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Overview of HOPE-MD Scenarios & Inputs

Presented to the Energy Resilience and Efficiency Working Group of the Maryland Commission on Climate Change

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Energy at Hopkins
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Agenda

I. HOPE-MD Overview

- Introduction
- Brief Model Structure & Components
- Key Features & Capabilities

II. Scenarios

1. Reference
2. Decarbonization Policy
3. Additional Policy Priority

III. Key Input Data

- Overview
- Comparison of Scenarios

IV. Preliminary Results, Next Steps, & Discussion

I. HOPE-MD Overview

HOPE
Holistic Optimization Program for Electricity

Model goal:

- Provide a production costing & resource/transmission expansion planning tool
- Evaluate portfolios of alternative investments for future electricity needs

Key features:

- Transparent, easy to use, flexible
- Open-source
- Captures essential technical & economic characteristics of renewable energy production, storage, and transmission

Technical implementation:

- Written in Julia programming language
- Utilizes Julia's optimization libraries (e.g., JuMP)
- Ensures computational efficiency with minimal costs to users
- Interfaces with familiar software for managing input data & analyzing results

Generation Transmission Expansion Planning Model (GTEP)

HOPE
Holistic Optimization Program for Electricity

- **Purpose**:
  - Analyze investment decisions under various policies and energy transition scenarios.
  - Support analyses on energy resilience and efficiency for the Maryland Climate Change Commission.

- **Objective**:
  - Minimize total system cost: Investment cost + Variable operation cost + Penalty for non-compliance with policies

- **Constraints and related inputs**:
  - Budget constraint
  - Power balance ⇔ Load & Import Profile, Renewable Energy Profile, Generator Data
  - Transmission transfer limit ⇔ Transmission Capacity
  - Generator operation constraints ⇔ Generator Data
  - Storage operation constraints ⇔ Storage Data
  - Resource adequacy requirements
  - Policies: ⇔ Other Input
    - Renewable portfolio standards (RPS)
    - Carbon emission limitations

Detailed Inputs for HOPE Model

HOPE
Holistic Optimization Program for Electricity

Resource Input

Generator
- Maximum capacity
- Technology
- Zone
- Flags (thermal, variable renewable, must_run, retired, unit commitment)
- Operational cost
- Emission factor
- Capacity factor
- Availability factor
- Forced outage rate
- Spinning reserve
- Ramp up/down
- Min up/down time
- Start up cost

Gen_candidate
- Maximum capacity
- Technology
- Zone
- Flags (thermal, variable renewable, must_run)
- Investment cost
- Operational cost
- Emission factor
- Capacity factor
- Availability factor

Demand
- Zone
- Demand
- State

Storage
- Storage type
- Zone
- Capacity (MWh),
- Max power (MW)
- Operating cost
- (Dis)Charging efficiency
- (Dis)Charging rate
- Emission factor
- Capacity credit

Storage_candidate
- Same as above
- Investment cost

Line
- From zone
- To zone
- From bus*
- To bus*
- KV*
- Capacity limit

Line_candidate
- Same as above
- Investment cost

Policy Input

Carbon policy
- Carbon emission cap for each state

RPS policy
- Renewable portfolio standards for each state

Time series Input

Solar_timeseries
- Rescaled hourly solar profile (0-1) for each zone

Wind_timeseries
- Rescaled hourly wind profile (0-1) for each zone

Load_timeseries
- Rescaled hourly load profile (0-1) for each zone

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II. Scenarios

1. **Reference:**
   - **No decarbonization policies**

2. **Decarbonization Policy:**
   - **Includes Maryland's regulations to achieve clean energy goals:**
     - **RPS mandate**
     - **Energy Storage Act**
     - **EV stock requirement**

3. **Additional Policy Priorities:**
   - **New data center development**
   - **Maryland's energy self-sufficiency, reducing out-of-state imports**

1. Reference

		Reference		
		Energy Efficiency (Typical Performance)		Energy Resilience
		Typical	**Constrained Electrification**	**Stressed**
Load Profile		Lower profile (year 2023)	Lower profile (year 2023)	Higher profile (year 2019)
Load Growth		0	0	Same as Typical
Imports		Year 2023 profile	Year 2023 profile	
Storage		Most or all (e.g. 70%) of Energy Storage Act goals met	No more than 50% of Energy Storage Act goals met	
Renewable Energy Growth	General Requirement	Renewable energy capacity follows RPS mandate	Renewable energy capacity follows RPS mandate	
	Solar PV	Solar 14.5% carve-out by 2030	No solar carve-out	
	Offshore Wind	Minimum of 1200 MW	No offshore wind requirement	
	Land-based Wind	No specific requirement	No specific requirement	
	Others	Fixed at 2.5% annually	Fixed at 2.5% annually	
EV		No influence on load	No influence on load	
Geothermal		No requirement	No requirement	
Data Center		No influence on load	No influence on load	

