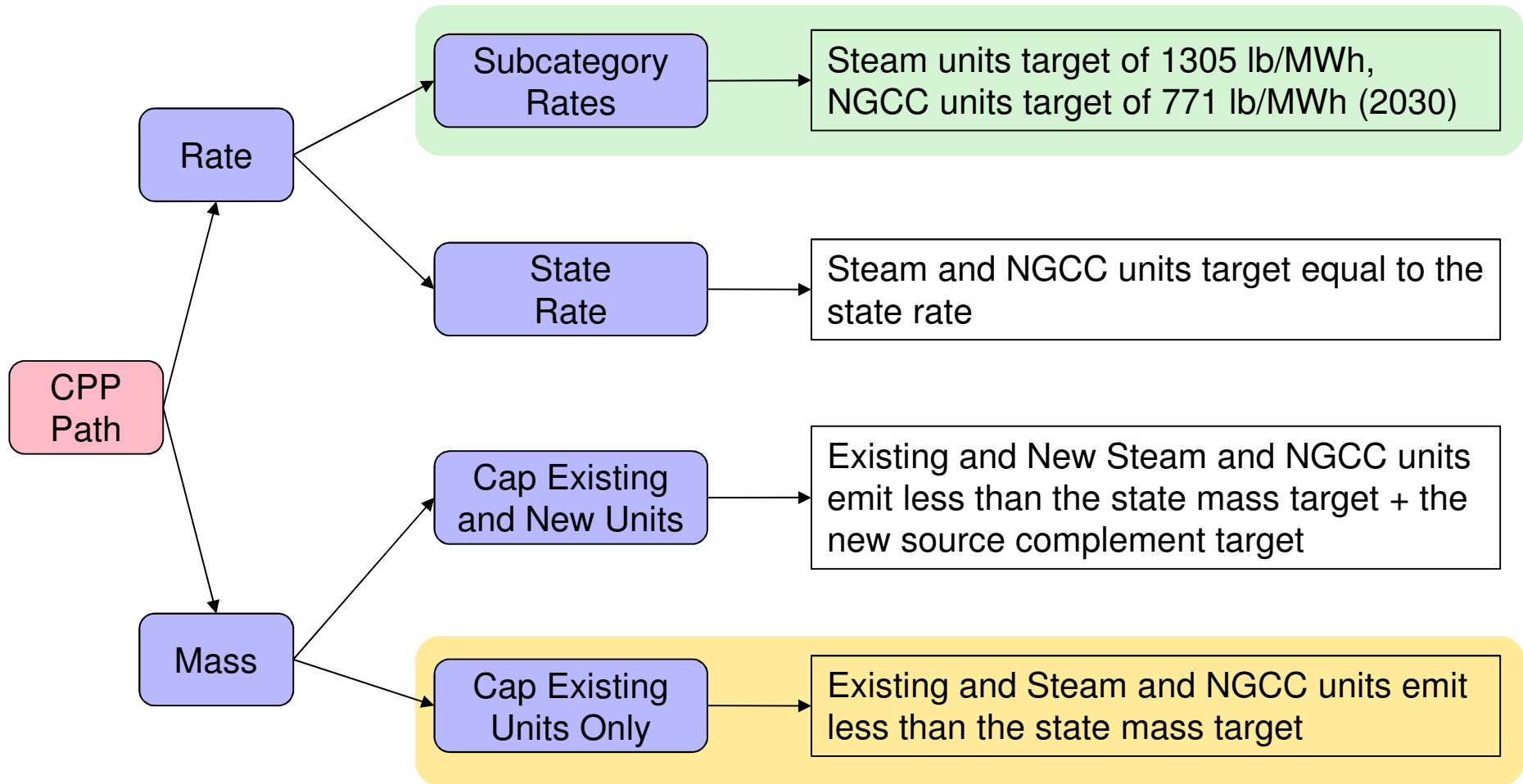


\* Assumes the use of up to 1% of each state's available land

## US-REGEN vs IPM (used by EPA for CPP design, RIAs)

- 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

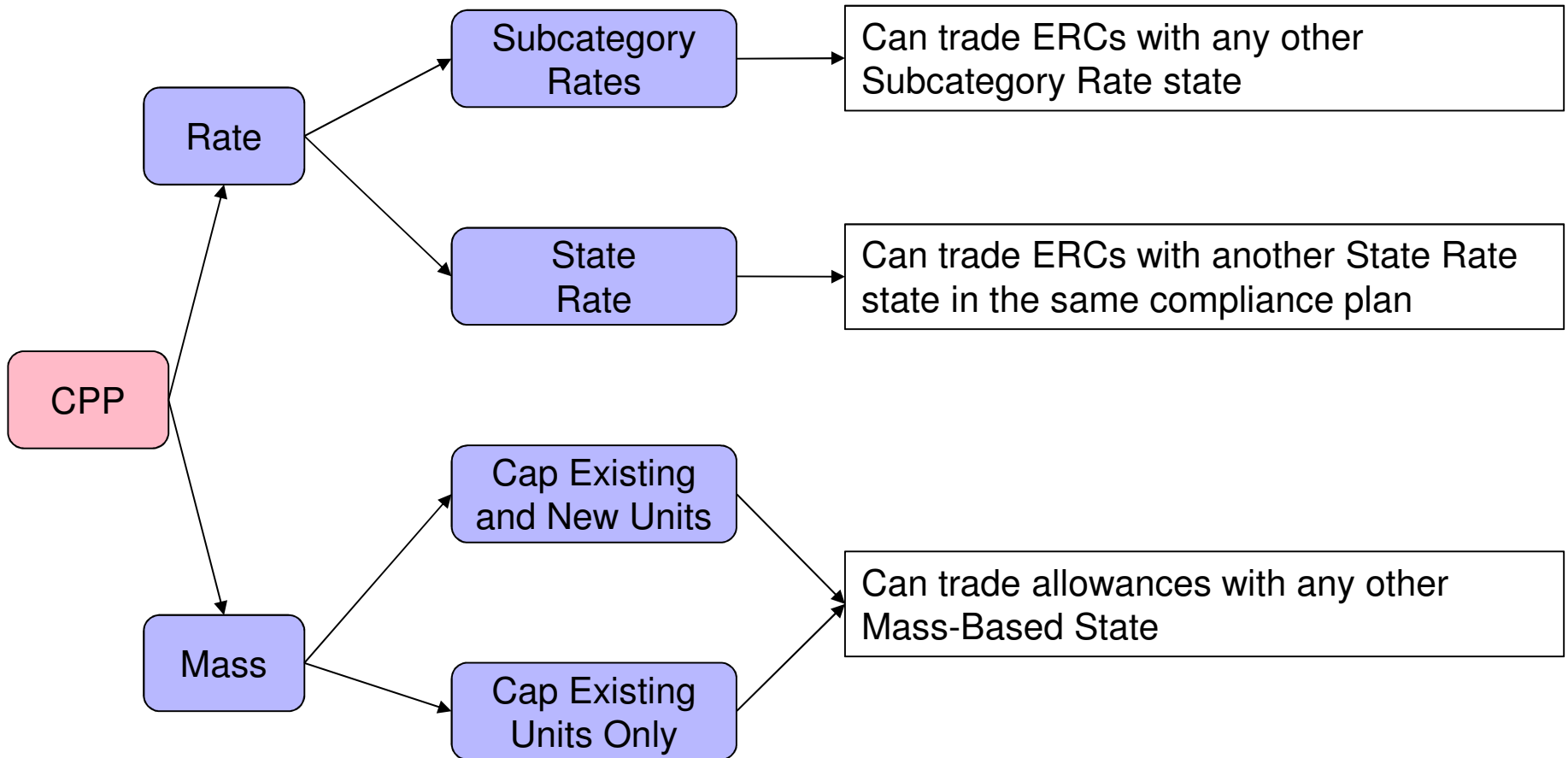
- Detailed representation of ERC sources by type
  - Zero, Fossil, Gas-Shift
- Inclusion of output-based set-asides for Existing Mass path
- Endogenous energy efficiency
  - US-REGEN can endogenously build energy efficiency (that counts towards CPP compliance)
  - Currently using EPA CPP proposal costs, 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

# Types of ERCs that State X can Create

|                         | Z-ERC  | F-ERC   | GS-ERC  |
|-------------------------|--|---|---|
| Description             | Created by new zero CO <sub>2</sub> measures such as RE/EE/NUC/T&D. 1 ERC per MWh. | Created by affected EGUs over-complying vs. target rate.                      | Created by existing NGCCs generating more than their 2012 baseline, per EPA formula                   |
| Geographic Restrictions | Can be created by State X for measures taken in <b>any other rate-based state*</b> | Can be created by State X by over-complying existing EGUs located in State X. | Can be created by State X by existing NGCCs only in State X and ONLY if State X does Subcategory Rate |
| Usage Restrictions      | Can only be used in State X unless inter-state trading allowed                     | Can only be used in State X unless inter-state trading allowed                | Can <b>only be used by steam units</b> in State X [unless inter-state trading allowed???              |

\* May also be created by *new renewable generation* in mass-based states, Canada, or Mexico, provided the power from the units is sold to any rate-based state.

