ASSESSING UTILITY SCALE ENERGY STORAGE ECONOMICS CONSIDERING GENERATION ADEQUACY SERVICES

Prof. Anderson Rodrigo de Queiroz
Overview

- Introduction
- Modeling Approach & Assumptions
- Results – North Carolina Case
- Impacts of Storage in Dispatch Costs - Brazil
- Final Comments
Introduction
Energy Storage Options for North Carolina

Favorable conditions for energy storage technologies to assist in managing the grid operation

Public utilities commission started efforts to analyze energy storage systems in the North Carolina (NC)

State Congressional Order HB589 of 2017 for carveouts of Solar Generation in NC

Technical study to determine the value of energy storage systems to NC consumers

Energy storage capacity greater than 1 GW would be economically viable considering prices in 2030

Recently Utilities started to include energy storage in their integrated investment plans

As of 08/2020 the state's largest Li-Ion battery system was deployed in Asheville 9 MW ($15 million)

There is still no significant state incentive for energy storage
Peak Capacity Deferral

- It refers to the practice of delaying the construction or installation of new generation capacity until it is necessary to meet peak electricity.

- How storage can contribute to postpone investments in generation.
Bulk Energy Time Shifting

- Practice of shifting the delivery of large amounts of energy from one period to another. Take advantage of differences in demand & prices.


Optimization Model Overview

- Energy system optimization model (Temoa) used for two purposes:
  - **Capacity expansion planning (CEP)** for the area in analysis under different scenario configurations
  - Operational dispatch considering system configurations from CEP and different deployment of storage technologies


- [https://github.com/TemoaProject](https://github.com/TemoaProject)
- [http://temoaproject.org](http://temoaproject.org)
**Approach, Data and Assumptions**

- **Analysis scenarios**

- **Temoa run** (Capacity Expansion)

- **Build out plans for the system**

- **Introduce Energy Storage**
  - *Assume a fixed duration (energy to power ratio) and efficiency*
  - *No energy storage is considered in the initial operational dispatch runs*

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**Total dispatch cost**

**Hourly generation dispatches**

**Run different storage-size configurations**

**Determine cost-optimal build plan for storage**

**Minimize operational costs with storage**

**Calculate change in production costs [$/year]**

**Run sensitivities**

- Storage technologies
- Storage costs
- Storage efficiency

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1 3 5 7 9 11 13 15 17 19 21 23

MW

1 3 5 7 9 11 13 15 17 19 21 23

Marginal Price ($/MWh)

1 3 5 7 9 11 13 15 17 19 21 23

Hour of the Day

8760 hours in 2030
Data & Assumptions

- **System representation:**
  - Carolina’s power system
    - 19412 MW avg demand (2017)
    - 33556 MW peak demand (2017)
  - 1.2% increase per year to 39185 MW peak demand (2030)

- **Existing power generators** represented as individual power plants
- **Future generators** grouped by their respective generation class

**Sources:**
- EIA Annual Electric Generator data, form EIA-860
- EIA electric utility data survey, form EIA-923
- EIA's U.S. Electric System Operating Data Tool
- NREL Annual Technology Baseline - ATB
- NREL Solar and Wind Energy Resource Assessment - SWERA
Analysis Scenarios

1. **Base case**
   - 2017 Carolinas Power generation system
   - HB589 solar PV deployments (5.9 GW by 2022)

2. **Duke IRP**
   - Fixed representation of the exchanges
   - Scenario matches the build-outs proposed by Duke’s 2017 Climate Report to Shareholders: 40% reduction in 2005 CO₂ emissions levels by 2030

3. **Expanded RPS**
   - RPS expanded to 2030 with a target of 40% for renewables (solar, wind, biomass, small hydro)

4. **Clean Energy Standard**
   - 60% target of clean energy sources by 2030

5. **Carbon Cap**
   - Duke’s 2017 Climate Report to Shareholders: 40% reduction in 2005 CO₂ emissions levels by 2030

6. **Natural Gas Prices**
   - High Projection from EIA AEO 2018

7. **Deployment of Plug-in Electric Vehicles**
Results – North Carolina Case
Base Case – Installed Capacity

Solar PV to reach 16.6 GW from 3.6 GW in the existing system

- 4.5 [GW]
- 2.1 [GW]
Charging/Discharging Profile - LI-1GW/4GWh

Example of a charging profile for a LI-1GW/4GWh during the course of 8760 hours in the operational model run.
Cost-Benefits Assessment