2. Decarbonization Policy

		Decarbonization Policy			
		Energy Efficiency		Energy Resilience	
		60/2031 Electrification	100/2035 Electrification	60/2031 Electrification (Stressed)	100/2035 Electrification (Stressed)
Load Curve		Reference + adjustment for EV charging	Reference + adjustment for EV charging	Stressed peak load profile + adjustment for EV charging	Stressed peak load profile + adjustment for EV charging
Load Growth		1.2%/y (per the Climate Solution Now Act)	1.2%	Same as 60/2031 Electrification	Same as 100/2035 Electrification
Imports		Reference	Reference		
Storage		All Energy Storage Act goals met	All Energy Storage Act goals met		
Renewable Energy Growth	General Requirement	Renewable energy growth in line with RPS mandate, 50% of electricity consumed by 2030	100% of the electricity consumed from clean & renewable sources by 2035.		
	Solar PV	Solar 14.5% carve-out by 2030	Solar 14.5% carve-out by 2030		
	Offshore Wind	Minimum of 1200 MW	Minimum of 1200 MW		
	Land-based	No specific requirement	No specific requirement		
	Others	Fixed at 2.5% annually	Fixed at 2.5% annually		
EV		EV penetration influences load profile	EV penetration influences load profile		
Geothermal		1% carve-out in 2028 and later	1% carve-out in 2028 and later		
Data Center		No influence on grid	No influence on grid		

