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Please Include "RGGI Leakage" in the Subject Line

"Economic Assessment of New Jersey re-joining the RGGI"

Modelling Methodology & Assumptions

Stakeholder Meeting

held at:

Montclair State University, Montclair, NJ, USA

December 13, 2019

Montclair State University CESAC Clean Energy and Sustainability Analytics Center

New Jersey Board of Public Utilities BPU

Argonne National Laboratory

Outline

- **Background**
- **Electricity Dispatch Model - AURORA**
  - Features, suitability of the model
  - Inputs, data sets used
  - Key assumptions
- **Integration of Electricity & Economic Models**
- **Economywide Model -** Computable General Equilibrium (CGE) Model
  - Features, suitability of the model
  - Inputs, data sets used
  - Key assumptions
- **Scenarios being analyzed**
  - Reference Case
  - NJ joining RGGI

Background

"An Economic Assessment (EA) of the Impacts of Potential *Leakage* from New Jersey rejoining the Regional Greenhouse Gas Initiative (RGGI)."

- Generation shifting, also known as, "leakage", is defined as a shift of electricity generation from electric generating units subject to RGGI to those that are not regulated under the initiative.

  - This may result in less efficient units being dispatch and a risk of increased carbon dioxide (CO_2) emissions.

- The EA focuses on:
  - assessing the potential size of the leakage, the economic impacts of the leakage potential, and their mitigation.

- The EA is performed by the CESAC team in collaboration with the Argonne National Lab (ANL).

- This presentation focuses on the assumption and methodology used to perform the EA

Electricity Dispatch Modeling

- This task is led by the Argonne National Lab (ANL) team:
  - **Dr. Prakash Thimmapuram**, Group Manager, Advanced Grid Modeling-Planning, Operations, and Controls.
  - **Dr. Todd Levin**, Principal Energy Systems Engineer
  - **Dr. Zhi Zhou**, Principal Computational Scientist

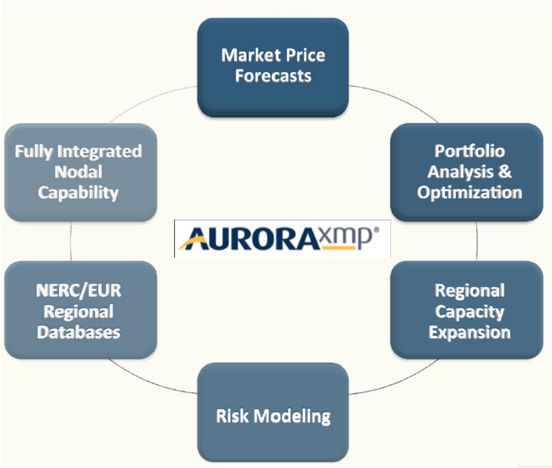
NEW JERSEY RGGI ANALYSIS: ASSUMPTIONS AND METHODOLOGY

