

Challenges in Modeling Rate vs. Mass Pathways for CPP Compliance

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

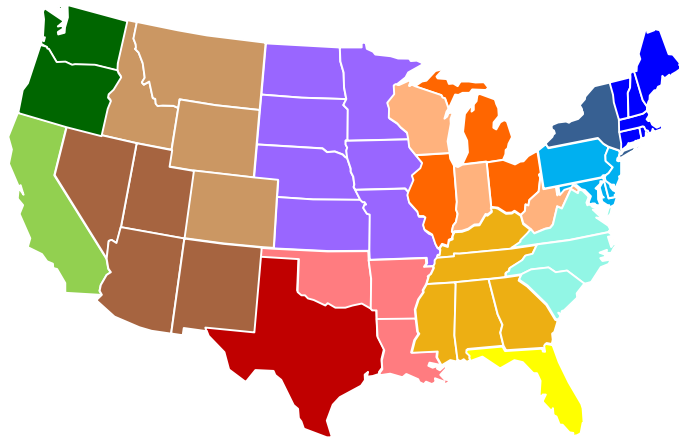
-- George Edward Pelham Box

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

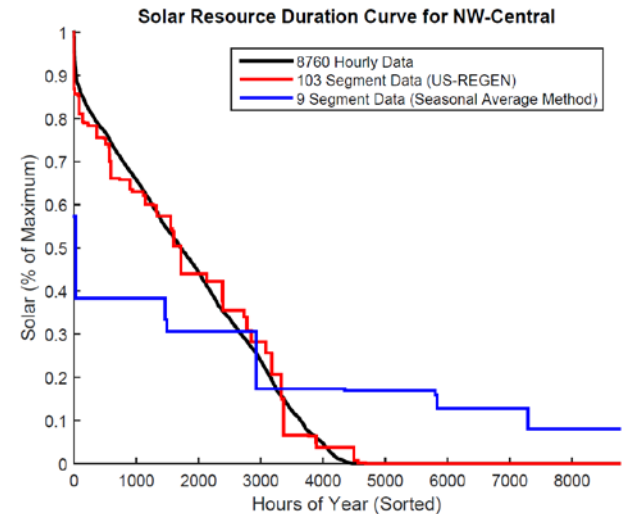
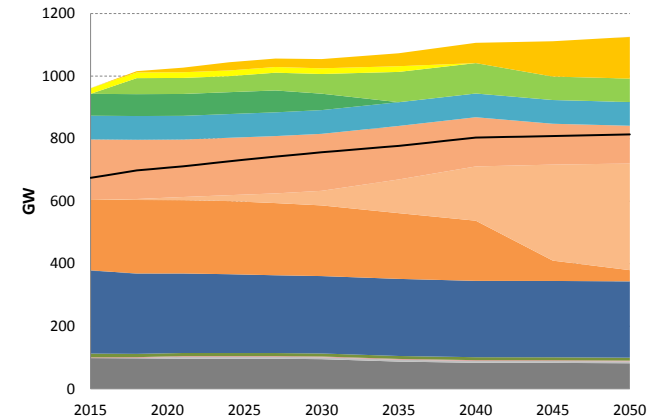
US-REGEN 48-State Version: EPRI's In-House Electric Sector Model for CPP Modeling

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



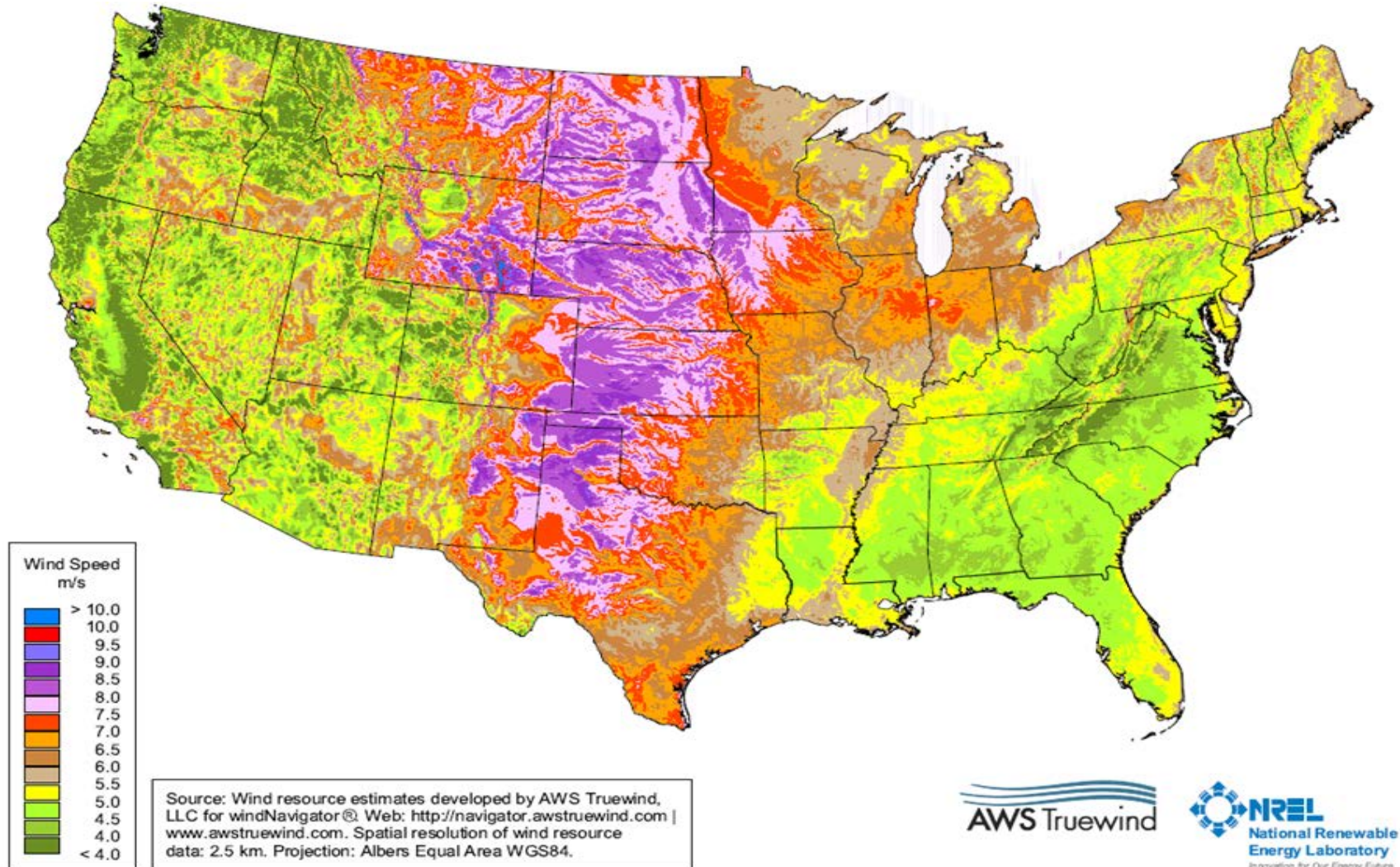
Electric Model: Key Features

- 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

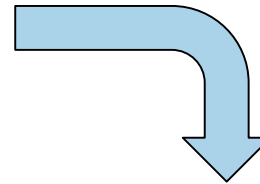
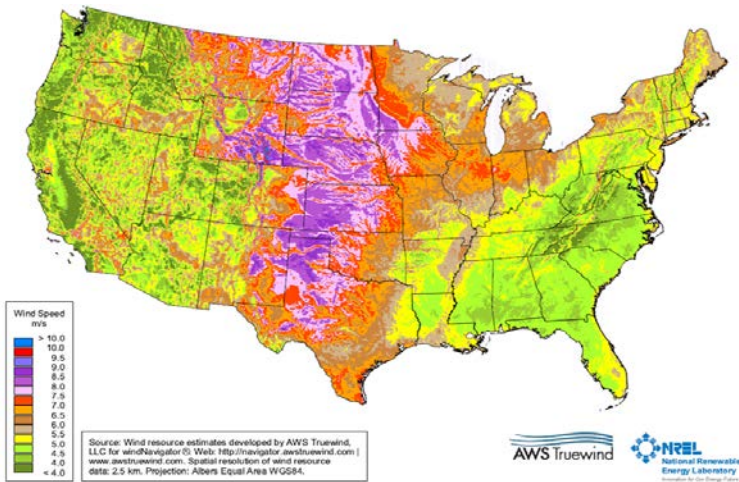
Renewable Resource Data