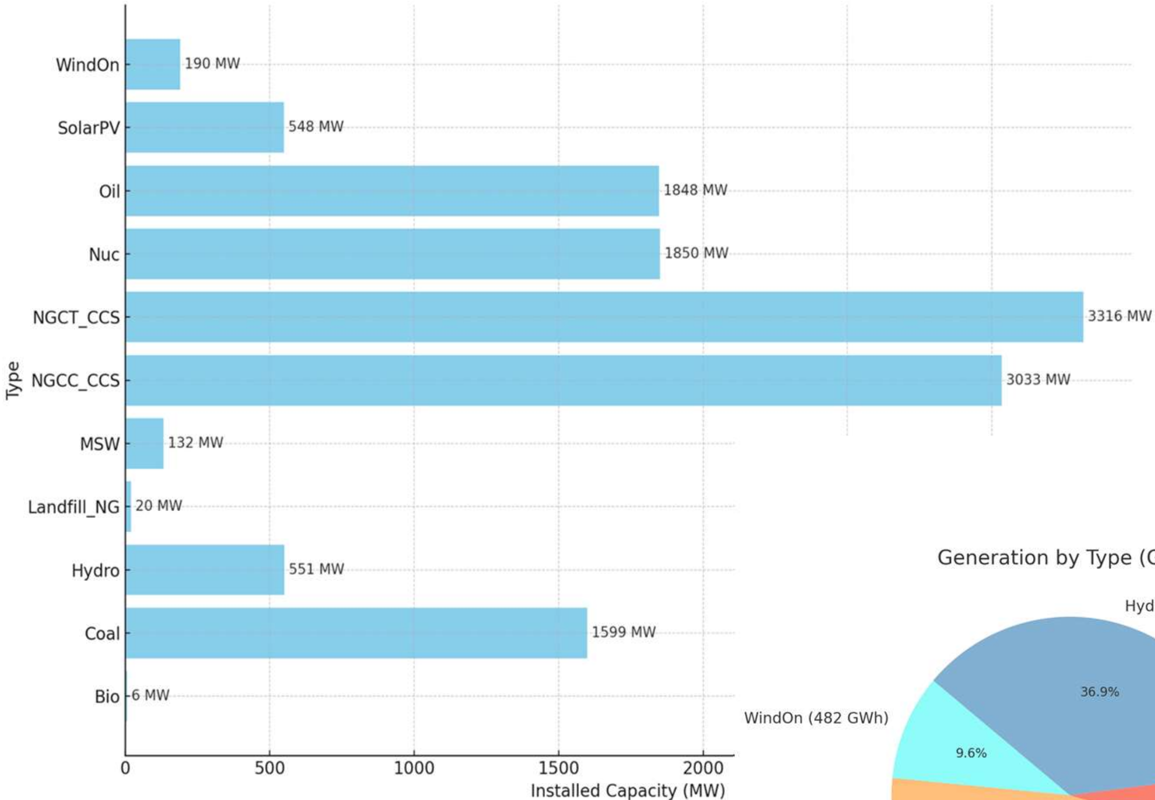
3. Additional Policies

		Specific Interest			
		Energy Efficiency (Typical Performance)		Energy Resilience	
		High Electrification + Data Center	High Electrification + Energy Self-Sufficiency	High Electrification + Data Center (Stressed)	High Electrification + Energy Self-Sufficiency (Stressed)
Load Curve		Reference case + adjustment for EV charging + adjustment for data centers	Reference case + adjustment for EV charging	High profile + adjustment for EV charging + adjustment for data center operation	High profile + adjustment for EV charging
Load Growth		1.2%	1.2%	Same as High Electrification + Data Center	Same as High Electrification + Energy Self-Sufficiency
Imports		Reference case	Reduced import profile to achieve energy self-sufficiency (e.g. 50%)		
Storage		All Energy Storage Act goals met	All Energy Storage Act goals met		
Renewable Energy Growth	General Requirement	Renewable energy growth in line with RPS mandate, 50% of electricity consumed by 2030	Renewable energy growth in line with RPS mandate, 50% of electricity consumed by 2030		
	Solar PV	Solar 14.5% carve-out by 2030	Solar 14.5% carve-out by 2030		
	Offshore Wind	Minimum of 1200 MW	Minimum of 1200 MW		
	Land-based Wind	No specific requirement	No specific requirement		
	Others	Fixed at 2.5% annually	Fixed at 2.5% annually		
EV		EV penetration influences load profile	EV penetration influences load profile		
Geothermal		1% carve-out in 2028 and later	1% carve-out in 2028 and later		
Data Center		Data centers influence load profile	No influence on load profile		

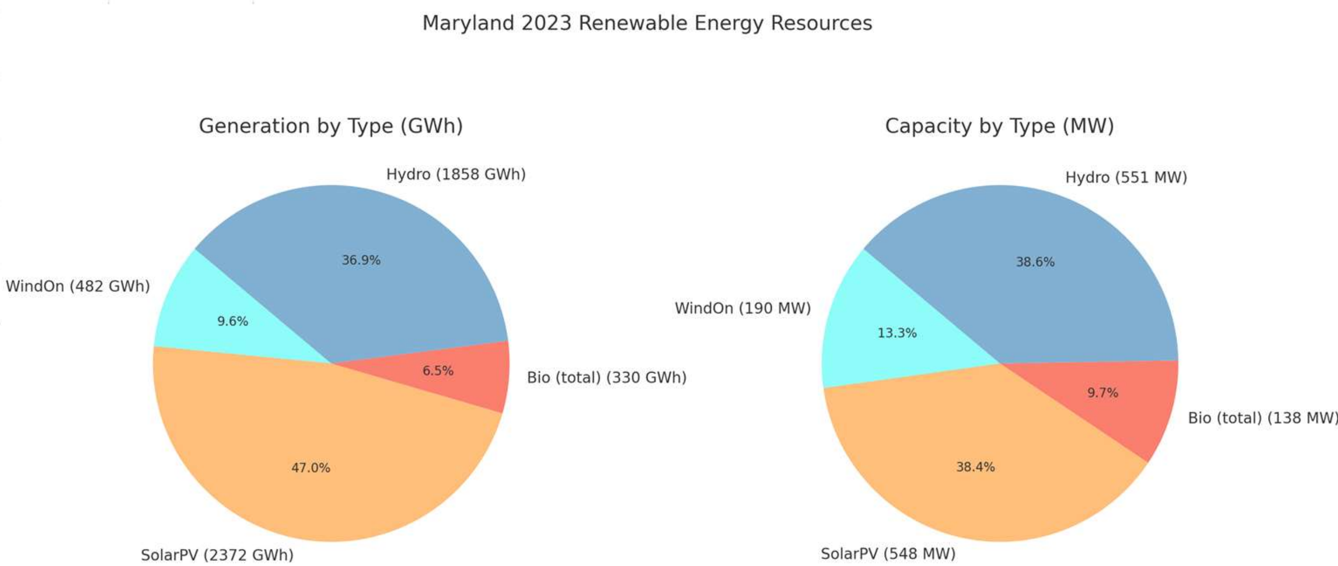
III. Key Input Data

- We apply the Holistic Optimization Program for Electricity (HOPE) model developed for the State of Maryland. Specifically, we use the GTEP (Generation and Transmission Capacity Expansion) version to simulate Maryland's system performance under various scenarios to achieve its clean energy goals by 2030 and 2035 (target years).
- **Key input data for grid simulations**:
  - Existing and candidate generators (capacity, capital & operating costs)
  - Load profiles for different PJM zones in Maryland
  - Transmission capacity between zones; typical import profile
  - Renewable generation profiles for wind & solar by zone
  - Capacity & cost of candidate transmission lines
  - Scenario-specific policy configurations such as RPS mandates and EV charging profiles

