2021 NIPSCO Integrated Resource Plan

Technical Webinar

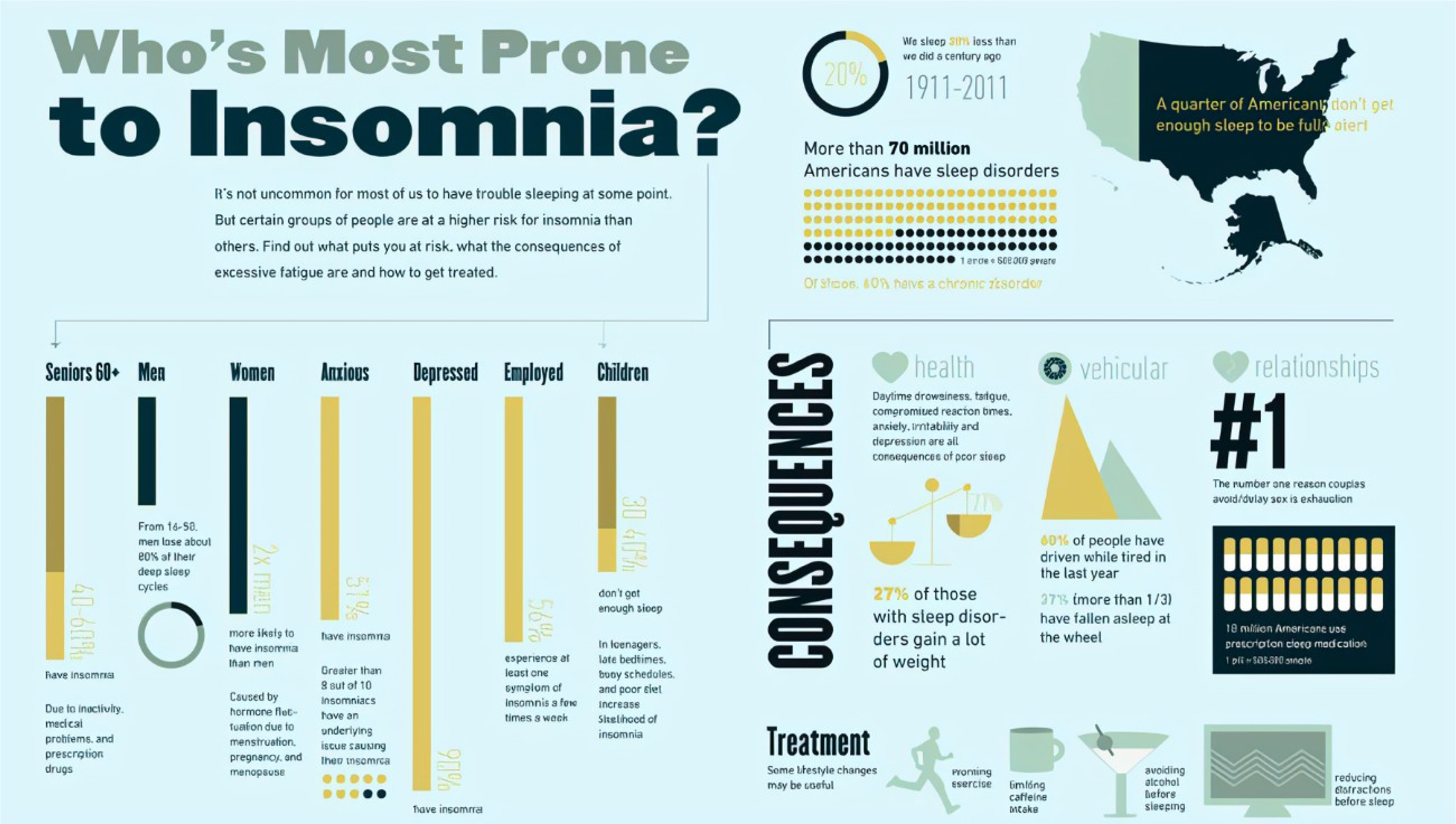
October 12th, 2021
9:00AM-12:00PM CT





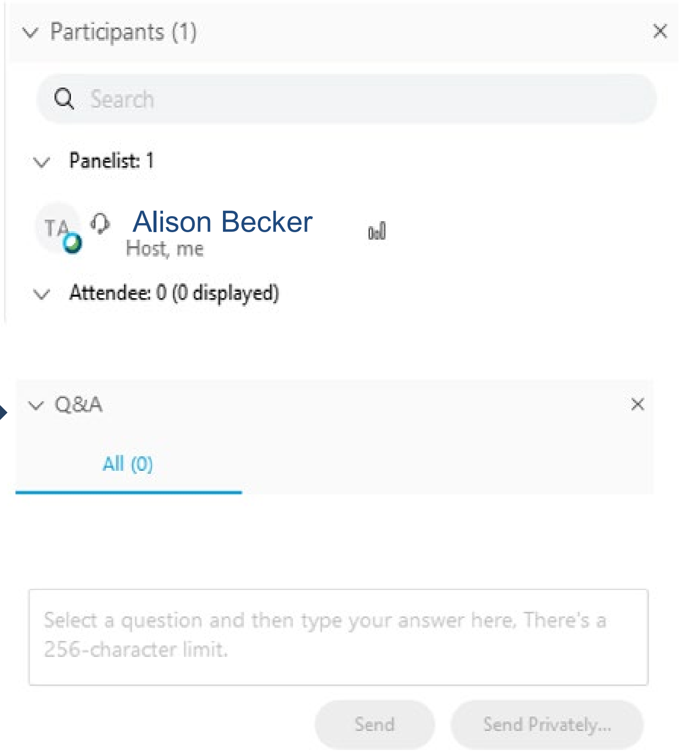



SAFETY MOMENT



TECHNICAL WEBINAR MEETING PROTOCOLS

- Your input and feedback is critical to NIPSCO's Integrated Resource Plan ("IRP") Process
- The Public Advisory Process provides NIPSCO with feedback on its assumptions and sources of data. This helps inform the modeling process and overall IRP
- We set aside time at the end of each section to ask questions
- Your candid and ongoing feedback is key:
  - Please ask questions and make comments on the content presented
  - Please provide feedback on the process itself
- While we will mostly utilize the chat feature in WebEx to facilitate comments, we will gladly unmute you if you would like to speak. Please identify yourself by name prior to speaking. This will help keep track of comments and follow up actions
- If you wish to make a presentation during a meeting, please reach out to Alison Becker (abecker@nisource.com)



AGENDA