# Compliance Pathway Determines Trading Partners





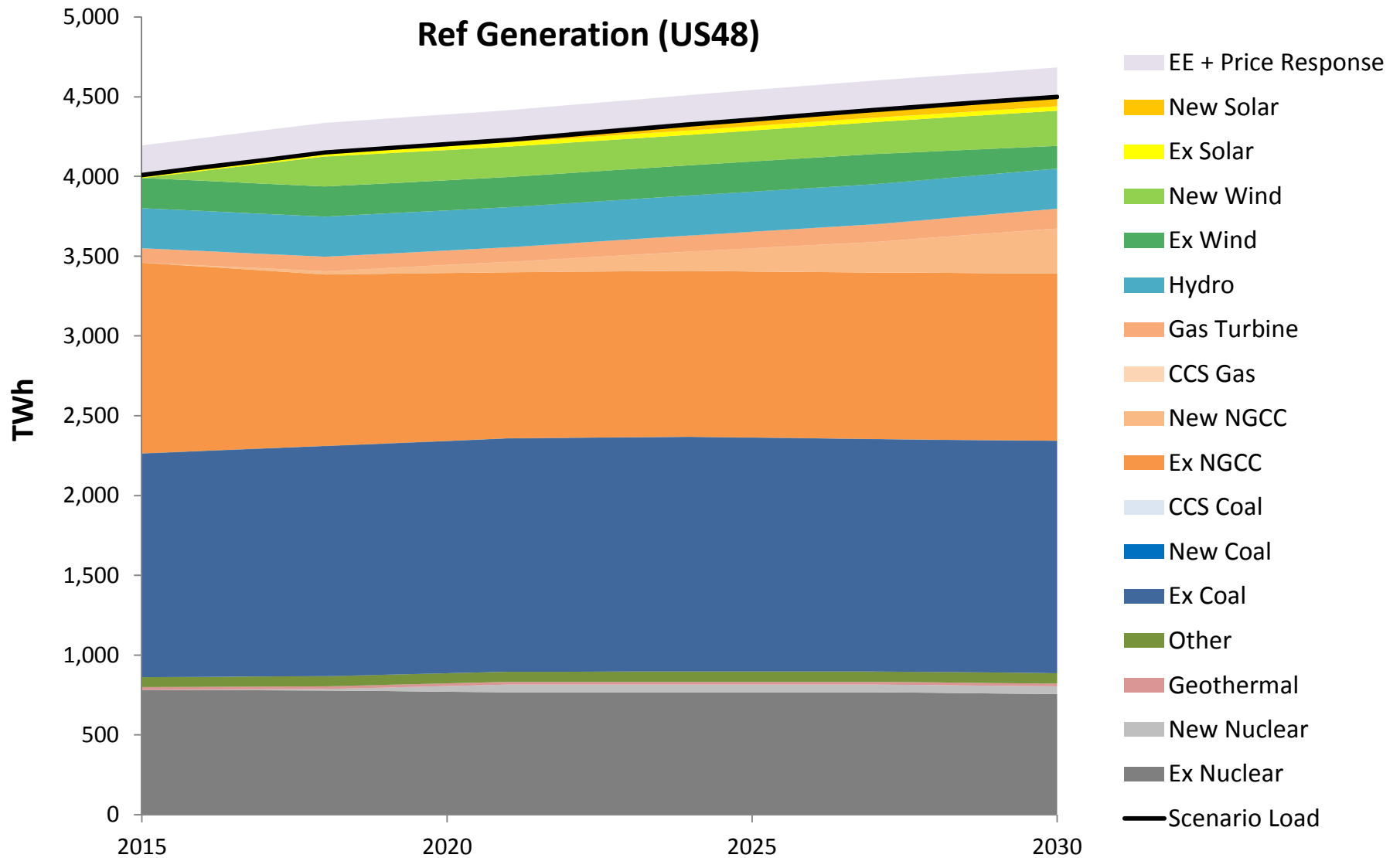
# Caveats for Following Model Results

- 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

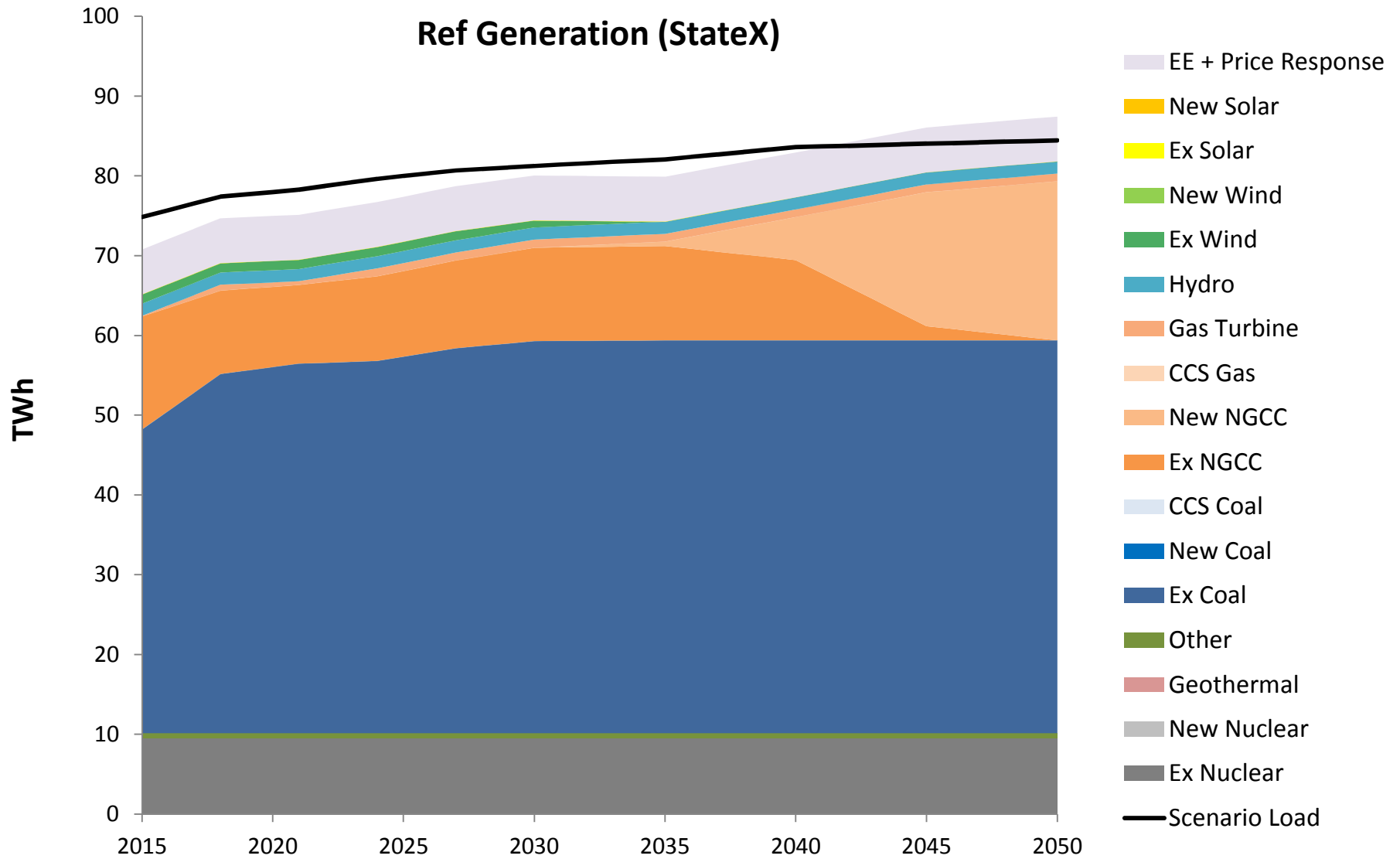
“Essentially, **all models are wrong**,  
but some are useful”.