Maryland Installed Capacity Overview



- Bar chart shows 2023 installed capacity mix for Maryland [1][2]:
  - **Natural Gas**: Largest share of installed capacity.
  - **Nuclear**: Provides significant and stable power generation.
  - **Coal**: A declining but still notable portion of the energy mix.
  - **Wind**: Key contributor to the state's renewable energy efforts.
  - **Solar**: Rapidly growing in installed capacity.



[1] https://www.eia.gov/electricity/data/eia860/
[2] https://globalenergymonitor.org/projects/global-integrated-power-tracker/download-data/

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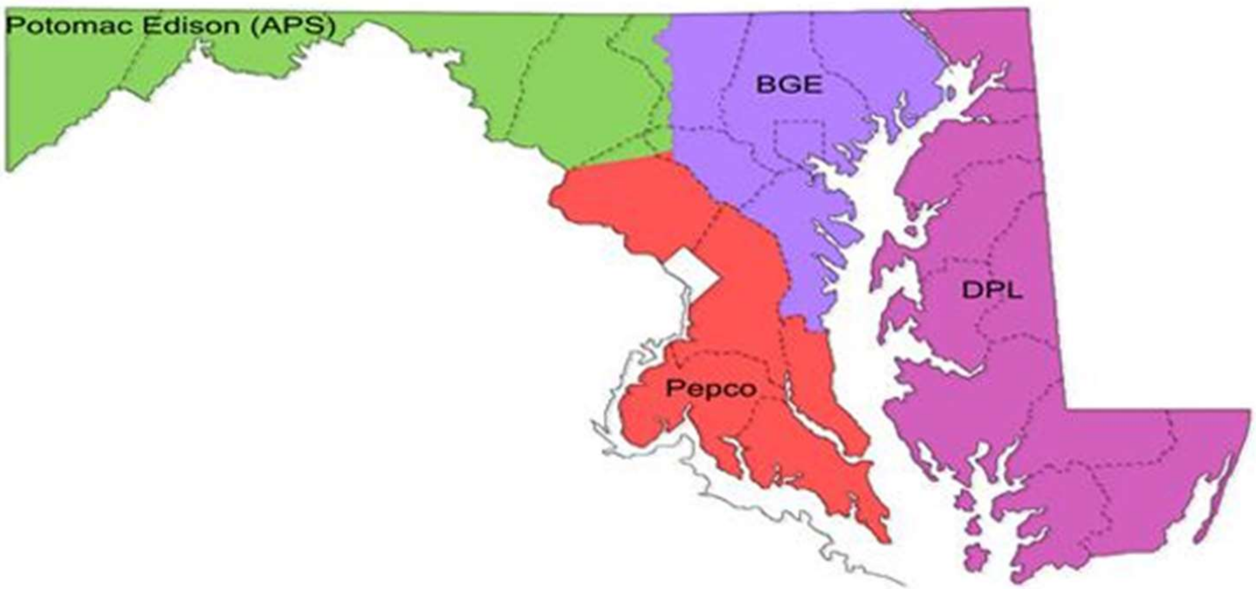
PJM Zones and Maryland



- PJM Zones serving Maryland:
  - **APS**, **BGE**, **DPL**, and **PEPCO**
  - **APS** and **DPL** also serve other states
- Load Profile Reporting:
  - PJM reports load profiles by zone.
  - For the Maryland portion of APS and DPL, load scaled based on the proportion of customers in Maryland as of 2023:
    - **APS**: 20% of total customers (288,758 in Maryland / 1,650,000 total)
    - **DPL**: 40% of total customers (218,578 in Maryland / 532,000 total)

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Load Profiles for Typical and Stressed Scenarios

- **"Typical" Scenarios**
  - Baseline: 2023 load profile
    - Represents average generation & total consumption
    - Wind and solar profiles are typical
- **Stressed Scenarios**
  - Higher (2019) load profile
  - Wind profile is typical
  - Solar profile lower than the recent average

Retail sales of electricity (million kilowatthours)	2019	2023
United States		
South Atlantic		
Maryland		
All sectors	60,721	56,808
Residential	27,534	26,154
Commercial	28,893	26,814
Industrial	3,718	3,433
Transportation	575	408
Other	--	--