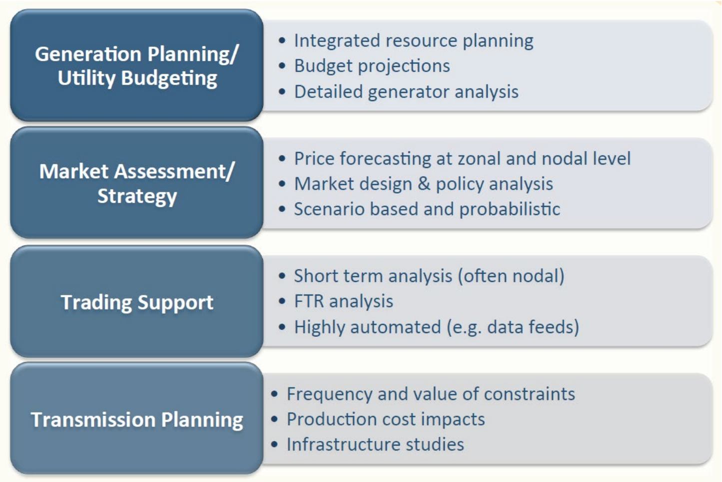
CENTER FOR ENERGY, ENVIRONMENTAL, AND ECONOMICS SYSTEM ANALYSIS

Argonne National Laboratory

AURORA ELECTRIC MODELING FORECASTING AND ANALYSIS SOFTWARE

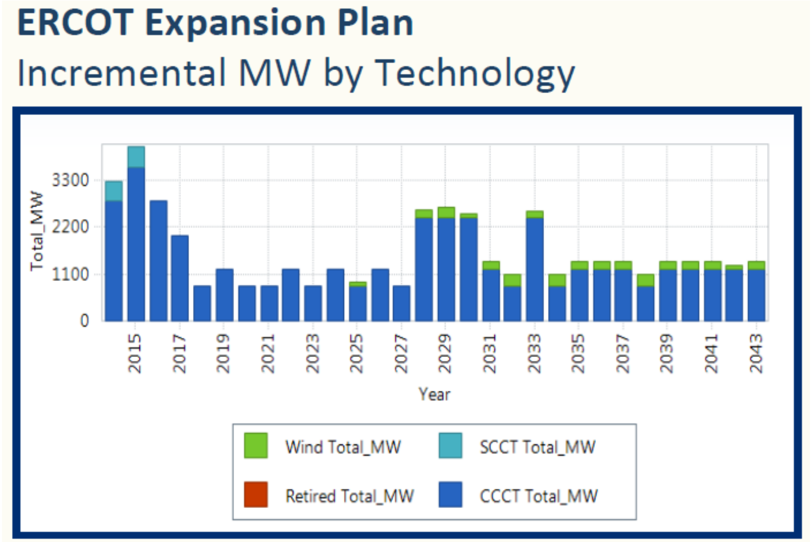
- Argonne will utilize AURORA, a commercial power system modeling tool, to conduct analysis
  - Argonne has 5+ years experience implementing AURORA for a variety of applications
- AURORA provides a numerous functionalities and supports key strategic analyses
- Short-term operational modeling and price forecasting: unit commitment and economic dispatch
- Long-term regional capacity expansion/investment modeling
- Stochastic risk analysis and portfolio optimization
- Security-constrained optimal power flow (SCOPF) and contingency (N-x) analysis





AURORA LONG-TERM EXPANSION MODELING

- Value-based, iterative logic
- Chronological valuation of existing and new resource options, including
  - Wind and renewables
  - DSM and conservation
- Economic retirement and retrofit options
- Convenient minimum and maximum build constraints
- Local and regional planning reserve margin requirements
- Federal/state policy initiatives can be represented (emissions, RPS)
- Results include
  - New capacity additions by year and technology
  - Retirement schedules
  - Capacity prices
  - Long-term market prices



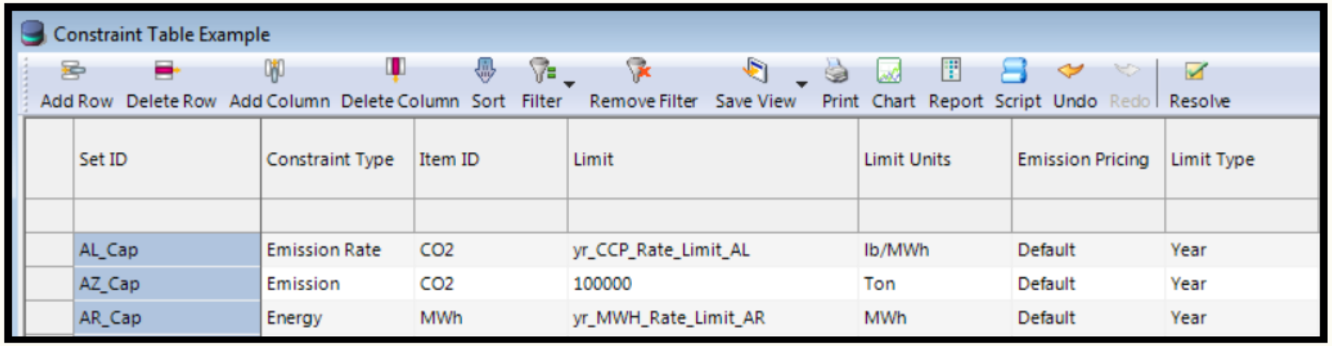
*Sample AURORA output

AURORA EMISSION AND RPS CONSTRAINTS

- **RPS Constraint (%)**: An annual RPS constraint can be entered for the portfolio to ensure that an adequate amount of renewable generation is acquired for the portfolio. The model will ensure that for each year

