New York State Reliability Council

Installed Capacity Subcommittee

White Paper on

Energy Limited Resources Modeling

Introduction

As the modernization of the electric grid continues, new resource types that are different from the conventional, large thermal generating units are being connected to the system and added to the supply mix. These new resource types include technology that has daily energy duration limitations, often due to various technical rather than economic reasons.

In 2019, the NYISO filed, and in 2020 FERC approved, tariff changes that became effective May 1, 2021 enhancing the ability of duration-limited resources to participate in the NYISO markets. These rules allow output limited resources to participate in the markets consistent with those limitations and requires owners of those resources to inform the NYISO of their elected energy output duration limitations by August 1st for the upcoming capability year (i.e., August 1, 2020 for the Capability Year beginning on May 1, 2021).

To accommodate this new classification of resources, and to account for its impact on the IRM, a proper modeling framework for the Energy Limited Resources (ELRs) is required. This whitepaper examines the modeling option using functionality in the GE MARS program and presents the testing outcomes using the newly developed functionality. Based on these testing results, this whitepaper proposes near-term recommendations on reflecting the impact of energy and duration limited resources in the IRM study and lays out future activities to continue enhancing the modeling framework.

Energy Limited Resources and Modeling Objectives

Based on the FERC approved Market Administration and Control Area Service Tariff (MST), the Energy Limited Resources ("ELR") are defined as:

> *"Capacity resources, not including BTM:NG Resources, that, due to environmental restrictions on operations, cyclical requirements, such as the need to recharge or refill, or other non-economic reasons, are unable to operate continuously on a daily basis, but are able to operate for at least four consecutive hours each day. Energy Limited Resources must register their Energy limiting characteristics with, and justify them to, the ISO consistent with ISO Procedures. Resources that meet the qualifications to be an Energy Limited Resource, and choose to participate in the wholesale market as an Energy Limited Resource…."*

According to the MST, resources that meet the ELR definition can elect their duration limitations and participate in the ICAP market. While it may not be possible at this point to prescribe all the resources that may or may not be qualified under the ELR definition, three general types of resources are identified as potential ELRs in the near term, and each has its own characteristics.

- Batteries:

Battery resources have sizable charging requirements. These resources also have more flexibility with the daily charging/discharging cycle, allowing faster response to changing market price signals throughout the day by switching between charging and discharging modes.

- Pumped Storage:
  Similar to the battery resources, pumped storage resources also have sizable charging requirements. However, pumped storage resources have limited flexibility with the daily charging/discharging cycle and may only be able to adjust output throughout the day.
- Fuel Limited Resources:
  Fuel limited resources have no, or limited charging requirements. Such resources are capable of providing various output levels throughout the day. Fuel limited resources have limitations with the duration of their maximum outputs on a daily basis, but have some flexibility with the timing of their maximum output levels. Examples of fuel-limited resources include hydro with no storage (*e.g.*, run-of-river), thermal units with limited fuel storage, and Demand Response resources.

In additional to these resource characteristics, these potential ELR resources also share certain general operating characteristics:

- ELRs will aim to provide their maximum sustainable output levels consistent with their duration limitations during periods of peak load.
- ELRs with charging requirements to withdraw energy from the bulk power system will aim to schedule charging during low price periods, or off-peak consumption periods.

The objectives of the ELR modeling framework are to capture these resource and operating characteristics that are consistent with their participation in the market, and therefore to reflect their expected behaviors as an ICAP Supplier and the resulting impact on the IRM. Other resource types, such as Distributed Energy Resources (DERs), may enter the market in the future as ELRs. These additional resource types may have unique resource and operating characteristics. Depending on their associated participation models, the ELR modeling framework will need to be expanded to capture these additional resource types and to reflect their respective characteristics.

ELRs Modeled in the 2021-2022 IRM Study

In August 2020, the NYISO received ELR elections that would be in effect starting May 2021. As a result, the 2021-2022 IRM study sought to capture the impacts of the energy and duration limitations of these elected ELRs.

In September 2020, the Installed Capacity Subcommittee (ICS) recommended that, for the 2021-2022 IRM study, the Final Base Case should include the modeling of the elected ELRs, reflecting the units' operating capabilities with their limitations. Meanwhile, the modeling tool in GE MARS was not ready for adoption, and the normal thermal unit modeling did not capture energy and duration limitations. As a result, the ICS recommended adopting the simplified methodology that was developed in the previous IRM study. The simplified methodology involved developing pre-determined hourly output shapes for the ELRs. Therefore, the NYISO worked with the NYSRC consultants and structured the output shapes based on the operating capabilities of the ELRs, and arranged the maximum output during the peak load period and the charging during off peak period. This ELR modeling resulted in a 0.9% impact of the IRM, as documented in the final IRM report.