-- George Edward Pelham Box

# Reference Scenario Provides Point of Reference but is Not a Forecast

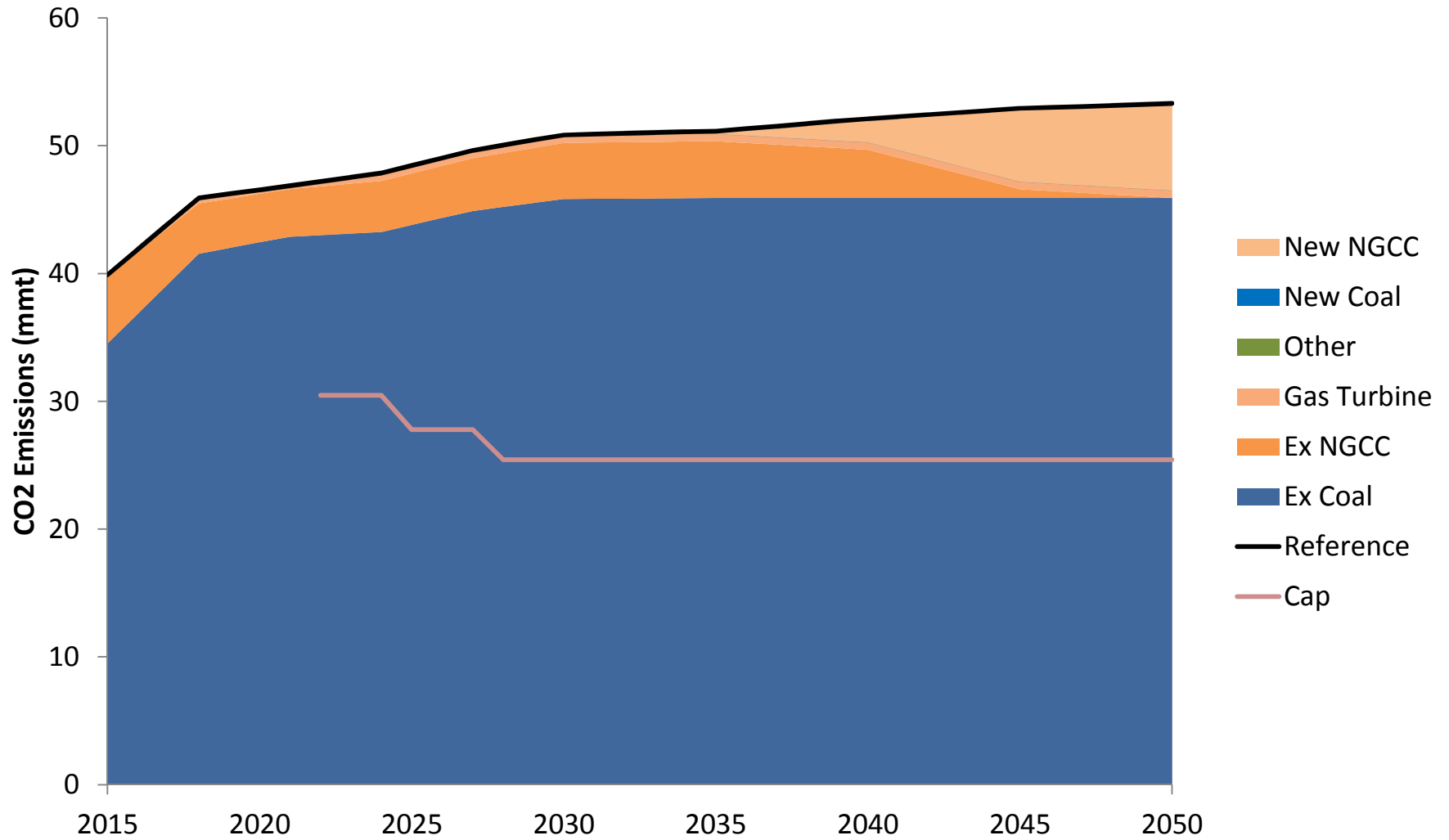


# StateX Reference Scenario



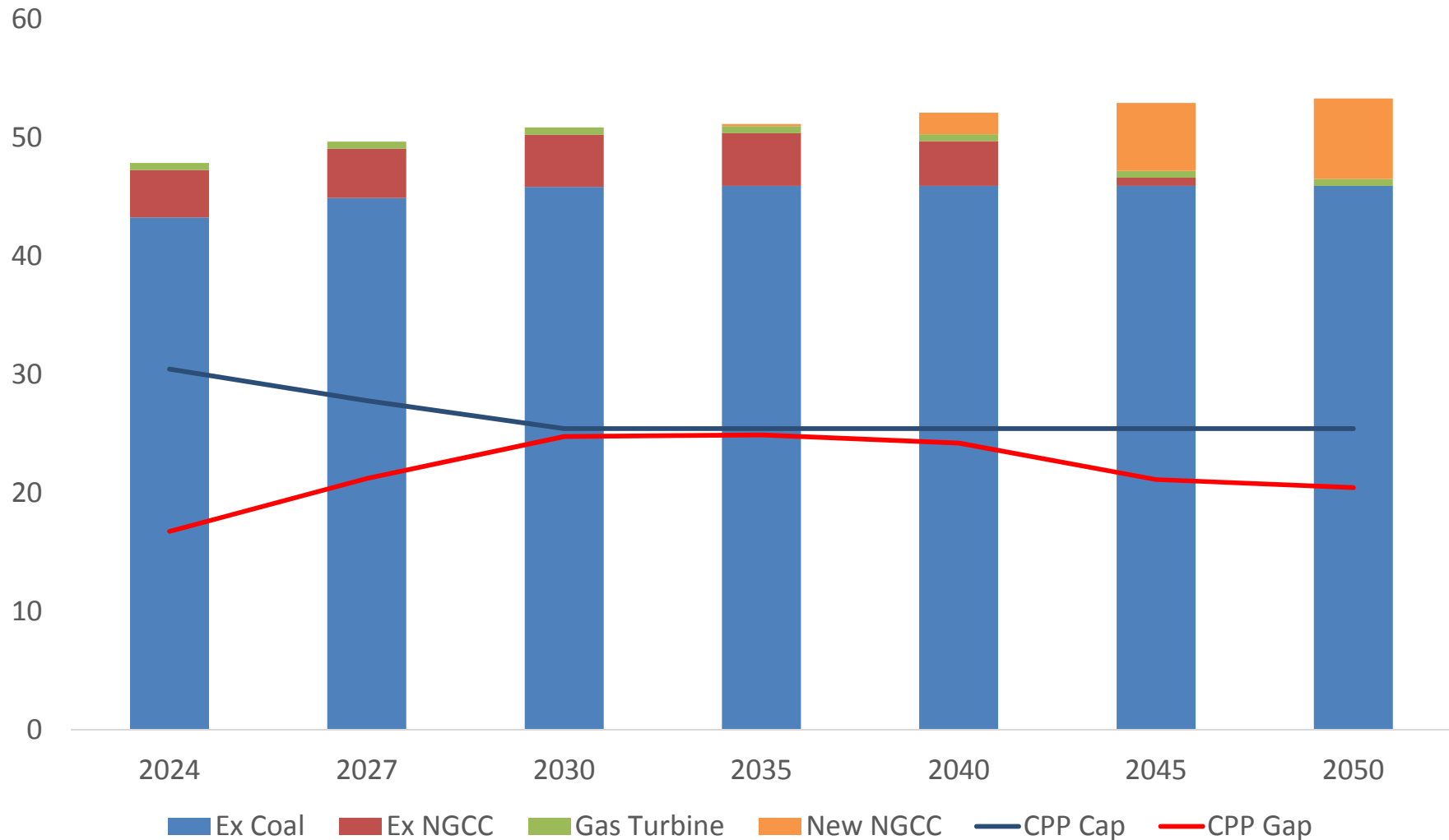
# Emissions vs. the Existing Mass Cap – Not Close

## CO2 Emissions - Ref (StateX)

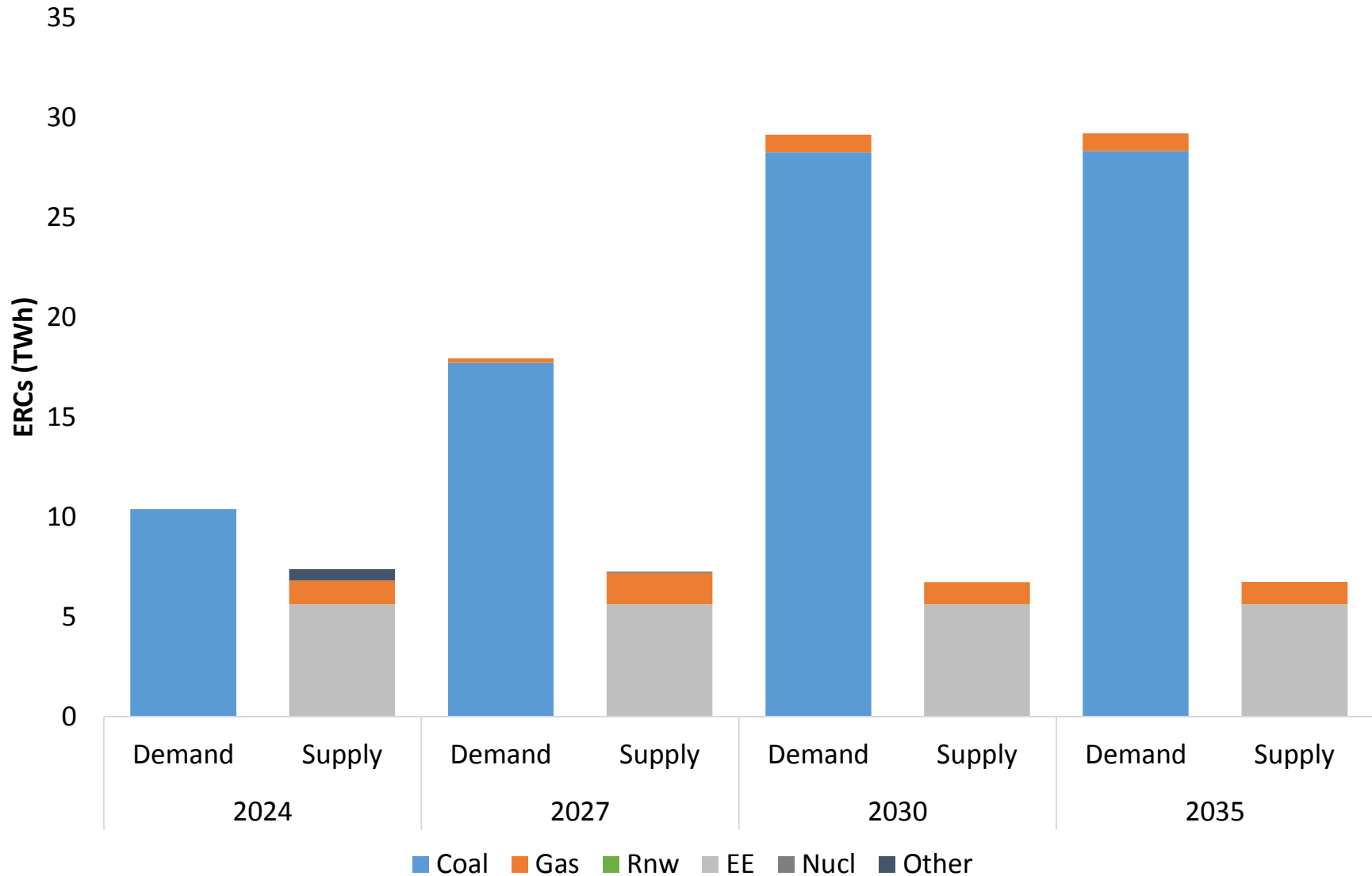


# Mass-Based Compliance Requires Substantial Allowance Purchases to Meet CPP Cap (Existing Mass)

StateX CPP Cap and CO2 by Source (million metric tons)



# Rate-Based Compliance for Reference Generation Requires Substantial ERC Purchases to Meet Target Rate



## Bottom Line

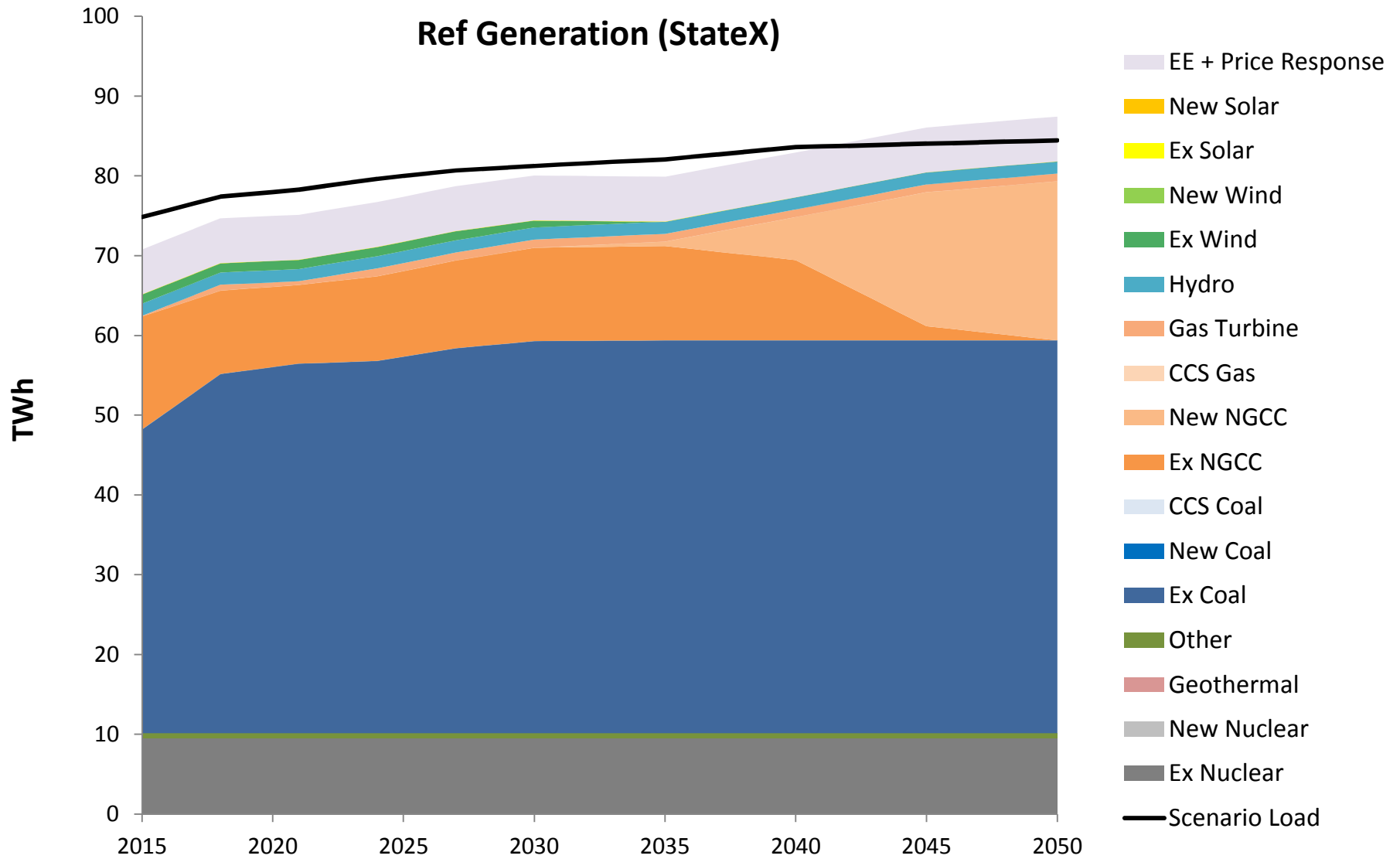
- From a BAU perspective StateX expected to have a heavy lift in meeting the CPP guidelines for either a Rate or a Mass approach
  - Coal key source of power
  - No major retirements of coal expected
  - Relatively low renewable expansion in reference scenario
- To meet CPP guidelines the state must (in combination)
  - Reduce coal output
  - Increase NGCC output
  - Find additional sources of power
    - New NGCC, wind and/or energy efficiency
    - Purchase ERCs or Allowances from other states
    - Import more power from other states



