Evaluation of Illinois' Policy Proposals on Resource Adequacy

Report for

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FOREWORD

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EXECUTIVE SUMMARY

The Illinois General Assembly passed Senate Bill 1699 (SB 1699) on November 9, 2023, and Governor Pritzker signed it into law on December 8, 2023, as Public Act 103-0580. Public Act 103-0580 directs the Illinois Power Agency to conduct a Policy Study to evaluate the potential impacts of proposals made during the Illinois General Assembly's Spring 2023 Legislative Session and provide policy recommendations for the General Assembly. The provisions of the Act related to the Policy Study are the same as those contained in House Bill 3445 (HB 3445) which the General Assembly passed on May 26, 2023. These policies include a utility scale offshore wind (OSW) project in Lake Michigan, energy storage systems (ESS) located throughout the state, and a High-Voltage Direct Current (HVDC) transmission line. To assess the impact the 3 policies in focus would have on system resource adequacy, this study evaluates their capacity value (or firm capacity contribution) and impact to loss of load metrics for the study years 2030 and 2040. The capacity value is measured in terms of Effective Load Carrying Capability (ELCC)[1] and the impact to loss of load is measured in terms of Loss of Load Expectation (LOLE)[2], the industry standard for assessing the impact on reliability.

All three proposals show a reduction in LOLE, and therefore an improvement in reliability. The reduction in LOLE is directly linked to the policy proposal's total capacity. The bigger capacity policies such as the HVDC Line and the ESS show the bigger improvement to Illinois' LOLE, whereas the smaller 200 MW OSW policy improves reliability less. For both study years 2030 and 2040, the combination of the three policies eliminates almost all LOLE in the system.

All three proposals also provide firm capacity contribution. The ELCC of generating resources is an important part of ensuring that there is adequate generation capacity to meet electricity demand all hours of the year. Evaluating how much firm capacity contribution a resource can provide, through its ELCC, helps determine how much generation capacity is needed in the system to maintain reliability. Through the two study years, the ELCC of the HVDC Line policy is the most stable, at 96% and 92% of its nameplate capacity. The ELCC of the OSW in Lake Michigan decreases through time, from 29% in 2030 to 20% in 2040. This is caused by the shifting in LOLE in Illinois as the load and resource mix shifts. The ESS' ELCC decreases from 94% to 64% from 2030 to 2040. Although its ELCC % decreases through time, its ELCC capacity increases since the amount of ESS added by 2040 is higher than 2030.

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[1] ELCC is a measurement of a resource's ability to produce electric energy when the grid is most likely to experience supply shortfalls, that is the resource's ability to prevent an outage due to a supply shortfall. ELCC is typically represented as a percentage of a resource's capacity.

[2] LOLE is the expected number of days where load cannot be met with available resources.

1 INTRODUCTION

The Illinois General Assembly passed Senate Bill 1699 (SB 1699) on November 9, 2023, and Governor Pritzker signed it into law on December 8, 2023, as Public Act 103-0580. Public Act 103-0580 directs the Illinois Power Agency to conduct a Policy Study to evaluate the potential impacts of proposals made during the Illinois General Assembly's Spring 2023 Legislative Session and provide policy recommendations for the General Assembly. The provisions of the Act related to the Policy Study are the same as those contained in House Bill 3445 (HB 3445) which the General Assembly passed on May 26, 2023. These policies include a utility scale offshore wind (OSW) project in Lake Michigan, energy storage systems (ESS) located throughout the state, and a High-Voltage Direct Current (HVDC) transmission line.[3] GE Energy Consulting (GEEC) assessed the impact that each of these policies has on the state's resource adequacy using GE's Multi-Area Reliability Software (GE MARS).

Resource adequacy refers to the ability of an electric power system to meet demand for electricity. Resource adequacy is a fundamental component of electric system reliability that is assessed through the use of simulation models. GE MARS is the simulation model that was used to assess the impacts on resource adequacy of the policy proposals.

To assess the impact the 3 policies in focus would have on system resource adequacy, this study evaluates their capacity value (or firm capacity contribution) and impact to loss of load metrics.[4] Additional to evaluating the impact that each policy would have on their own, the capacity value and impact to loss of load metrics of the three policies together is calculated. The loss of load metrics that are reported are the daily LOLE, hourly Loss of Load Expectation (LOLH)[5], and Expected Unserved Energy (EUE)[6]. Each metric is reported monthly and annually for Illinois, MISO, and PJM. The years 2030 and 2040 were studied in this analysis. [7]

1.1 GE Multi-Area Reliability Simulation (GE MARS) software

A loss of load expectation (LOLE) reliability evaluation was performed for different scenarios. The GE MARS model was used to calculate the daily LOLE, in days per year, for each case. The daily LOLE determines the numbers of days in which a loss of load (i.e., a power outage/disconnection) would be expected to occur on average across a large number of system conditions[8].

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[3] The SOO Green HVDC Line was used as the source for the supply of the renewable energy credit program.

[4] For additional information on resource adequacy and the loss of load metrics defined for the report, see Mauch, B., Millar, D., and Dorris, G. Resource Adequacy Modeling for a High Renewable Future, National Regulatory Research Institute. Washington, D.C., June 2022.

[5] LOLH is the expected number of hours where load cannot be met with available generation.

[6] EUE is the expected amount of load in MWh that cannot be met with available generation.

[7] Workpapers to support this study can be found at: https://ipa.illinois.gov/ipa-policy-study/draft-policy-study-supporting-information.html

[8] For a thorough description of how daily LOLE is calculated in reliability models, please refer to Stephen, Gord; Tindemans, Simon H.; Fazio, John; Dent, Chris; Figueroa Acevedo, Armando; Bagen, Bagen; et al. (2021): Clarifying the Interpretation and Use of the LOLE Resource Adequacy Metric. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.17054219.v2

GE MARS is based on a sequential Monte Carlo simulation,[9] which provides a detailed representation of the hourly loads, generating units, and interfaces between the interconnected areas. In the sequential Monte Carlo simulation, chronological system histories are developed by combining randomly generated operating histories of the generating units with the inter-area transfer limits and the hourly chronological loads. Consequently, the system can be modeled in great detail with accurate recognition of random events (e.g., equipment failures), as well as deterministic rules and policies, which govern system operation, without the simplifying or idealizing assumptions often required in analytical methods.

GE MARS uses state transition rates rather than state probabilities, to describe the random forced outages of thermal units. State probabilities give the probability of a unit being in a given capacity state at any particular time and can be used if one assumes that the unit's capacity state for a given hour is independent of its state at any other hour. In contrast, a sequential Monte Carlo simulation recognizes the fact that a unit's capacity state in a given hour is dependent on its state in previous hours and influences its state in future hours. It thus requires the additional information that is contained in the transition rate data.

More relevant project experience on how GE-MARS is used in industry can be found in Appendix D.

2 METHODOLOGY

This section describes how the GE MARS model of Illinois, as well as the areas outside of Illinois that are part of PJM, and MISO was developed and simulated.