While these pre-determined output shapes were aligned with the periods that typically experience the highest loss-of-load risk, the profiles were not dynamic or optimized. Therefore, a more flexible or optimal dispatch schedule for these resources is desirable to offer a more sustained modeling solution for ELRs.

MARS Modeling Functionality

The GE MARS program contains two unit types that are suitable to model the characteristics of ELRs. The logic behind these unit types keeps track of the energy balance when units generate or charge. Thus, the capacity and energy limits of the units are respected, but the units are dynamic in nature and their behavior can adapt to system conditions during the simulation.

The first model is called Energy Limited Type 3 (EL3). This unit type has been available in GE MARS for several years but was refined and new features were added during the analysis of ELRs. This unit type is designed to represent resources that do not require withdrawing energy from the system for charging, and have energy "budgets" that are deployed by the system on an as-needed basis. The energy generated by these units is stored in a real (or virtual) tank and is usually available at the beginning on each month, representing the monthly energy limit for the unit to use. Unlike the next unit type, ELC does not consider charging from the grid to replenish the tank. Figure 1 shows a conceptual representation of an EL3 unit. These units have been used in the past to represent dispatchable hydro (with monthly energy budgets based on historical water in-flows) or demand response programs (where the amount of energy or frequency of usage is limited).

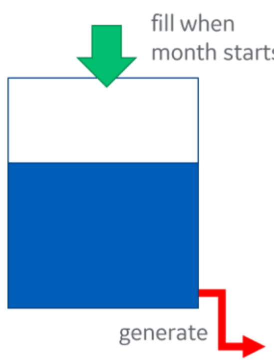

Figure 1. Conceptual representation of Energy Limited Type 3 (EL3) units

EL3 units can be modeled with a wide range of constraints and parameters. All of these parameters can be updated on a monthly basis to represent seasonal trends. The key parameters include:

- Monthly energy budgeted (MWh); maximum amount of energy to be used in a month, which becomes available at the beginning of each month
- Maximum generation (MW); maximum amount to be generated in an hour
- Minimum generation (MW); it represents a portion of the capacity that is always generated (*e.g.*, to represent the minimum flows conditions in a hydro unit). This feature is optional for users to choose depending on the characteristics of the modeled unit.

- Maximum storage (MWh): optionally, the amount of energy that can be carried over from one month to the next when not used. This feature is optional for users to choose depending on the characteristics of the modeled unit.

The frequency of use of EL3 units can be limited in several ways. Users may use one or more of these constraints and GE MARS will model EL3 unis and meet all of them. Some of the limits include:

- Maximum number of hours, which can be modeled as:
    - Hours per day
    - Hours per month
    - Hours per year
- Maximum number of days, as either:
    - Days per month
    - Days per year
- Maximum energy (MWh) used per day

EL3 units also keep track of the number of "calls" requested, with a call being one or more consecutive hours of usage. Currently, calls can be limited as follows:

- Number of calls per day
- Number of calls per month
- Number of calls per year
- Maximum energy (MWh) per call
- Minimum and maximum duration (hours) for each call

Additional restrictions can be imposed on EL3 units:

- Allowing generation "window" to allow generation only during certain hours of the day; the default is to allow generation during all hours
- Establishing if a unit should generate before or after certain emergency operating procedures (EOPs), allowing the user to establish the dispatch order of different ELRs and EOPs

Energy Storage (ES) units are the second GE MARS unit type that can be used to represent ELRs. This model was developed over the last year, finalized during this analysis and officially released in GE MARS version 4.1.1749. Like the EL3 model, the unit has an energy storage tank from which energy is drawn when required by the system. As the diagram in Figure 2 shows, the unit also has the ability to charge its storage tank from the grid, which is the main difference between ES and EL3 units. If needed, the unit will account for energy losses in the charge-discharge cycle.

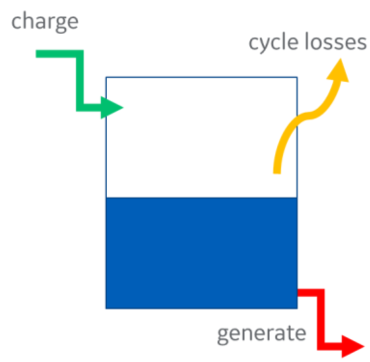

Figure 2 Conceptual representation of Energy Storage (ES) units

The key parameters for ES units include:

- Resource storage (MWh), maximum energy that the tank can hold
- Maximum generation capacity (MW), limits the output in any give hour
- Optionally, round-trip efficiency (%), to represent losses in a charge-discharge cycle
- Optionally, maximum charge capacity (MW), limits the charging in any give hour (typically defaults to the generation capacity)

The accounting of charging and discharging in MARS is performed in terms of energy. Thus, if a unit has the capacity to hold a certain number of hours' worth of energy, the storage capacity must be converted to energy terms (in MWh, usually the number of hours times the unit rating). For instance, a 100 MW unit with four hours of storage will be represented with a storage of 400 MWh. In the absence of other restrictions, this storage can be used at full output for four hours or for longer periods at lower output levels (*e.g.*, eight hours at 50 MW).