- 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

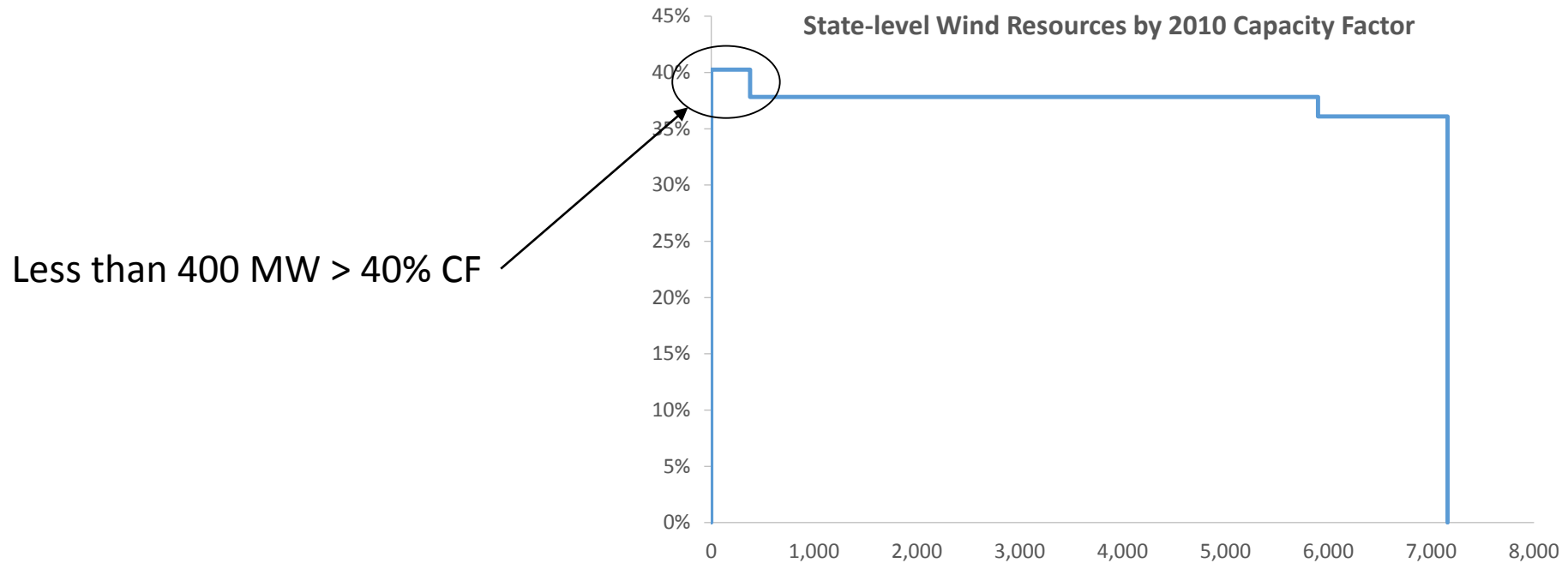
Location of Wind Resource by State



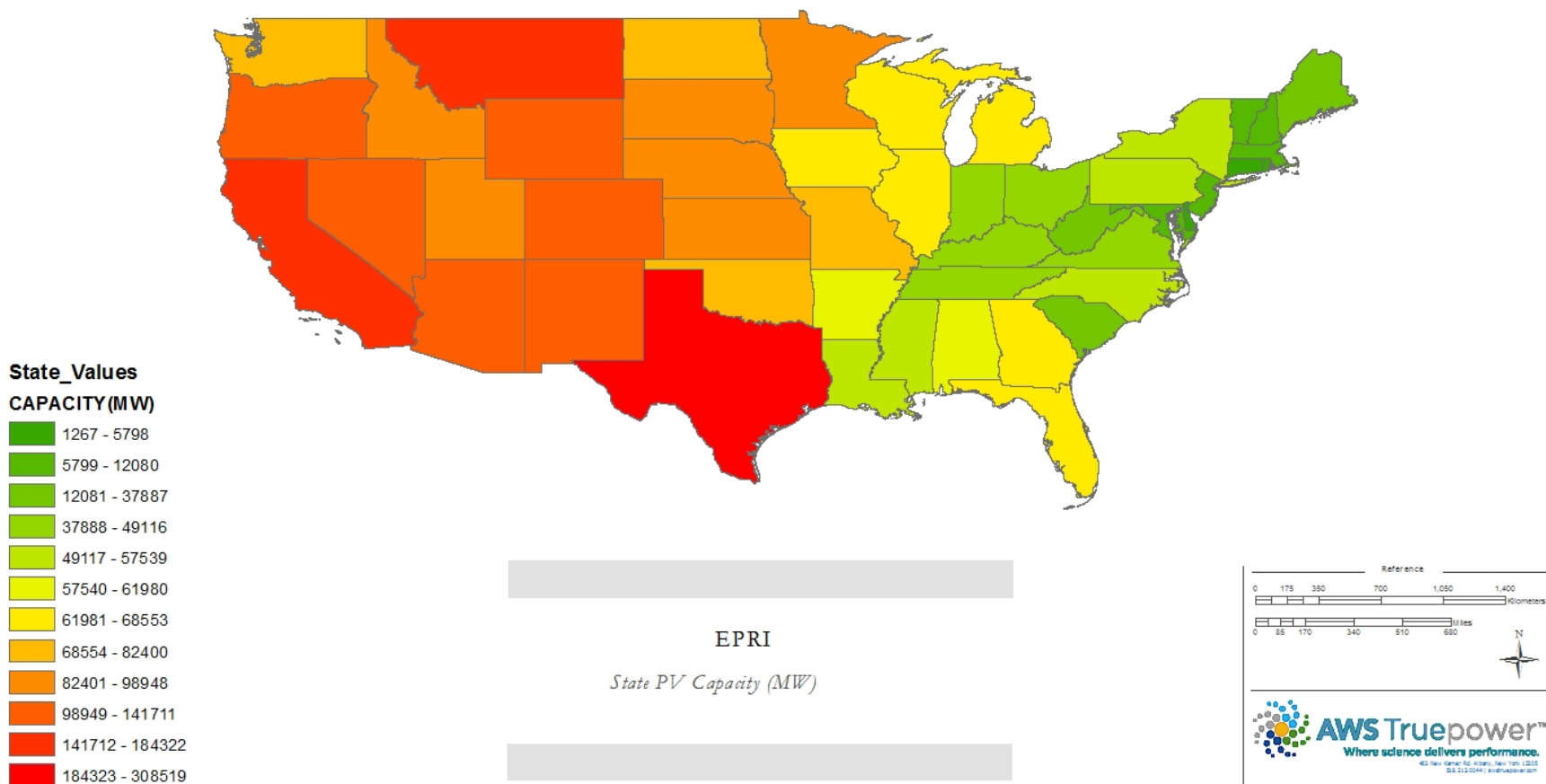
Location of Wind Resources by State



State-Level Wind Resource Base



Location of Central PV Resource by State

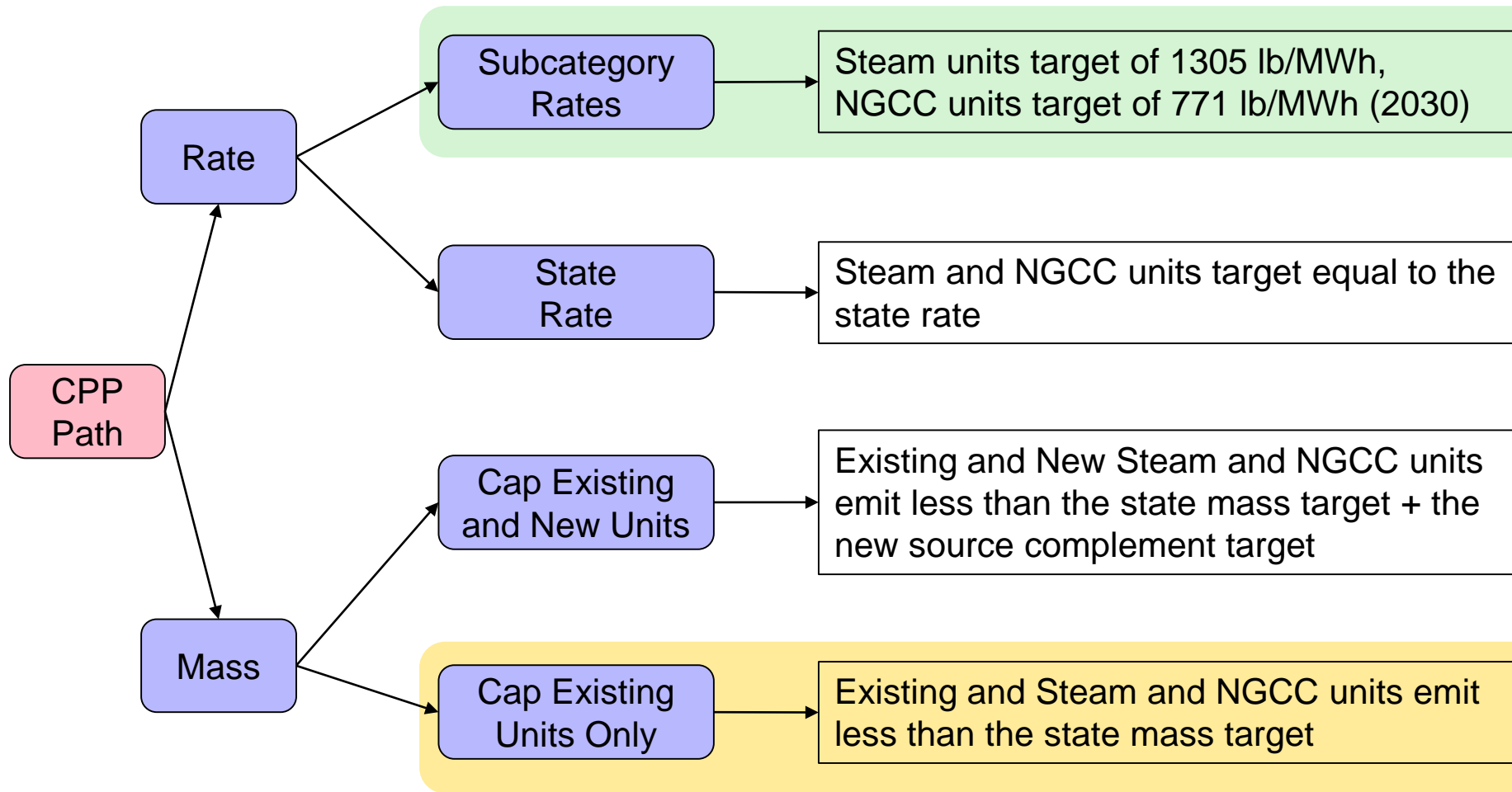


* Assumes the use of up to 1% of each state's available land

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

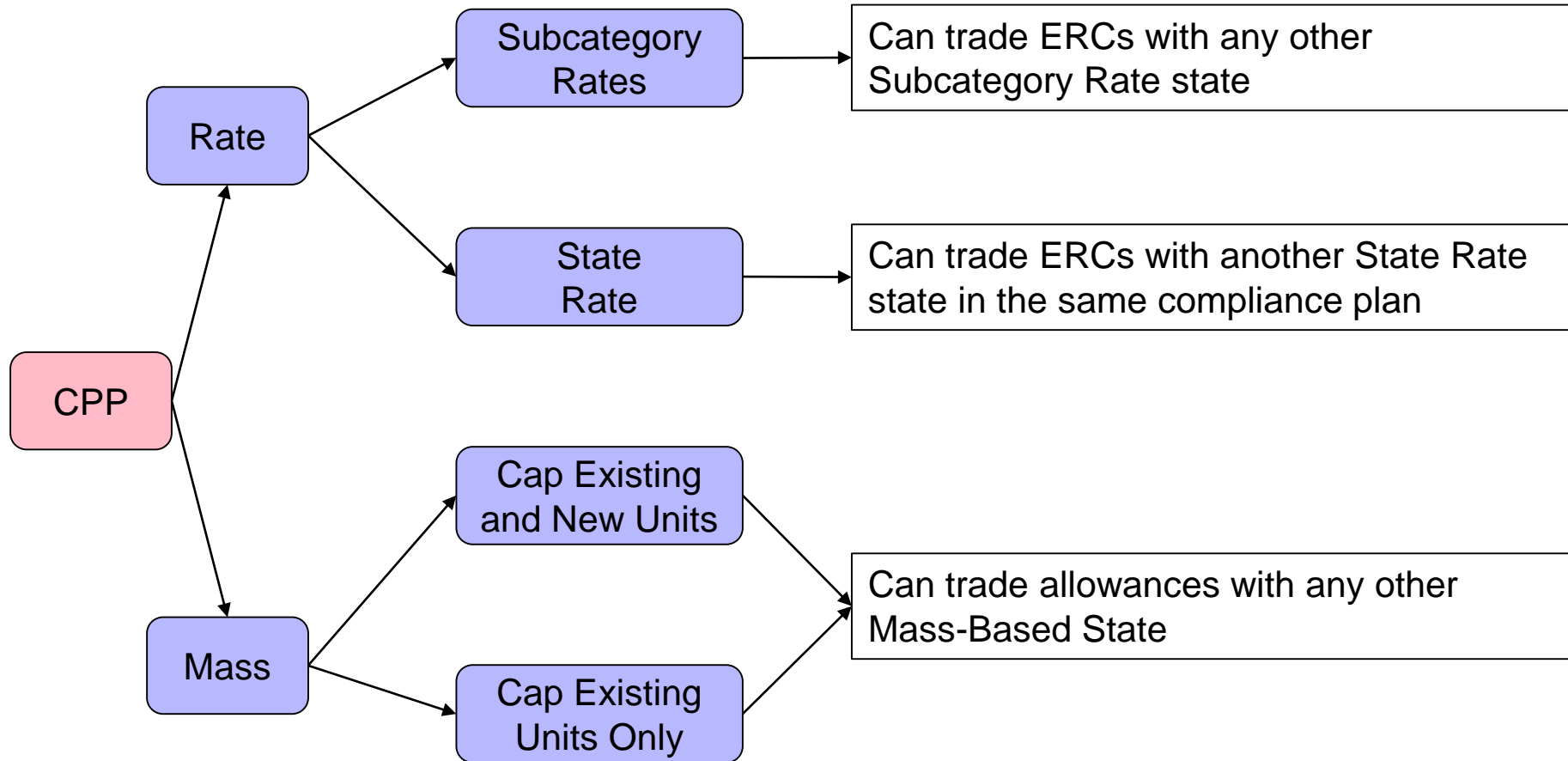
- Detailed representation of ERC sources by type
 - Zero, Fossil, Gas-Shift
- Inclusion of output-based set-asides for Existing Mass path
- Endogenous energy efficiency
 - US-REGEN can endogenously build energy efficiency (that counts towards CPP compliance)
 - Currently using EPA CPP proposal costs, 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 ₂ 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 any other rate-based state*	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 only be used by steam units 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.