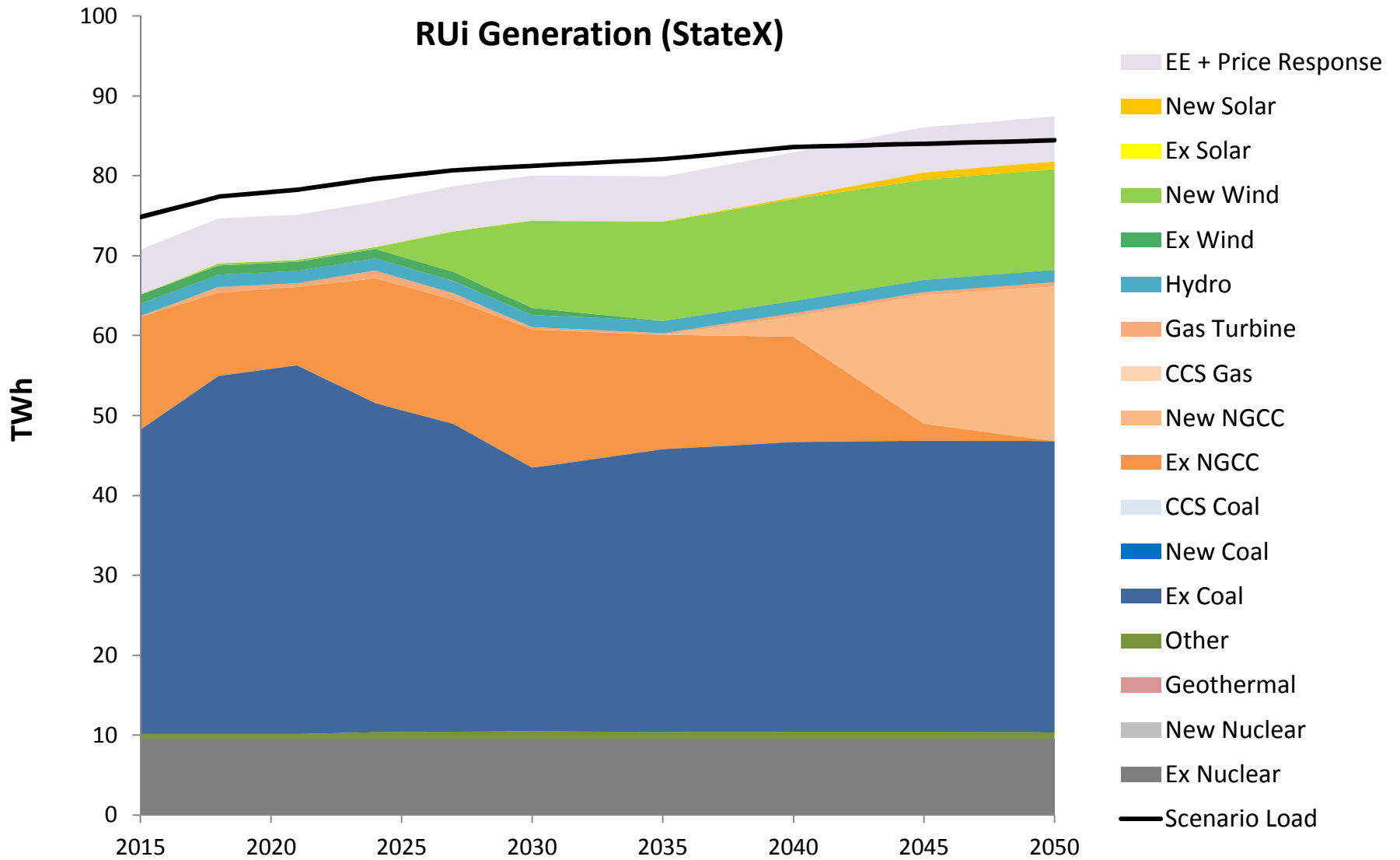
## Compliance as an Island (State-level DYI Compliance)

- Simple example illustrates basic economics
- By “island” we mean state meets CPP targets through in-state means only (no compliance trading)
- Not thought to be realistic policy alternatives
- Interstate power flows locked at reference levels to more fully isolate compliance mechanisms
- Cover 2 core pathways (e.g., RUi with “i” for island)
  - Subcategory Rate (RUi)
  - Existing Mass (MXi)
- No state is an island (w/o adding a lot of constraints)

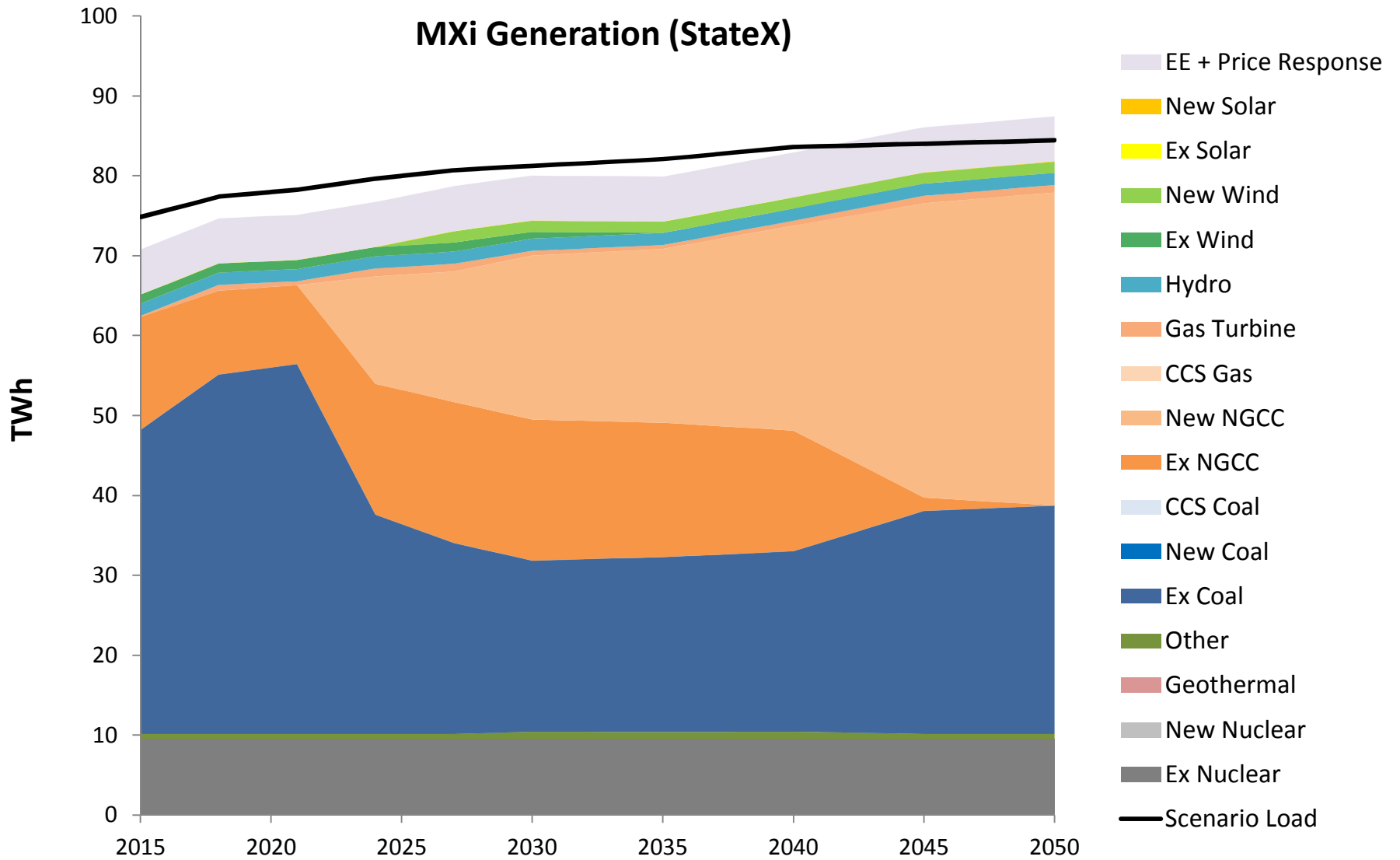
# StateX Reference Scenario



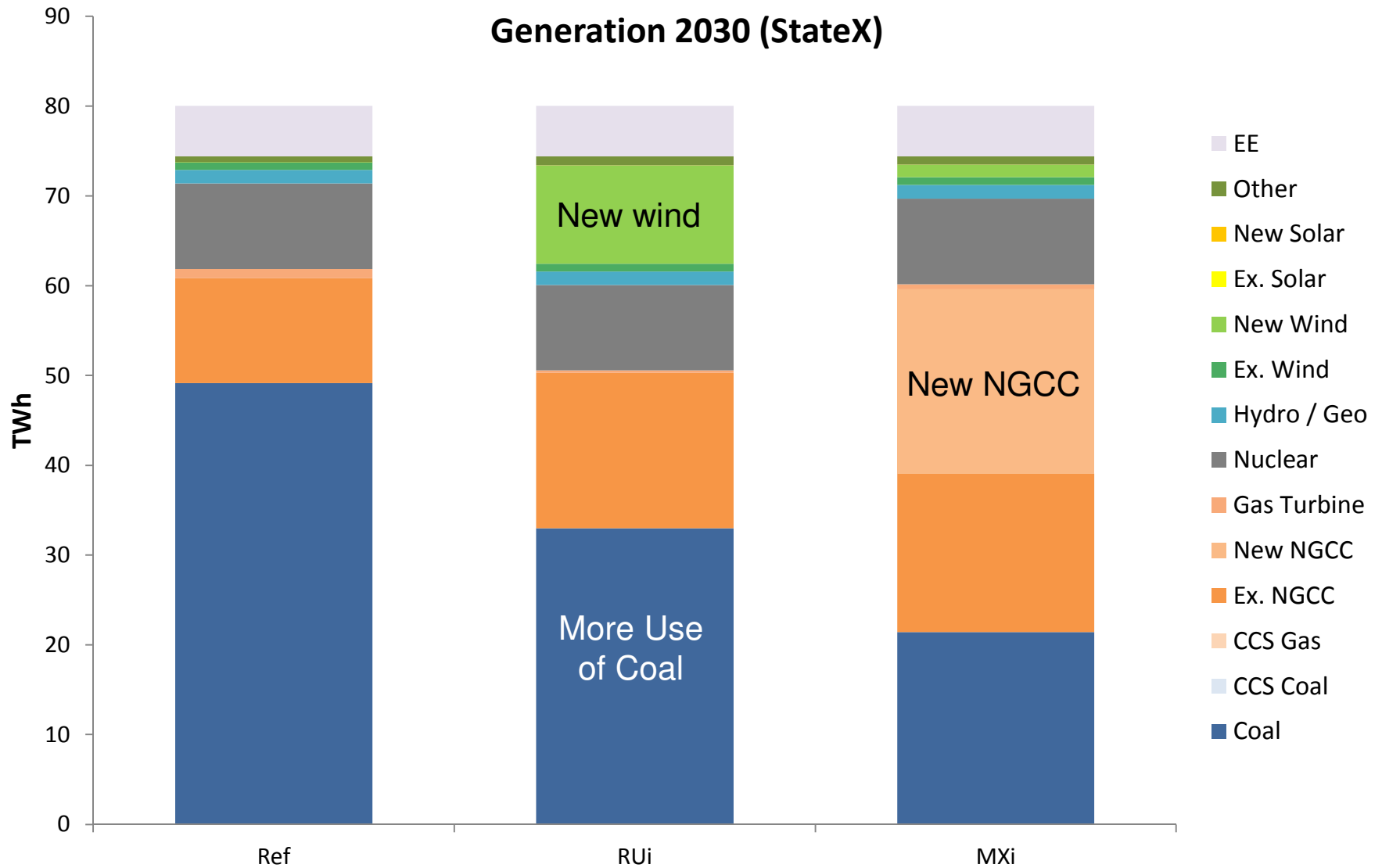
# Subcategory Rate Compliance as an Island