All of the constraints and limits for EL3 generation are also available for ES units, including frequency of usage, modeling of calls, generation windows and dispatch order.

Generation from EL3 and ES units is considered after GE MARS has performed the balanced of load and non-ELR resources (including thermal and shape-based generators). EL3 and ES units will attempt to deliver capacity to the system, subject to several limits:

- Energy and capacity limits for the unit (to provide that the stored energy has not been depleted)
- Limits of use, such as number of hours or energy per day
- Transmission limits if the unit is not located in the area experiencing shortages

Charging of ES units is considered after all the EOPs and ELR generation decisions have been made, and is subject to the following limits:

- A unit can only charge if it is not generating (generation takes priority, in order to assist the system)
- A unit can only charge from excess energy and cannot create a system shortage to charge
- A unit cannot use capacity used for system reserves
- Transmission limits must be respected
- A unit can charge up to its maximum storage capacity

These two new models are included in the simulations presented in the remainder of the paper.

Testing Methodology

The NYISO worked with GE Energy Consulting to develop the test suite to investigate the impact of the different models. To understand the impact of the GE MARS functionality, a base case was developed with no ELR modeling. All units were modeled as thermal units, similar to the way units were modeled before the 2020 IRM study. Additional cases were created with ELRs modeled under the simplified methodology, i.e., using pre-determined output shapes that are also developed using the same base case, and compared with the testing cases.

In order to have relevant test results, the recent IRM database was selected to construct the base case for the testing. The base case captures the following necessary adjustments:

- The recent IRM database contained the elected ELR resources for the 2021-2022 study as pre-determined output shapes. Therefore, the existing ELR modeling was removed in the base case.
- External units that utilize the GE MARS ELR functionality were removed in order to isolate the impacts of the tested functionality.
- Other corrections of external area modeling, such as missing transition rates, were also implemented during the development of the base case.

With the established base case, three units were selected for the testing. For all the testing units, the modeling parameters for ES or EL3 unit types were consistent with their pre-determined output shapes, such as having the same maximum MW and daily MWh limit. For fuel limited resource, its EL3 modeling also include a minimum output that represents the lowest output from the unit throughout the day and the remaining portion to be dispatched by the model.

- Unit A: a small storage resource unit modeled using ES unit type
- Unit B: a small fuel-limited resource unit modeled using EL3 unit type
- Unit C: a large fuel-limited resource unit modeled using EL3 unit type

It should be noted that the thermal modeling of the testing units in the base case was conducted at the units' ICAP amount, with an appropriate outage rate. Currently, outage rates are not captured in the ELR functionality, and pre-determined output shapes and the ES/EL3 unit types are modeled at the units' UCAP. Therefore, all the testing results are more conservative compared to the base case, but results of different testing cases can be compared on the same basis.

The testing suite was organized as shown in Table 4 in the Appendix 2, with the following major categories:

- Base case: all ELR units modeled as thermal units
- Benchmark cases: converting ELR units to fixed-shaped units
- Basic ELR functionality: use of EL3 and ES models
- Enhanced ELR modeling: ELR functionality combined with the following features:
  - Deferring the dispatch of the EL3/ES units until after all the EOPs have been considered
  - Dispatching the EL3/ES units before reserves and EOPs are considered
  - Limiting the dispatch of EL3/ES units to certain hours of the day

The testing matrix also included combining the pre-determined output shapes and the enhanced ELR modeling with limiting dispatch to an output window. The results from the testing cases and benchmarking case were compared using three metrics: a) impacts on daily loss of load expectation (LOLE, in days/year); b) unit dispatch profiles and, c) usage of Emergency Operating Procedures (EOPs)[1]. It is important to note that, due to the differences in size, location, and the energy/duration limitation, each of the testing units will have different impacts on each of the three metrics. Therefore, comparing results across the three testing units would likely yield the differences driven by the characteristics of these units. Results with the same testing unit(s) provide meaningful comparison, which demonstrates the impact of the GE MARS functionality.

The logic behind these categories will be discussed in the next section, where the results are presented.

Testing results

The NYISO and GE Energy Consulting started the analysis by comparing the base case, the benchmark cases (with fixed shapes) and the behavior of the basic EL3/ES models. Very early on, it was clear that the use of basic EL3 and ES models was not sufficient for use in the NYISO IRM model. Two major contributors indicated the modeling needed to be improved:

- The model is calibrated so that NYCA has an LOLE of 0.1 days/year, which means that the amount of load typically exceeds available capacity for a few days in the first few load forecast uncertainty (LFU) levels; and
- The model is set up to allow external assistance from other pools only after the first seven Emergency Operating Procedure (EOP) steps have been considered. In the test case, the external assistance was capped at 3,500 MW.