Net generation for all sectors (thousand megawatthours)	2019	2023
United States		
South Atlantic		
Maryland		
All fuels	39,326	36,104
All solar	1,460	2,372

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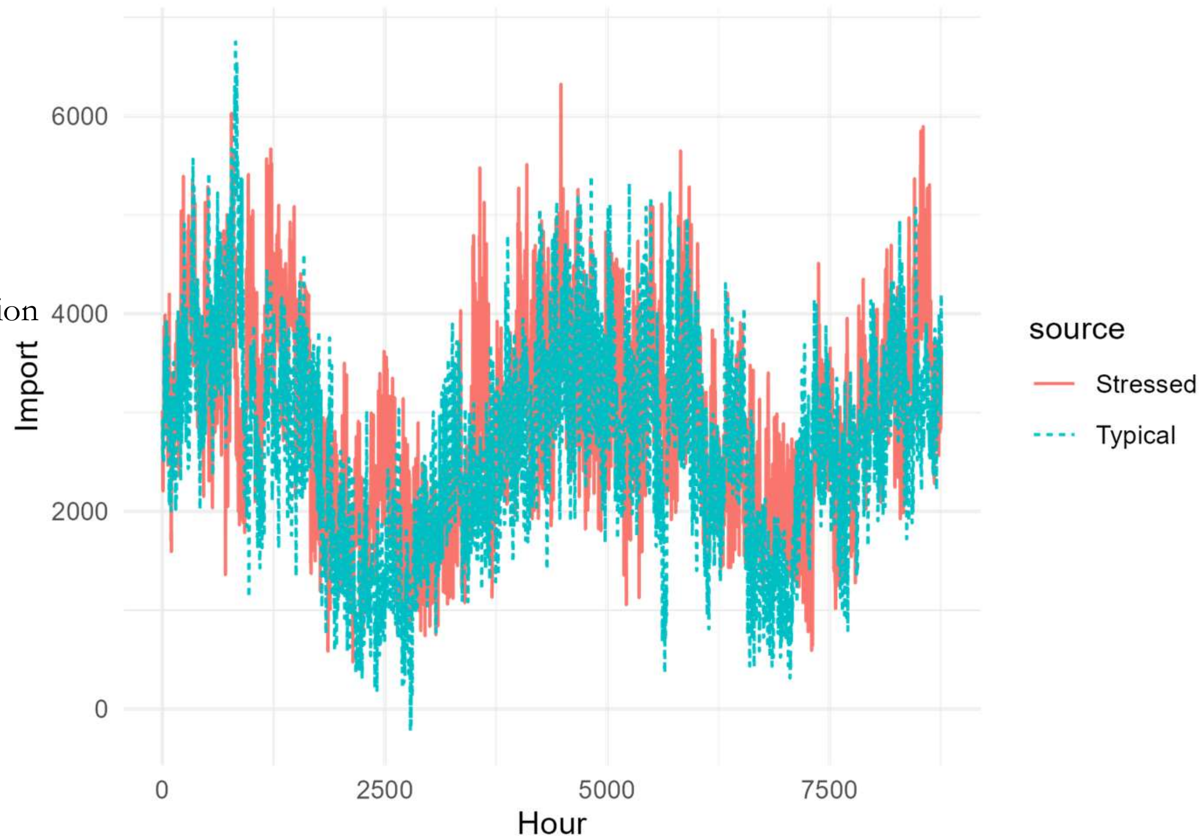
Comparison of Typical and Stressed Load Profiles

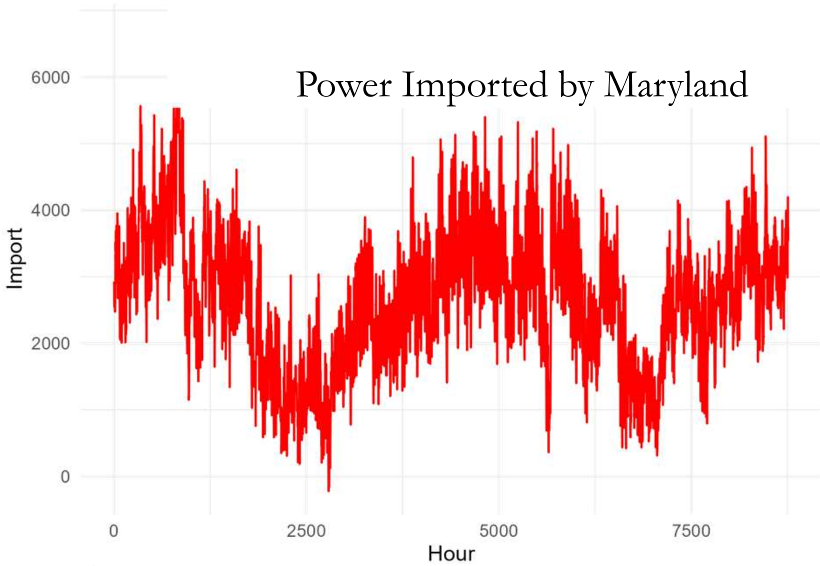
- **"Typical" Scenarios**
  - Baseline: 2023 load profile
    - Represents average generation & total consumption
    - Wind and solar profiles are typical
- **Stressed Scenarios**
  - Higher (2019) load profile
  - Wind profile is typical
  - Solar profile lower than the recent average