# Existing Mass Compliance as an Island

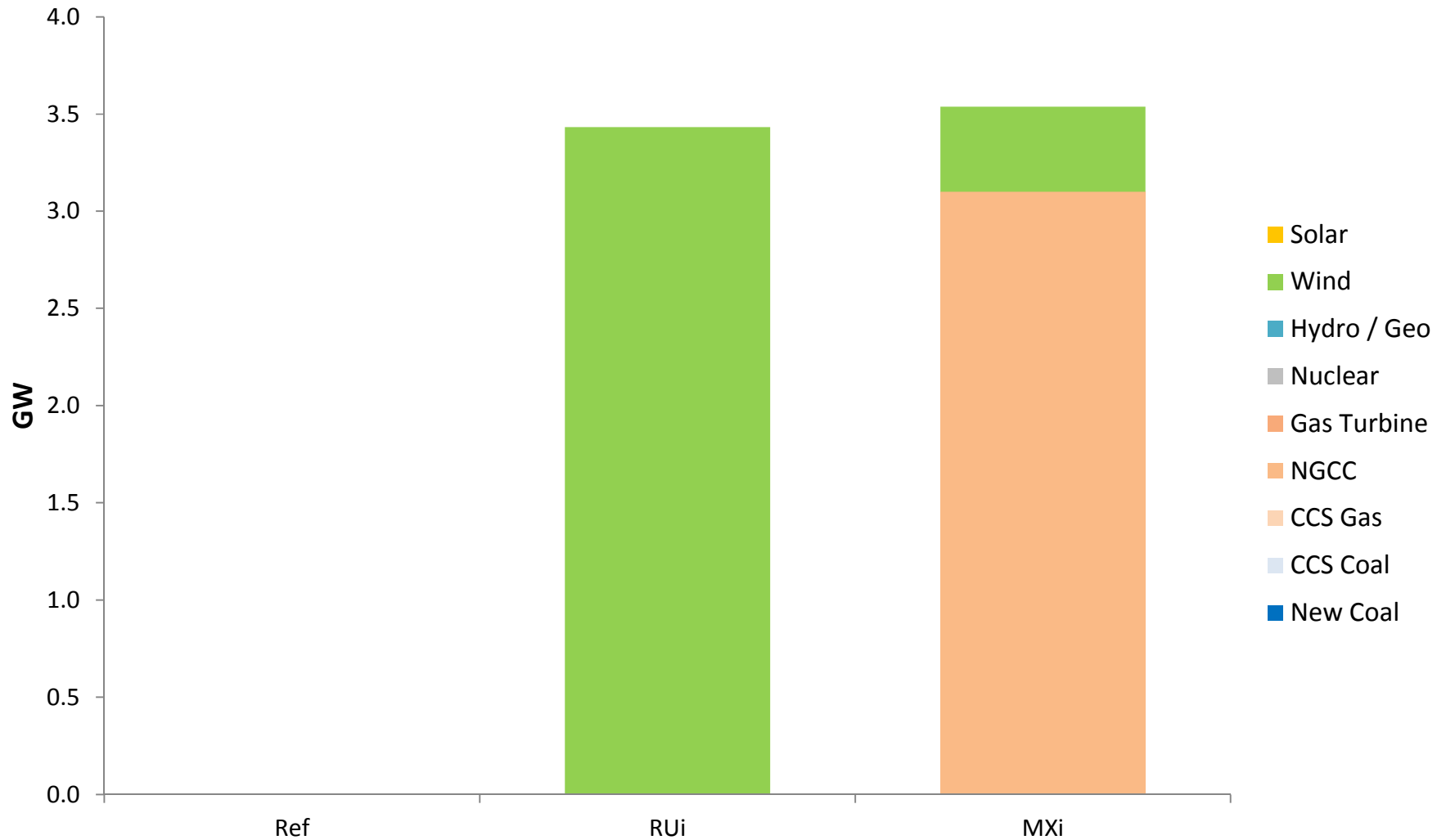


# CPP Compliance as an Island Requires Overhaul of the Generation Mix for Either Rate or Mass Pathways



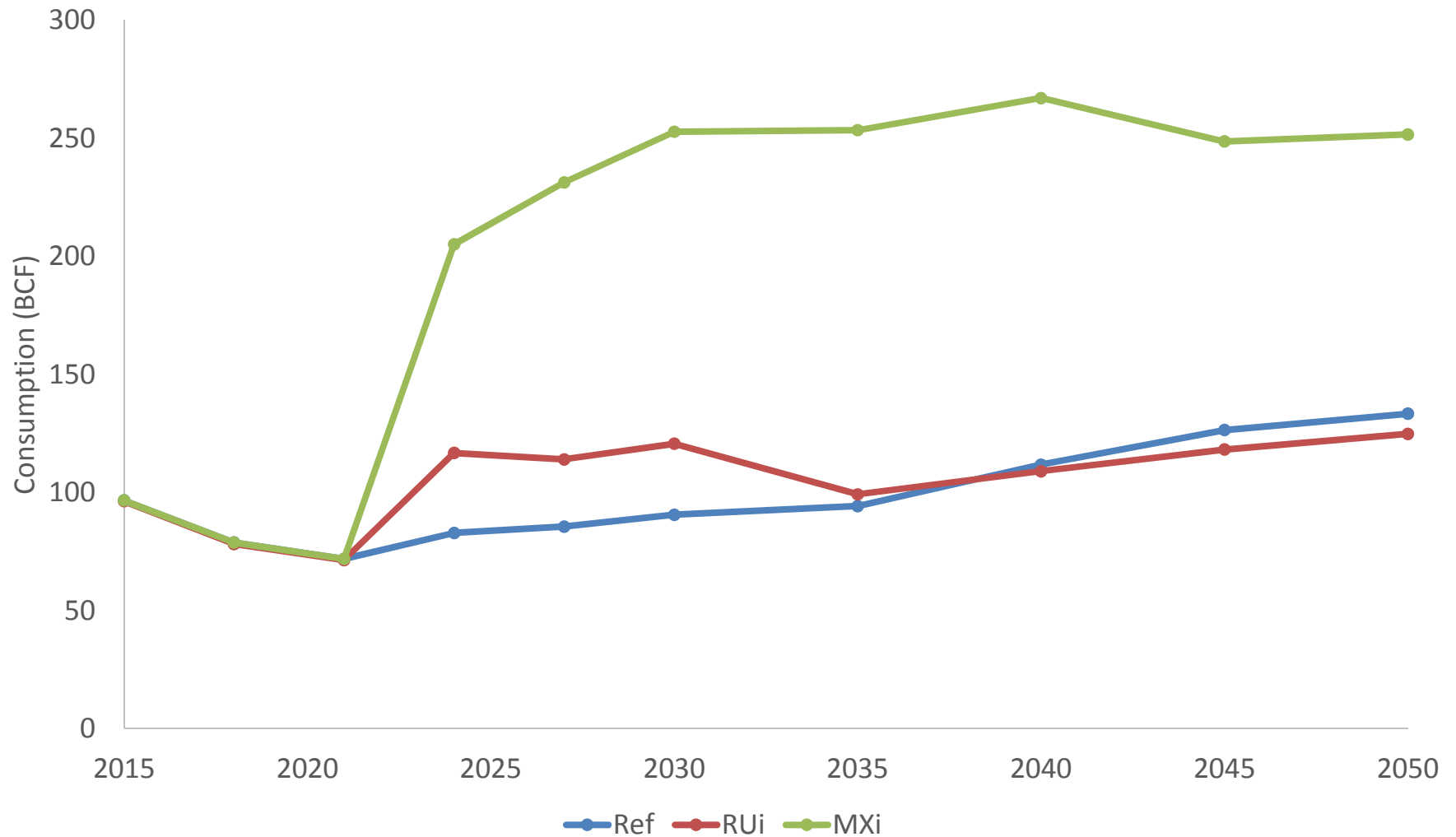
# Island Compliance Depends on New Investment in Wind (for Rate Path) or New NGCC (for Mass Path)

Cumulative Capacity Additions in 2030 (StateX)