  [RPS Resource Generation (MWh)] >= [RPS Percent] * [Annual Demand (MWh)]

- **Emission Constraints**:
  - Model annual constraints on emissions (amount and intensity) by resource group
  - Capability to use in short-term and long-term studies
  - Follows a two-step process
    - Derive a shadow price that reveals the value/cost of enforcing the emission limit
    - Run the chronological dispatch with the shadow price applied (as a $/MWh cost adder)



Set ID	Constraint Type	Item ID	Limit	Limit Units	Emission Pricing	Limit Type
AL_Cap	Emission Rate	CO2	yr_CCP_Rate_Limit_AL	lb/MWh	Default	Year
AZ_Cap	Emission	CO2	100000	Ton	Default	Year
AR_Cap	Energy	MWh	yr_MWH_Rate_Limit_AR	MWh	Default	Year

AURORA POWER SYSTEM REPRESENTATION

- Modeling will consider territories covered by PJM, NYISO and ISO-NE
  - As well as some interactions with MISO, SERC, and Eastern Canada

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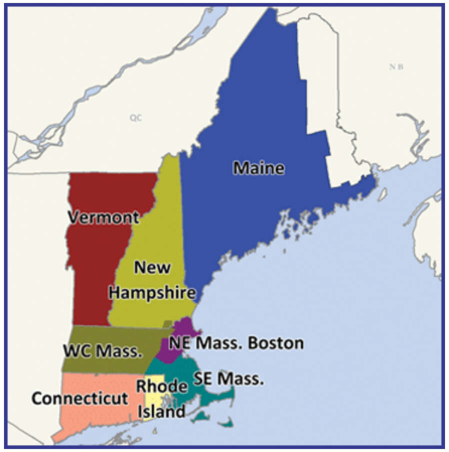
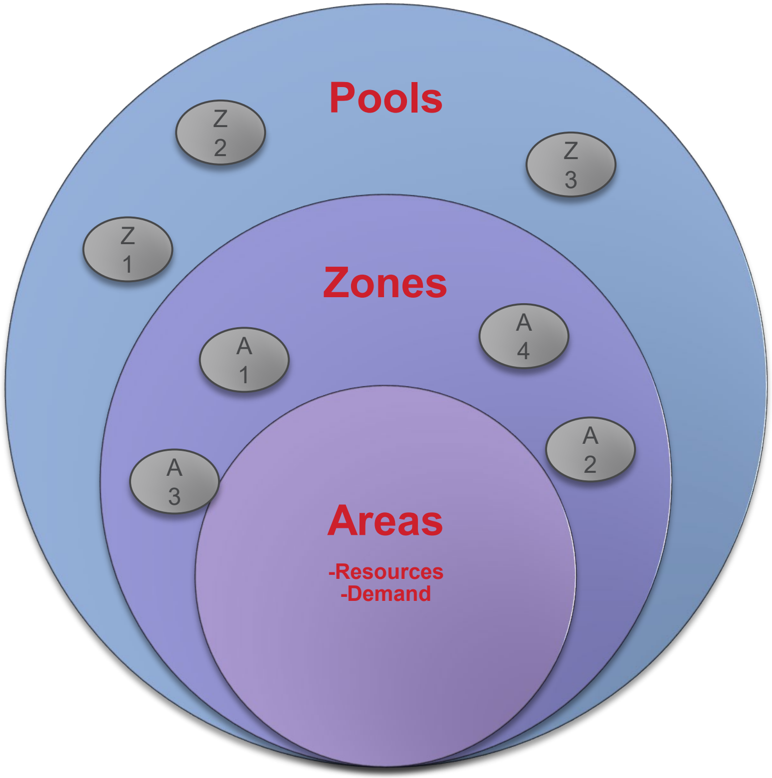


- RGGI member states
  - PJM: Connecticut, Delaware, Maryland, New Jersey
  - NYISO: New York
  - ISONE: Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