The following items are included in the PJM and MISO database:

- Pools and Areas
- Load forecast and load forecast uncertainty
- Generating units (thermal, hourly modifiers, and energy limited resources)
- Hourly load, wind, and solar profiles
- Interface transmission limits between areas
- Emergency operating procedures

2.1 Policies Modeled

The three policies modeled in this study are a utility scale OSW project in Lake Michigan, ESS located throughout the state, and a High-Voltage Direct Current (HVDC) Renewable Energy Credit program. The policies are modelled in GE MARS as follows:

- HVDC Line: 2,650 MW of wind in Iowa modeled with hourly profiles from NREL's WIND TOOLKIT for the historical years 2007-2013,[10] 1,850 MW of solar in Iowa modeled with hourly profiles from

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[9] In a Monte Carlo simulation analysis uncertainty for modeling variables is addressed by re-running the simulation many times selecting values for uncertain variables through a random draw from a probability distribution of values for that variable. For a more thorough description on a Monte Carlo Simulation, please refer to: Haringa, Glenn E., Jordan, Gary A., Garver, Leonard L. (1991): Application of Monte Carlo Simulation to Multi-Area Reliability Evaluations. https://home.engineering.iastate.edu/~jdm/ee552/GE_MARS-Description.pdf

[10] NREL's Wind Integration National Dataset (WIND) Toolkit, which is the source for the 2007 - 2013 vintage data used for the Policy Study modeling is currently the publicly available data source that best meets the needs of power system modeling. An update and upgrade for the

NREL's NSRDB for the historical years 2007-2013, 650 MW of 4-hour energy storage.[11] A transfer limit from Iowa to Illinois of 2,100 MW applied.

- OSW in Lake Michigan: 200 MW offshore wind in Lake Michigan modeled with hourly profiles from NREL's WIND TOOLKIT for the historical years 2007-2013.
- ESS: 7,460 MW of ESS modeled with GE MARS energy storage model with 4 hours of storage duration and 85% round trip efficiency, and 40 MW of 10-hour energy storage. By 2030, 1,460 MW of 4-hour energy storage and the 40 MW of 10-hour storage are available.

2.2 Pools and Areas

The GE MARS model consists of Pools and Areas, where Areas are assigned to different Pools. In this model, the Pools are PJM and MISO. MISO is divided into a northern and southern section, MISON and MISOS. Regions of MISO in or north of Kentucky are in MISON, any region in or south of Arkansas are in MISOS. The assignment of each Area to Pool can be found in Appendix A. The Areas in Illinois are treated separately and apart from MISO and PJM, in the evaluation and calculation of ELCC and LOLE improvement to Illinois. Specifically, this means that Illinois is modeled in isolation from the rest of PJM and MISO, and no market-specific externality (such as the ability to participate within one of the ISO's power or capacity marketplaces) is considered.[12]

2.3 Capacity by Unit Type

Table 1 shows the capacity by unit type in the MISO and PJM model. Table 2 separates the data to show how much capacity of each unit type is included in the Illinois region of the model.

WIND Toolkit, the Wind Toolkit Long-Term Ensemble Dataset (WTK-LED), is currently being assembled and validated but is not yet ready for release. A report on the WTK-LED can be found at https://www.esig/weather-data-for-power-system-planning.

[11] The generation mix was provided to the IPA by SOO Green as part of an optimization study they conducted.

[12] GEEC notes that, under present capacity market rules in PJM, HVDC transmission such as SOO Green are not able to qualify as capacity resources and thus would not be economically compensated for any capacity contributions made within PJM. However, capacity market compensation (or lack thereof) for a given modeled policy resource does not impact the goals of this specific study scope, which centers specifically around the added system reliability benefits of the various policy scenarios, such as the transmission resource in question, as modeled.

Table 1. Capacity (MW) by unit type for PJM and MISO.

	MISON		MISOS		PJM	
MARS Unit Type	**2030**	**2040**	**2030**	**2040**	**2030**	**2040**
BATTERY	4,489	6,972	170	3,165	9,915	18,215
CC-GAS	28,470	44,184	16,943	19,443	55,209	55,209
CC-OTH	2,300	2,300	192	192	1,362	1,362
CT-GAS	16,981	21,121	3,690	4,050	12,316	12,316
CT-OTH	5,800	5,800	0	0	8,336	8,336
DPV	638	638	223	223	17,666	29,759
HYDRO	1,337	1,337	736	736	3,155	3,155
IC-GAS	908	908	231	231	370	370
IC-OTH	1,595	1,595	40	40	836	836
NUC	6,127	4,533	5,228	5,228	31,985	31,985
OSWIND	0	0	0	5,000	8,660	22,800
PUMPSTG	2,342	2,342	28	28	5,244	5,244
ST-COL	23,028	12,896	4,238	2,560	27,143	23,706
ST-GAS	886	886	5,758	5,758	1,729	1,729
ST-OTH	1,954	750	2,249	2,249	3,333	3,333
UPV	15,604	24,181	956	956	46,951	77,951
WIND	43,489	55,850	185	185	19,455	27,955

Table 2. Capacity (MW) by unit type for Illinois.

	Illinois	
MARS Unit Type	**2030**	**2040**
BATTERY	137	137
CC-GAS	7,181	10,181
CC-OTH	0	0
CT-GAS	1,503	1,863
CT-OTH	385	385
DPV	3,408	5,590
HYDRO	41	41
IC-GAS	35	35
IC-OTH	208	208
NUC	11,441	11,441
OSWIND	0	0
PUMPSTG	0	0
ST-COL	1,928	1,928
ST-GAS	16	16
ST-OTH	93	93
UPV	2,535	2,535
WIND	9,600	9,600

MARS Unit Type Acronym Definitions:

- CC-GAS: Combined Cycle Gas
- CC-OTH: Combined Cycle Other, non-gas
- CT-GAS: Combustion Turbine Gas
- CT-OTH: Combustion Turbine Other, non-gas
- DPV: Distributed Solar
- IC-GAS: Internal Combustion Gas
- IC-OTH: Internal Combustion Other, non-gas
- NUC: Nuclear
- OSWIND: Offshore Wind
- PUMPSTG: Pumped Storage Hydro
- ST-COL: Coal Steam Turbine
- ST-GAS: Natural Gas Steam Turbine
- ST-OTH: Steam Turbine Other, non-gas

- UPV: Utility Solar

2.4 Load Forecasts

Historical hourly load profiles for each Area are used in this study for the years 2007-2013, which is consistent with the NREL WIND Toolkit data. These load profiles are scaled to an annual forecasted coincident Pool peak load such that the expected peak load across the profiles matches the values in Table 3.

Table 3. Pool peak load for study years.

Year	Name	Peak (MW)
2030	MISOS	33,139
2030	MISON	94,077
2030	PJM	159,683
2040	MISOS	36,962
2040	MISON	103,023
2040	PJM	160,497

Table 4. Pool load forecast uncertainty multipliers.