- **Energy Savings**
  \[ ES^k_i = TC_{NS} - TC_i \quad \forall i \in I_k, \forall k \in K \]

- **Capacity Value**
  \[ CV^k_i = (ECP_i \times P_i) \times CONE \quad \forall i \in I_k, \forall k \in K \]

- **Total Benefits**
  \[ SB^k_i = ES^k_i + CV^k_i \quad \forall i \in I_k, \forall k \in K \]

- Finding the best storage configuration
  \[ \arg\max_P \{ SB^k_i - (P_i \times RR^k_i) \} \]

  *CONE for a Gas CT estimated at 113 ($/kW-year)
## Total Benefits vs Revenue Requirements

Total net benefits ($/kWyr) of lithium-ion batteries and pumped hydro for **shifting energy** over time and **deferring new investments** in generation.

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### Duration (h) | 0.3GW | 1GW | 3GW | 5GW
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We can observe that several configurations of Li-Ion and PSH would provide positive benefits to the NC system projected to 2030.

[https://energy.ncsu.edu/storage/](https://energy.ncsu.edu/storage/)
Impacts of Storage in Dispatch Costs - Brazil
Modeling Framework – Brazilian System

- **Hydro-dominant Power System** (~70% of production of 65GWavg)
- Individual Hydro and Thermal Plants Representation
- **Interconnection between Regions**
- De-rating factor, efficiency, capacity factor, and transmission losses

**Outputs:**
- Generation dispatch per plant
- Storage Charge/Discharge
- Energy Exchanges between Regions
- Total Operational Costs
Results – 1GW/4h Deployed in the Northeast

Optimization model decides to charge energy storage off peak and discharge at peak time.

Case: Deployment of 1GW/4h NE

- Increase of Usage off Peak (Charge)
- Discharge at Peak time
- Reduction in Coal and Natural Gas
Results – 2GW/8h Deployed in the Southeast
Impacts in Total Operational Dispatch Costs

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<th>Operational Costs</th>
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<td><strong>Caso Base</strong></td>
<td>R$ 3,095,735,478.81</td>
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<td><strong>PMO JAN 2021</strong></td>
<td><strong>0.5GW/4h NE</strong> R$ 3,027,438,253.09 R$ 68,297,225.72 2.21%</td>
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<td><strong>1GW/4h NE</strong> R$ 2,968,356,135.78 R$ 127,379,343.03 4.11%</td>
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<td><strong>2GW/4h NE</strong> R$ 2,873,845,056.25 R$ 221,890,422.56 7.17%</td>
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<td><strong>4GW/24h NE</strong> R$ 2,802,850,998.80 R$ 292,884,480.01 9.46%</td>
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<td><strong>2GW/8h SE</strong> R$ 2,721,487,681.82 R$ 374,247,796.99 12.09%</td>
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<td><strong>PDE 2030</strong></td>
<td><strong>Caso Base</strong> R$ 12,062,398,526.10 - -</td>
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<td><strong>0.5GW/4h NE</strong> R$ 11,986,997,334.80 R$ 75,401,191.30 0.63%</td>
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<td><strong>1GW/4h NE</strong> R$ 11,921,727,024.20 R$ 140,671,501.90 1.17%</td>
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<td><strong>2GW/4h NE</strong> R$ 11,812,433,223.20 R$ 249,965,302.90 2.07%</td>
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<td><strong>4GW/24h NE</strong> R$ 11,821,421,457.50 R$ 240,977,068.60 2.00%</td>
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<td><strong>2GW/8h SE</strong> R$ 11,754,140,482.30 R$ 308,258,043.80 2.56%</td>
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**Significant reductions** in terms of total operational dispatch costs, reaching **12%** in a case with **2GW/8h of pumped hydro storage** placed in the Southeast region of the country.
Final Comments

- This is the **first comprehensive** open-source modeling effort to develop projections for the **Carolinas power system**
- It can be used to **assess economic, technical, and policy futures** and provide valuable insights to decision makers
- Model and analyze other scenarios, e.g.:
  - Bidirectional capabilities for EVs
  - 100% of clean energy
  - Wider range of future fuel prices and policies
- Framework adapted to investigate energy storage in **Brazil**
- Collaboration with Polytechnic de Torino to look at **Italy and European cases**
Thank You!

adequeiroz@nccu.edu
ardequei@ncsu.edu
https://ardequeiroz@github.io