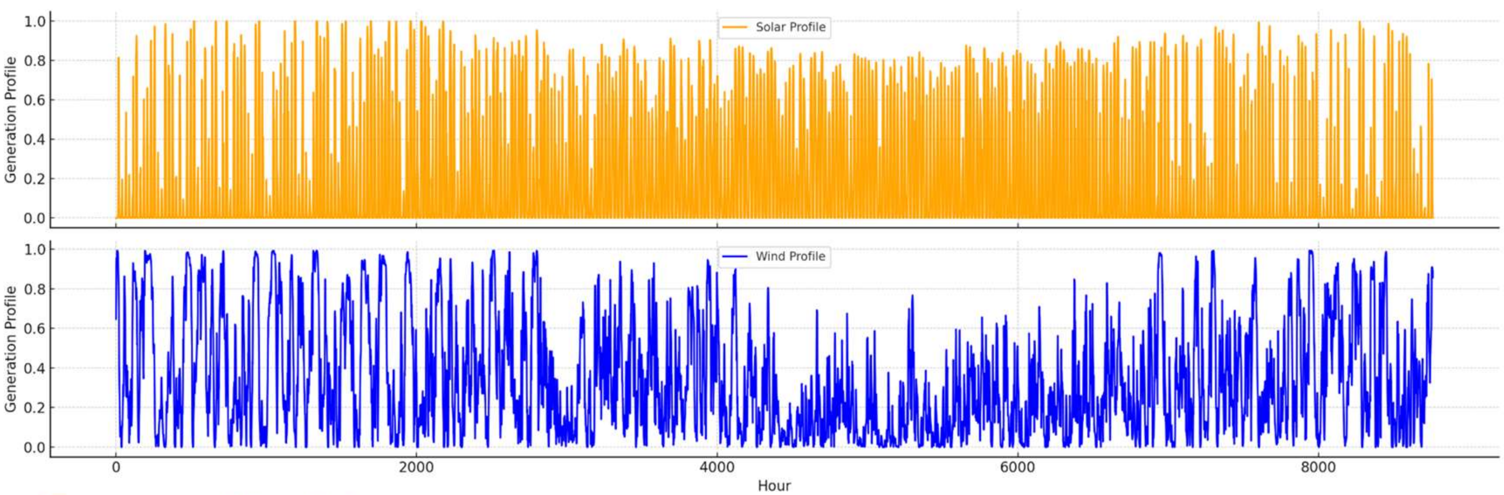
Import & Renewable Energy Profiles

- Apply the net import profile on the right from a typical year to both the typical & strained scenarios to simulate normal support from other states in PJM.

- Zone-specific wind & solar generation profiles below (APS-MD area 2023 profile as an example below) indicate the available renewable generation for each simulated hour [3].