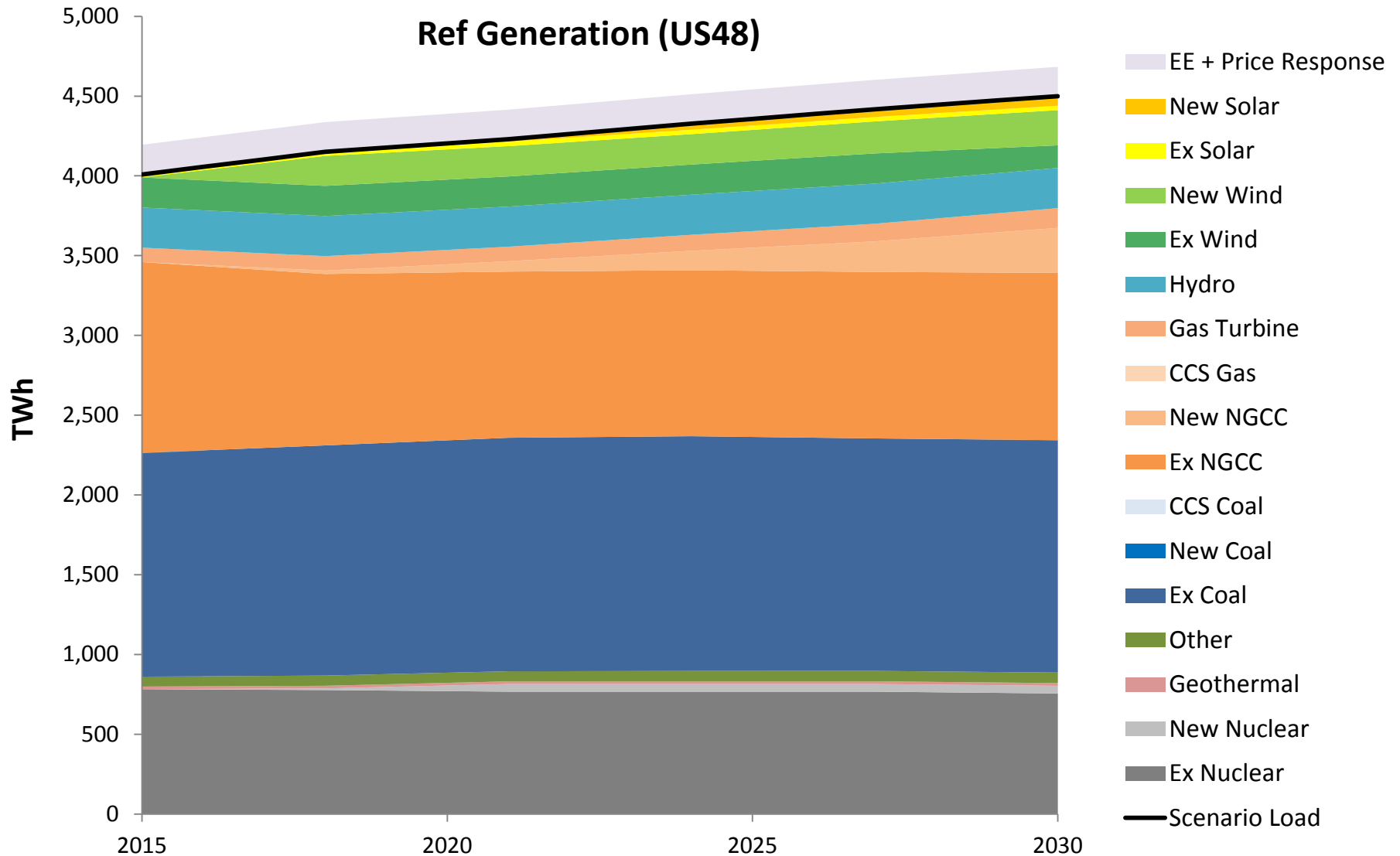
Compliance Pathway Determines Trading Partners