Figure 3 represents a very simplified demonstration of the issue at hand, for one of the peak load days in the model, which coincides with one of the days when LOLE is accumulated. Because the model is calibrated to experience a certain number of shortages, the typical resources are close, but slightly lower than peak load. Graphically, this is represented by the blue line (resources) that does not completely cover load during the peak hours. Those peak hours are represented as the shaded blue area and, ideally, the system would reserve ELR energy to be dispatched during those hours.

[1] Other metrics such as LOLH and EUE are also reported for all test cases in Appendix 2, Table 5.

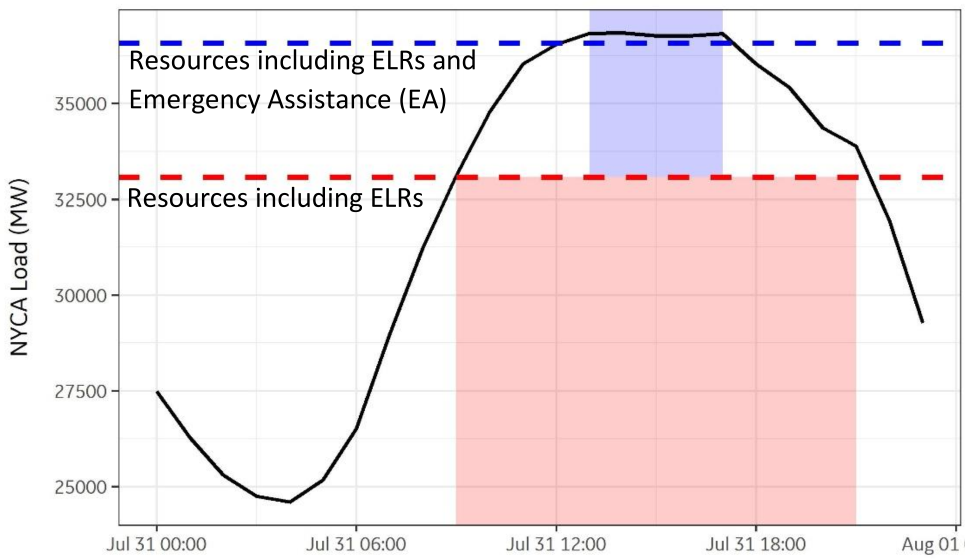

Figure 3. Timing of peak load and EL3/ES dispatch

However, the total resources line includes the 3,500 MW of external assistance, which is not activated until after the first seven EOP steps (prior to the 10-minute reserves). This means that for the initial EOPs, the amount of resources is closer to the red line. For those EOPs, GE MARS experiences shortages for a wider range of hours (shaded in red). When GE MARS encounter one of those hours, it starts dispatching ELRs, to alleviate those perceived shortages, because GE MARS solved each hour sequentially, without any look ahead.

The result is that ELRs get dispatched earlier in the day (at the start of the red shaded area) and those units effectively run out of energy when the system experiences the actual hours of risk (blue shaded area). The ELR energy is used during hours where reliance on external assistance would be sufficient to arrest the shortages, leaving little to no energy left for the actual hours of risk.

Based on these observations, the team explored different approaches to better align the ELR output with the hours of risk, which lead to the testing categories listed in the previous section. These approaches include:

- Defer ELR dispatch until after EOPs have been considered and external assistance has been accounted for;
- Fix ELR dispatch before EOPs are dispatched, but accounting for external assistance; and
- Setting generation windows, disallowing ELR generation before certain hours.

For smaller units, such as batteries and pumped storage resources, generation windows were set to generate after 1 p.m., which was found to be a good compromise to capture loss of load events. For a large unit, especially those fuel limited resources with various output throughout the day, having a single hour to enable generation would result in the unit generating at maximum output at the start of the output window and staying at maximum output for a sustained period of time. To address this issue, the approach outlined in Appendix 1 was adopted and applied to Unit C, which resulted in the division of the units into five equal, smaller portions. The generation windows for those smaller portions were staggered so that there was a one-hour delta between the start of each window. The resulting model allows Unit C to gradually increase its generation between 7 a.m. and 11 a.m.

All the cases simulated listed in Table 4 in Appendix 2 were simulated and all the results are included in the Appendix 2. For simplicity, a subset of the results is presented in this section by including only the combinations that had the three testing units all modeled using the same methodology, thermal modeling, fixed shapes, or the EL3/ES units.

Table 1 summarizes the reliability metrics for the different cases. As previously mentioned, the basic EL3/ES modeling (TC-4), which dispatches the ELRs as last resource before the EOP step 1, does not produce a dispatch that aligns with the hours when the system is at risk, and reliability metrics worsen. Deferring generation until after all the EOPs (TC-4A)[2] produces similar results to the fixed shape dispatch. The window to limit EL3/ES dispatch generation produces the smallest daily LOLE amongst all cases, aside from the base case.