Pool	Load level	Load uncertainty multiplier	Probability
PJM	1	1.139	0.62%
PJM	2	1.093	6.06%
PJM	3	1.047	24.17%
PJM	4	1.000	38.30%
PJM	5	0.953	24.17%
PJM	6	0.907	6.06%
PJM	7	0.861	0.62%
MISO	1	1.111	0.62%
MISO	2	1.074	6.06%
MISO	3	1.037	24.17%
MISO	4	1.000	38.30%
MISO	5	0.963	24.17%
MISO	6	0.926	6.06%
MISO	7	0.889	0.62%

2.5 Hourly Load, Wind, and Solar Profiles

Historical hourly load profiles from the years 2007-2013 are used and scaled to the forecasted load peak for the year of study. Hourly wind and solar profiles for the years 2007-2013 are used and scaled to unit capacity in the future study year. Wind generation profiles are created with wind speed data from NREL's WIND Toolkit, which are then converted to a generation profile using GEEC's proprietary wind tool. Solar generation profiles are created with irradiance data from NRELs National Solar Radiation Database (NSRDB) and then converted to MW output profiles using NREL's System Advisory Model (SAM) to get an aggregate solar shape for each GE MARS load area.

2.6 Interface Transfer Limits

Figure 1 and Table 5 show the bubble diagram of the GE MARS MISO and PJM model used for this study. There are no transfer limits within each bubble, so areas in the same bubble can import and export to each other freely. Figure 1 shows how each bubble is connected to the rest of the system. Yellow bubbles represent MISOS, green bubbles represent MISON, blue bubbles represent PJM, and the red bubble represents Illinois. Table 3 shows the import and export limit that each bubble has with its neighbors. The assignment of areas to bubbles can be found in Appendix A.

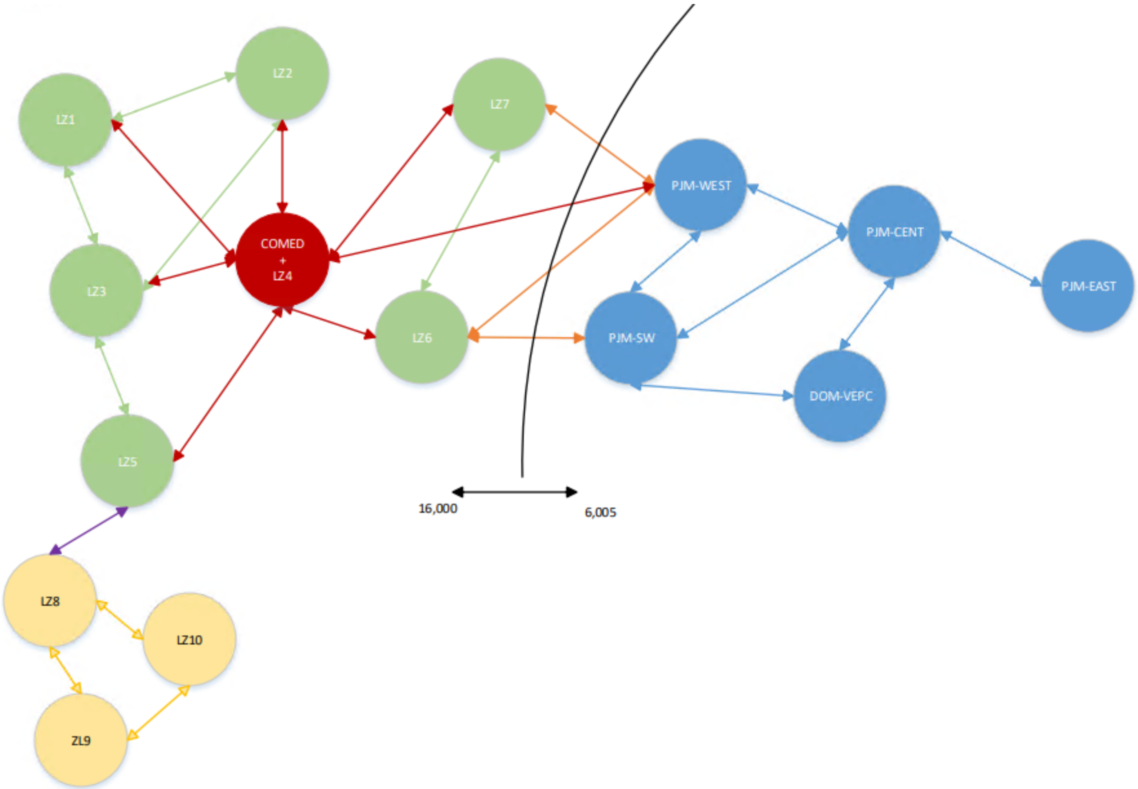

Figure 1. Bubble limit diagram of PJM and MISO Model.

Table 5. MW limit of import and export for each bubble.

Bubble	Import Limit [MW]	Export Limit [MW]
PJM-EAST	7,397	-
PJM-CENT	10,180	8,221
DOM-VEPC	7,365	7,410
PJM-SW	13,269	14,286
PJM-WEST	1,602	2,499
LZ1	6,528	4,321
LZ2	4,905	4,198
LZ3	14,375	7,002
LZ4 + COMED (Illinois)	7,884	99,999
LZ5	5,380	99,999
LZ6	8,818	2,703
LZ7	6,340	4,413
LZ8	4,729	5,503
LZ9	6,080	2,240
LZ10	3,064	2,878
MISO	16,000	6,005
PJM	6,005	16,000

2.7 Emergency Operating Procedures

Table 6 summarizes the emergency operating procedures (EOPs) modeled in the database. Each EOP has an amount of capacity associated with it which the system can use when needed.

Table 6. Emergency Operating Procedures for PJM and MISO.

Pool	EOP	MW
PJM	Operating Reserves	(3,400)
PJM	Curtailable Load	7,065
PJM	No 30-min Reserves	2,765
PJM	Voltage Reduction	2,201
PJM	No 10-min Reserves	635
PJM	Appeals	400
MISON	Operating Reserves	(3,906)
MISON	Curtailable Load	4,674
MISON	No 30-min Reserves	2,670
MISON	Voltage Reduction	2,200
MISON	No 10-min Reserves	1,236
MISON	Appeals	400
MISOS	Operating Reserves	(1,376)
MISOS	Curtailable Load	1,646
MISOS	No 30-min Reserves	941
MISOS	Voltage Reduction	775
MISOS	No 10-min Reserves	435
MISOS	Appeals	141

2.8 LOLE Improvement methodology

The LOLE determines the numbers of days in which a loss of load (i.e., a power outage/disconnection) would be expected to occur on average across variety of system conditions. LOLE of 0.1 days/year is a de-facto standard, or criteria, in industry for probabilistic reliability metrics, sometimes referred to as "1 day in 10 years". The criteria of 0.1 days/year LOLE is used as the starting point for our analysis of LOLE improvement and ELCC calculations to allow the impacts to reliability of different resources to be comparable. By using the criteria of a LOLE of 0.1 days/year for this analysis, it shows how each policy improves the reliability of the Illinois system if the system's reliability is at "criteria" (LOLE of 0.1 days/year).

To calculate the improvement to reliability that each policy has on the Illinois system, the initial system was brought to criteria (LOLE of 0.1 days/year) by adding or removing perfect capacity. Perfect capacity is capacity that is always available (no forced or planned outages). Once the Illinois system was at criteria, GEEC added the policy of interest to the database and a new LOLE was calculated. This calculation was done for each policy, and in each simulation, Illinois was isolated from the rest of PJM and MISO, with all of PJM and MISO interconnected. This allows us to calculate the reliability impact that the policy has on Illinois' resource adequacy in a bubble, as well as how they might impact the surrounding regions[13].