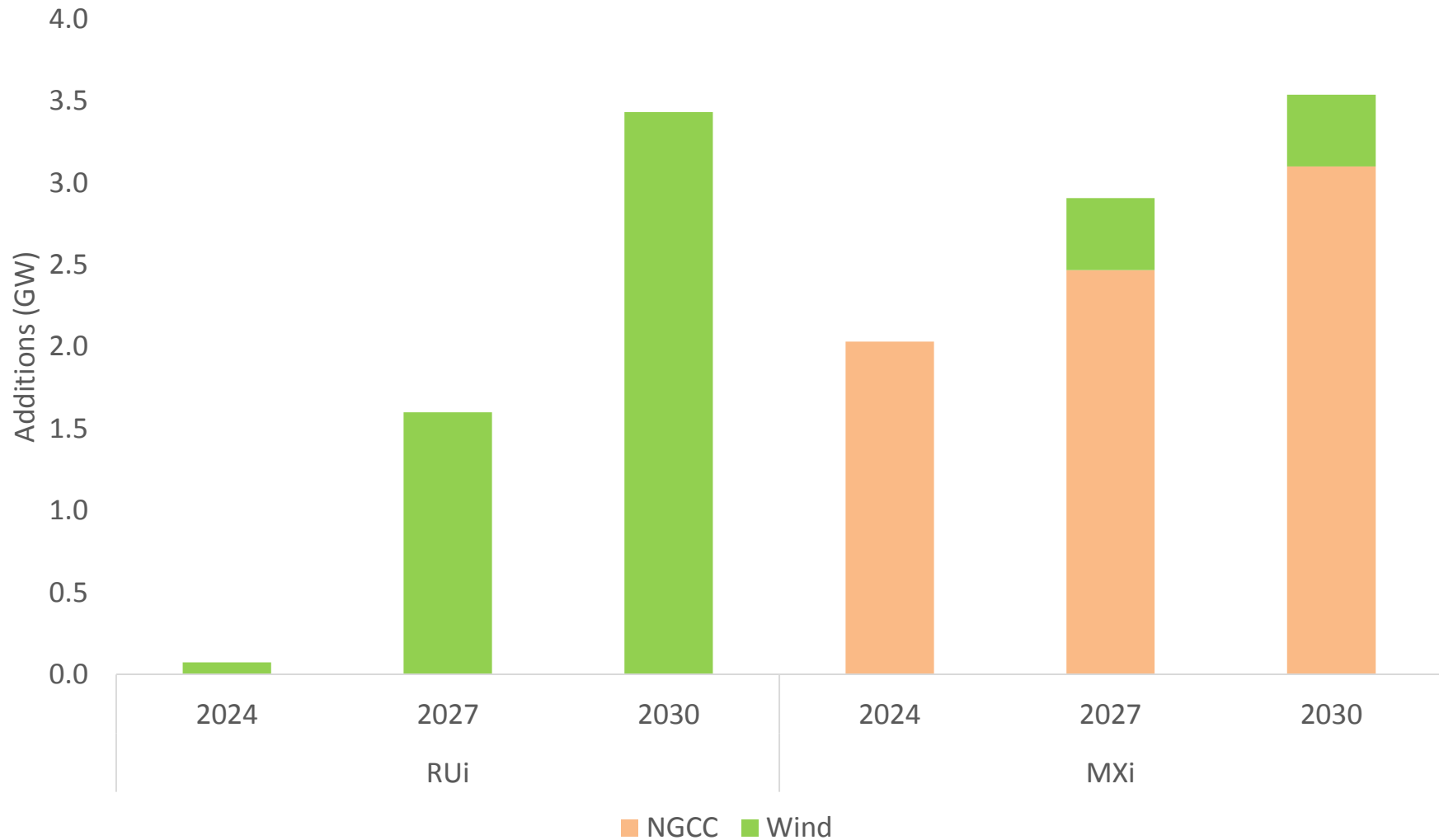
# Mass Pathway Requires Much Greater Use of Natural Gas

## Electric Sector Gas Consumption - StateX



# With Island Compliance Rate Path Provides More Time Before Investment Needed for Compliance

StateX Generation Additions by CPP Path

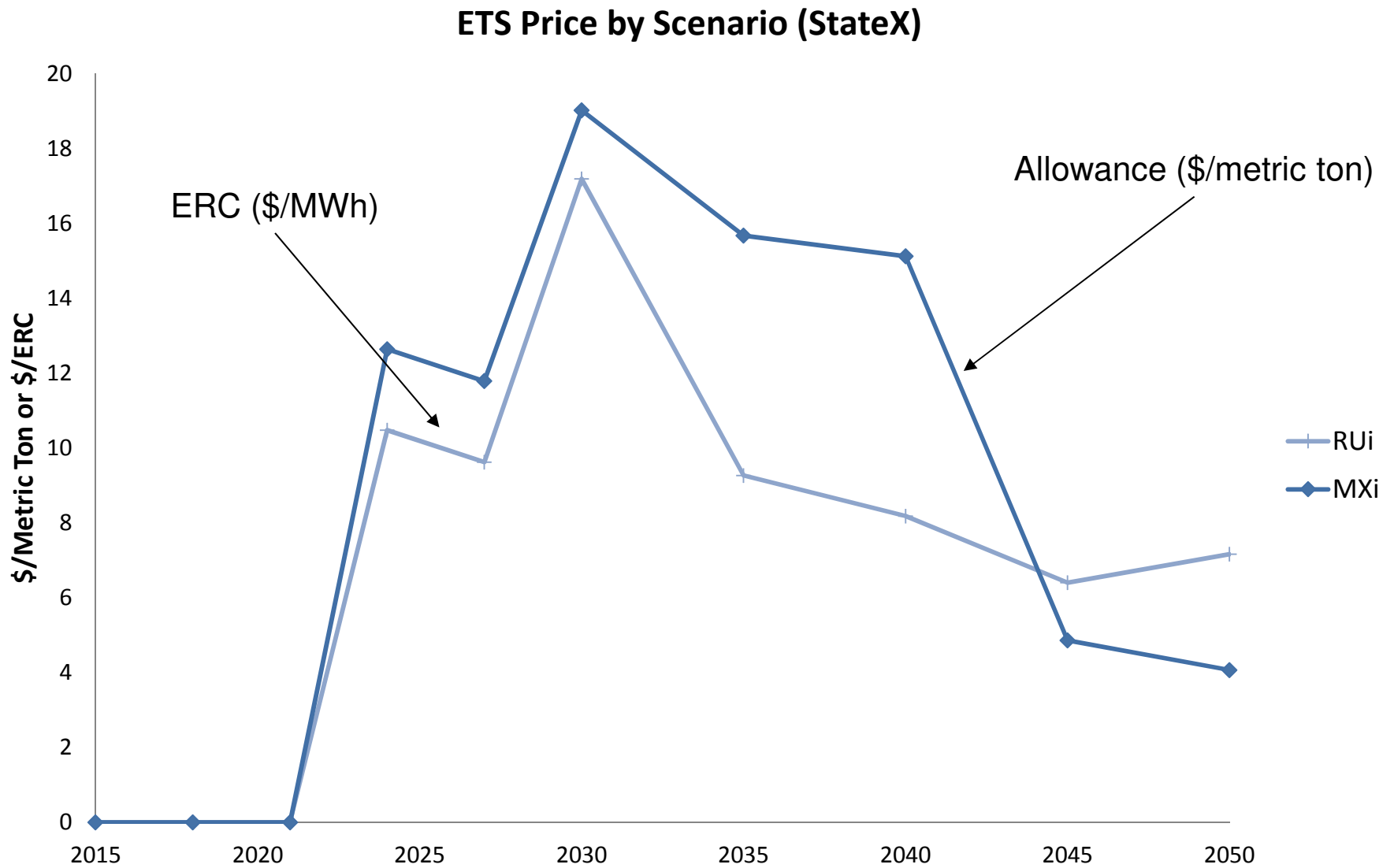




## Observation

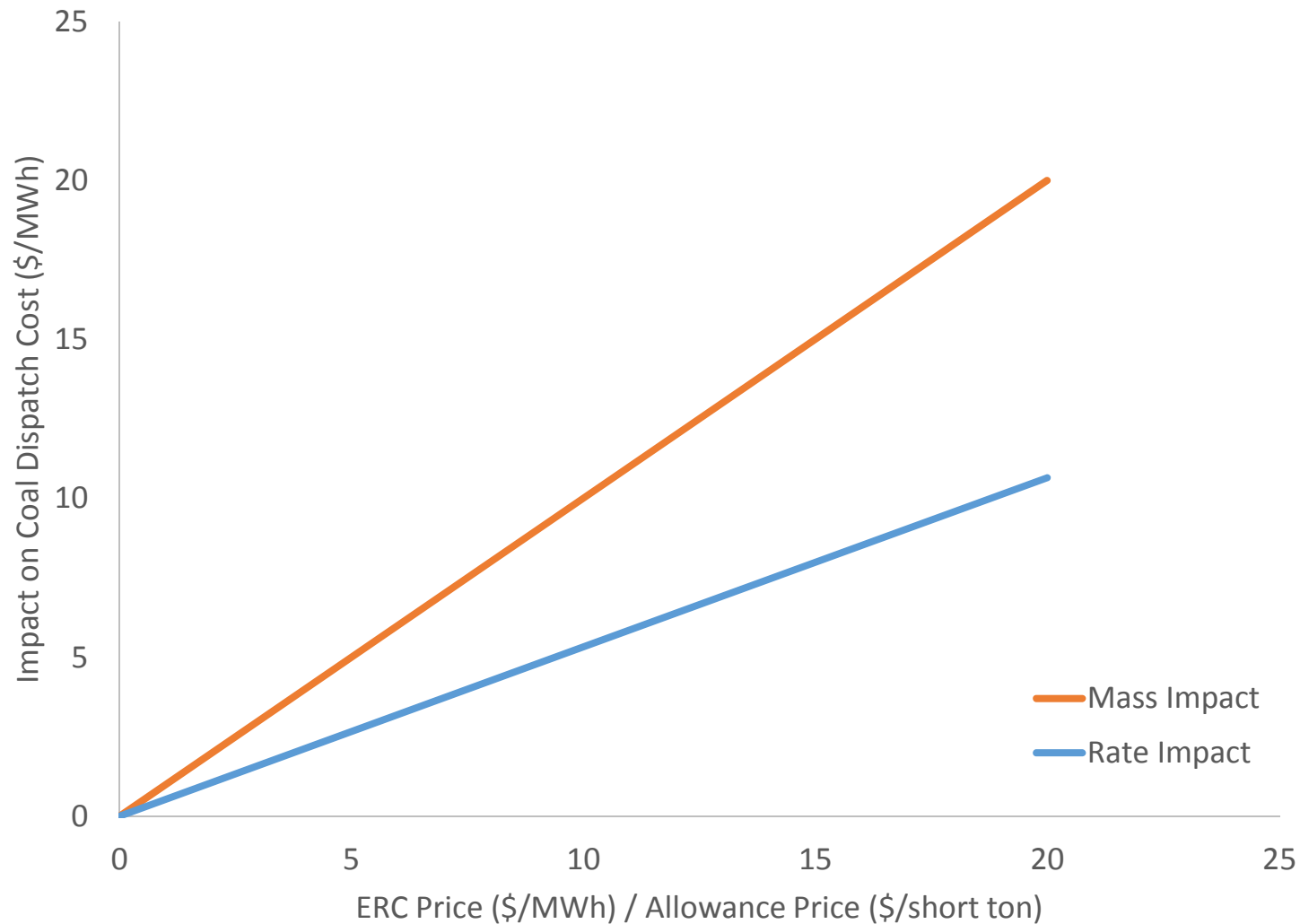
- Strong cost saving opportunities from participating in compliance markets for ERCs and Allowances
- Yet reasonable concern over counting on yet-to-be-formed markets for compliance
- Also reasonable to be concerned over the risk of CPP-driven investments being stranded if markets develop with low prices
- It appears that with the Rate path StateX has extra time to see if markets develop before committing to a non-market path to compliance
  - Island Mass path requires 2 GW of new NGCC capacity in 1<sup>st</sup> period
  - Island Rate path only requires a 100 MW of wind in 1<sup>st</sup> period