Table 1. Reliability metrics for selected cases

Case name	Case Description	Daily LOLE (days/year)	Hourly LOLE (hours/year)	EUE (MWh/year)
Base case	ELRs modeled as thermal units	0.100	0.340	235.0
BC-4	ELRs modeled as fixed shapes	0.113	0.419	297.3
TC-4	ELRs modeled with basic EL3/ES	0.233	0.816	775.2
TC-4A	ELRs dispatch after EOPs	0.110	0.377	267.7
TC-4C	ELRs dispatch with output window - ES output window: after 1 p.m.; - EL3 small unit output window: after 1 p.m., - EL3 large unit output window: gradually start between 7 a.m. and 11 a.m.	0.104	0.401	297.8

Because the IRM database modeling process involves setting external control areas to a predetermined reliability level, it is important to analyze the impact that the modeling of NYISO ELRs has on their LOLE. Table 2 summarizes daily LOLE levels for Quebec, Ontario, New England, and PJM. The changes in LOLE for all the control areas are similar to that of the NYCA LOLE.

[2] Note that there was no change to the reserve level in the test cases with deferring ELR output after all EOPs.

Table 2. Daily LOLE for External Control Areas

Case name	Case Description	Quebec	Ontario	New England	PJM
Base Case	ELRs modeled as thermal units	0.106	0.113	0.113	0.181
BC-4	ELRs modeled as fixed shapes	0.109	0.121	0.116	0.182
TC-4	ELRs modeled with basic EL3/ES	0.106	0.126	0.160	0.197
TC-4A	ELRs dispatched after EOPs	0.112	0.115	0.119	0.184
TC-4C	ELRs dispatched with output window - ES output window: after 1 p.m.; - EL3 small unit output window: after 1 p.m., - EL3 large unit output window: gradually start between 7 a.m. and 11 a.m.	0.108	0.120	0.114	0.180

Finally, Table 3 shows EOP usage for the selected cases. When the units are represented as thermal units, they are available homogeneously during the day, leading to the lowest numbers of EOP calls. Those number increase when the units are modeled as shapes (BC-4), which is consistent with the capacity of those units being available for a subset of the hours. Amongst the EL3/ES cases, the base model (TC-4) leads to the smallest EOP usage numbers, while the cases generating after the EOP calls (TC-4A) lead to the highest numbers (because their generation is limited during peak). Based on the potential SCR usage, the case with generation window (TC-4C) produces about 20 days/year less SCR usage comparing to the fixed shapes.

During the 2021-2022 IRM study, a significant increase in the EOP usage was observed due to the energy output and duration limitations of the ELRs. Early in 2021, as requested by the ICS and the Executive Committee ("EC"), the NYISO performed an additional analysis with re-distribution of reserve[3]. It should be noted that such treatment was not included in the Base Case and all the test cases in this white paper. If the same re-distribution of reserves were adopted, the results of lower EOP usage would be expected to be consistent with the early 2021 analysis.

Table 3. EOP use for cases, in days/year

EOP Reference	**Description**
SCR	Special Case Resource
Man Volt Red	5% Manual Voltage Reduction
30 min Res	30-minute Reserve
Rem 5% VR	5% Remote Voltage Reduction
Vol Curt	Voluntary Curtailment
Pub Appeals	Public Appeals
10 mins Res	10-minute Reserve

[3] https://nysrc.org/PDF/MeetingMaterial/ICSMeetingMaterial/ICS%20Agenda%20243/AI%2011%20-%20ICS%20Briefing%20on%20increased%20EOP%20use.pdf

Case name	Case Description	SCR	Man Volt Red	30 min Res	Rem 5% VR	Vol Curt	Pub Appeals	10 min Res
Base Case	ELRs modeled as thermal units	8.86	5.31	5.19	3.29	2.67	2.37	0.26
BC-4	ELRs modeled as fixed shapes	174.00	146.91	143.71	70.03	62.79	62.72	0.36
TC-4	ELRs modeled with basic EL3/ES	14.09	12.98	12.95	12.12	12.04	12.02	0.51
TC-4A	ELRs dispatched after EOPs	356.49	353.14	352.65	324.15	319.60	319.49	3.98
TC-4C	ELRs dispatched with output window - ES output window: after 1 p.m.; - EL3 small unit output window: after 1 p.m., - EL3 large unit output window: gradually start between 7 a.m. and 11 a.m.	151.58	123.41	120.60	52.96	48.01	47.96	0.30

These results show that the EL3/ES models can be used to model ELRs in the NYISO footprint, increasing the flexibility of these units when compared to fixed shape dispatch. Other approaches for EL3/ES modeling led to either higher reliability metrics such as LOLEs or higher EOP usage.