AURORA TOPOLOGY

<u>**Three levels of spatial aggregation**</u>

1. Planning Pools
   - Implement planning reserve margin
2. Transmission Zones
   - Aggregated transmission constraints
   - Contractual power flows
3. Demand Areas
   - Similar to balancing authorities
   - Hourly demand profiles



POWER SYSTEM REPRESENTATION

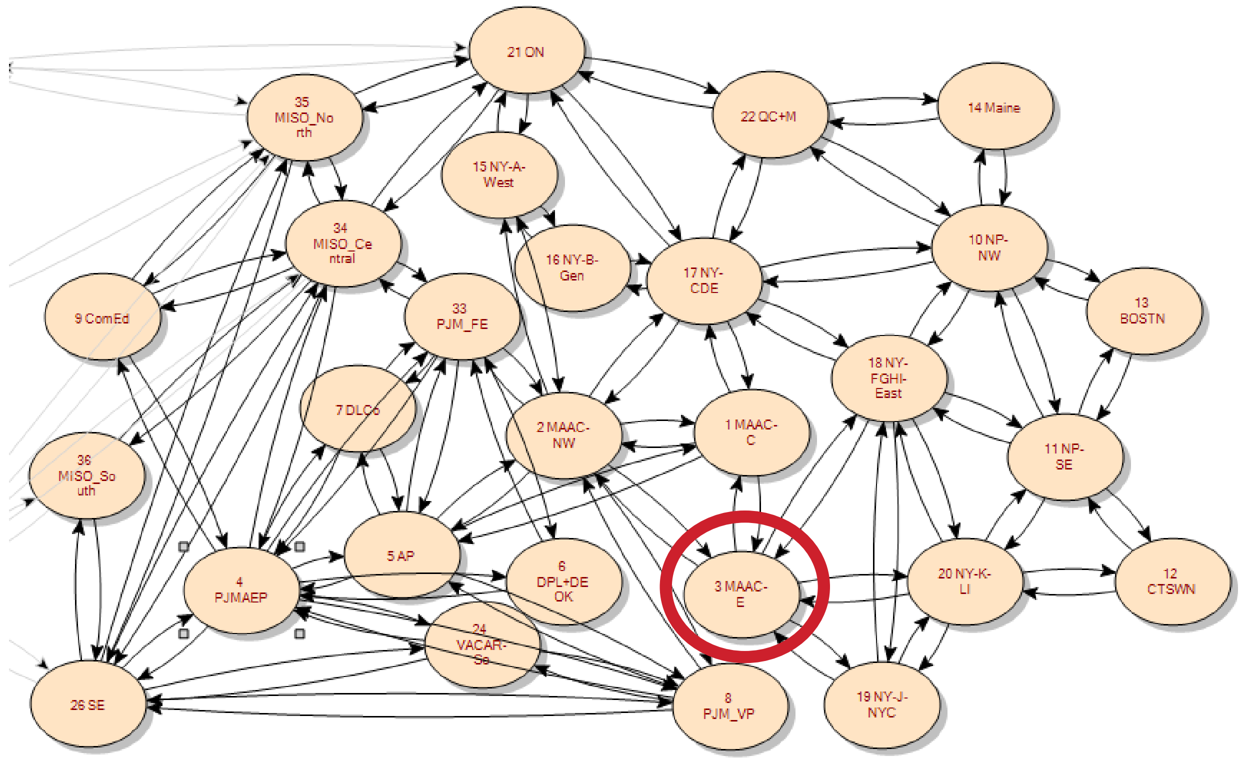
Data Sources

Transmission Network

- 28 zones
- NPCC USA
- PJM RPM CETL Limits
- Includes wheeling costs, transfer losses

- ***Demand Areas***
  - 101 areas
  - FERC Form 714
  - NERC ES&D;
  - PJM forecast for PJM related Areas
- ***Generation Units***
  - 16,000+ units
  - NERC Electricity Supply and Demand (ES&D),
  - EIA-860
  - New unit costs and characteristics based on EIA's Assumptions to the Annual Energy Outlook