Renewable Profiles

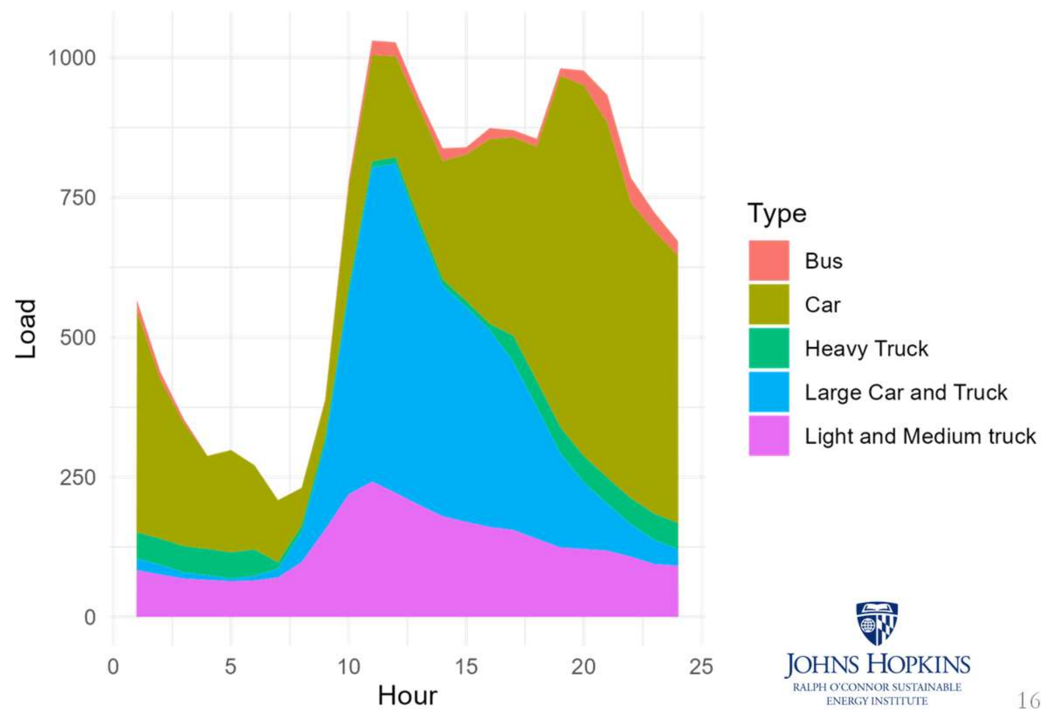


[3] https://www.renewables.ninja/

Impact of EV Adoption on Load Profiles

Type	2020	2025	2030	Unit
Car	5330	180224	823947	vehicles
Large Car and Truck	3088	95180	426817	vehicles
Bus	4	1742	3010	vehicles
Heavy truck	0	653	2321	vehicles
Light truck	1625	34589	41889	vehicles
Medium truck	125	5103	13358	vehicles

- According to the Advanced Clean Cars II Rule and the Zero Emission Vehicle (ZEV) Program, increased EVs will reshape the load profile due to EV charging behavior.
- EV stock data based on projections from Maryland's Climate Pollution Reduction Plan.
- The system-wide additional load from EV charging (immediate charging strategy) based on this EV stock in the year 2030 is illustrated on the right [4][5][6].



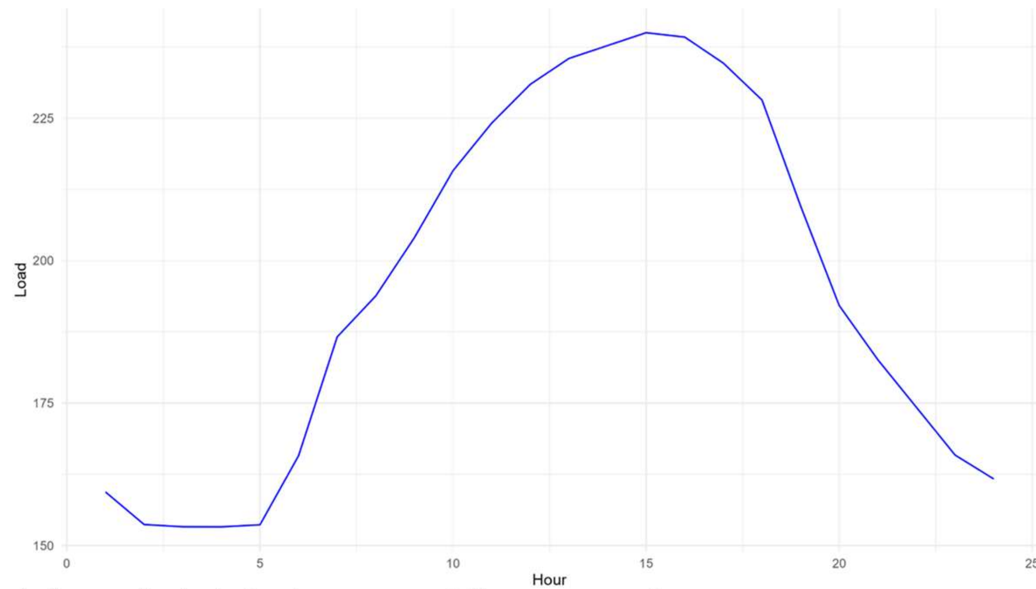
[4] https://www.nwcouncil.org/2021powerplan_plug-electric-load-profiles/
[5] https://www.energy.ca.gov/publications/2019/california-investor-owned-utility-electricity-load-shapes
[6] https://www.osti.gov/dataexplorer/biblio/dataset/1787031

Impact of Data Center Growth on Load Profiles

- Maryland's Data Center incentive from Critical Infrastructure Streamlining Act of 2024 expected stimulate more data centers in the state.
- Data centers require substantial power for computing, storage, cooling, & other needs.
- The typical additional load for a mixed-use 240 MW [7] data center is shown on the right [8].
- The load impact of data centers will be zone-specific, based on the planned capacity and location of each data center.

