Preliminary results from ELR testing in the NYISO footprint

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- Operating earnings and EPS, which is earnings from continuing operations excluding non-service-related pension costs of our principal pension plans.
- GE Industrial operating & Verticals earnings and EPS, which is operating earnings of our industrial businesses and the GE Capital businesses that we expect to retain.
- GE Industrial & Verticals revenues, which is revenue of our industrial businesses and the GE Capital businesses that we expect to retain.
- Industrial segment organic revenue, which is the sum of revenue from all of our industrial segments less the effects of acquisitions/dispositions and currency exchange.
- Industrial segment organic operating profit, which is the sum of segment profit from all of our industrial segments less the effects of acquisitions/dispositions and currency exchange.
- Industrial cash flows from operating activities (Industrial CFOA), which is GE's cash flow from operating activities excluding dividends received from GE Capital.
- Capital ending net investment (ENI), excluding liquidity, which is a measure we use to measure the size of our Capital segment.
- GE Capital Tier 1 Common ratio estimate is a ratio of equity

Today’s objectives

Quick refresher of new models for ELR

Present metrics for testing approach

Presentation of preliminary results with one storage unit

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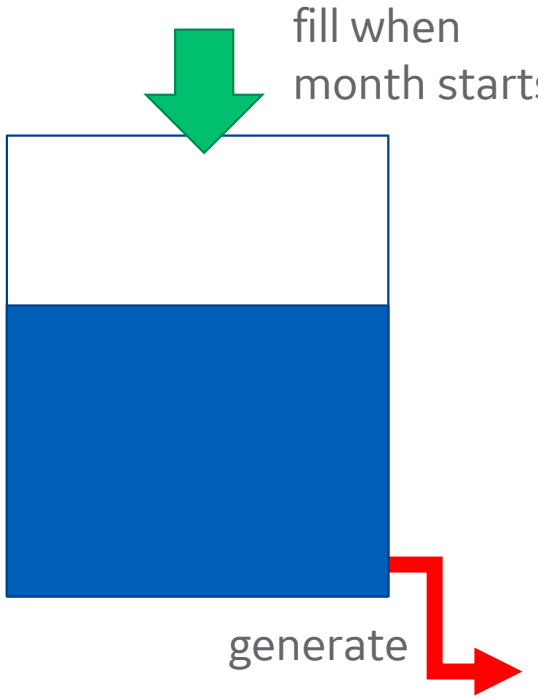
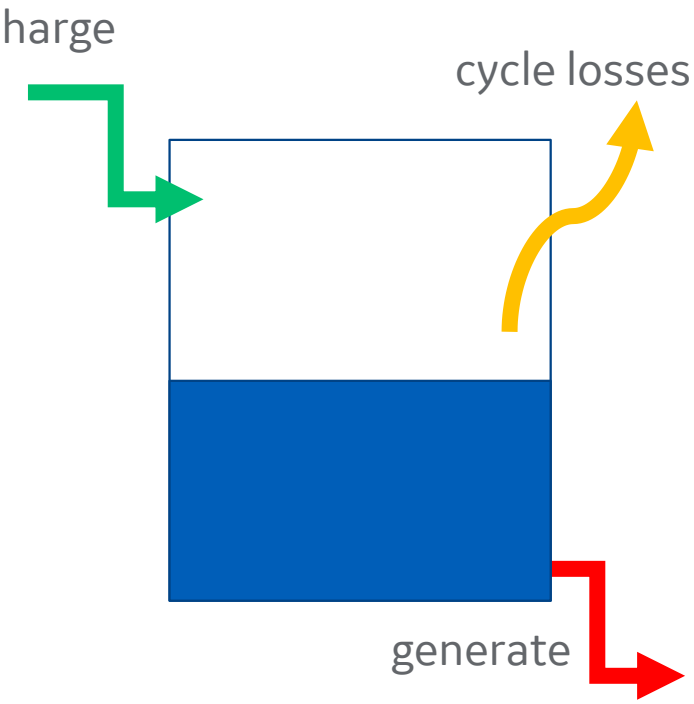
As-needed energy limited (EL3) and Dynamic storage (ES): possible usage to model ELRs



Hydro without pumping

Demand response contracts



Pumped hydro storage

Battery

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Caveats for today's presentation

Goal: presenting framework and metrics to evaluate dynamic vs. fixed shape models

Use available working NYISO data. Comprehensive testing is expected to start soon.