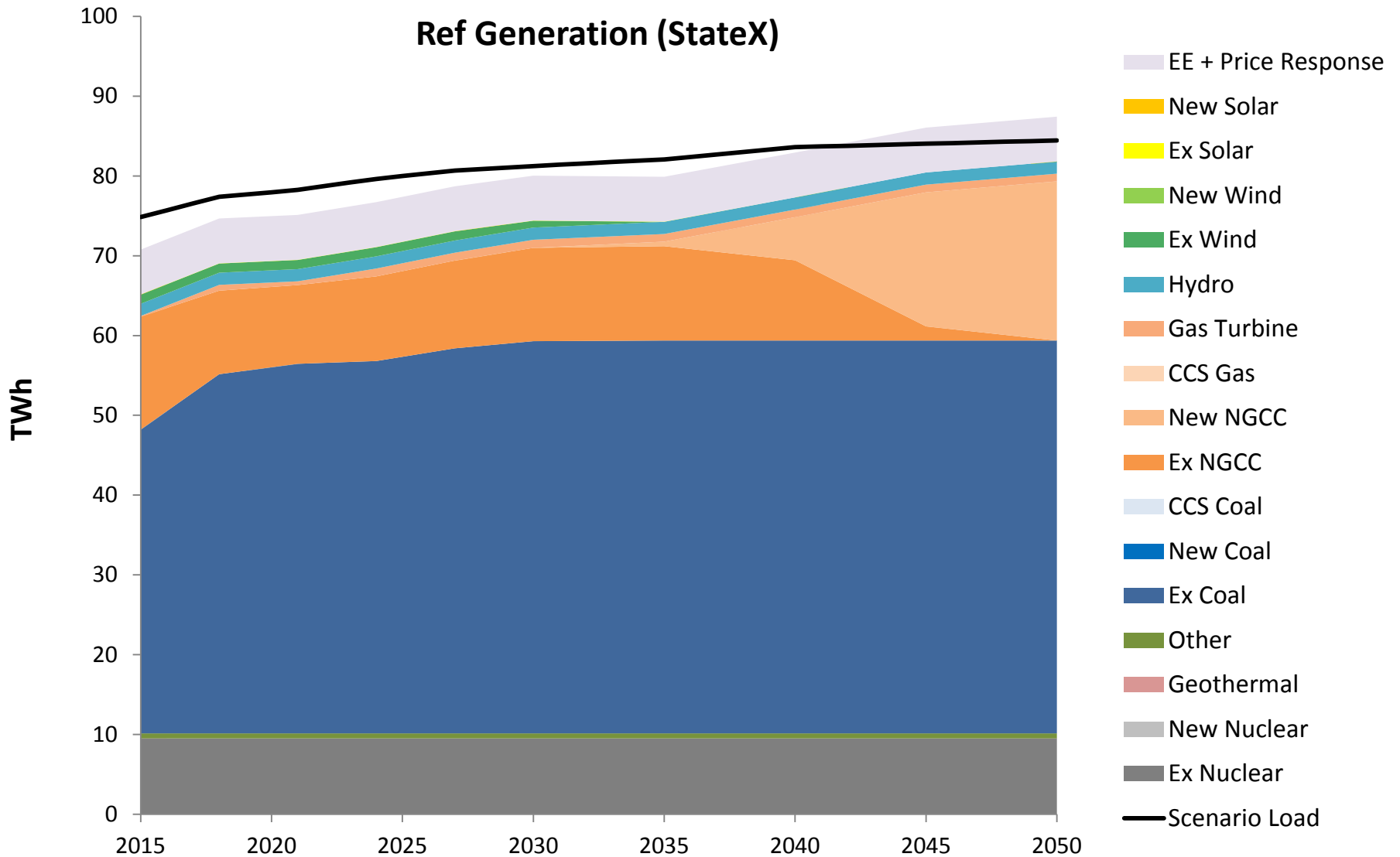
Caveats for Following Model Results

- 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

Reference Scenario Provides Point of Reference but is Not a Forecast

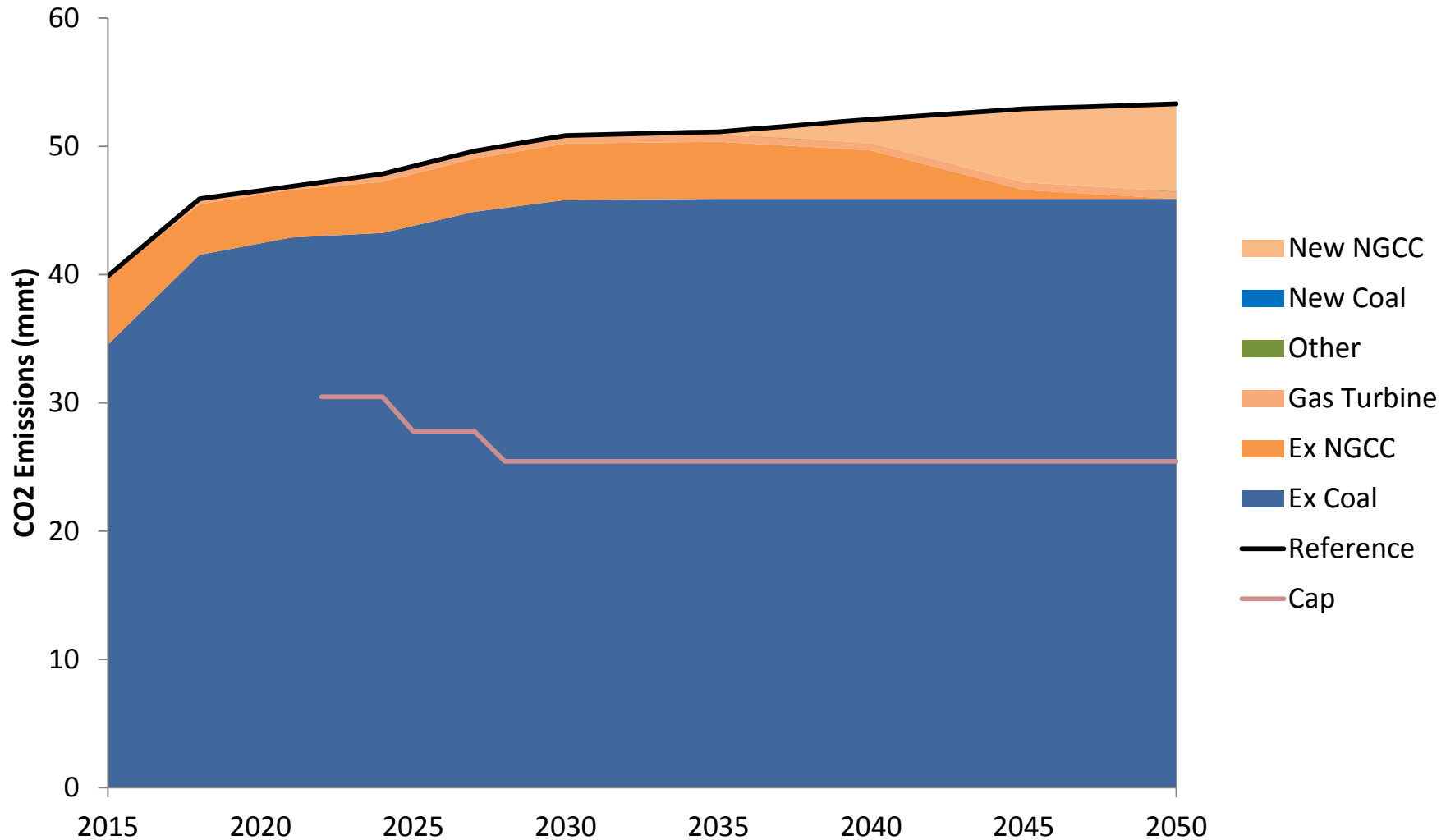


StateX Reference Scenario



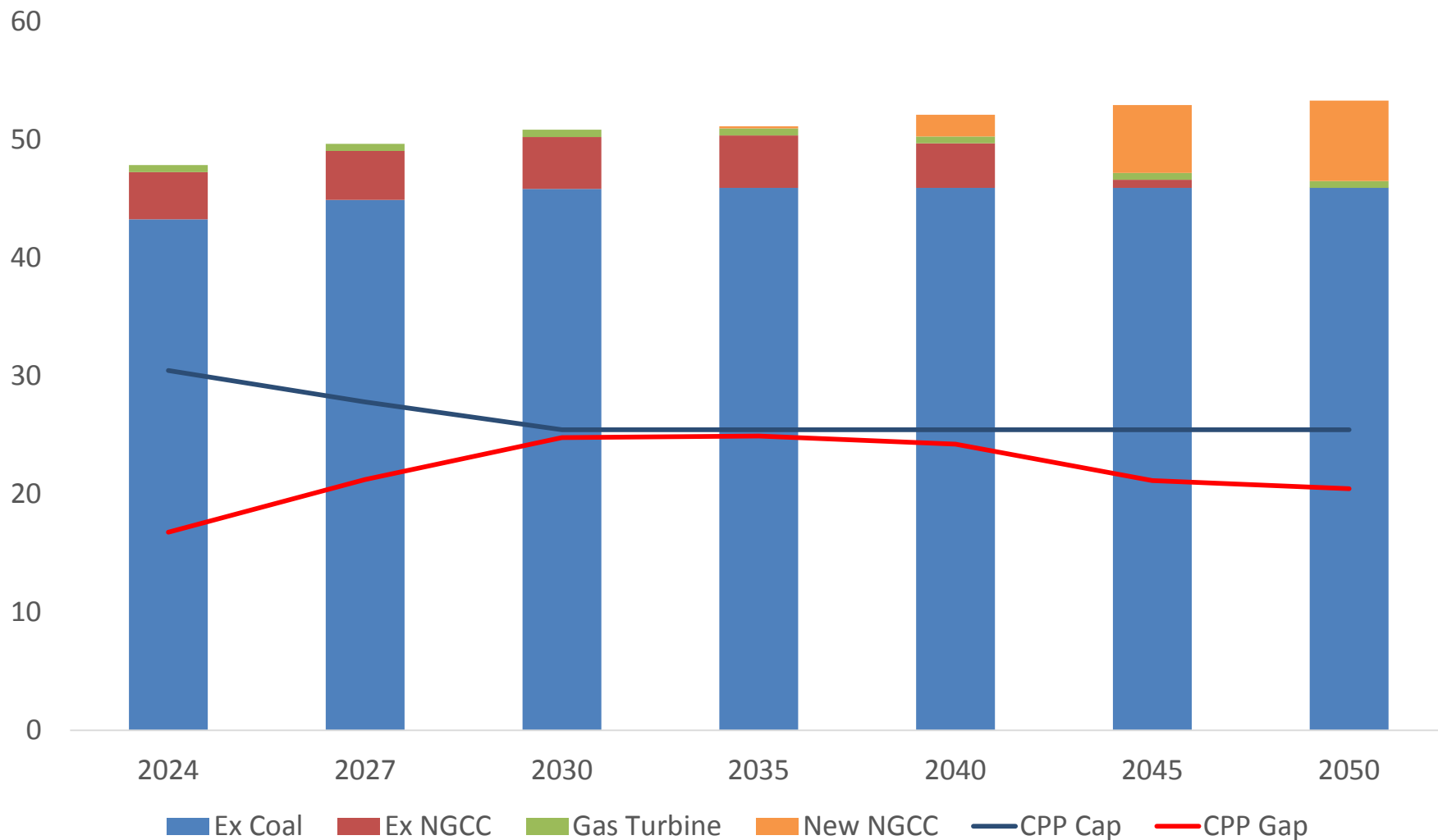
Emissions vs. the Existing Mass Cap – Not Close

CO2 Emissions - Ref (StateX)

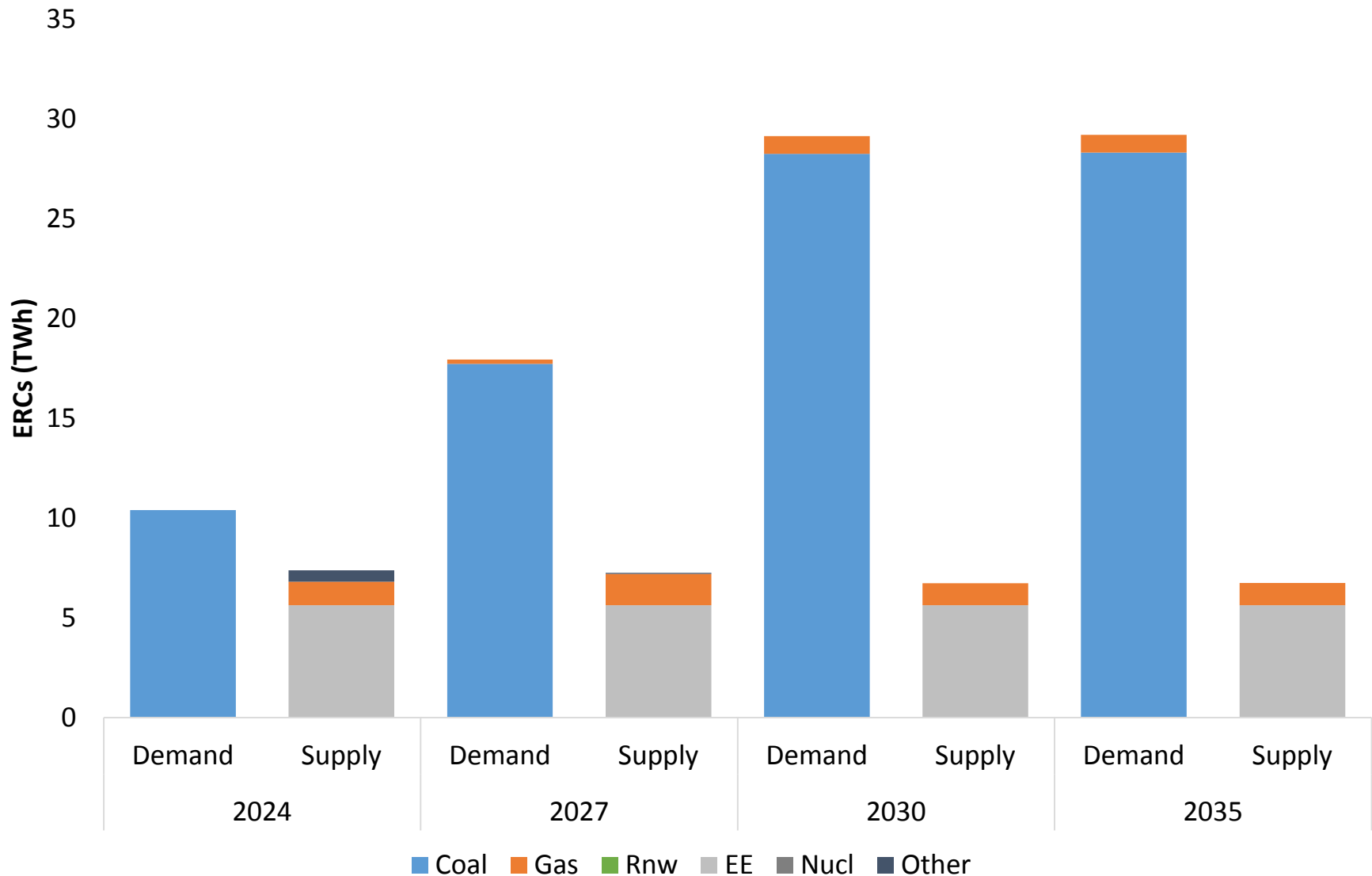


Mass-Based Compliance Requires Substantial Allowance Purchases to Meet CPP Cap (Existing Mass)

