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Electrical Energy Storage Participation in the NYISO Electricity and Frequency Regulation Markets

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Background

- NYISO restructured its "Regulation and Frequency Response Service" in June 2013 to comply with FERC Order 755
- After restructuring a regulation resource is required to submit two-part Bids:
  - A **Regulation Capacity Bid** indicating the MW and $/MW it makes available to NYISO
  - A **Regulation Movement Bid** indicating the price ($/MW) for each MW of Regulation Movement it can provide when instructed
- With the two Bids the NYISO creates a Composite Bid Price:

$$B^{\text{reg}} = B^{\text{cap}} + M_{\text{RM}} B^{\text{mov}}$$

- Idea is to prevent incentives for expensive movement offers and low capacity offers

- Reg. movement multiplier: a factor that relates the actual Regulation Capacity with the actual Regulation Movement. It is computed based on historical data. The current value (2018) is 13. Same for all participating resources
- **Regulation Performance Index:** measures the accuracy of regulating resources
- **Regulation Performance Charge:** for resources responding *poorly* to the AGC signal
  - Charge is based on the Regulation Capacity that was not provided plus 10%

Note, in the Day-Ahead Market:
- There is NO Regulation Movement Scheduled
- There is NO Regulation Movement Clearing Price

EES in the NYISO Market

- **Objective:** Determine maximum potential revenue from participation in arbitrage and arbitrage + regulation **Day-Ahead Market** for the NYISO

For arbitrage the optimization problem:

State of charge

$$S_{i+1} = \eta_{\text{s}} S_i + \eta_{\text{c}} q_i^{\text{r}} - q_i^{\text{d}}$$

Objective function

$$\max_{q^{\text{d}}, q^{\text{r}}} \sum_{i \in \mathcal{T}} [(\lambda_i - C_d) q_i^{\text{d}} - (\lambda_i + C_r) q_i^{\text{r}}] e^{-Ri}$$

subject to:

$$\underline{S} \le S_i \le \overline{S} \qquad \forall i \in \mathcal{T}$$
$$0 \le q_i^{\text{r}} + q_i^{\text{d}} \le \overline{Q} \qquad \forall i \in \mathcal{T}$$

For arbitrage and regulation the optimization problem:

State of charge

$$S_{i+1} = \eta_{\text{s}} S_i + \eta_{\text{c}} q_i^{\text{r}} - q_i^{\text{d}} + \eta_{\text{c}} \delta_i^{\text{rd}} q_i^{\text{reg}} - \delta_i^{\text{ru}} q_i^{\text{reg}}$$

Objective function in the Day-Ahead Market

$$\max_{q^{\text{d}}, q^{\text{r}}, q^{\text{reg}}} \sum_{i \in \mathcal{T}} [\lambda_i (q_i^{\text{d}} - q_i^{\text{r}} + \delta_i^{\text{ru}} q_i^{\text{reg}} - \delta_i^{\text{rd}} q_i^{\text{reg}}) + \lambda_i^{\text{cap}} (q_i^{\text{reg}} - 1.1(1 - \gamma_i) q_i^{\text{reg}})]$$

subject to:

$$\underline{S} \le S_i \le \overline{S} \qquad \forall i \in \mathcal{T}$$
$$0 \le q_i^{\text{r}} + q_i^{\text{d}} + q_i^{\text{reg}} \le \overline{Q} \qquad \forall i \in \mathcal{T}$$

Table 1: Parameters of Energy Storage Market Participation Model

	Decision Variables	Units
q_i^{r}	Energy recharged in period i	MWh
q_i^{d}	Energy discharged in period i	MWh
q_i^{reg}	Energy used for regulation in period i	MWh
S_i	State of charge in period i	MWh
	Storage Parameters	**Units**
$\overline{S}$	Max. energy storage capacity	MWh
$\overline{Q}$	Energy charged/discharge rating (in one period)	MWh
$\underline{S}$	Min. energy storage capacity	MWh
η_{s}	Self-discharge efficiency	%/h
η_{c}	Round trip efficiency	%
	Market Parameters	**Units**
λ_i	Electricity price in period i	$/MWh
λ_i^{cap}	Regulation capacity price in period i	$/MWh
λ_i^{mov}	Regulation movement price in period i	$/MWh
β_i	Movement in period i	-
δ_i^{ru}	Fraction of regulation up used in period i	-
δ_i^{rd}	Fraction of regulation down used in period i	-
γ_i	Performance index in period i	-
R	Interest/discount rate	-