Quantum Loophole Unveils Deals for 4 Customers, 240 Megawatts of Power

Data center developer Quantum Loophole says it has lined up deals for a whopping 240 megawatts of capacity at its new hyperscale campus in Frederick County, Maryland. The company is building a 2,100-acre campus to provide cloud computing companies with huge sites to support years of growth.

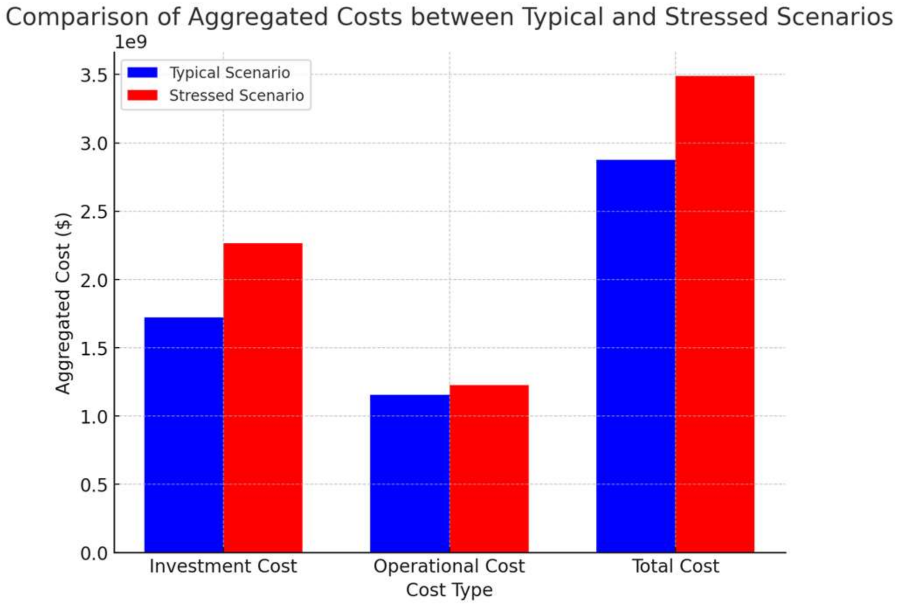


[6] https://www.datacenterfrontier.com/hyperscale/article/11436950/quantum-loophole-unveils-deals-for-4-customers-240-megawatts-of-power
[7] https://energy.lbl.gov/publications/demand-response-and-open-automated

IV. Preliminary Results

Holistic Optimization Program for Electricity

- **Scope of preliminary results:**
  - Conduct simulations for typical days under both Typical and Stressed scenarios from **Reference Scenario**, without factoring in decarbonization policies or additional policy priorities.
  - Typical days are selected as one day per season, but in subsequent stages, the analysis will cover the entire year.
  - The current simulation results are solely for illustrating the model's functionality and should not be cited as final outcomes.
  - Constraints related to generation and transmission capacity expansion, driven by specific decarbonization policies, will be incorporated
  - Additional constraints and infrastructure changes related to load, transmission, and other factors, such as data center requirements or self-sufficiency goals, will be addressed
- **System cost results (Objective)**



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Next Steps, Discussion, & Future Work

- **Scenario discussion and input considerations:**
  - Explore different scenario assumptions (see tables)
  - Define features such as modeling years, peak load forecasts, technology costs & efficiency
- **Model adjustments for decarbonization policy scenarios:**
  - Implement RPS targets for renewable energy generation, and siting constraints
  - Mandate storage capacity expansion to align with the Energy Storage Act
  - Account for the impact of a significant increase in EV stock on the load profile.
- **Setting additional policy priorities:**
  - Scenarios involving data centers: how many, where they will source power, how this will be modeled, and green power requirements (e.g., 24-7 green power).
  - Explore implications of Maryland reducing its reliance on imported electricity from other PJM states, including specific reductions in total energy (MWh) or peak load (MW).
  - Discuss any additional priority resources that should be included, such as geothermal, weatherization, or DERs.