Zonal Transmission Topology



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KEY ASSUMPTIONS: SCENARIOS

- Reference scenario
  - NJ is not in RGGI
  - 22.5% RPS by 2021
  - 50% RPS by 2030
  - 2% electricity efficiency improvement relative to baseline projections
  - Minimum 400 MW of solar added per year through 2030
  - Minimum 7,500 MW of offshore wind added by 2034
  - Minimum 2,000 MW of battery storage added by 2030
- Sensitivity scenario
  - NJ joins RGGI
  - RGGI emissions budget increases accordingly
  - All else above remains the same

METHODOLOGY

- Model will be executed through 2035
  - Considering a representative subset of hours
- Investment/Retirement Analysis
  - Generation units enter/exit the system based on projected net present value
  - Subject to RPS and reserve margin constraints
- Will consider two primary scenarios
  - NJ **does not** participate in RGGI
  - NJ **does** participate in RGGI
  - May consider additional parameter sensitivity scenarios as needed
- Will analyze the CO_2 emissions that result in each scenario
  - Focus on potential leakage effects
    - Occurs when a decrease in NJ emissions is offset by an increase elsewhere

KEY ASSUMPTIONS: RGGI

- The RGGI emissions target is modeled as a constraint
- Assumptions
  - NJ joins in 2020.
  - NJ CO2 allocation is 18 million tons of CO2 in 2020
  - 3% annual reduction of the cap from baseline consistent with program & rule requirements (including the 2021-2025 bank allowance adjustment).

Regional emissions constraint (input) → **Emissions price (output)**


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Economic Modelling

NJPOWER - Computable General Equilibrium (CGE) Model for New Jersey and RGGI region

- This task is led by the CESAC team:
  - **Dr. Pankaj Lal**, Director CESAC
  - **Dr. Dileep Birur**, Associate Director CESAC
  - **Dr. Bernabas Wolde**, Program Manager CESAC
  - **Mr. Erik Lyttek,** Research Assistant CESAC
  - **Ms. Nicole Provost,** Research Assistant CESAC

NJPOWER Model – a multi-region CGE model

- We are developing a CGE model (NJPOWER), a multi-region multi-sector global Computable General Equilibrium (CGE) model, with explicit New Jersey, RGGI and rest of US regions.
- The standard model is based on Purdue University based Global Trade Analysis Project (GTAP), a widely used global economy-wide data base and model for CGE analyses.
- GTAP-Power data base provides disaggregated electricity generation by source and operational characteristics such as Base vs. Peak load.
- We disaggregate the New Jersey and RGGI regions, based on sector level production data, value added data, state GDP, and input-output tables.
- The dynamics in the NJPOWER model would come from capital accumulation, labor productivity, and other exogenous macro variables such as growth in GDP, population, and labor supply.
- This GTAP based CGE modeling framework is widely used for regulatory analysis of trade, environmental policies (e.g., US EPA on RFS2; CARB on LCFS).

An Overview of the Economywide CGE Model - **NJPOWER**

Data Base:

GTAP data includes:

- Regional Input-output tables.
- Disagg. electricity sector from the GTAP-Power data base.
- CO_{2e} emissions.
- International trade data.
- Preference & economic parameters
- Tariffs, taxes, & subsidy rates.

Other supporting data:

- New Jersey & RGGI states data on: gross state product, value added, employment, electricity generation, GHGs emissions.

Data Base Split with NJ & RGGI in USA

NJPOWER Model

Behavioral equations determine:

- Household demand
- Intermediate demand
- Net foreign demand
- Demand and supply of primary factors (Land, Labor, Capital)

Other Features:

- Energy substitution
- Electricity diff. by base & peak loads.
- Emission accounting
- Emission trading

Scenarios/Shocks:

- Baseline case
- Energy policies
- Environmental policies
- Economic policies

Model determines change in:

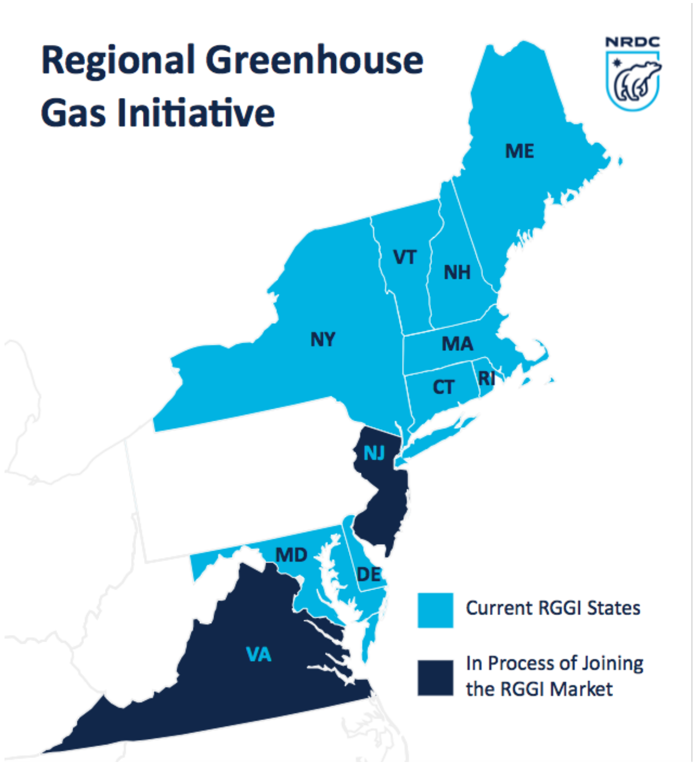
Output:

- GDP
- Employment
- Production, consumption imports, exports of goods & services.
- Prices by sectors & agents.
- Emissions from fossil fuels.
- Change in wages, land rents, & returns to capital.
- Change in welfare.

Methodology… Disaggregating NJ & RGGI regions

- We used the latest available GTAP data base which pertains to 2014, and updated the data base to reflect 2018 economy, based on historical data from secondary sources such as:
  - U.S. Bureau of Economic Analysis (BEA)
  - World Economic Outlook 2019 from International Monitory Fund (IMF)

- Splitting of regions within the US:
  - New Jersey and
  - RGGI regions (comprising the nine states together: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont).
  - Used sector level production data, state GDP, value added, and input-output tables from the U.S. BEA.



What is a Computable General Equilibrium (CGE) Model?