Evaluate the directional movement of LOLE/LOLH/EUE with different models and identify the effect of selected features.

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Modeling of ES units

Under the simplified methodology in last year's IRM, a fixed shape is created with full output during peak load (and full charging scheduled off-peak)

Dynamic storage (ES) units modeled with:

- Maximum rating (MW)
- Maximum storage capacity (MW * hours of storage)
- In base model, only allow one discharge cycle per day (energy per day)

Sensitivities of the ES model:

- Change dispatch order
- Limit generation to certain hours of the day
- Remove one-cycle-per-day constraint (not part of today's model test)

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Today's model test

NYISO footprint with one ELR unit represented as:

- Fixed shape (DS) model – like 2020 IRM model
- Dynamic storage (ES) model
- Dynamic storage (ES) model, but generating decisions happen after all EOPs have been applied
- Dynamic storage (ES) model, but generation can only happen after 1pm

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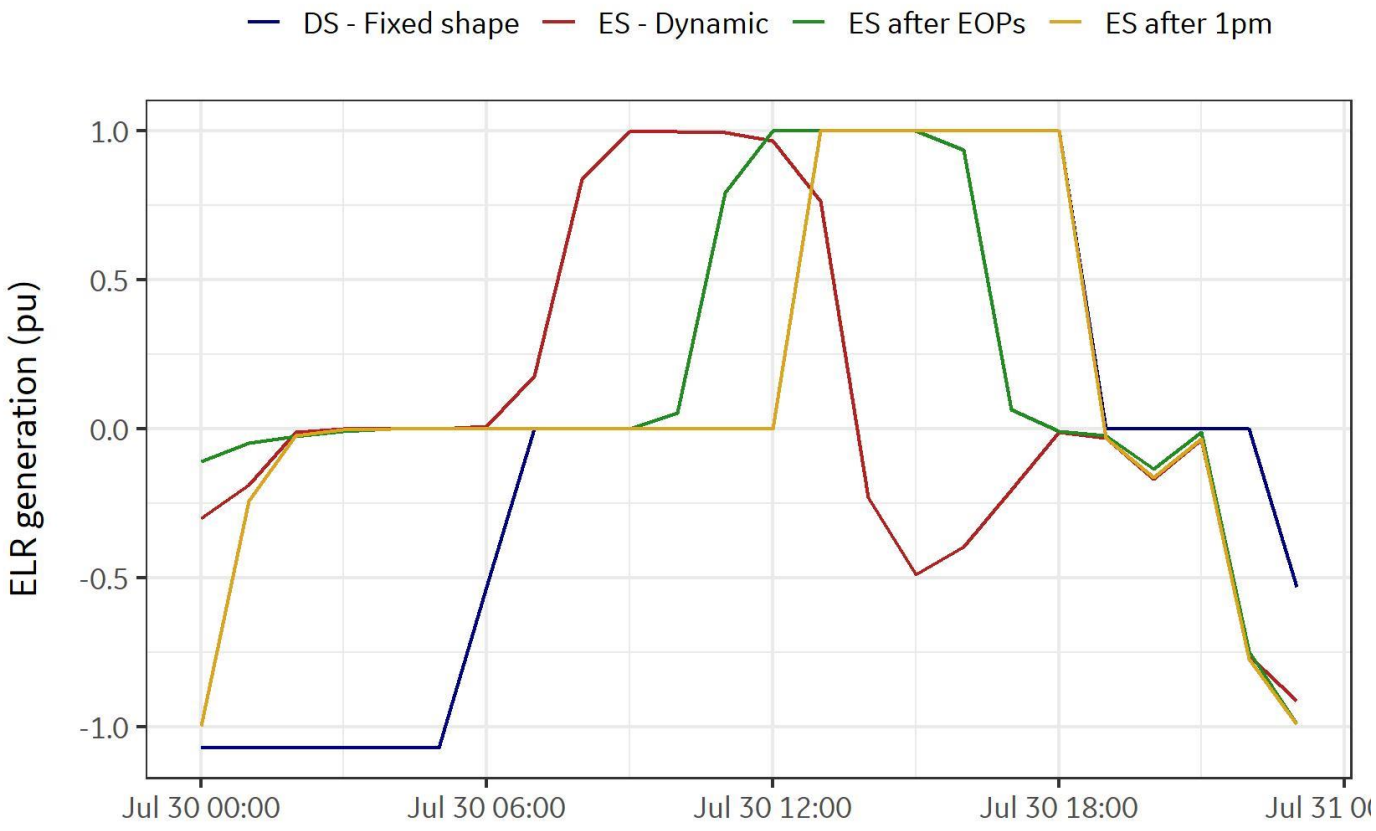
Dispatch for a high-load day
LFU step 1 (highest load multipliers)