Time *Central Time	Topic	Speaker
9:00-9:05AM	Webinar Introduction, Safety Moment, Meeting Protocols, Agenda	Alison Becker, Manager Regulatory Policy, NIPSCO
9:05-9:15AM	Reliability Approach in the IRP	Fred Gomos, Director Strategy & Risk Integration, NiSource
9:15-9:45AM	Economic Reliability Analysis - Real-Time Market Dynamics & Ancillary Services	Pat Augustine, Vice President, CRA Goran Vojvodic, Principal, CRA
9:45-10:00AM	Break	
10:00-11:55AM	Qualitative Assessment of Reliability Attributes - Scoring Criteria & Results	Fred Gomos, Director Strategy & Risk Integration, NiSource Hisham Othman, VP, Transmission and Regulatory Consulting, Quanta Technology, LLC
11:55AM-12:00PM	Next Steps	Alison Becker, Manager Regulatory Policy, NIPSCO

RELIABILITY APPROACH IN THE IRP

Fred Gomos, Director Strategy & Risk Integration, NiSource

SETTING THE CONTEXT FOR ASSESSING RELIABILITY IN THE IRP

Previous Reliability Assessments

- In the 2018 IRP, NIPSCO began including reliability risk metric in the scorecard used to evaluate the performance of various resource portfolios