# ERC and Allowance Prices – StateX Island



# Note that \$ for \$, ERC Prices have Approximately Half the Impact on Coal Operating Costs as Allowance Prices

Impact of ERC and Allowance Prices on Coal Unit Dispatch Costs



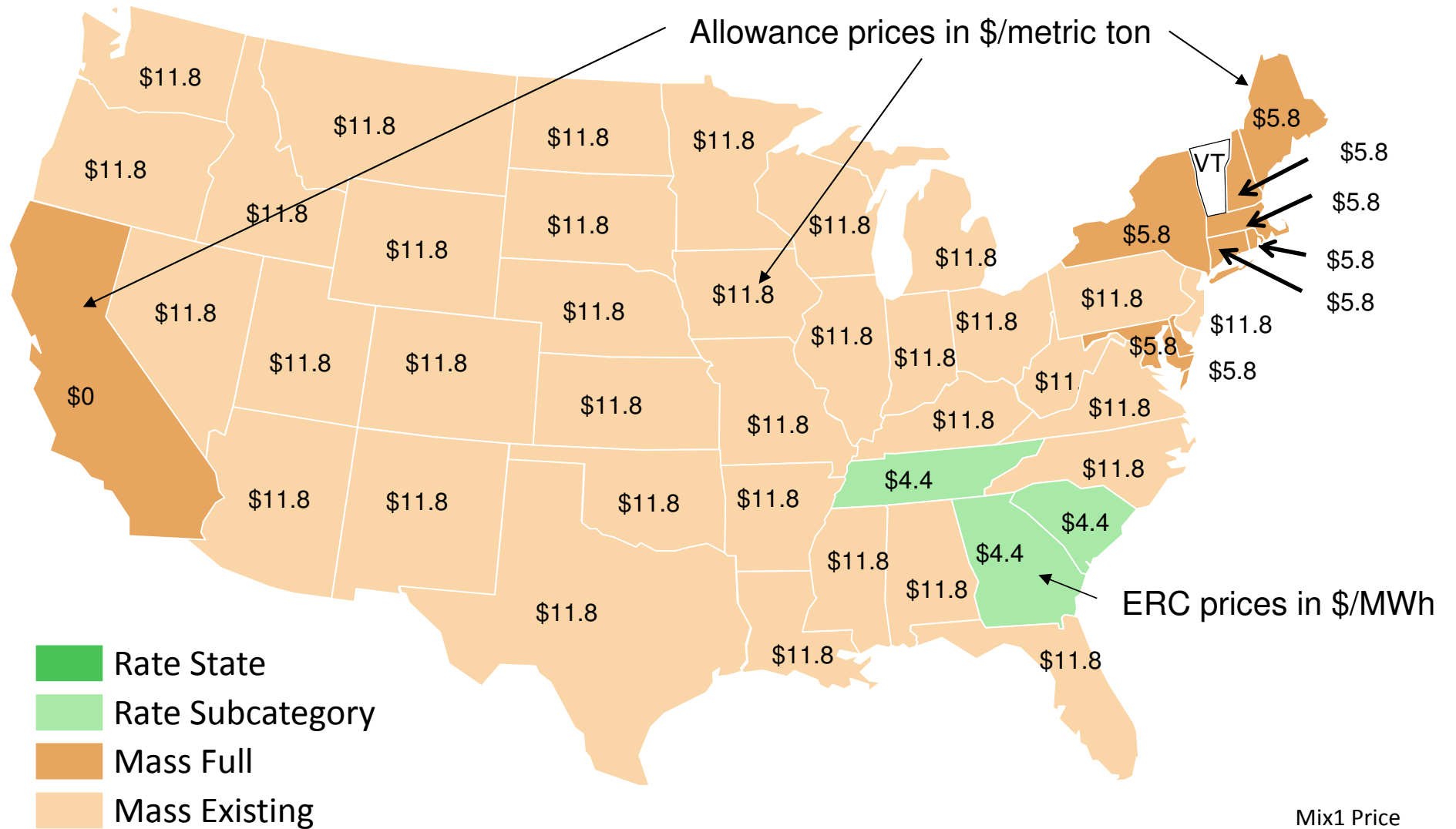
# Compliance with Trading

- Opportunity to reduce cost
- Trade-off is reliance on a market
  - Slow to develop?
  - Liquidity?
  - Exposure to additional external forces
  - Lower volatility?
- Mix1 and Mix2 and Mix5 provide alternative possible market outcomes

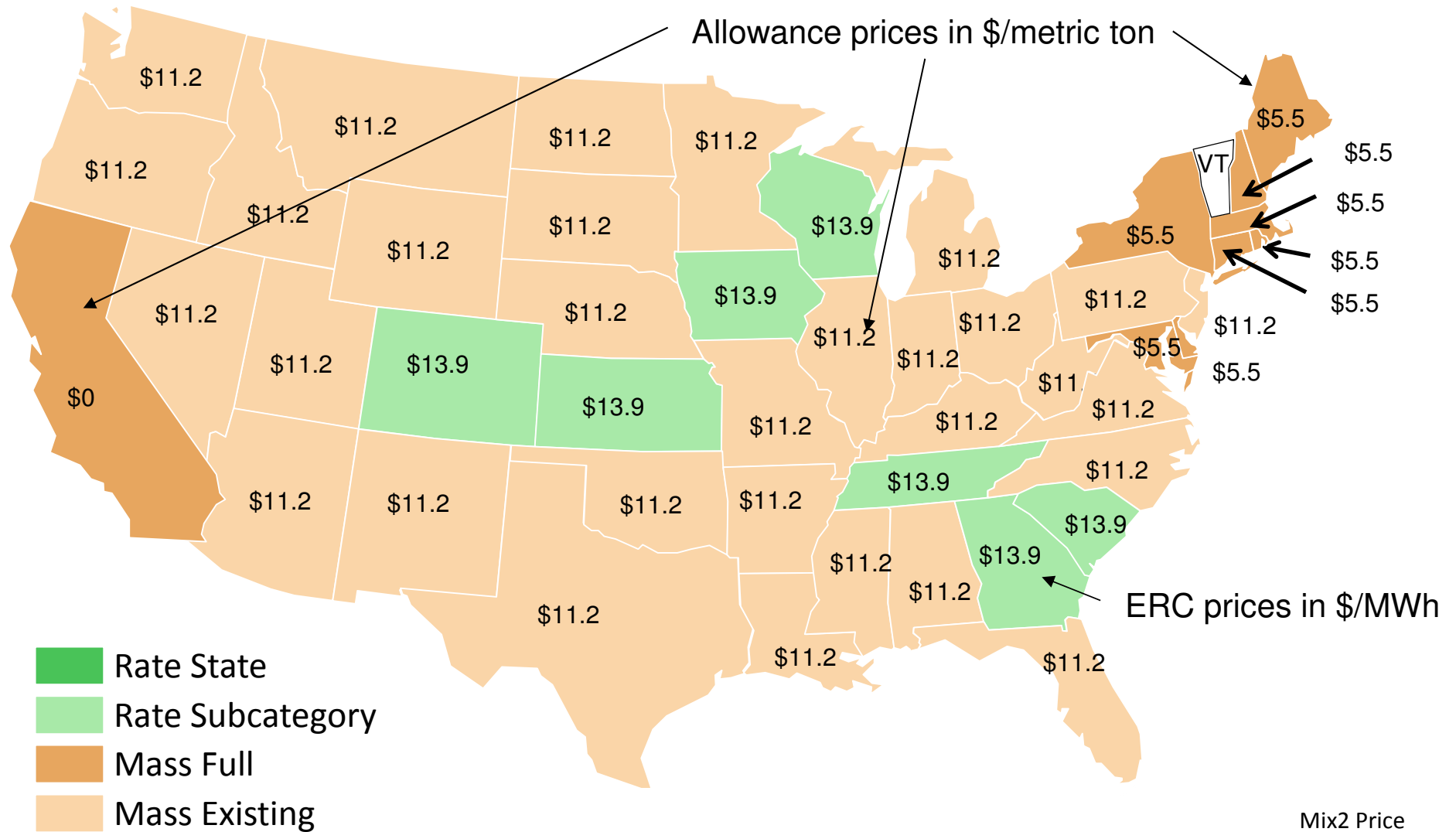
## Uncertainty in Policy Choice by Other States Represented with Three Alternative Mixes of Rate-Mass Choices

- All assume California and RGGI states choose Full Mass (with NSC) pathway, and do not trade with each other or other states
  - Already capping emissions from new and existing sources
  - Concerned that trading may undercut spirit of their own goals
- All assume that states with pending new nuclear choose Subcategory Rate
- Mixes differ over how rest of states choose Subcategory Rate or Existing Mass Pathways
- Exclude NSC Mass as tends to be more costly and emission effects can be offset by allowance trading and changing power flows
- Exclude State Rate pathway as no clear cost benefit and expect to have limited ability to benefit from trade