Results

Revenue by stream for the NYISO, CAPITL load zone for the case of arbitrage plus frequency regulation. Year 2017.
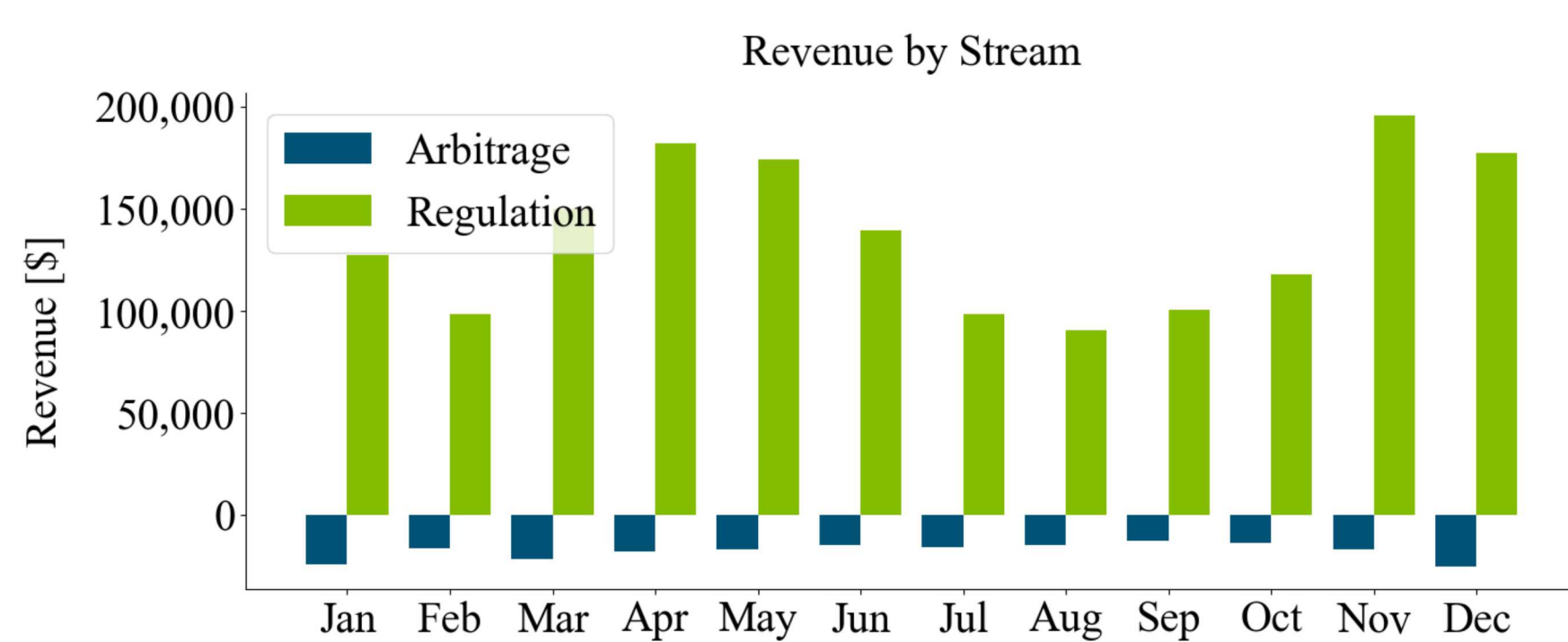