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



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



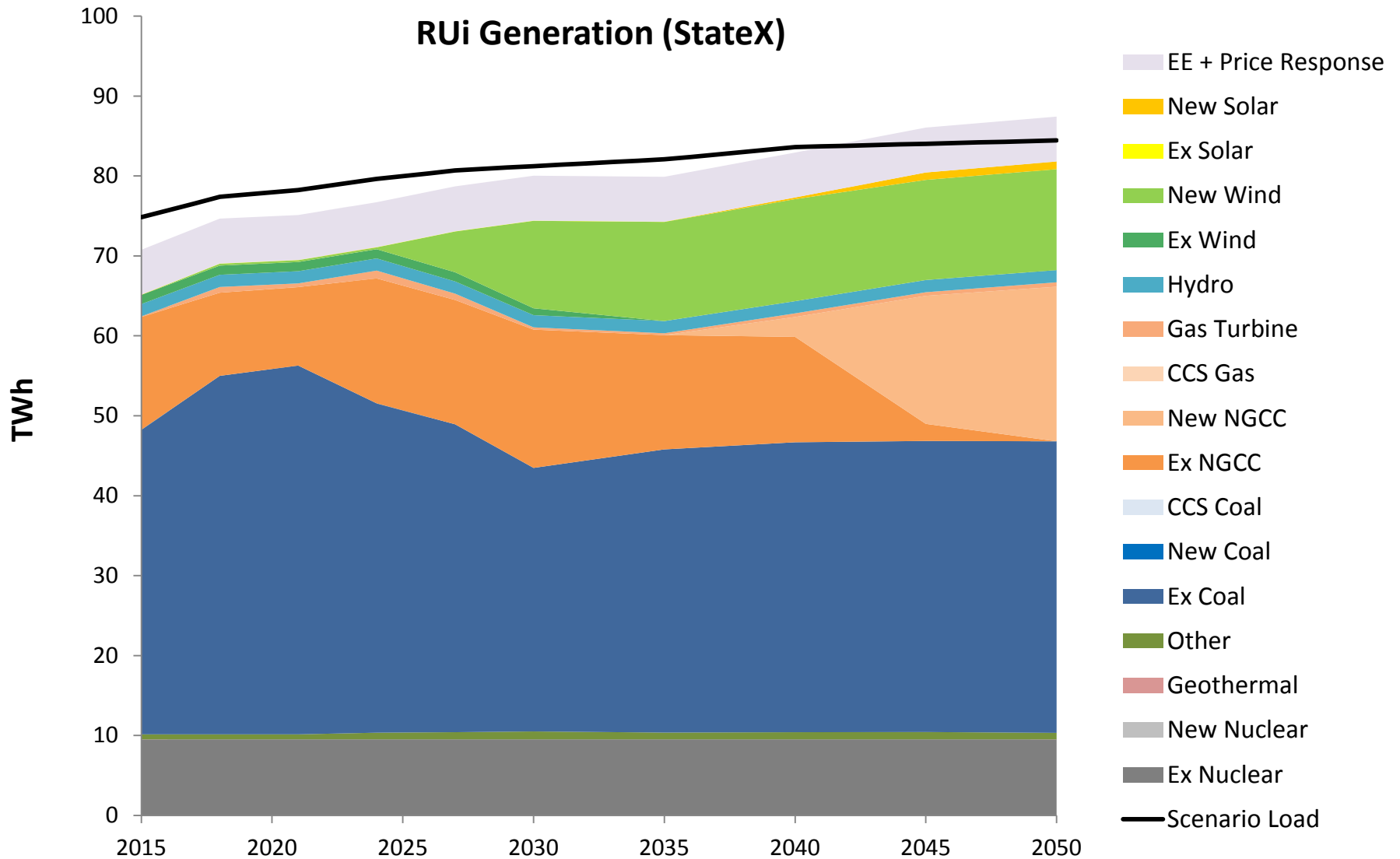
Bottom Line

- 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

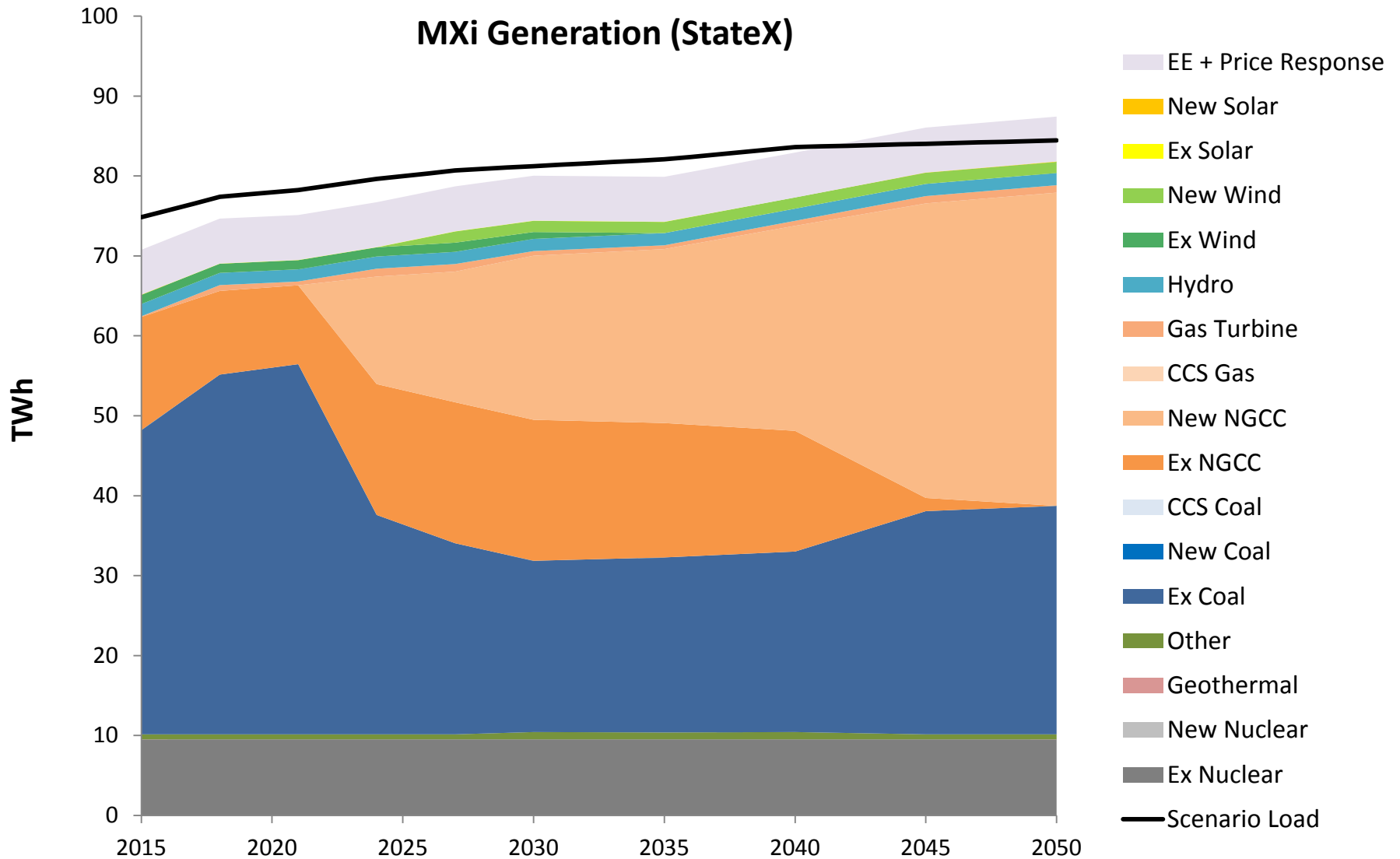
Compliance as an Island (State-level DYI Compliance)

- 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)

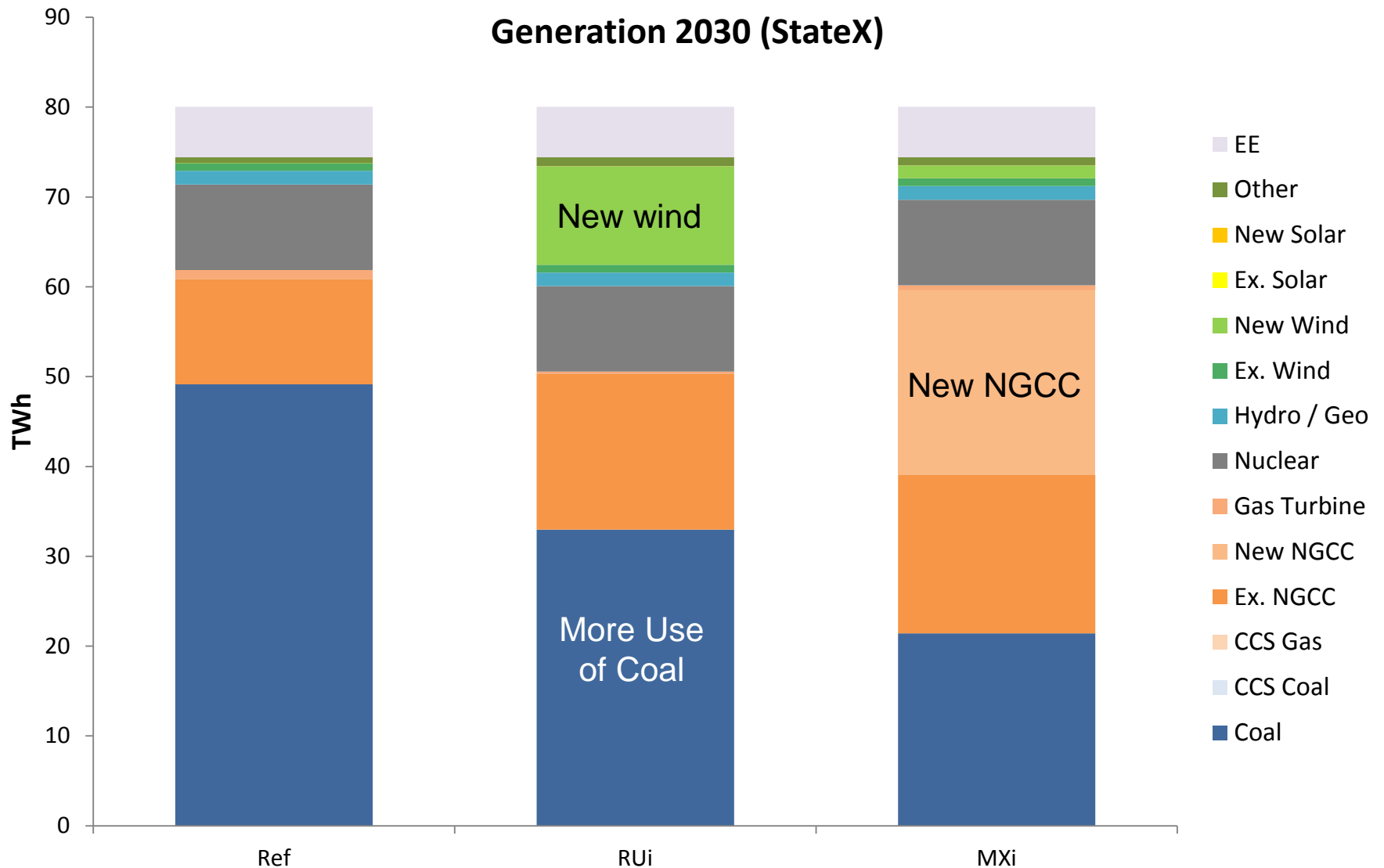
Subcategory Rate Compliance as an Island



Existing Mass Compliance as an Island

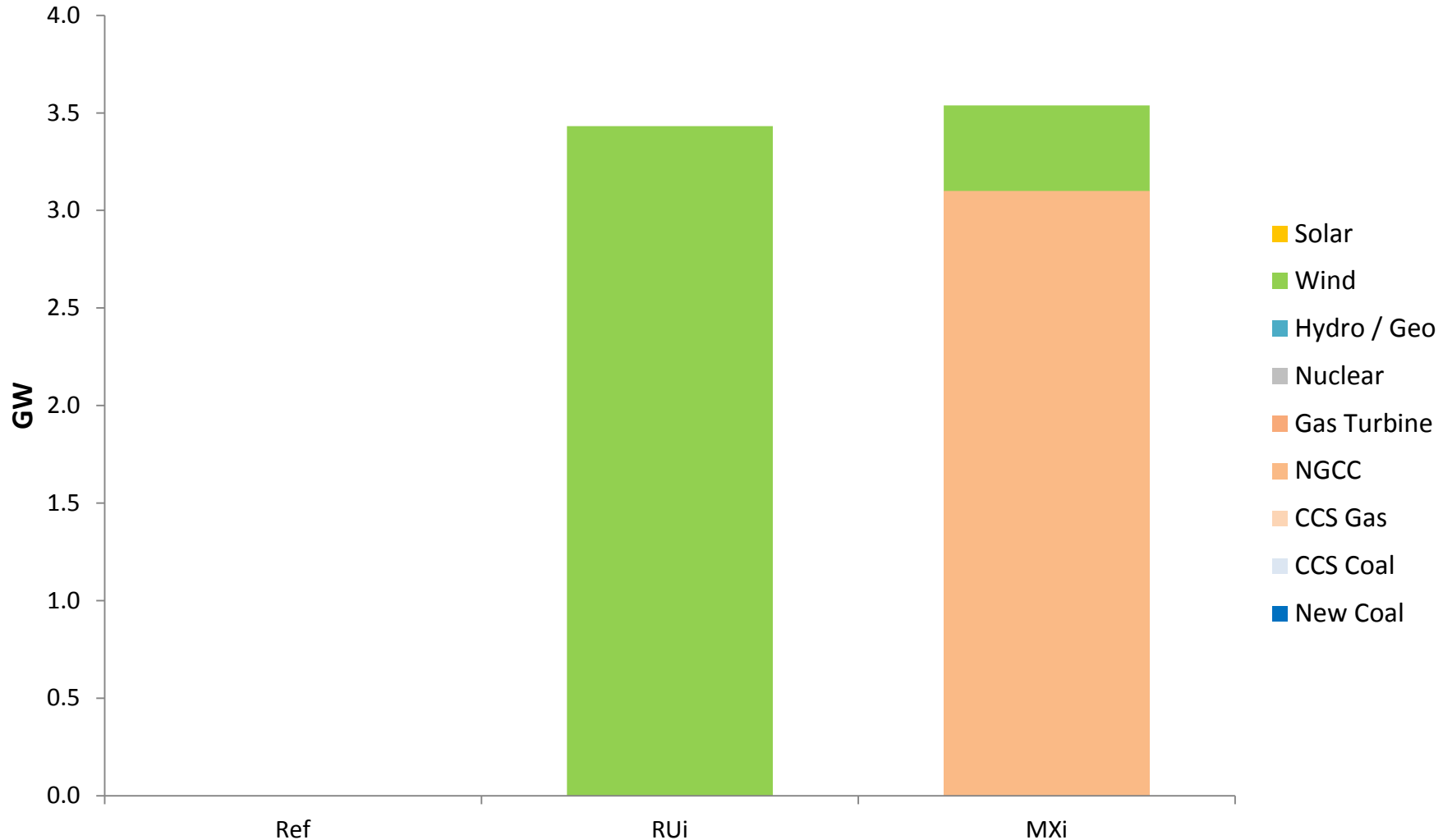


CPP Compliance as an Island Requires Overhaul of the Generation Mix for Either Rate or Mass Pathways