GE Energy Consulting and the NYISO will continue improving the modeling of ELRs in future years, as these units become more prevalent in the system. One future enhancement will include the ability to model outage rates in the modeling of ES and EL3, to represent how these units may become unavailable during certain events[4]. Given than generation windows are the best performing option for EL3/ES units, GE Energy Consulting will explore ways of how those limits can be fined tuned to smooth capacity availability for larger units, streamlining the modeling used for UNIT C in this analysis. This may also be necessary in the medium term, as more ELR capacity is present in the NYISO system. With larger amounts of ELRs in the system, it may be necessary to widen the output windows, and analysis of operational patterns will be performed to that effect. Beyond widening the output windows, additional treatments may include establishing different output window based on unit size or using combinations of output windows and dispatching after EOPs.

In the long term, it might be beneficial to include additional capabilities to better align the dispatch of ELRs with the main system risk hours. This could include the ability of GE MARS to weigh whether it is more beneficial to generate at a given hour or later. This would require GE MARS to include a look-ahead functionality and, possibly, the inclusion of forecast errors that would affect such a decision.

[4] Current modeling of EL3/ES is based on the use of UCAP values as the unit capacity, whereas ICAP values were used in the base case when ELRs were modeled as thermal units with outage rates

Considerations and Recommendations for IRM Modeling

Based on the observations and conclusions through the testing, ICS has the following considerations for the recommendations for modeling ELRs in the IRM.

There are general advantages of adopting the GE MARS functionality.

- The GE MARS functionality provides more flexible dispatches of the ELR resources, while requiring less prescribed inputs from the user. These are the advantages over the simplified methodology where pre-determined output shapes were developed to model ELRs. The NYISO embraces the value of having an algorithm-determined and less prescriptive ELR modeling framework through the GE MARS functionality.
- The GE MARS functionality along with implementing an output window effectively provides a better match between the flexible dispatch of the ELR resources and the expected high LOLE risk period, and therefore, may lead to better outcomes in reducing the system level LOLE

While the GE MARS functionality produces promising outcomes through the testing, continued enhancements are required to improve modeling accuracy and to account for the evolution of increasing ELR penetration.

- When modeling fuel-limited resources using the EL3 unit type, implementing a gradual output window is recommended. Additional prescribed inputs are required, such as establishing the different phases of the gradual output window and available energy for each phase. Approaches to minimize these prescriptive inputs are required to achieve the advantages over the pre-determined output shapes.
- Random outages can impact resource performance in addressing system shortages, and hence impacting the system LOLE. Currently, random outages are not reflected in the modeling of ELRs. Capturing ELRs' random outages in the GE MARS functionality is required to improve the modeling accuracy.
- The current GE MARS functionality with the output window feature is sufficient to model today's system with limited numbers of ELR resources. When the penetration of ELR increases, having one single output window for all the ELR units would not be appropriate. Additional features or modeling changes will be required in order to accommodate the modeling requirement for the system in the future.

Due diligence is needed when adopting major modeling changes.

- ELRs are expected to have sizable impact on the IRM outcome. The modeling of ELRs also have impacts on various steps in the EOP modeling. When adopting major modeling changes, due diligence is needed to ensure a smooth transition.
- The GE MARS functionality produces promising outcomes under the testing environment. Applying the functionality in various studies and multiple scenarios will further substantiate its performance and identify other unintended consequences.
- The 2021-2022 Capability Year marks the first year of ELRs' participation in the ICAP market. Additional experience with the ELR in the market will also help inform the characteristics of ELRs and further refine the modeling functionality.

- As previously recommended by the Installed Capacity Subcommittee (ICS), the modeling of ELRs needs to reflect the operating capabilities of the elected units. Therefore, the capabilities of the ELR units will be reviewed for each modeling cycle. Such review, similar to the one conducted during 2021-2022 IRM study, will result in the collection of information used to develop the output shapes. The pre-determined output shapes, under the simplified methodology, can offer a comparative IRM impact, with controllable and relatively stable representations of ELRs.

Based on the above considerations, the NYISO makes the following recommendations on the modeling approach for ELRs in the IRM study:

- The 2022-2023 IRM study should include the demonstration of IRM impacts using both simplified methodology and the GE MARS functionality
  - Review the operating capabilities of elected ELR units and collect necessary information to conclude the units' capabilities and facilitate the modeling process.
  - Use the collected information to develop the pre-determined output shapes for elected ELRs based on the units' operating capability, with the same guiding principles from previous IRM studies. Improve the output shapes development with updated information or better methodology.
  - Only if no unintended consequences are identified, adopt, with caution, the ES unit type for battery and storage resources, and EL3 unit type for fuel limited resources. The modeling parameters for ES and EL3 unit types are consistent with the units' operating capabilities based on the review. Apply appropriate output windows for both unit types, using the process and methodologies developed by GE.
  - Considering all other improvements planned for the 2022-2023 IRM model, the NYISO prefers including the pre-determined ELR output shapes in the Final Base Case (FBC) and adopting the ES and EL3 types in a sensitivity case. This will help minimizing the potential disruption during the FBC development, in case unexpected issues were discovered when applying the ELR functionality.
- In the near future, continue to collaborate with GE to enhance the MARS ELR functionality to capture unit outage rates, and to explore ways to apply limitations beyond the output window approach to accommodate the future increase of ELR penetration.
- In the longer term, significant penetration of ELR resources is expected. Modeling enhancements should be considered in conjunction with other improvements and impacts on the Resource Adequacy model. This includes, among other things, the potential of incorporating forward-looking capabilities into the GE MARS algorithm. Over time, the experience with ELR performance will also inform the understanding of resource characteristics, and in turn helps to refine the objectives for the ELR modeling framework.