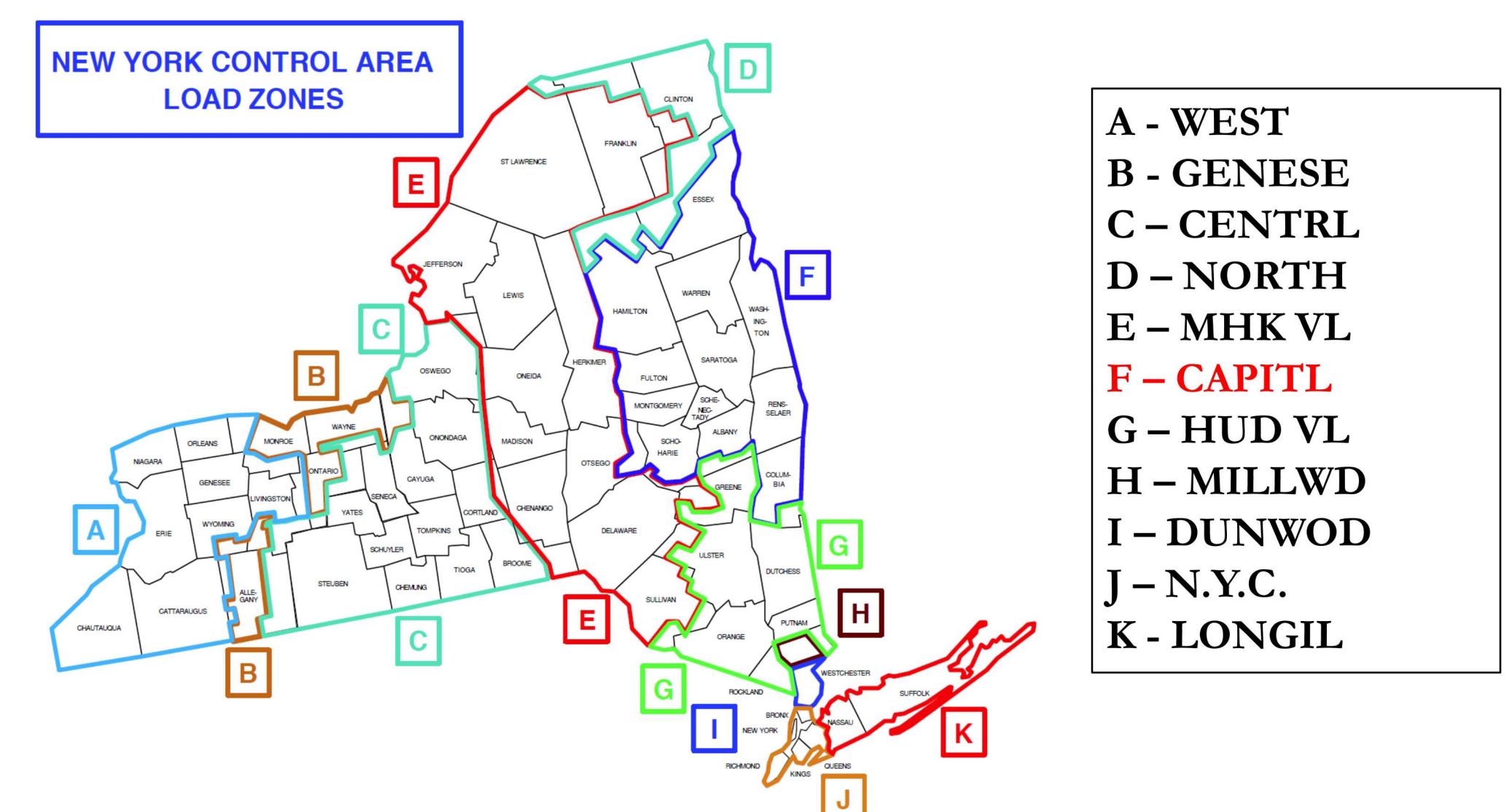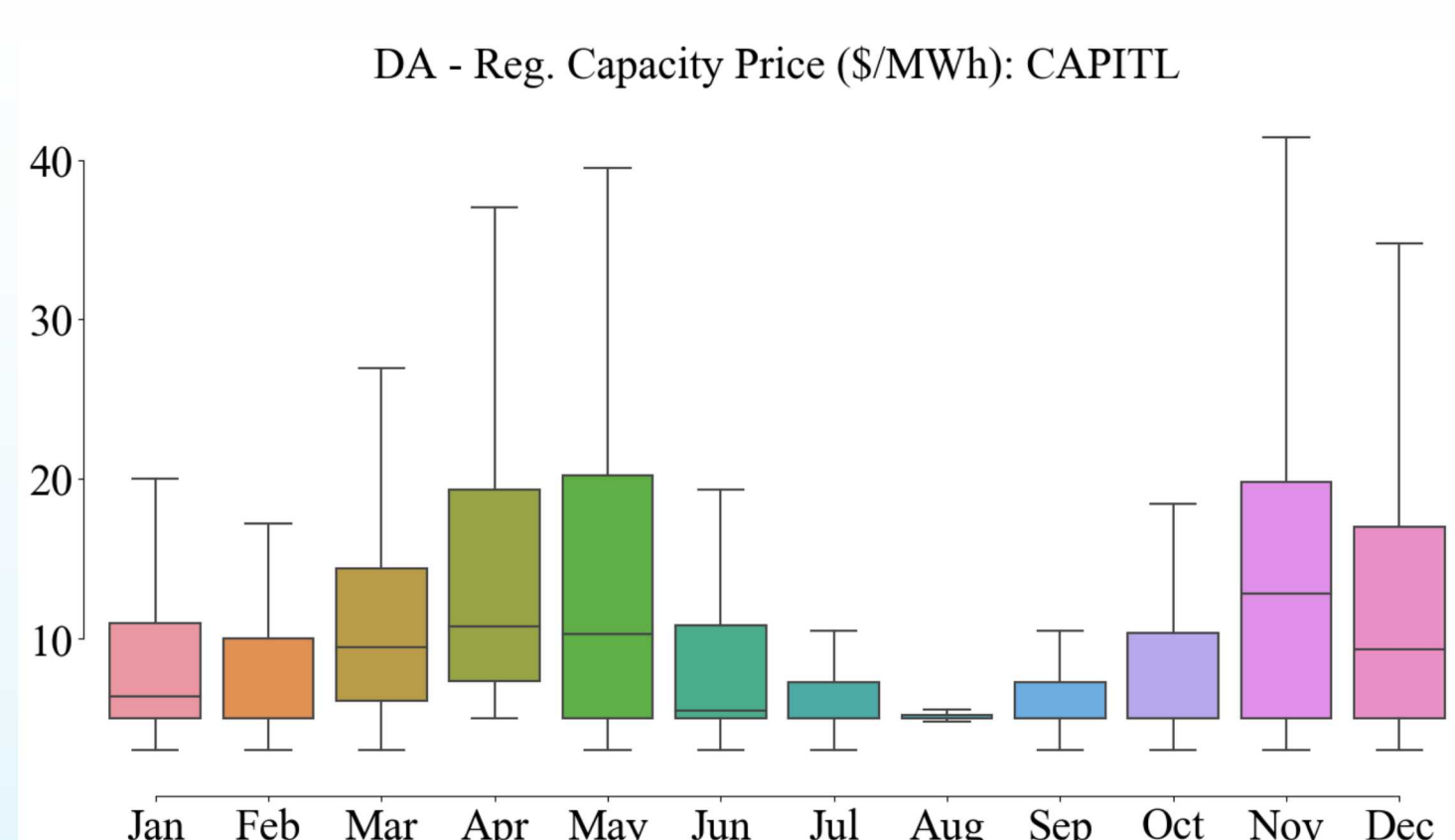