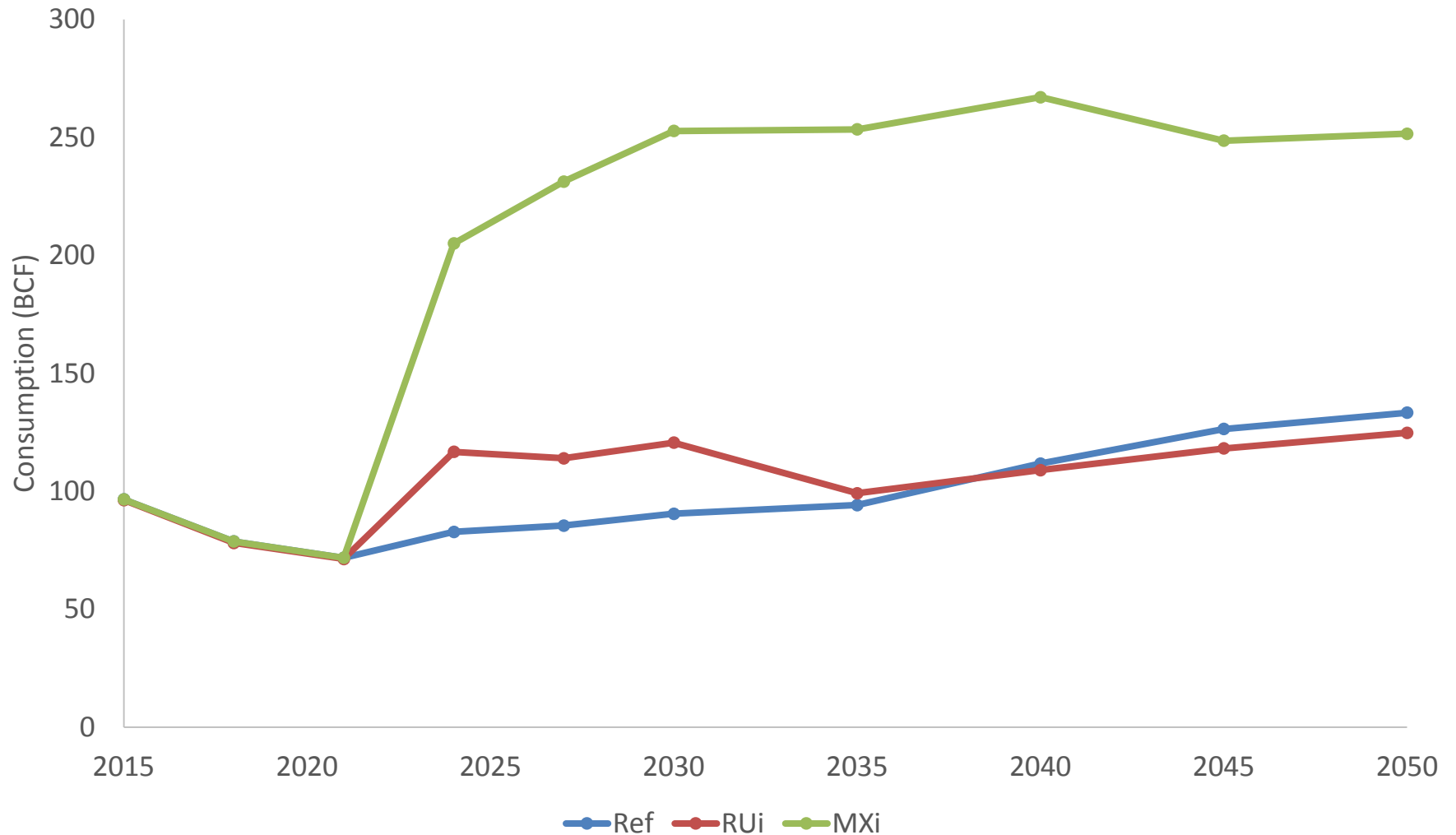
Island Compliance Depends on New Investment in Wind (for Rate Path) or New NGCC (for Mass Path)

Cumulative Capacity Additions in 2030 (StateX)



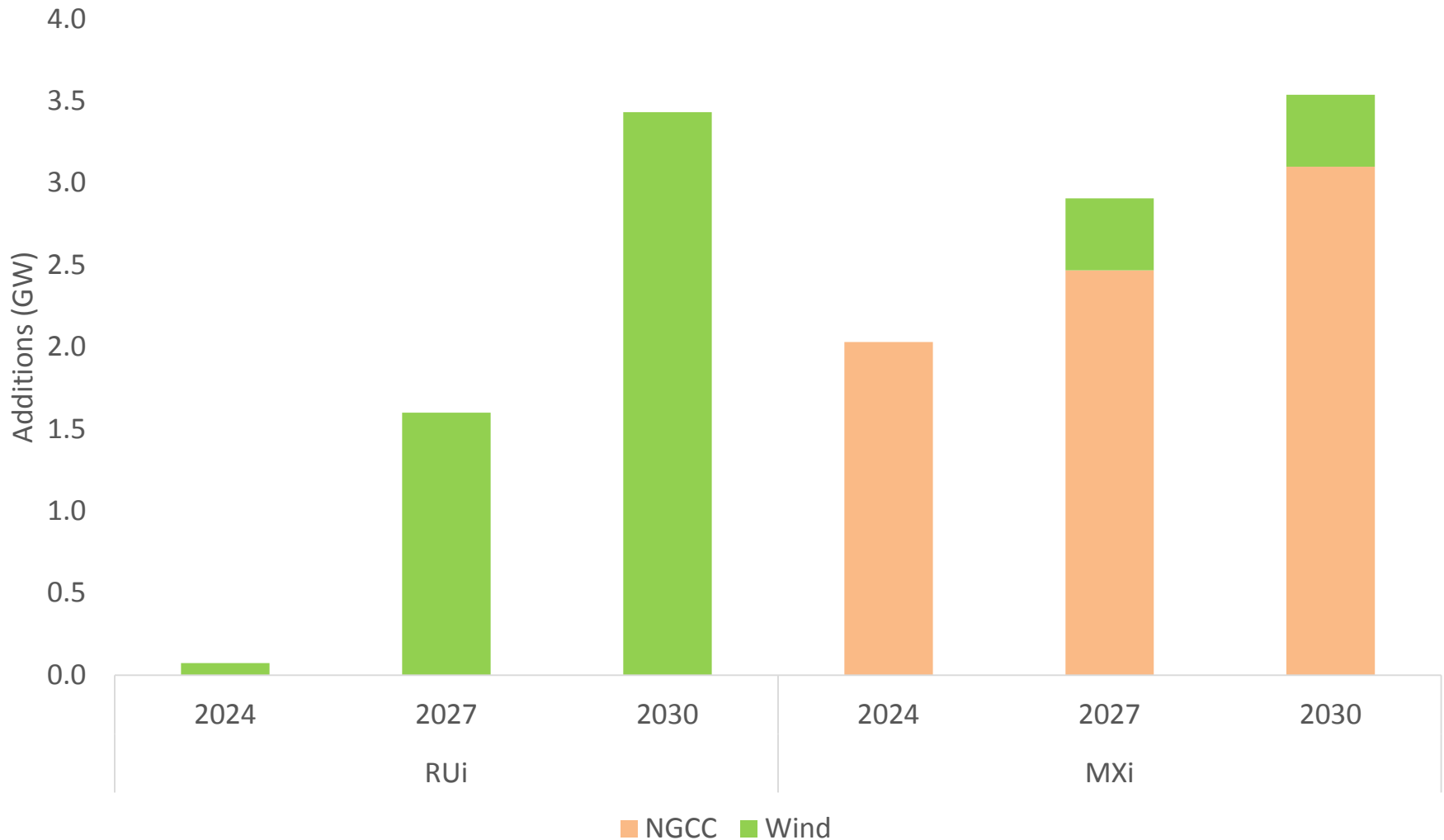
Mass Pathway Requires Much Greater Use of Natural Gas