Fixed shape generates 1-6pm

Unconstrained ES generates before EOPs are applied

ES dispatch after EOP has flexibility to generate before/after the 1-6 window

ES after 1pm sometimes generated at 7pm or later

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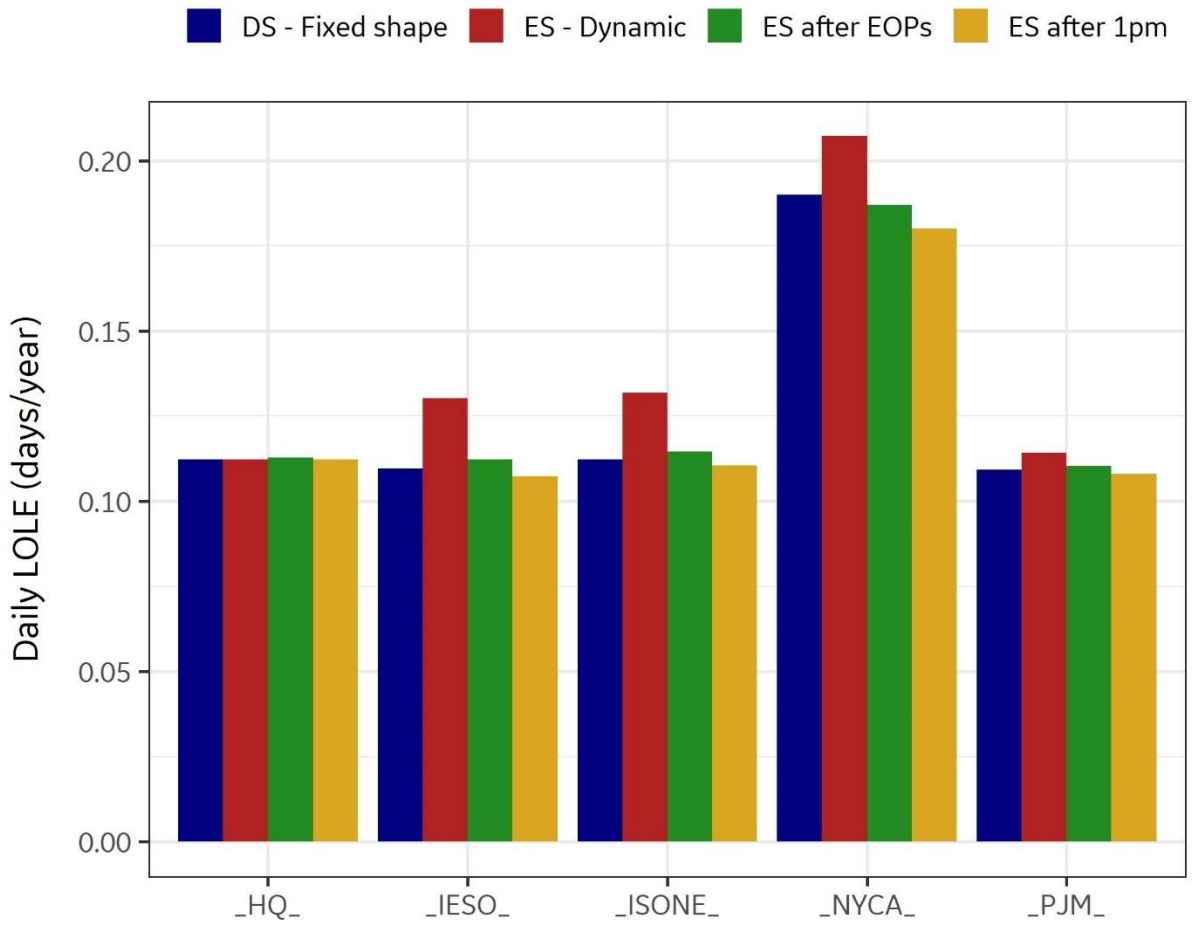
NYCA metrics and external pools LOLE