2.9 Capacity value methodology

To calculate the capacity value of each policy, Effective Load Carrying Capacity (ELCC) is calculated using GE MARS. The ELCC of a resource is the additional load that can be served while maintaining the same reliability level (LOLE of 0.1 days/year). This calculation allows us to determine how much capacity each policy contributes to improving the systems' reliability. The method for each policy is as follows:

1. Start with the initial system at criteria (LOLE of 0.1 days/year).
2. Add the policy resource being studied and record the region's new LOLE.
3. Iteratively remove perfect capacity from the region until the LOLE returns to the initial LOLE value.

The resulting perfect capacity removed in step 3 is the ELCC of the resource.[14]

In this study, the ELCC calculations are once again done using an isolated Illinois system, where there are no internal transfer limits in Illinois. For the ELCC calculations on the HVDC Line and OSW policies, the perfect capacity removed in step 3 is done at the same area as the injection point of the policies. For the calculation of the ESS ELCC and the ELCC of all 3 policies modeled together, the perfect capacity in step 3 was removed from each area based on the nameplate capacity in those areas. Since there are no transfer limits between the areas for this calculation, that placement of where the perfect capacity is removed does not change the results of the study but was done to be consistent with the modeling of the policies.

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[13] Please note that the intention of this analysis is not to evaluate existing reliability metrics of the Illinois system, but to evaluate the three standalone (and combination of) policy proposals and their various reliability contributions on an apples-to-apples basis.

[14] http://www.nrel.gov/docs/fy15osti/63038.pdf

3 LOLE IMPROVEMENT

This section describes the LOLE improvement that each policy has on the system. Section 3.1 describes their impact on the Illinois system when it is isolated from the rest of MISO and PJM. Section 3.2 describes their impact to the entire MISO and PJM systems. It should be noted that this exercise was designed to generate results that shed light on the reliability value of the various policies being examined. Bearing that in mind, the study is not intended to predict the real reliability of Illinois' electrical system in 2030 or 2040.[15] In this regard the study is starting from the initial perspective that the existing system is "meeting" its reliability standard at 0.1 LOLE (days/year), and thus the intent of assessing the various policy scenarios was not to evaluate whether the existing system construction (e.g., status quo) on its own is reliable, but more so to evaluate and measure the impact that the various policy scenarios would have on "improving reliability," e.g., demonstrating the net LOLE improvement from a starting point of 0.1 LOLE (days/year) of enacting different policies or combinations of policy scenarios.

3.1 LOLE of Illinois

To calculate the impact that each policy has on improving the reliability of the system, GEEC first adjusted perfect capacity in Illinois so that its LOLE was at criteria (0.1 days/year). With the system at criteria, each policy was added to the system individually, and a combination of all three, to calculate their reductions in LOLE. As a reminder, the total capacity available for each policy was 2,100 MW for the HVDC Line, 200 MW for the OSW project in Lake Michigan, and 1,500 MW in 2030 and 7,500 MW in 2040 for the ESS.

With the Illinois system at criteria, and no policies modeled, the characteristic of the loss of load for the study years 2030 and 2040 are shown in Figures 2 and 3. Figure 2 shows the LOLE by month for the two study years. The months that the loss of load occurs is the same for each year, July and August, however, between 2030 and 2040 there is an increase in the LOLE in July, and a decrease in August.

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[15] Additionally, it should also be noted that this study accounted for state policies, such as the Climate and Equitable Jobs Act (CEJA) of 2021, that limits generator emissions and promotes renewable generation in the future.

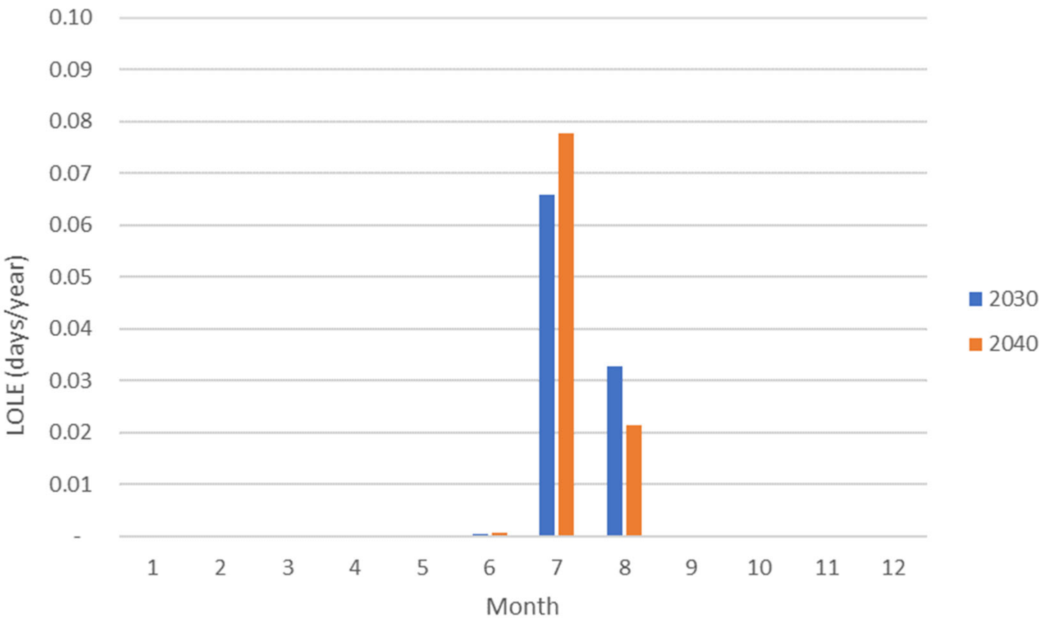

Figure 2. LOLE of Illinois by month.

Figure 3 shows the hourly LOLE (or LOLH) by hour of day for both July and August. Due to the changing load forecast, and resource mix, the loss of load in 2040 is shifted to later in the evening.

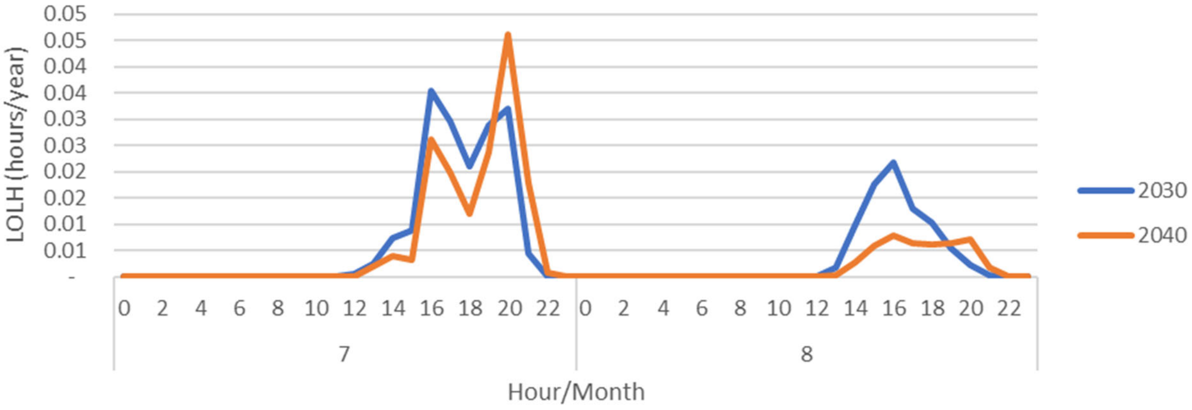

Figure 3. Typical day LOLH for July and August.