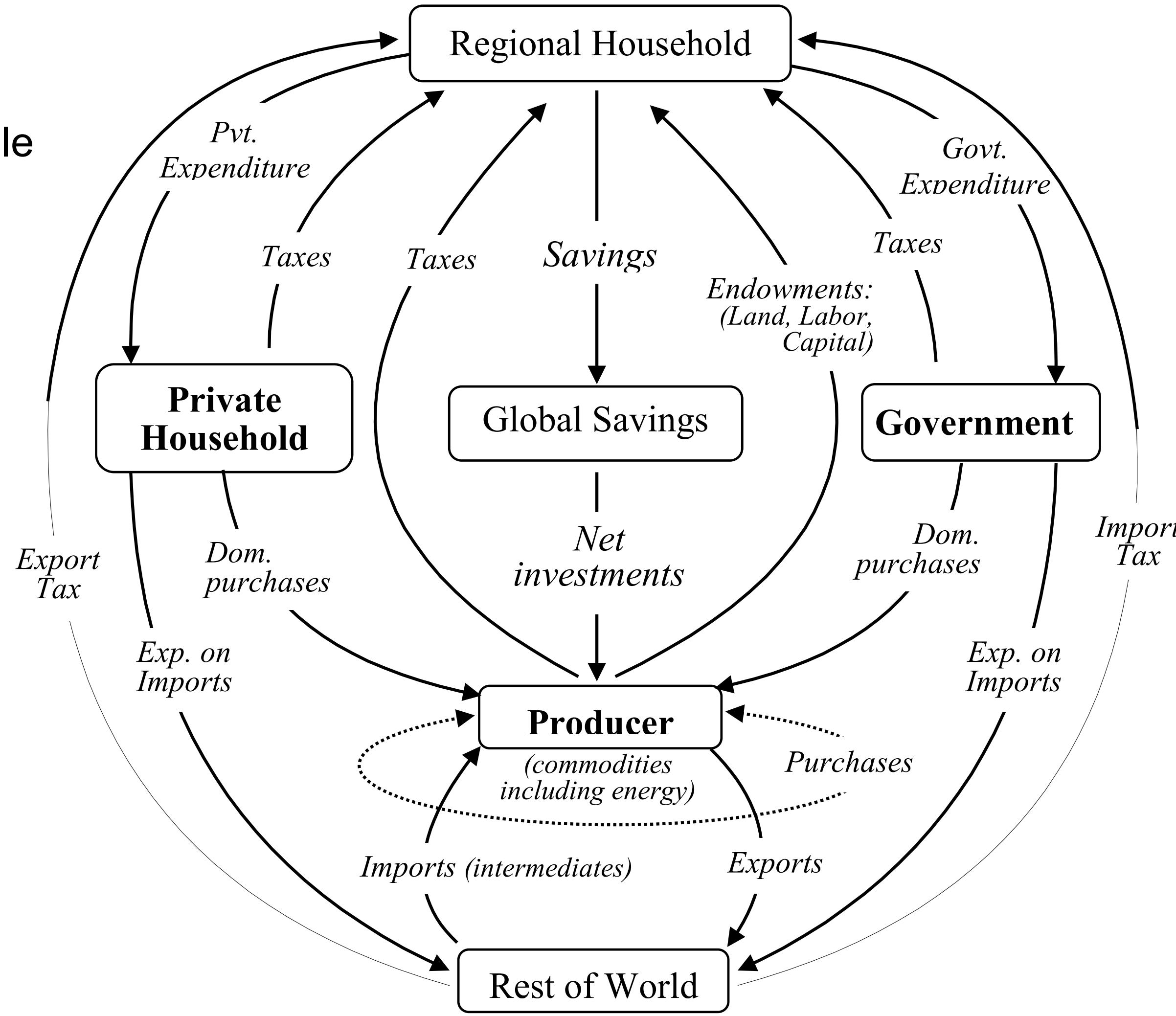
- NJPOWER – CGE Model:
  - The NJPOWER model is *computable* because it is structured by a set of equations that define how firms and households allocate scarce resources.
  - The NJPOWER is *general* because it tracks all linkages among the 27 aggregate goods and services across the aggregated global regions that comprise the modeled economy.
  - The NJPOWER model produces an economy-wide *equilibrium* by imposing these core conditions:
    - equilibrium in all markets,
    - zero economic profits,
    - the regional household is on its budget constraint, and
    - global investments equal global savings.
    - The global trade balance condition determines the world price.

Structure of the NJPOWER CGE Model

- **Key Assumptions:**
  - Perfect Competition
  - Constant returns to scale
  - Walrasian adjustment

- **Behavioral relationships:**

- Regional household – Cobb-Douglas utility function
- Producer –nested Constant Elasticity of Substitution (CES) function
- Private Household – Constant Difference Elasticity (CDE) function.