Scenario	LOLE (days/yr)	LOLE (hours/yr)	LOEE (MWh/yr)
DS - Fixed shape	0.190	0.650	395.9
ES - Dynamic	0.207	0.671	492.6
ES after EOPs	0.187	0.638	398.5
ES after 1pm	0.180	0.613	373.6

ES dynamic generation improves metrics, unless its is completely unconstrained

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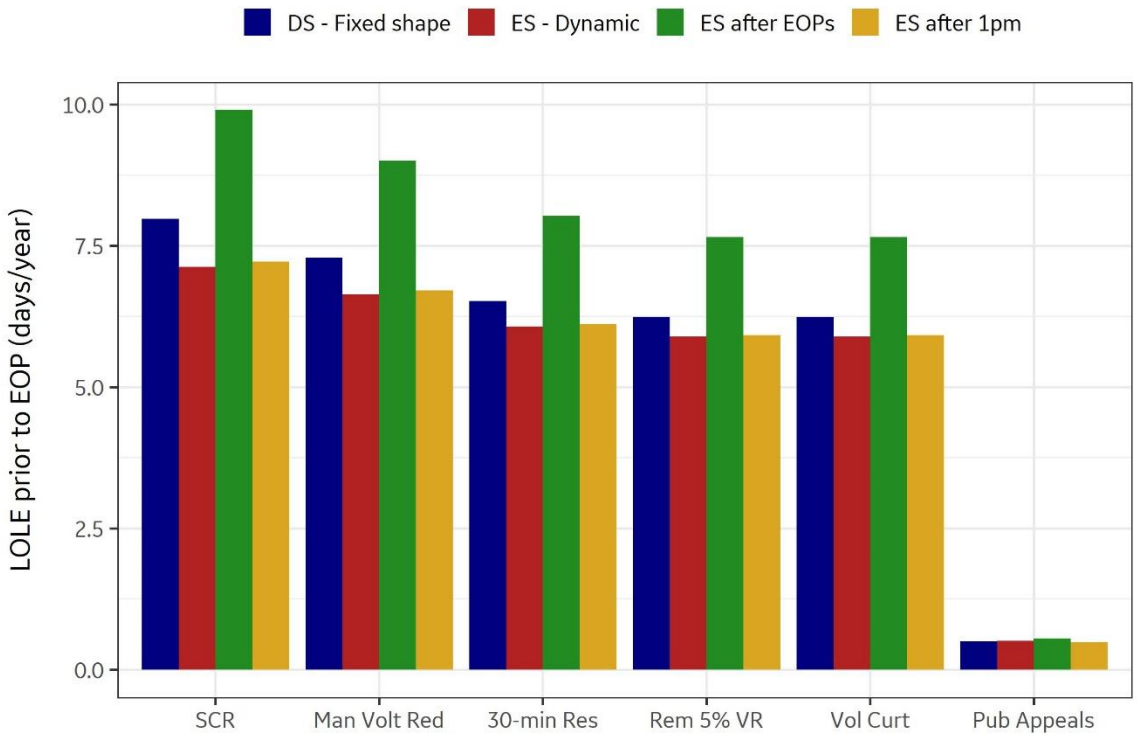
LOLE prior to each EOP step (days/year)