Disclaimer for Future Use:

Please note that the conclusions and recommendations pertaining to this whitepaper reflect the work and progress achieved as of May 2021. The modeling framework for ELR resources will evolve overtime. Please refer to the more recent report for the latest progress on ELR modeling framework.

APPENDIX 1- Approach and Methodology to Determine EL3 Output Window for large units

Applying a generation window for EL3 units typically leads to 100% of the dispatchable portion of those units to be used at the start of the window, with many hours of generation at the maximum rating. Such behavior is not representative of how these units are typically dispatched and it may violate the operating capability of the units; i.e., the maximum number of hours that a unit may be able to generate at maximum output.

To better align the behavior of the unit in the GE MARS simulation, the analysis followed the steps described below. This methodology was applied to Unit C in the analysis, but the procedure is general enough that it can be applied to other fuel limited units.

First, we analyze the generation during a typical day and the total number of hours that a unit is capable of generating at (or near) capacity. The unit is typically dispatched at the minimum overnight and early in the morning. This value is used as the minimum generation level for the EL3 and is not considered dispatchable.

The remaining of the unit is then split into equal portions with the goal of smoothing the generation output. Each portion is assigned with an independent generation window, with a one-hour offset between them. This limits the rate at which the unit can increase its generation from minimum to maximum generation (in MW/h).

The second data point that needs to be determined is which hour of the day the unit is first allowed to generate at maximum capacity. This can be derived from the typical daily generation of the unit (as observed from operations). This hour will typically determine the first hour for which all the divisions can generate simultaneously.

In the case of Unit C, it was determined that 11 a.m. was a reasonable first hour to full-capacity generation. The unit was tested with five and six equal portions, but the differences in metrics (LOLE, EOP usage) were negligible. Therefore, Unit C was ultimately divided into five smaller EL3 units, with the first one starting its generation window at 7 a.m. and the last one at 11 a.m.

Future versions of GE MARS may include logic to allow fine-tuning windows of a single unit, without the need to divide the physical unit into five different EL3 units.

APPENDIX 2– Testing Matrix and Additional results

Table 4. ELR Testing Matrix

Test category	Name	UNIT A model	UNIT B model	UNIT C model
Base case	Base case	Thermal	Thermal	Thermal
Benchmark cases	BC-1	Shape	Thermal	Thermal
	BC-2	Thermal	Shape	Thermal
	BC-3	Thermal	Thermal	Shape
	BC-4	Shape	Shape	Shape
Basic ELR functionality	TC-1	ES model	Thermal	Thermal
	TC-2	Thermal	EL3 model	Thermal
	TC-3	Thermal	Thermal	EL3 model
	TC-4	ES model	EL3 model	EL3 model
ELR model, defer dispatch after EOPs	TC-1a	ES after EOPs	Thermal	Thermal
	TC-2a	Thermal	EL3 after EOPs	Thermal
	TC-3a	Thermal	Thermal	EL3 after EOPs
	TC-4a	ES after EOPs	EL3 after EOPs	EL3 after EOPs
ELR model, dispatch before reserves and EOPs*	TC-1b	ES before EOPs	Thermal	Thermal
	TC-2b	Thermal	EL3 before EOPs	Thermal
	TC-3b	Thermal	Thermal	EL3 before EOPs
	TC-4b	ES before EOPs	EL3 before EOPs	EL3 before EOPs
ELR model with output window	TC-1c	ES with window	Thermal	Thermal
	TC-2c	Thermal	EL3 with window	Thermal
	TC-3c	Thermal	Thermal	EL3 with window
	TC-4c	ES with window	EL3 with window	EL3 with window
ELR with output window, others as shape	TC-1d	ES model	Shape	Shape
	TC-2d	Shape	EL3 model	Shape
	TC-3d	Shape	Shape	EL3 model

*This test category includes allowing earlier assistance from the external area as a signal for ELR dispatch, which is different from all other test categories. Caution should be taken when comparing the results with other test categories.