TABLE I: ESR Parameters

Parameter	Value
$\overline{S}$	5 MWh
$\overline{Q}$	20 MWh
$\underline{S}$	0 MWh
η_{s}	98 %/h
η_{c}	85 %
γ	0.95

NEW YORK CONTROL AREA LOAD ZONES

A - WEST
B - GENESE
C – CENTRL
D – NORTH
E – MHK VL
F – CAPITL
G – HUD VL
H – MILLWD
I – DUNWOD
J – N.Y.C.
K - LONGIL

RCP for the NYISO, CAPITL load zone for 2017. Note the seasonality.

LMPs for the NYISO, NORTH and LONGIL load zones for 2017. LONGIL has the highest prices while NORTH has the lowest.
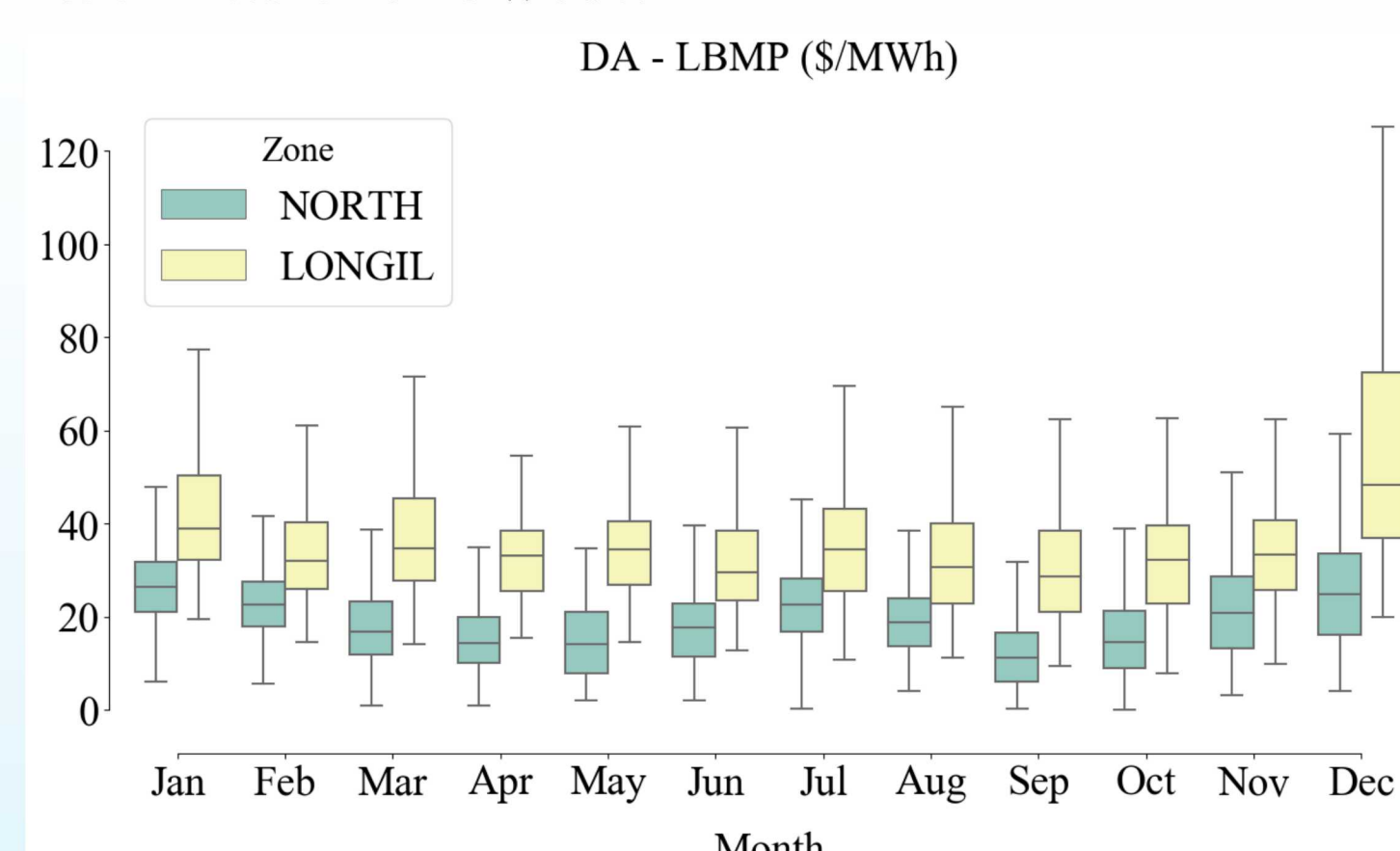
2017 yearly revenue for the arbitrage plus regulation case for different NYISO load zones as a function of the performance index.