EOP	DS - Fixed	ES - Dynamic	ES after EOPs	ES after 1pm
SCR	7.977	7.128	9.908	7.219
Man Volt Red	7.286	6.646	9.009	6.713
30-min Res	6.521	6.077	8.026	6.116
Rem 5% VR	6.244	5.895	7.656	5.922
Vol Curt	6.240	5.893	7.651	5.920
Pub Appeals	0.503	0.516	0.558	0.489
10-min Res	7.286	6.646	9.009	6.713

Increase in EOP usage is greatest when ES unit is dispatched last, but that leads to smallest LOLE
DS unit has higher EOP usage because charging counts towards shortages (ES model does not)

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Usage of EL3 model (currently under testing)

An as-needed resources output varies

For the fixed shape (DS) model the generation is repeated every day, with full output scheduled during the peak load period

EL3 model for as-needed resource:

- Maximum capacity
- Minimum dispatch
- Daily energy budget

Potential sensitivity for the as-needed portion

- Dispatch order
- Limit generation to hours of day

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Next steps

Continue testing of EL3 MARS model

- Model all NYISO ELRs using the ES/EL3 modeling capability (testing on 1 ELR was discussed in this presentation)

Conduct the comprehensive testing with full suite of cases, using benchmarking NYISO data

Analysis of results and summary as a white paper

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Backup slides (from Feb. 3 meeting)

Overview of updated MARS unit types

Next MARS version will include improved modeling of energy-limited resources:

- More powerful
- New dynamic energy storage (ES) model

Both models share significant portions of the modeling, but capture different unit types

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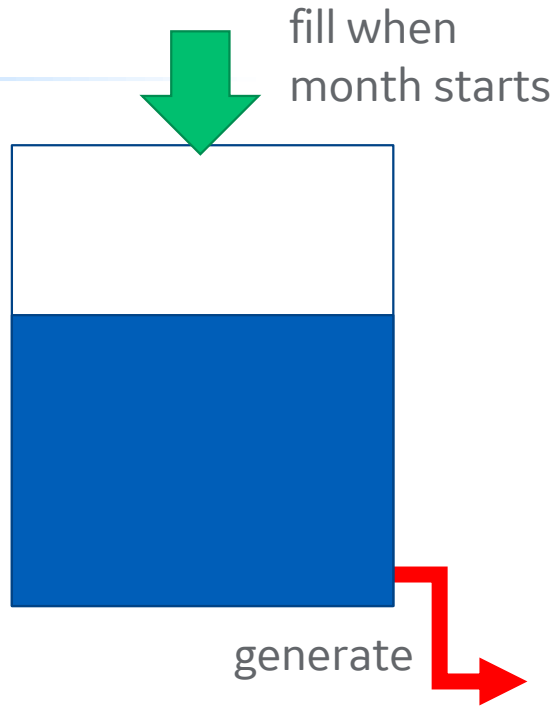
Energy-limited type 3 (EL3) model

Used to represent units that have:

- Energy budget (MWh) to be used in a month
- Maximum generation output (MW)
- Optionally, minimum generation (MW), *e.g., run of river output*
- Optionally, ability to transfer unused energy from one month to another



Think of a storage tank that you fill at the beginning of the month and you use when you need it