3.2 LOLE Improvement on Illinois

The reduction to LOLE is directly linked to the policy’s total capacity. The bigger capacity policies such as the HVDC Line and the ESS show the bigger improvement in LOLE, whereas the smaller 200 MW OSW policy improves reliability less. For both study years, the combination of the three policies eliminates almost all LOLE in the system. Figure 4 and Table 7 show the LOLE of Illinois when it is isolated from the rest of PJM and MISO with each policy modeled. While not visible in Figure 4, the LOLE of ESS in 2040 and the combination for both years is zero.

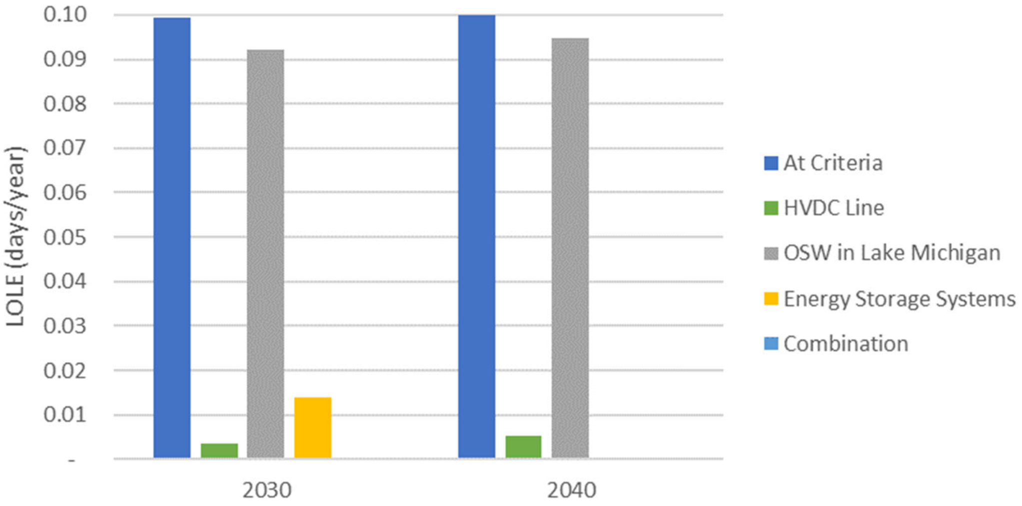

Figure 4. LOLE of Illinois for each policy case.

Table 7. LOLE of Illinois for each policy case.

	LOLE (days/year)		Decrease in LOLE	
Case	**2030**	**2040**	**2030**	**2040**
At Criteria	0.10	0.10		
HVDC Line	0.00	0.01	0.10	0.09
OSW in Lake Michigan	0.09	0.09	0.01	0.01
Energy Storage Systems	0.01	0.00	0.09	0.10
Combination	0.00	0.00	0.10	0.10

3.3 LOLE Improvement on PJM and MISO

Perfect capacity was adjusted from the areas in PJM, MISON, and MISOS until each pool had a LOLE of 0.1 days/year. The capacity adjusted from each area was based on the area's noncoincident peak load. The LOLE by MARS bubble is shown in Figure 5.

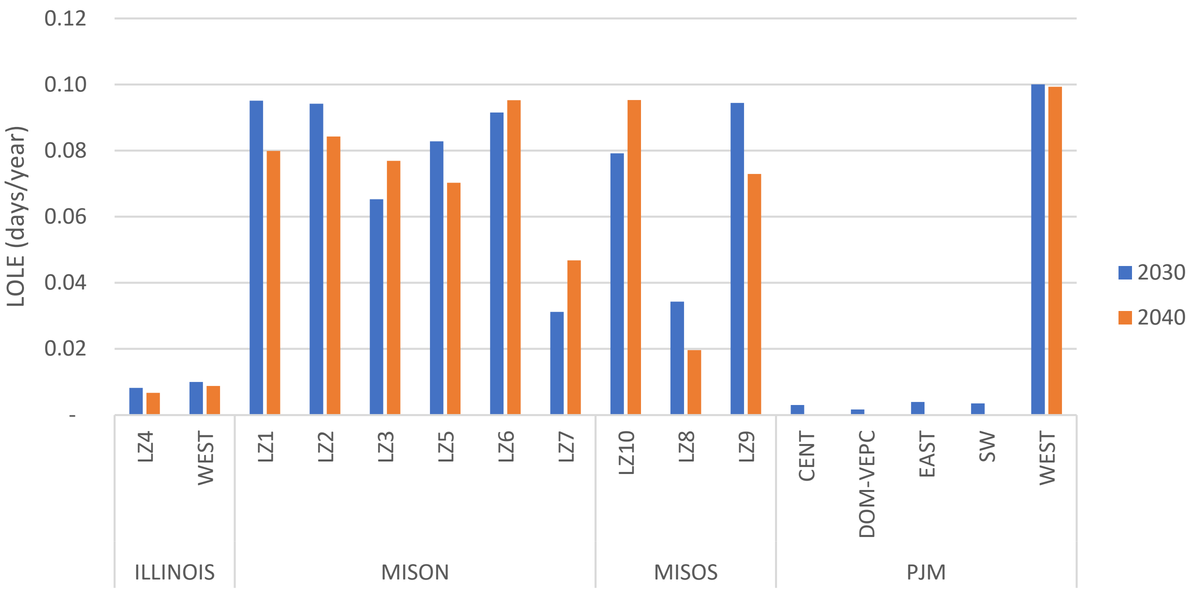

Figure 5. LOLE by bubble when PJM, MISON, and MISOS are at criteria.

The LOLE improvement for PJM and MISO is summarized in Figure 6. Similar to the trends shown with the improved reliability to Illinois, the HVDC Line and ESS show a bigger improvement in LOLE than the OSW in Lake Michigan. The policies added to Illinois have a better improvement to reliability for the MISO pools than they do for PJM.

The reason that these policies have a better improvement to MISO's LOLE than PJM is not caused by the policies themselves, but because of the location of the LOLE in the system. Figure 5 shows the LOLE by bubble for the case where each pool is at criteria (LOLE of 0.1 days/year) before any of the policies are added. This chart shows that for MISO, the LOLE is spread across multiple bubbles and the loss of load for MISO is not isolated to a specific bubble that is unable to import capacity from the rest of the Pool, but because there is a shortage of capacity across the Pool. For PJM that is not the case, the LOLE is primarily in PJM-WEST. Table 5 shows the import limits for each bubble, and the limit into PJM-WEST of 1,602 MW is the driving factor to the PJM LOLE. There is excess capacity in PJM that is unable to assist PJM-WEST because of its import limit, when more capacity is added through these policies in Illinois, their capacity is unable to reach PJM-WEST because the interface limit is already binding. For MISO, the LOLE is spread across multiple zones, and there are multiple connections with Illinois and MISO bubbles so the capacity is able to flow into the bubbles that need it to reduce their LOLE.