Electric Sector Gas Consumption - StateX



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

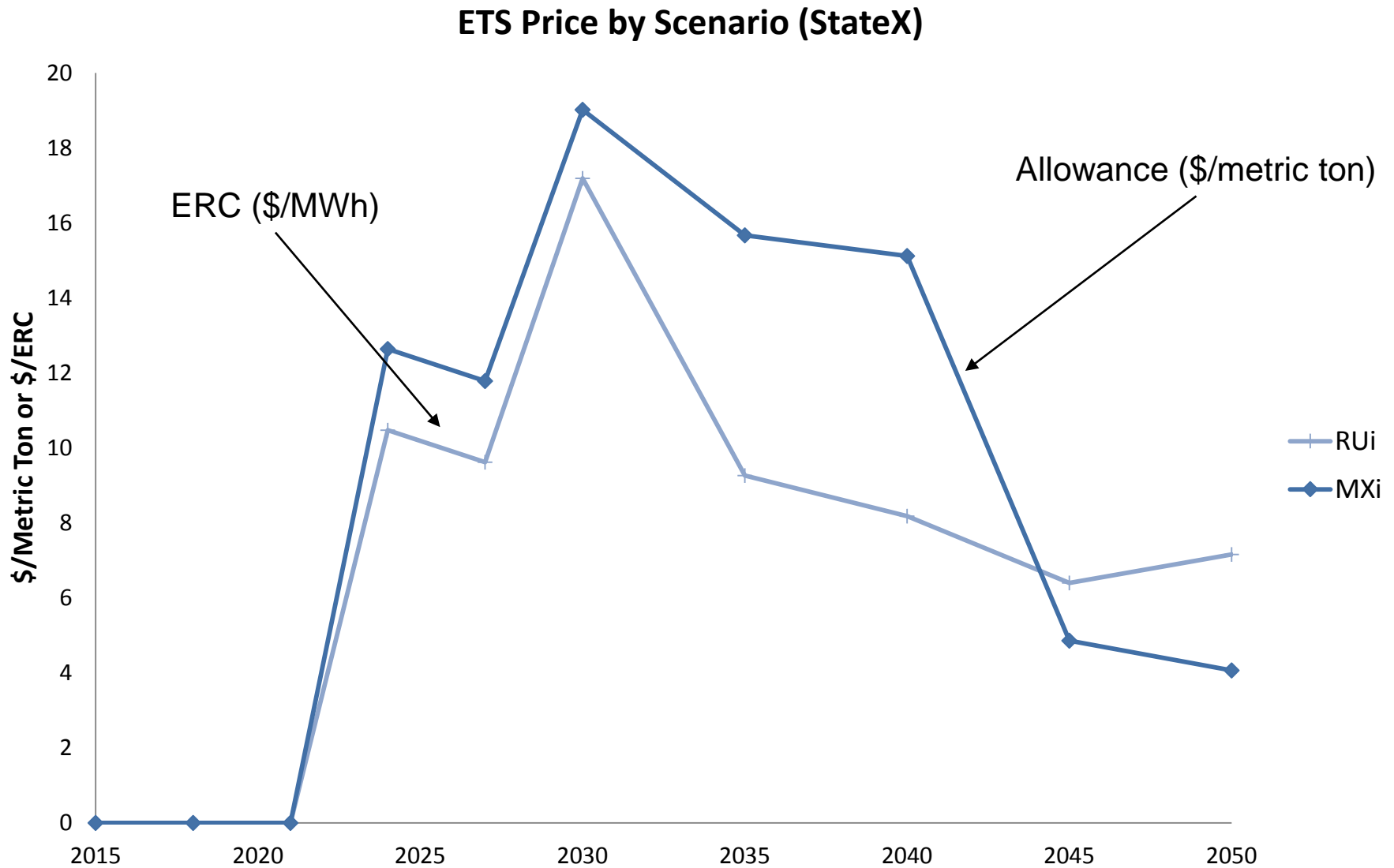
StateX Generation Additions by CPP Path



Observation

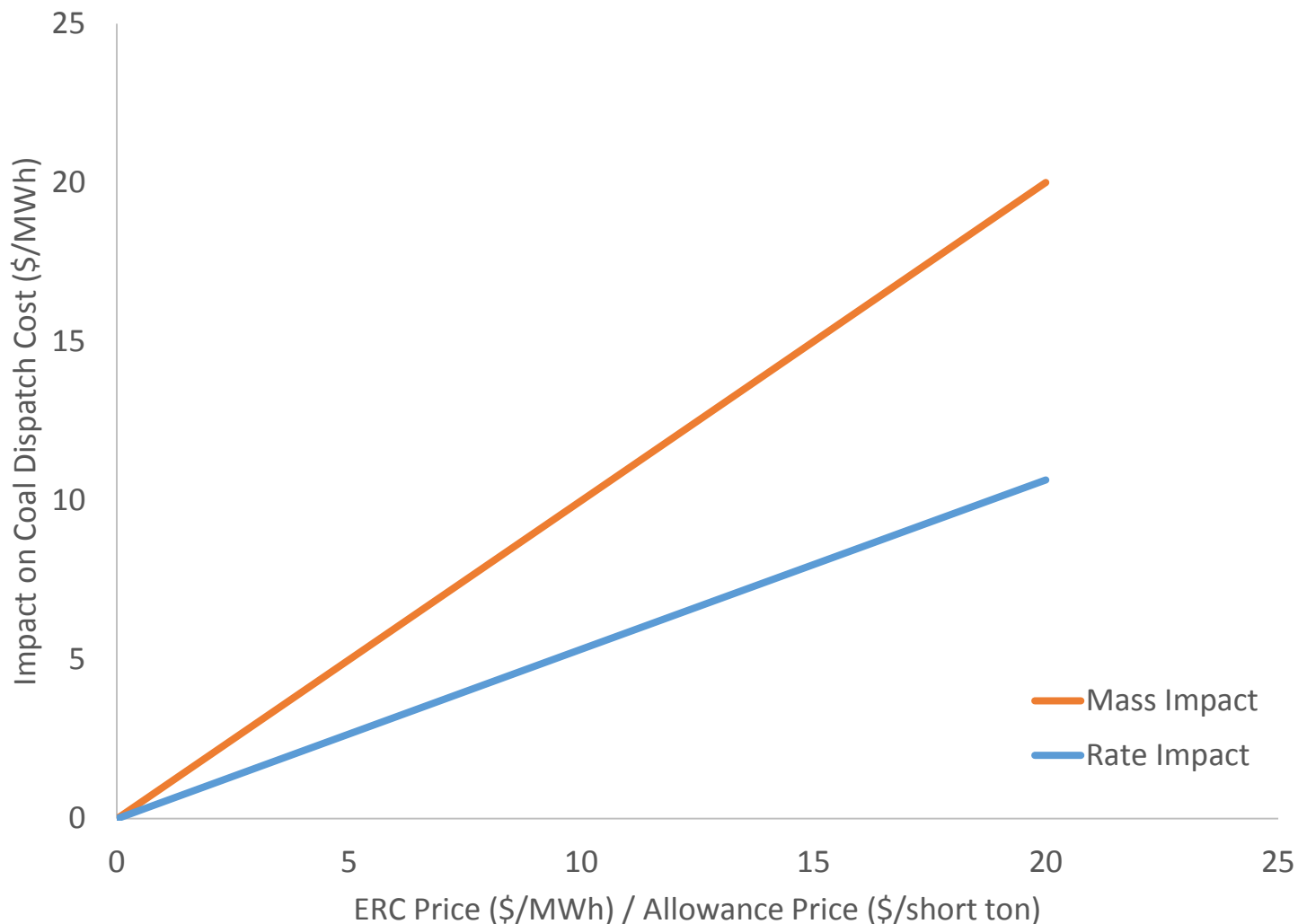
- Strong cost saving opportunities from participating in compliance markets for ERCs and Allowances
- Yet reasonable concern over counting on yet-to-be-formed markets for compliance
- Also reasonable to be concerned over the risk of CPP-driven investments being stranded if markets develop with low prices
- 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 1st period
 - Island Rate path only requires a 100 MW of wind in 1st 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



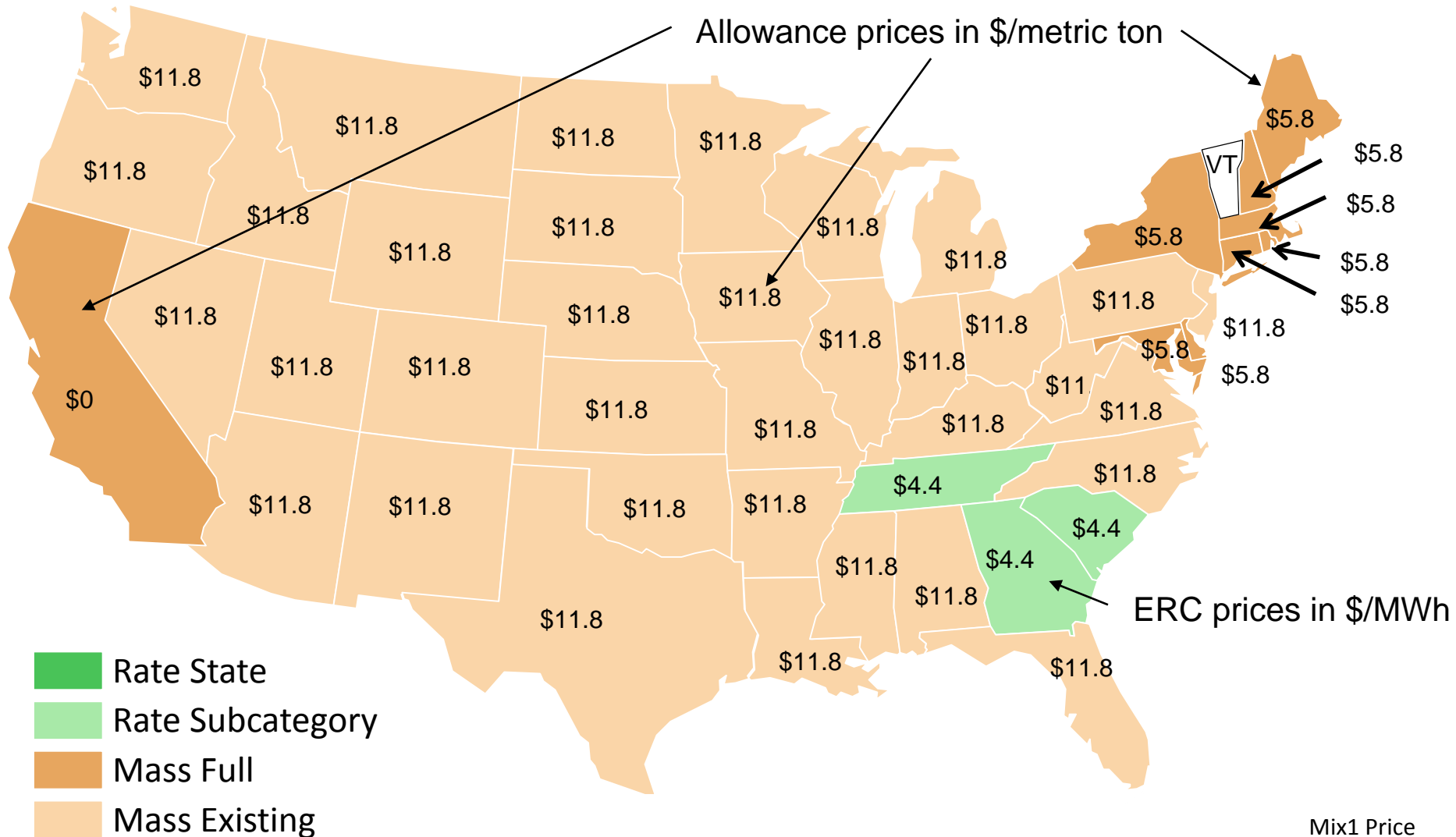
Compliance with Trading

- 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

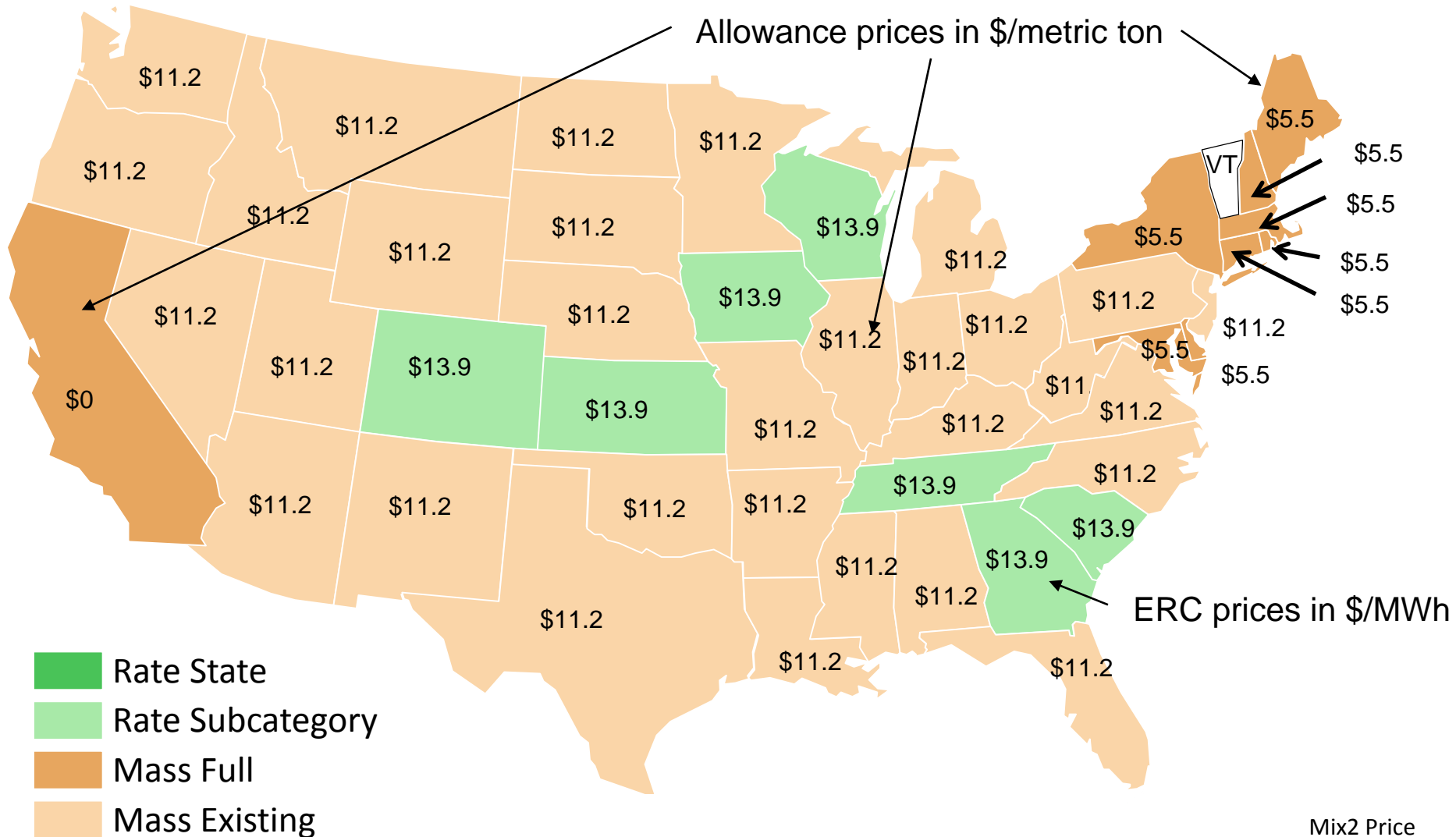
- All assume California and RGGI states choose Full Mass (with NSC) pathway, and do not trade with each other or other states
 - Already capping emissions from new and existing sources
 - Concerned that trading may undercut spirit of their own goals
- All assume that states with pending new nuclear choose 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)