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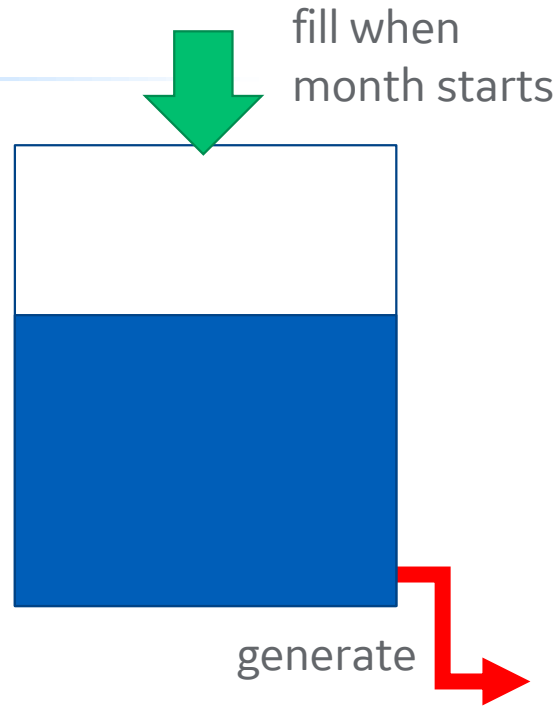
Energy-limited type 3 (EL3) model – additional constraints

Additional constraints may include

- Limit hours/days per year
- Limit hours/days per month
- Limit hours/energy per day

These are optional but can be used specific operational constraints or contract restrictions



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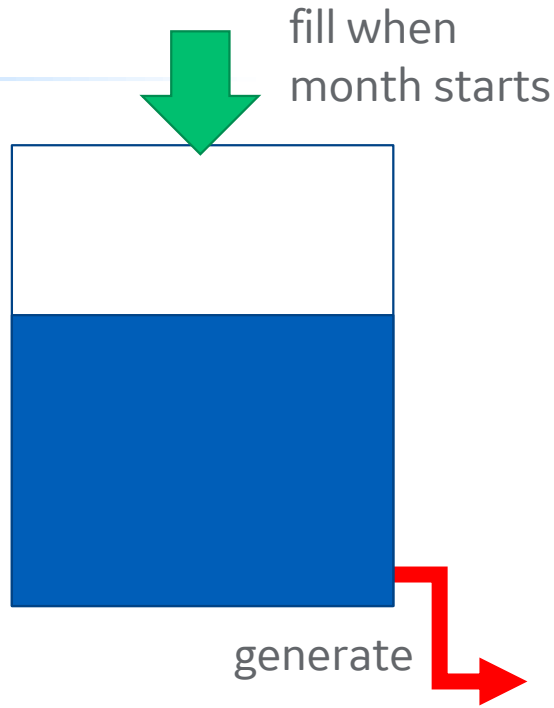
Energy-limited type 3 (EL3) model – when is it called?

- MARS first considers the balance of capacity/load
- Area and pool exchanges are considered
- If there is a shortage, the EL3 unit will attempt to dispatch:
  - Subject to limits of available capacity/energy
  - Subject to limits of use
  - Subject to transmission limits



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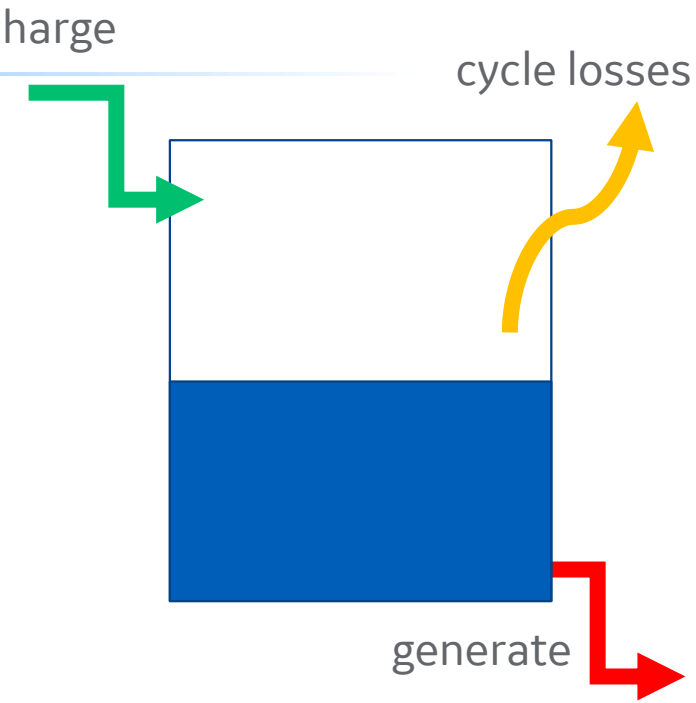
Energy storage (ES) model