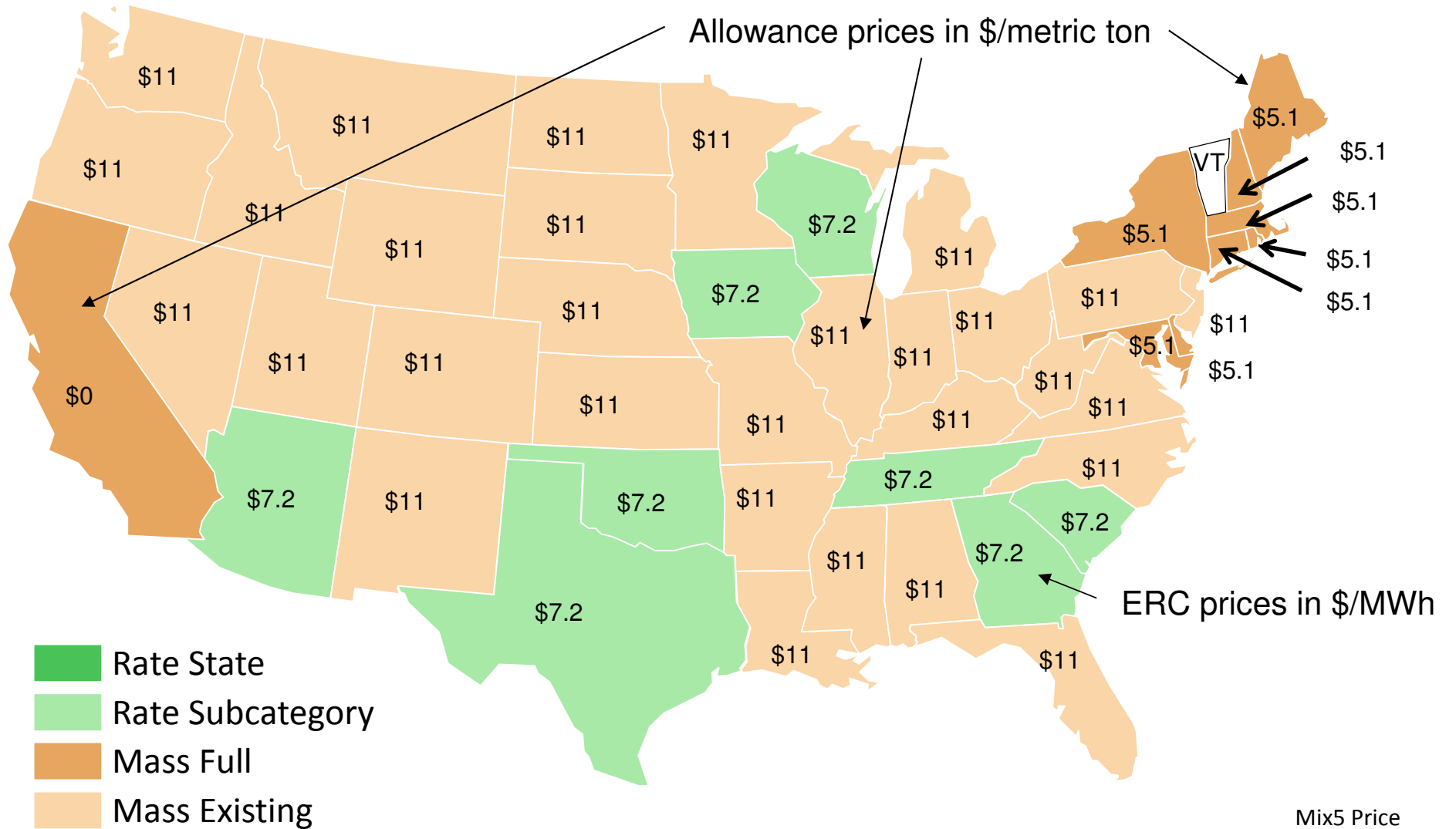
# 2030 Mix1 ERC/Allowance Pricing (Low Gas Prices)



# 2030 Mix2 ERC/Allowance Pricing (Low Gas Prices)



# 2030 Mix5 ERC/Allowance Pricing (Low Gas Prices)

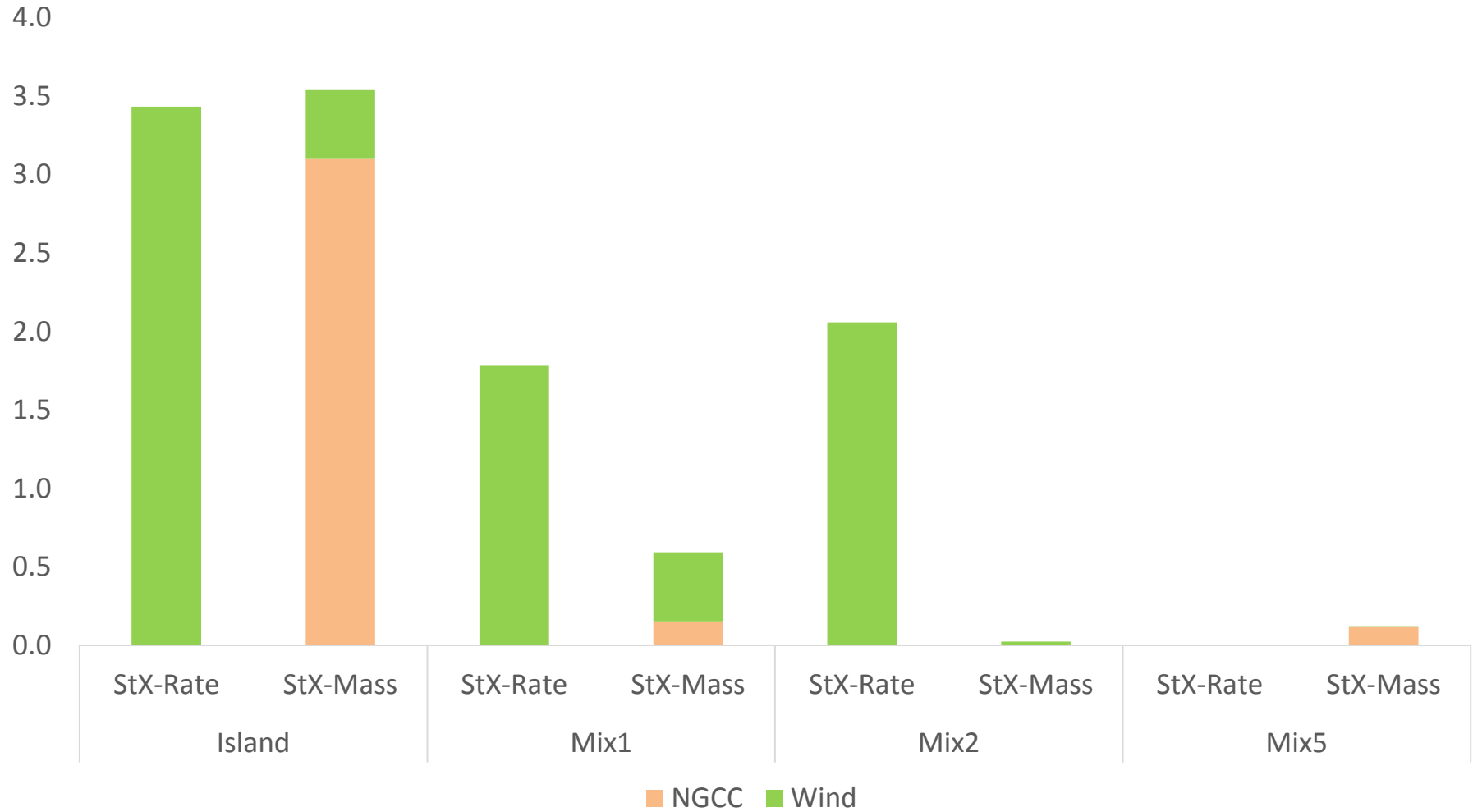


Mix5 Price



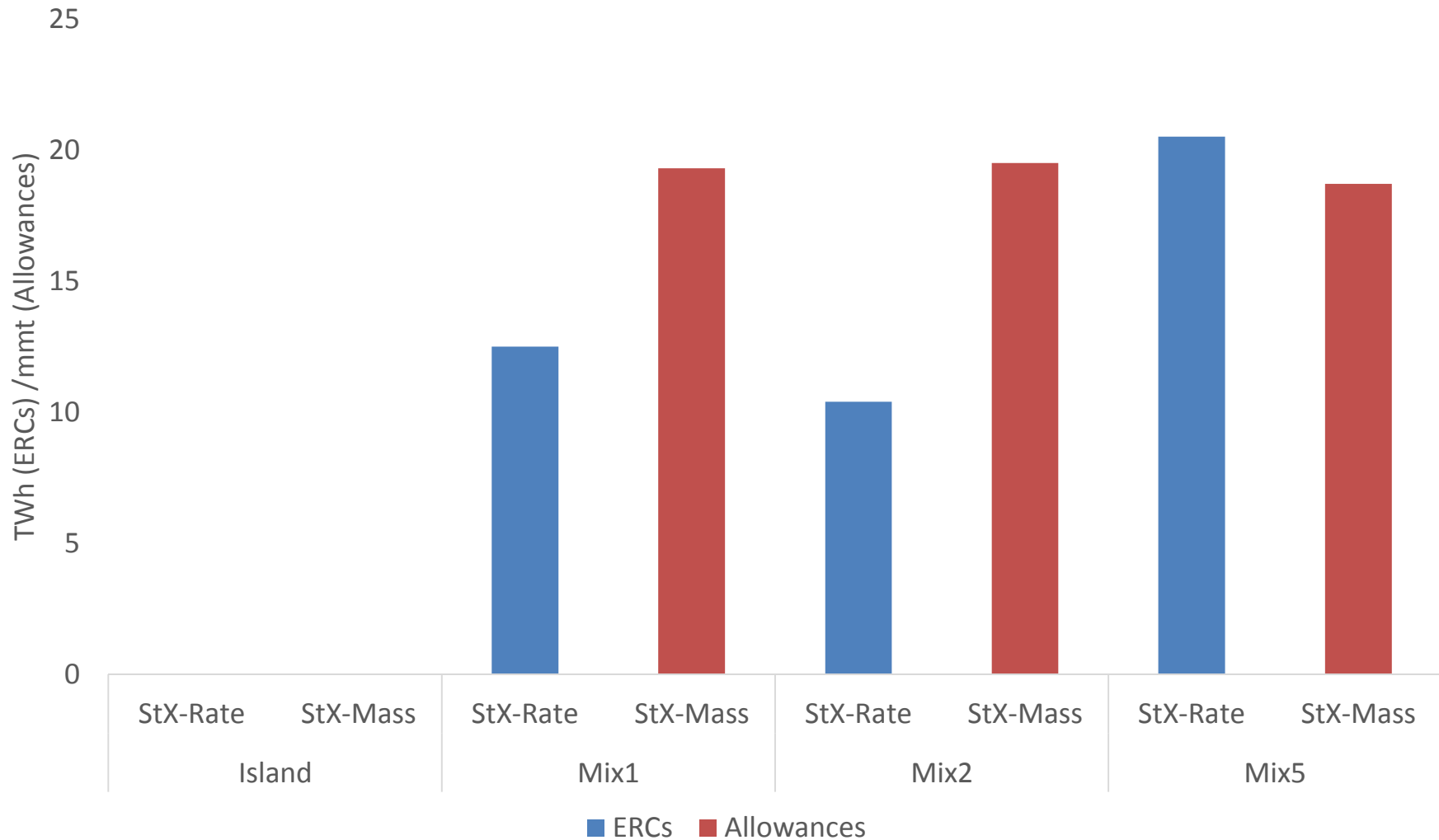
# Investment Needed for Compliance

2030 Cumulative Generation Additions (GW)



# With Low Investment (e.g. Mix5) Comes High ERC/Allowance Import Dependence

StateX 2030 Trading Element Imports by CPP Pathway



## 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 and Mix5 probably more realistic
- Many states nominally committed to mass path through existing state policies, e.g., California and RGGI states, would be in compliance with the CPP by choosing rate pathway
- With trade, selecting Full Mass has no CO<sub>2</sub> value nationally
- 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

## High-level perspective

- This is a big deal
  - First real CO2 regulation
  - Embroils almost all the states
- In absence of “simple” CO2 control technology, EPA taking “system” approach to get meaningful reductions
  - That means forcing/incenting influx of renewables, gas redispatch, and maybe energy efficiency
- Final rule is very complicated
  - Many pathways to compliance
  - Lots of fine print on how you can comply, and who you can trade with
- Trading is central to cost management
- Up to the states to pick pathways
- We’re probably not done with CO2 regulation



# Together...Shaping the Future of Electricity