Table 5. Reliability metrics for all cases

Case name	Daily LOLE (days/year)	Hourly LOLE (hours/year)	EUE (MWh/year)
Base Case	0.100	0.340	235.0
BC-1	0.102	0.374	266.3
BC-2	0.099	0.340	235.0
BC-3	0.102	0.352	244.2
BC-4	0.113	0.419	297.3
TC-1	0.166	0.524	452.8
TC-2	0.100	0.343	236.5
TC-3	0.139	0.476	379.2
TC-4	0.233	0.816	775.2
TC-1A	0.096	0.346	255.8
TC-2A	0.099	0.340	235.1
TC-3A	0.096	0.317	193.6
TC-4A	0.110	0.377	267.7
TC-1B	0.103	0.370	278.4
TC-2B	0.099	0.340	235.3
TC-3B	0.104	0.352	240.2
TC-4B	0.119	0.422	323.0
TC-1C	0.101	0.372	265.3
TC-2C	0.099	0.340	234.9
TC-3C	0.101	0.355	249.8
TC-4C	0.104	0.401	297.8
TC-1D	0.110	0.411	294.1
TC-2D	0.113	0.418	297.3
TC-3D	0.105	0.404	298.6

Note: The Base Case includes all three testing units modeled as thermal units, at ICAP with their associated outage rates. All benchmarking cases and test cases are based on the use of UCAP values as the unit capacity, with no outage rates. When testing the individual unit in isolation, the resulting daily LOLE may perform better than the Base Case, depending on the outage rate of the specific unit.

Table 6. Daily LOLE for external pools

Case name	Quebec	Ontario	New England	PJM
Base Case	0.106	0.113	0.113	0.181
BC-1	0.106	0.113	0.114	0.181
BC-2	0.106	0.113	0.113	0.181
BC-3	0.109	0.120	0.113	0.181
BC-4	0.109	0.121	0.116	0.182
TC-1	0.106	0.123	0.158	0.196
TC-2	0.106	0.113	0.113	0.181
TC-3	0.106	0.116	0.114	0.182
TC-4	0.106	0.126	0.160	0.197
TC-1A	0.098	0.103	0.113	0.181
TC-2A	0.098	0.103	0.113	0.181
TC-3A	0.113	0.114	0.114	0.182
TC-4A	0.112	0.115	0.119	0.184
TC-1B	0.106	0.112	0.114	0.181
TC-2B	0.106	0.113	0.113	0.181
TC-3B	0.116	0.133	0.114	0.182
TC-4B	0.116	0.135	0.119	0.184
TC-1C	0.106	0.113	0.114	0.180
TC-2C	0.106	0.113	0.113	0.181
TC-3C	0.108	0.119	0.113	0.181
TC-4C	0.108	0.120	0.114	0.180
TC-1D	0.109	0.121	0.115	0.181
TC-2D	0.109	0.121	0.116	0.182
TC-3D	0.108	0.120	0.114	0.181

Table 7. EOP use for all cases, in days/year

Case name	SCR	Man Volt Red	30 min Res	Rem 5% VR	Vol Curt	Pub Appeal s	10 min Res
Base Case	8.86	5.31	5.19	3.29	2.67	2.37	0.26
BC-1	10.34	5.90	5.75	3.68	2.97	2.63	0.29
BC-2	8.87	5.31	5.19	3.29	2.67	2.37	0.26
BC-3	176.06	150.05	147.12	73.47	66.12	66.01	0.29
BC-4	174.00	146.91	143.71	70.03	62.79	62.72	0.36
TC-1	8.65	5.35	5.24	3.53	2.99	2.74	0.41
TC-2	8.86	5.31	5.19	3.29	2.67	2.38	0.26
TC-3	13.61	12.33	12.30	11.45	11.36	11.33	0.33
TC-4	14.09	12.98	12.95	12.12	12.04	12.02	0.51
TC-1A	13.98	8.52	8.30	5.73	4.69	4.22	0.48
TC-2A	8.89	5.32	5.20	3.30	2.68	2.38	0.26
TC-3A	355.50	352.03	351.51	321.07	316.49	316.40	3.61
TC-4A	356.49	353.14	352.65	324.15	319.60	319.49	3.98
TC-1B	13.98	8.52	8.30	5.73	4.69	4.22	0.39
TC-2B	8.89	5.32	5.20	3.30	2.68	2.38	0.26
TC-3B	355.50	352.03	351.51	321.07	316.49	316.40	2.98
TC-4B	356.49	353.14	352.65	324.15	319.60	319.49	3.00
TC-1C	9.51	5.66	5.52	3.59	2.92	2.60	0.29
TC-2C	8.86	5.31	5.18	3.29	2.67	2.37	0.26
TC-3C	154.27	126.96	124.21	55.56	50.53	50.48	0.27
TC-4C	151.58	123.41	120.60	52.96	48.01	47.96	0.30
TC-1D	173.99	146.90	143.70	70.03	62.79	62.71	0.35
TC-2D	174.00	146.91	143.71	70.03	62.79	62.72	0.36
TC-3D	151.61	123.38	120.57	52.91	47.96	47.90	0.30