Used to represent units that have:

- Capacity storage (MWh)
- Maximum generation output (MW)
- Ability to refill the storage (MW) when not generating
- Optionally, round-trip efficiency (%) to represent losses in the charge/generate cycle



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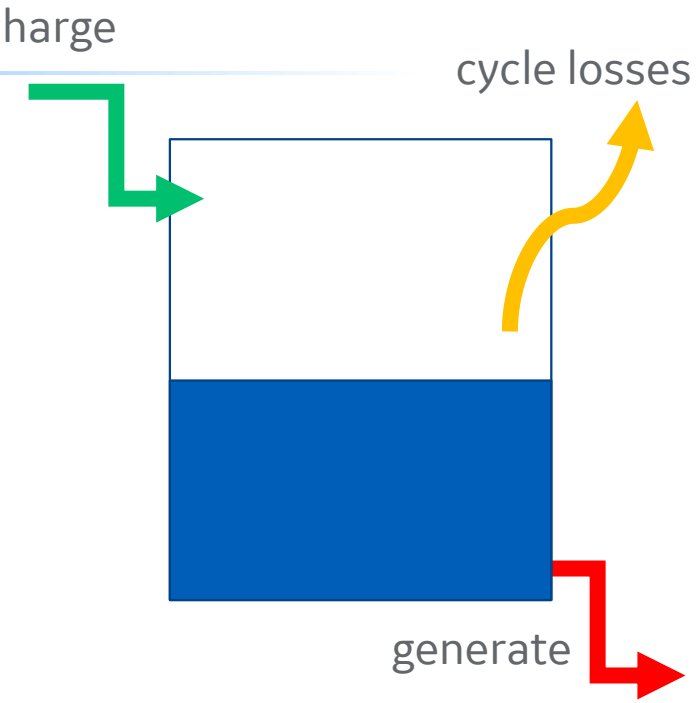
Energy storage (ES) model – when is it called?

Same time that EL3 units are considered, limited to:

- Capacity and energy balance
- Transmission constraints
- Usage limits (if defined)

If not used for an hour and there is available excess capacity, it will attempt to charge

- Limited to charging capacity, transmission
- Charge from excess capacity
- Don't use EOP or reserves



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Generalized modeling

All modeling to date is general, not specific to NYISO and NYSRC's needs

Other NPCC Areas studying adoption for hydro, contract modeling

Other features added:

- Control number of calls (one or more consecutive hours)
- Control during which EOPs the unit can generate
- Enable disable charging and/or generation by hour of day (to better align with operational profiles)

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Advantages over a fixed shape

Determining a fixed shape requires an initial run to know what hours of the day the generation is typically needed

Risks of fixed shapes:

- "Overfitting" the model (too much knowledge of NYCA LOLE)
- Not robust over different scenarios (e.g., a high-solar scenario)
- Fixed shape behaves the same for all load forecast uncertainty

EL3/ES models require fewer assumptions/inputs/knowledge

- More robust over wider range of scenarios
- LOLE results may be higher/lower, not guaranteed to outperformed fixed shape