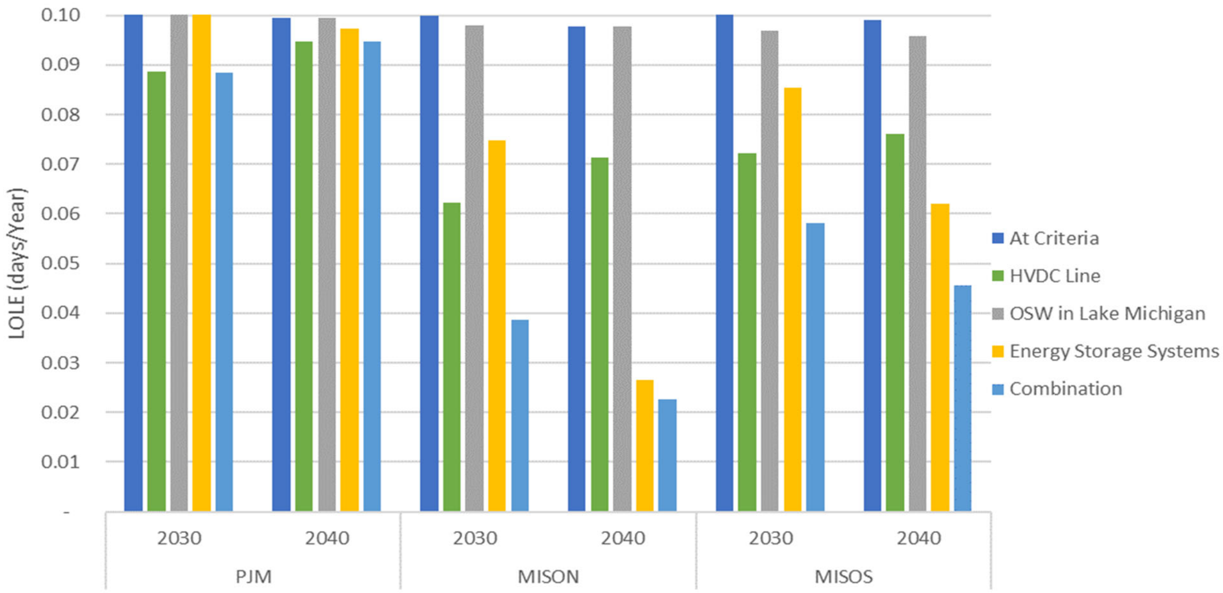

Figure 6. LOLE of PJM, MISON, and MISOS for each policy in Illinois.

4 ELCC RESULTS

This section describes the ELCC results on each of the modeled policies. Figure 7 and Table 8 show the ELCC results for each policy. Through the two study years, the ELCC of the HVDC Line policy is the most stable, at 96% and 92% of its nameplate capacity. The ELCC of the OSW in Lake Michigan decreases through time, from 29% in 2030 to 20% in 2040. This is caused by the shifting in LOLE in Illinois as the load and resource mix shifts, as seen in Figure 3. The ESS' ELCC decreases from 94% to 64% from 2030 to 2040.[16] Although its ELCC % decreases through time, its ELCC capacity increases since the amount of ESS added by 2040 is higher than 2030. Section 4.1 investigates this saturation effect of ESS in more detail. Please note that the ELCCs generated in the below results reflect those calculated for the purposes of this study and within the singular footprint of the state of Illinois. Any published capacity accreditation information at the ISO-level (either from PJM or MISO in this instance) reflects ELCC figures computed using aggregated system-wide metrics and data. In short, ELCC data published by the ISOs for ISO resources cannot be assumed to be equivalent to those computed at the state-level, as is done in this present analysis.

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[16] Please note that these ELCC values are annual averages for 2030 and 2040. It should be understood that ELCC, like LOLE, vary across time, and that ELCC of the three policies may increase or decrease within a given season or month based on system conditions.

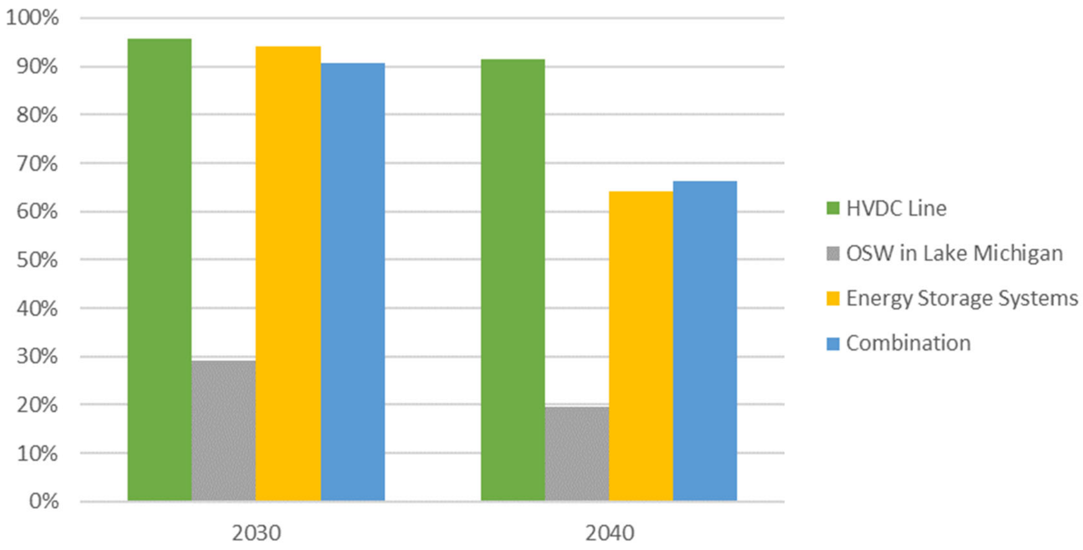

Figure 7. ELCC (%) of each policy.

Table 8. ELCC of each policy.

	Nameplate MW		ELCC MW		ELCC %	
Case	**2030**	**2040**	**2030**	**2040**	**2030**	**2040**
HVDC Line	2,100	2,100	2,012	1,923	96%	92%
OSW in Lake Michigan	200	200	58	39	29%	20%
Energy Storage Systems	1,500	7,500	1,414	4,802	94%	64%
Combination	3,800	9,800	3,447	6,487	91%	66%

4.1 ESS ELCC Saturation

To properly illustrate the saturation effect of the ESS' ELCC, Figure 8 calculates the ELCC % of ESS at different capacities, in 1,000 MW increments, for the study year 2040. For capacities up to 4,500 MW of ESS, its ELCC is stable and consistently 98% of its nameplate capacity. As the capacity increases beyond 4,500 MW, its ELCC % decreases to 64% of its nameplate capacity at 7,500 MW.