Dynamics in NJPOWER Model

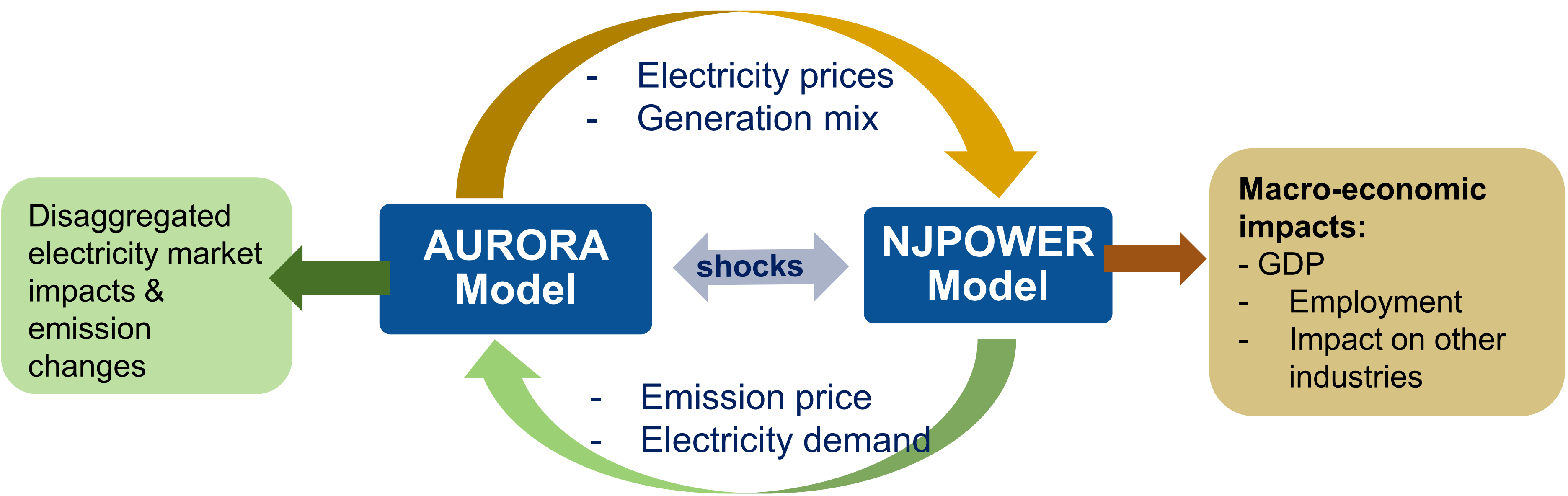
- **Dynamics in the NJPOWER Model:**
  - The dynamics in the NJPOWER model would come from
    - capital accumulation, labor productivity, and other exogenous macro variables such as GDP growth and labor supply.
    - We develop the comparative static version of Power model and then adapt into the dynamic version of the GDynE (dynamic GTAP-Energy) model.
- **Developing CGE Baseline:**
  - We develop the baseline projections (2018 through 2034) for all the explicit regions within the US and the rest of the world aggregate, on macro variables such as:
    - growth in state GDP,
    - growth in population,
    - growth in labor force/employment,
    - Any other assumptions such as energy price forecasts (IEA).
- **Policy Analyses:** The scenarios include reference & NJ joining RGGI.

Sectoral Aggregation in NJPOWER Model

Agriculture	CoalBLely	Automobile
Fishery	NuclearBLely	RoadTranspt
Forestry	GasBLely	OthTranspt
Coal	HydroBLely	Water
Oil	OtherBLely	Chemicals
NatGas	WindBLely	Oth_Inds
Oil_Pcts	GasPely	En_Int_Ind
GasDistn	OilPely	Constructn
	SolarPely	Services
	TnD_Ely	

Integrating Electricity Market and Economic Models

- AURORA model provides detailed characterization of electricity markets, which is preferable when estimating GHGs emission changes due to changes in electricity generation and transmission.
- However, AURORA model does not consider how changes in electricity sector would affect rest of the economy.
- We combine the strengths of technologically rich AURORA model with the strengths of economywide NJPOWER model, and generate the macroeconomic implications of energy/emission policies.



Scenario – Reference Case: Assumptions

- An anticipated Reference future where NJ does not re-join RGGI, may include any additional policy interventions, resource requirements, etc.

  - **Emissions**: Renewable Portfolio Standard – 50% by 2030.
  - **Electricity**: PJM carbon content – PJM meets state RPS & chooses state least cost approach.
  - **Efficiency** in Electricity consumption: -2%/year (assumes PJM already includes -0.75% EE in forecast)
  - **Efficiency** in Natural Gas consumption: -0.75%/year
  - **BTM Solar PV** – 400+MW/year
  - **Storage**: 600 MW by 2021, and 1400 MW by 2030.
  - **Off-shore Wind:** 7500 MW by 2034.

Scenario – **NJ Joining RGGI**: Assumptions

- **NJ Join RGGI** - relative to Reference scenario, NJ will participate in RGGI.
  - The analysis focuses on:
    - ✓ CO_2 emissions from New Jersey and the RGGI states relative to their projected Reference case levels.
    - ✓ Impacts on New Jersey's fleet of electric generation sources.
    - ✓ The import and export of electricity between RGGI and non-RGGI states and NYISO.

Montclair State University

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Thank you

https://www.montclair.edu/cesac