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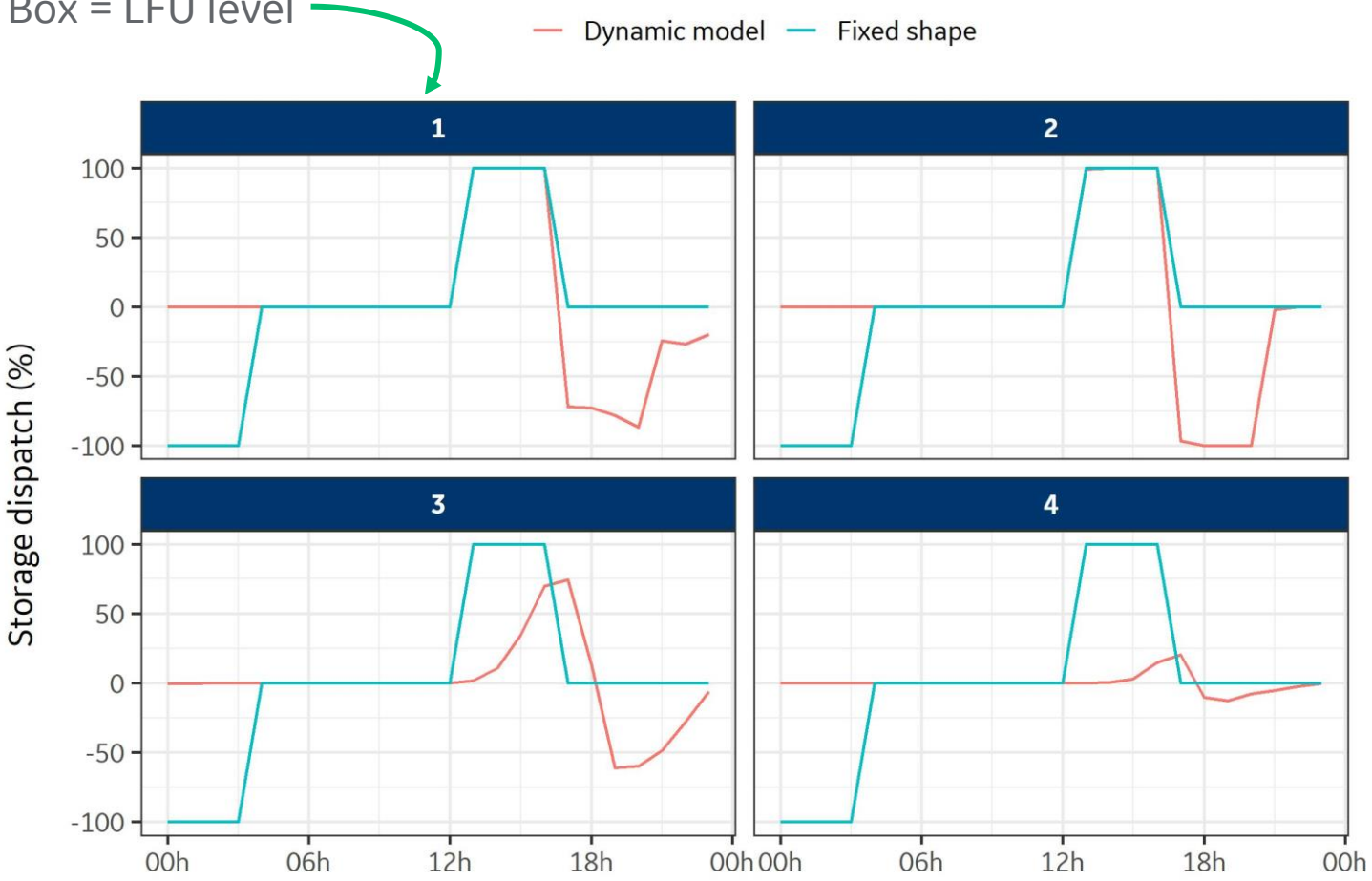
Comparison of fixed shape vs. dynamic modeling
4 hours of storage

Box = LFU level



- Levels 1 and 2 generate at the same hours, full output
- Levels 3 and 4 don't use 100% of output, but generate over a wider window, later
- Storage charges as soon as they are able

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