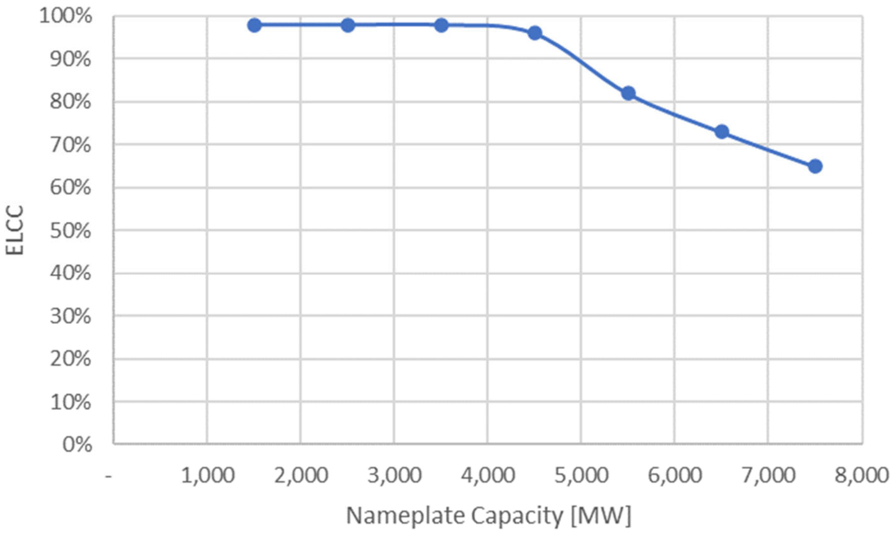

Figure 8. ELCC of storage as the capacity increases.

As more of the same energy limited resource (wind, solar, storage) is added to a system, the LOLE shifts to when that resource is less available, causing its ELCC to get saturated and decrease. A few other reports which show this are:

- Evaluation of ELCC Methodology in the ISO-NE Footprint (page 58)[17]
- Incremental ELCC Study for Mid-Term Reliability Procurement (page 29)[18]
- ELCC Concepts and Considerations for Implementation (page 24)[19]

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[17] https://www.iso-ne.com/static-assets/documents/2022/10/a09b_mc_2022_10_12-13_rca_nrdc_report.pdf

[18] https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/20210831_irp_e3_astrape_incremental_elcc_study.pdf

[19] https://www.nyiso.com/documents/20142/24172725/NYISO%20ELCC_210820_August%2030%20Presentation.pdf

APPENDIX A: AREA TO BUBBLE AND POOL

Illinois	
Area Name	**MARS Bubble**
AMILA	LZ4+COMED
CWLPA	LZ4+COMED
SIPCA	LZ4+COMED
COMEDA	LZ4+COMED

MISON	
Area Name	**MARS Bubble**
DPCA	LZ1
GREA	LZ1
MDUA	LZ1
MPA	LZ1
NSPA	LZ1
OTPA	LZ1
SMPA	LZ1
ALTEA	LZ2
MGEA	LZ2
UPPCA	LZ2
WECA	LZ2
WPSA	LZ2
ALTWA	LZ3
MECA	LZ3
MPWA	LZ3
AMMOA	LZ5
CWLDA	LZ5
BRECA	LZ6
DUKINA	LZ6
HEA	LZ6
IPLA	LZ6
NIPSA	LZ6
SIGEA	LZ6
CONSA	LZ7
DECOA	LZ7

MISOS	
Area Name	**MARS Bubble**
EESMSA	LZ10
SMEPAA	LZ10
EESARKA	LZ8
CLECA	LZ9
EESGSUA	LZ9
EESLAA	LZ9
EESNOA	LZ9
EESTXA	LZ9
LAFAA	LZ9
LAGNA	LZ9
LEPAA	LZ9

PJM	
Area Name	**MARS Bubble**
APSA	CENT
DUQA	CENT
PENELECA	CENT
DOMA	DOM-VEPC
AECOA	EAST
BGEA	EAST
DPLA	EAST
JCPLA	EAST
METEDA	EAST
PECOA	EAST
PEPCOA	EAST
PPLA	EAST
PSEGA	EAST
RECOA	EAST
UGIA	EAST
DUKKYA	SW
DUKOHA	SW
EKPCA	SW
AEPA	WEST
DAYA	WEST
FEATSIA	WEST

APPENDIX B: LOLH AND EUE RESULTS FOR ILLINOIS

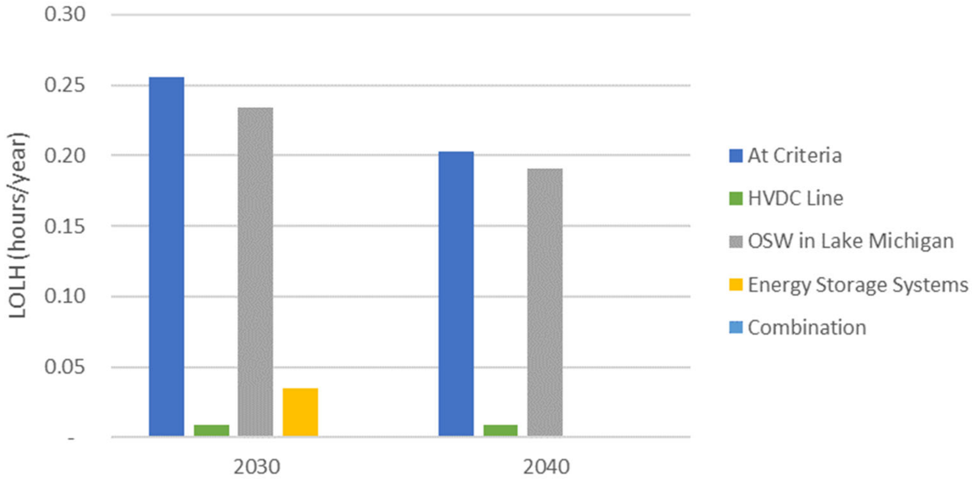

Figure 9. Loss of Load Hours for Illinois from each policy case.

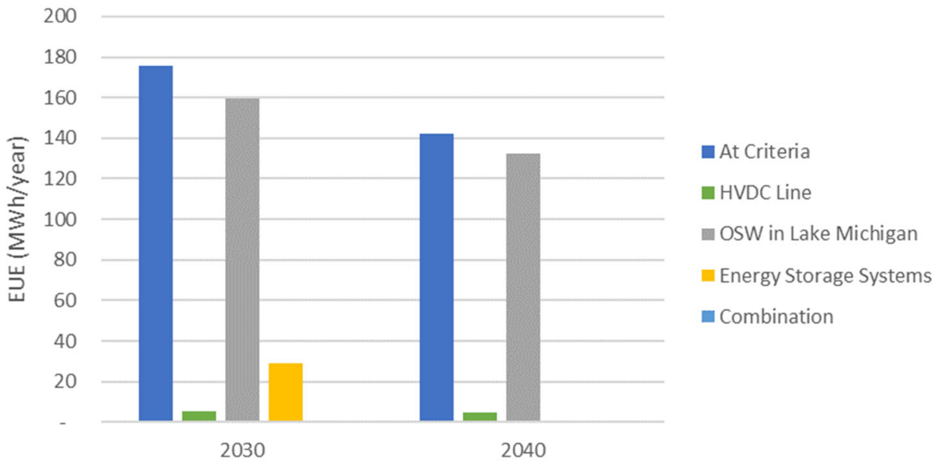

Figure 10. Expected Unserved Energy for Illinois from each policy case.