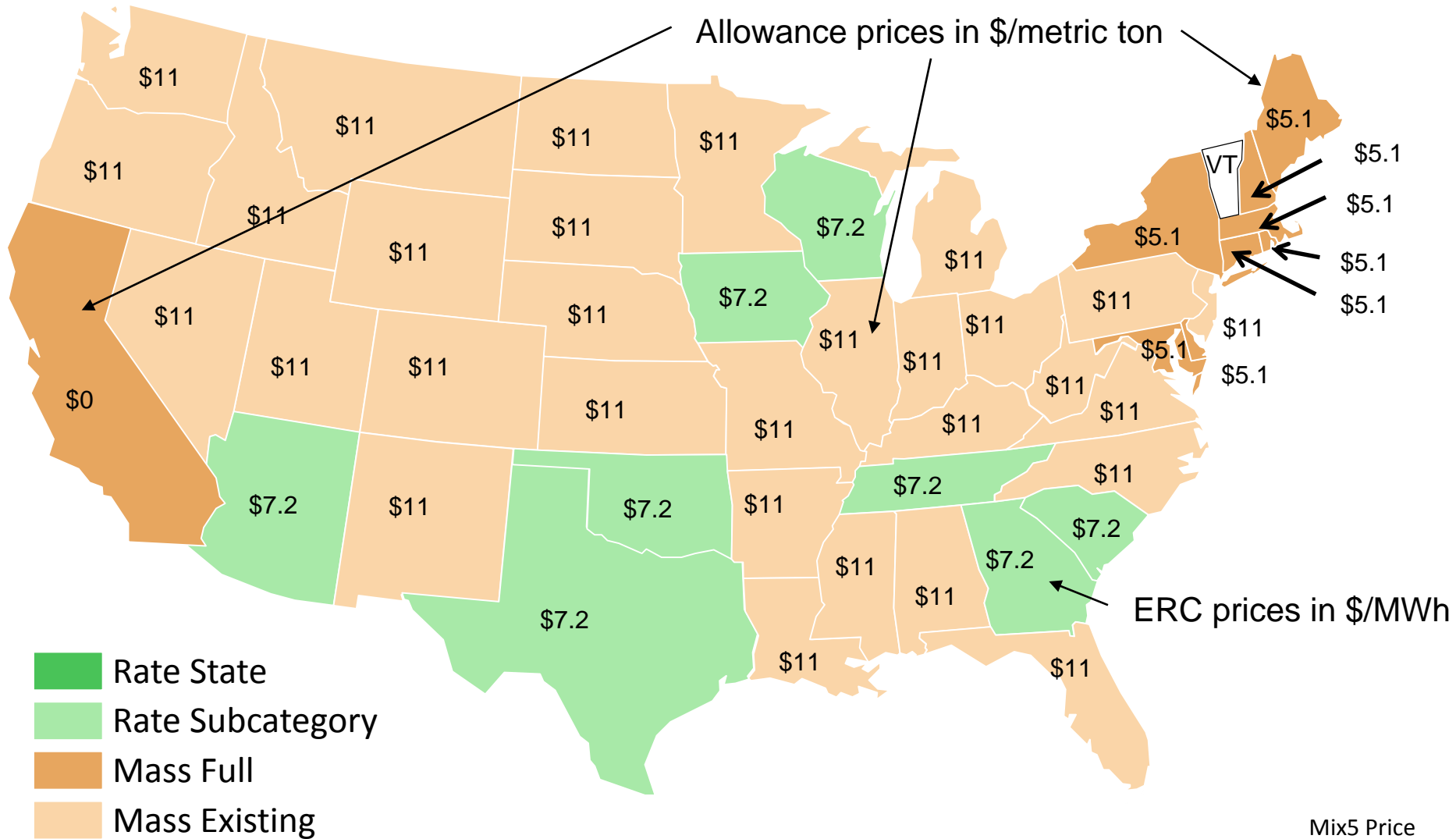


Mix1 Price

2030 Mix2 ERC/Allowance Pricing (Low Gas Prices)

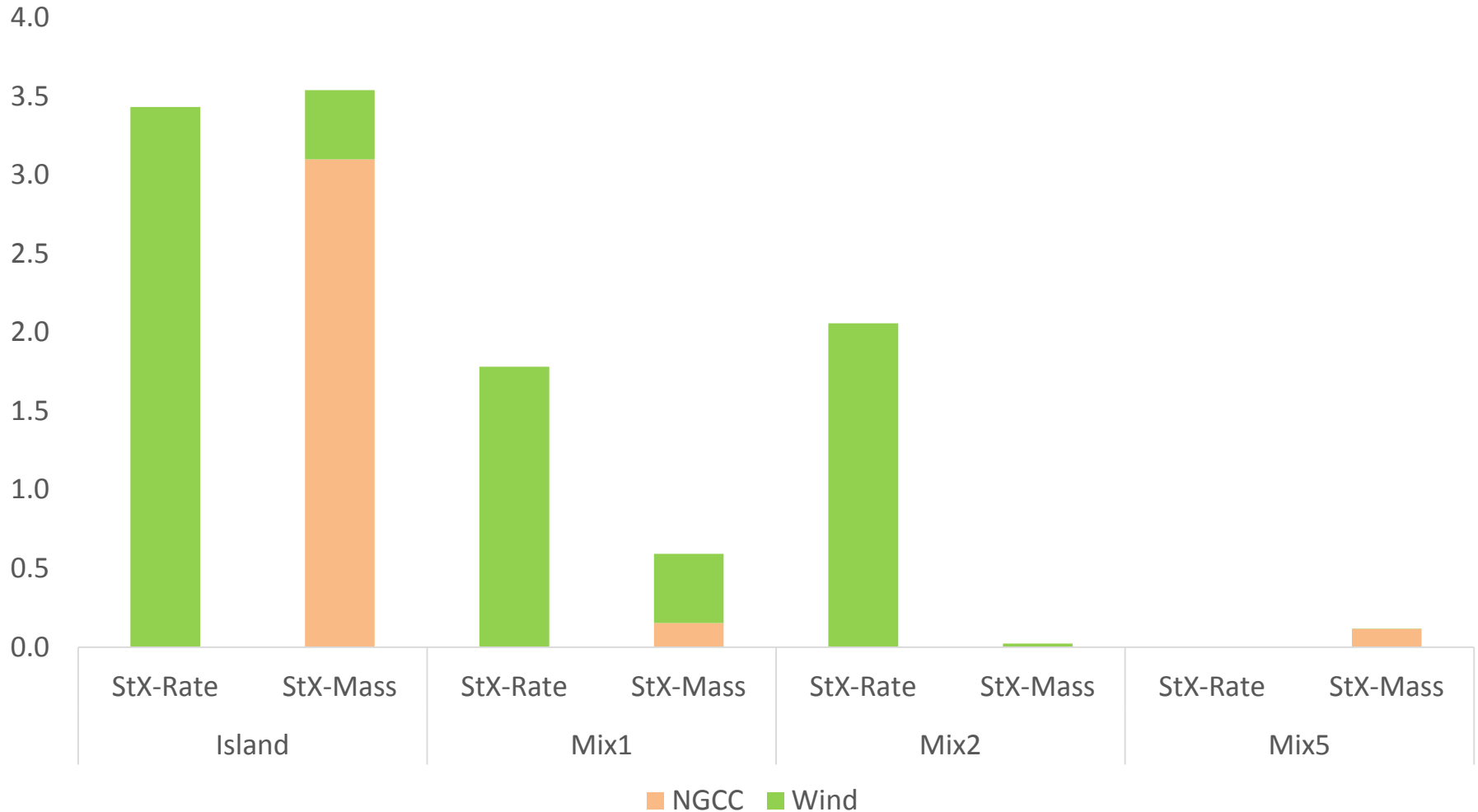


2030 Mix5 ERC/Allowance Pricing (Low Gas Prices)



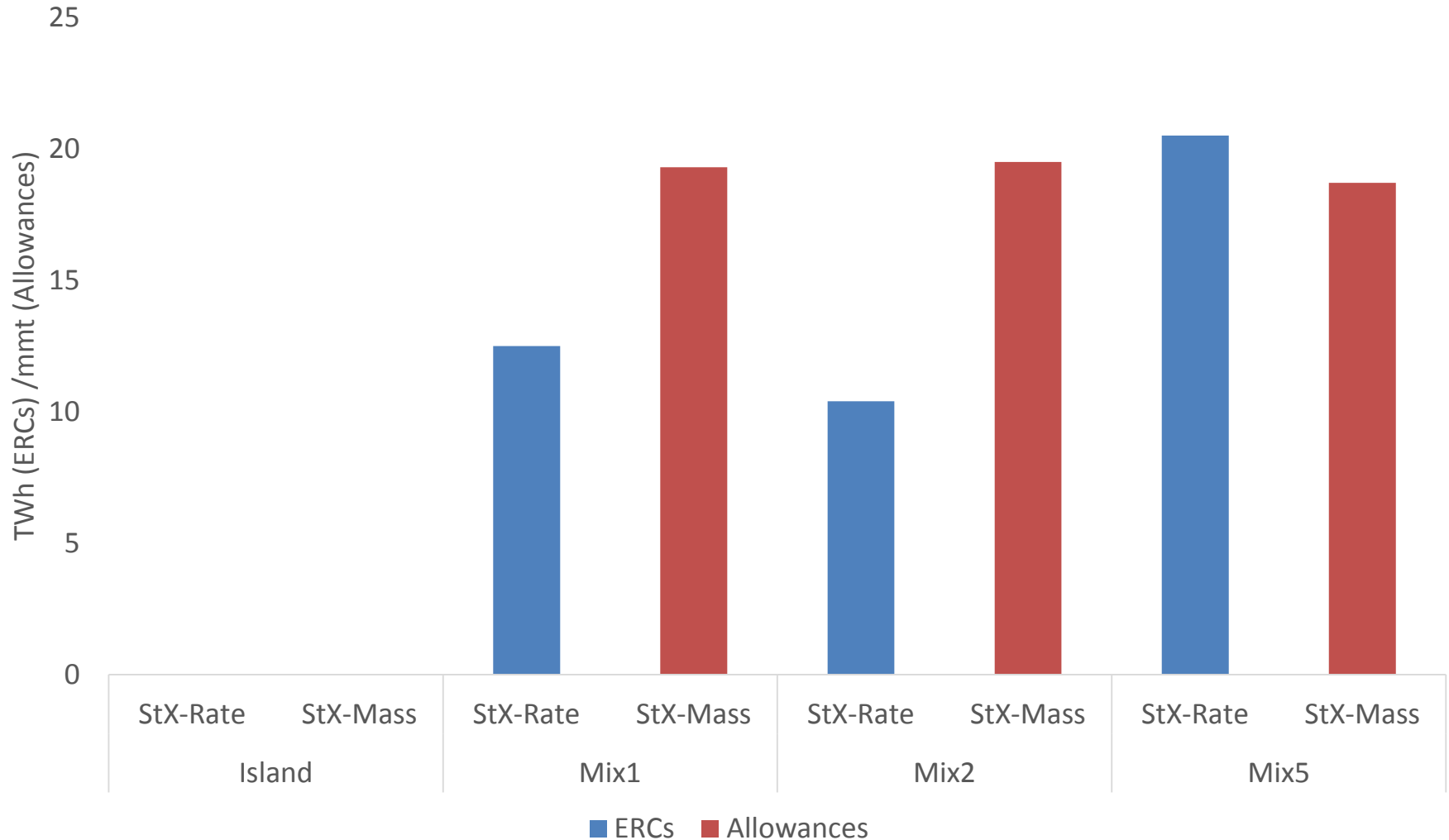
Investment Needed for Compliance

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 CO₂ 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



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