Table 9. LOLH and EUE for Illinois from each policy case.

	LOLH (hours/year)		Decrease in LOLH		EUE (MWh/year)		Decrease in EUE	
Case	**2030**	**2040**	**2030**	**2040**	**2030**	**2040**	**2030**	**2040**
At Criteria	0.26	0.20			176	142		
HVDC Line	0.01	0.01	0.25	0.19	5	5	171	138
OSW in Lake Michigan	0.23	0.19	0.02	0.01	159	132	16	10
Energy Storage Systems	0.04	0	0.22	0.20	29	0	147	142
Combination	0.00	0	0.25	0.20	0	0	175	142

APPENDIX C: RELEVANT MARS PROJECT EXPERIENCE

The following is a relevant list of projects that GE Energy Consulting has completed and highlight our capabilities in the reliability and resource adequacy space using GE-MARS:

1. NPCC resource adequacy assessments

Client name: Northeast Power Coordinating Council, Inc. (NPCC)

Date: Ongoing since the late 2000's

GE Energy Consulting supports the Northeast Power Coordinating Council, Inc. (NPCC) in their resource adequacy analysis, including:

- Summer and winter reliability assessments
- Long-Range Reliability Overview
- Tie Benefits analysis
- Response to the NERC Probabilistic Assessment
- Other special assessment (natural gas/electricity coordination, renewable integration)

GE Energy Consulting coordinates the modelling of the five member Areas of NPCC in the US and Canada, along with the neighboring PJM and MISO, with a combined footprint of a third of the North American system. The modelling is performed using the GE Multi-Area Reliability System (GE-MARS) software and involves the ingestion and coordination of the individual models, accounting for differences and inconsistencies.

GE Energy Consulting prepares reliability analysis and contributes to the NPCC technical reports that determine whether their footprint is adequately equipped to provide power in the near term (through seasonal assessments) and long-term (for the next 5 years). GE Energy Consulting also determines the benefit that each Area receives from being interconnected to their neighbors, through a bi-annual Tie Benefits analysis.

In addition to these recurring studies, GE Energy Consulting provides additional support to NPCC to study advanced topics and ensure that emerging issues are appropriately accounted for in the standard resource analysis. One or two of said studies are performed every year and presented to internal stakeholders.

GE Energy Consulting also assists NPCC in the completing of necessary documentation to respond to required reporting to NERC.

NPCC assessment reports can be found here.

2. NYISO reliability and reserve margin support

Client name: New York Independent System Operator (NYISO)

Date: Ongoing since the early 1990's

GE Energy Consulting provides software and consulting support for all NYISO reliability studies. This includes support in the process that sets the Installed Reserve Margin (IRM), which drives the capacity market requirements, as well as assistant with their Reliability Needs Assessment (RNA) – a long-term assessment of the capacity needs in the New York footprint. GE Energy Consulting develops standard and custom software to support NYISO analytical needs and has been doing so for decades.

GE Energy Consulting has been providing its services to the New York grid, both to the New York Power Pool and then through the NYISO. In recent years, the support that GE Energy Consulting provides includes the licensing the of the GE-MARS model, improvement of the model to address emerging challenges, review of NYISO studies and assistance to their staff. The modeling framework that we support informs the needs and requirements of the New York capacity market.

Additionally, GE Energy Consulting carries out specific advanced studies for the NYISO and presents the results to the New York Reliably Council. Some of the most recent studies include the advanced modeling of Energy Limited Resources or the capacity valuation of storage devices.

Lastly, throughout 2023, GE Energy Consulting has been supporting NYISO in the determination of a methodology for the accreditation of resources for its capacity market.

3. SERC resource adequacy support

Client name: SERC Reliability Corporation

Date: Ongoing since 2012

GE Energy Consulting provides modelling and consulting assistant to SERC to complete their required reporting to NERC's Probabilistic Assessment process. To complete this bi-yearly study, the GE Energy Consulting modelling team builds a representation of SERC and the neighboring regions and analyses the reliability needs of the area, along with examination of special sensitivities, such as:

- Impact of increasing renewables in the system
- Correlation of electricity and natural gas events
- Decrease of reliability performance as maintenance increases

GE Energy Consulting has been assisting SERC with their reliability studies for nearly a decade and has been performing the relevant model maintenance and analysis to respond to NERC's requests to complete the ProbA analysis. GE Energy Consulting also conducted custom scenarios that analyzed the SERC system under a wide range of stress conditions.

4. Value and Role of Pumped Storage Hydro under High Variable Renewables

Client name: The United States Department of Energy (DOE)

Date completed: 2021

The goal of this project was to evaluate the economic and technical benefits of using Pumped Storage Hydropower (PSH) to support high renewable penetrations across the Western United States. This project uses a similar methodology as we propose here for NYSERDA. To accomplish this task, the following tasks were performed:

1. **Tool development** (PSH dispatch)**:** A pumped storage scheduling tool was developed to optimize a plant's economic dispatch in both energy and ancillary service markets. Dynamic models were developed for the Doubly Fed Induction Machine (DFIM) PSH and the Fully Fed (FF) PSH.
2. **Production cost simulation** was performed to evaluate the impact of PSH on system-wide production cost, emissions, curtailment, and thermal unit cycling under various scenarios.

3. **Off-peak hourly risk screening:** Production cost simulation results were screened to identify new, off-peak hours of risk. For example, **we identified springtime intervals of high wind and solar but low synchronous unit headroom that could present frequency stability risks**.
4. **Adequacy analysis:** Production cost scenarios were also used to quantify the impact of pumped storage hydro reservoir size on system adequacy. This probabilistic assessment was performed using GE MARS (Multi-Area Reliability Simulation).
5. **Dynamics analysis** was performed to investigate the dynamic capabilities of variable speed PSH in a high-renewable penetration system.
6. **Iterative round trip:** The dynamics analyses enabled us to identify new stability constraints to address the risks identified. These new constraints were fed back into our Production Cost model such that steps 1 through 5 above were repeated to test the effectiveness of the mitigations identified.

The above “round-trip” economic-to-technical iterative simulations enabled the GE team to identify and determine the cost-benefit of new measures to enable high renewable penetrations using pumped-storage-hydro. The ground-breaking methodology outlined here would have similar applicability in other systems moving towards high levels of variable inverter-based renewables.

The report can be found here.

5. Evaluation of ELCC Methodology in the ISO-NE Footprint

Client name: Natural Resource Defense Council (NRDC)

Date completed: 2022

The goal of this project was an attempt to explore the impacts of critical methodological design choices for ISO-NE’s RCA reform, as ISO-NE seeks to implement an ELCC-type accreditation methodology for resources beginning in its 19th Forward Capacity Auction (FCA 19), to be held in February 2025 for capacity year June 1, 2028, to May 31, 2029. ISO-NE has proposed to use a variant of ELCC known as MRI, which is conceptually and quantitatively similar to the marginal ELCC accreditation approach discussed in this report. Understanding the implications of the transition to an ELCC/MRI based capacity accreditation, including the methodological junctions to be confronted en route to a final market design proposal, was the core focus of this project.

The report can be found here.