2018 Retirement Scorecard

Criteria	Description
Cost to Customer	• Impact to customer bills • Metric: 30-year NPV of revenue requirement (Base scenario deterministic results)
Cost Certainty	• Certainty that revenue requirement falls within the most likely range of distribution of outcomes (75% certainty that cost will be at or below this level) • Metric: 75th percentile of cost to customer
Cost Risk	• Risk of extreme, high-cost outcomes • Metric: 95th percentile of cost to customer
Reliability Risk	• Assess the ability to confidently transition the resources and maintain customer and system reliability • Metric: Qualitative assessment of orderly transition
Employees	• Net impact on NiSource jobs by 2023 • Metric: Approximate number of permanent NiSource jobs affected
Local Economy	• Property tax amount relative to NIPSCO's 2016 IRP • Metric: Difference in NPV of estimated modeled property taxes on existing assets relative to the 2016 IRP

- As part of the 2020 Portfolio Analysis to support NIPSCO renewable filings, the reliability criteria were further expanded to consider operational flexibility

2020 Portfolio Analysis

Criteria	Description
Cost to Customer	• Impact to customer bills • Metric: 34 year NPV of revenue requirement (Base scenario deterministic results)
Long term Optionality	• Flexibility resulting from combinations of ownership, duration, and diversity • Metric: MW weighted duration of generation commitments
Capital Requirement	• Estimated amount of capital investment required by portfolio • Metric: 2020 -2023 capital needs
Fuel Security	• Power plants with reduced exposure to short-term fuel supply and/or deliverability issues (e.g., ability to store fuel on-site and/or requires no fuel) • Metric: Percentage of capacity sourced from resources other than natural gas (2025 UCAP MW sourced from non-gas resources)
Environmental	• Carbon intensity of portfolio / Total carbon emissions • Metric: Total annual carbon emissions (2030 short tons of CO_2) from the generation portfolio
Operational Flexibility	• The ability of the portfolio to be controlled in manner to respond to changes in load (dispatchable) • Metric: % of 2025 Controllable MW in gen. portfolio

2021 IRP Approach

1 Ensure consistency with MISO rules evolution

- Seasonal resource adequacy
- Future effective load carrying capability (ELCC) accounting

2 Expand Uncertainty Analysis

- Incorporation of renewable output uncertainty
- Broadening risk analysis to incorporate granular views of tail risk

3 Incorporate New Metrics

- Incorporating new scorecard metrics informed by stochastic analysis and capabilities of portfolio resources

CORE ECONOMIC MODELING CAPTURES SOME ELEMENTS OF RELIABILITY

Additional analysis and assessment is required for a fuller perspective

Focus of NIPSCO's IRP (Resource Adequacy, Energy Adequacy) — *NIPSCO coordinates with MISO* (Operating Reliability)

	Resource Adequacy	Energy Adequacy	Operating Reliability
Definition:	Having sufficient resources to reliably serve demand	Ability to provide energy in all operating hours continuously throughout the year	Ability to withstand unanticipated component losses or disturbances
Forward Planning Horizon:	Year-ahead	Day-ahead	Real-time or Emergency
Reliability Factors:	Reserve margin, ELCC and energy duration	Dispatchability, energy market risk exposure	Real Time Balancing System
IRP Modeling Approach:	Portfolio development constraints, with ELCC and seasonal accounting	Hourly dispatch analysis, including stochastic risk	**Ancillary services analysis (regulation, reserves), with sub-hourly granularity**

ECONOMIC ANALYSIS ALONE DO NOT CAPTURE THE FULL VALUE OF RESOURCES

- NIPSCO participates in the Midcontinent Independent System Operator (MISO) in a variety of roles with various compliance standards and responsibilities
- These responsibilities and standards are met in part by existing resources

Role	Definition
Energy, Capacity, and Ancillary Services Market Participant	Offers resources into markets and procures services on behalf of load to ensure adequate provision of energy, capacity, and ancillary services to support system reliability
Transmission Owner (TO)	Owns and maintains transmission facilities
Transmission Operator (TOP)	Responsible for the reliability of its local transmission system, and that operates or directs the operations of the transmission facilities

- As a TOP, NIPSCO is <u>required</u> to comply with a variety of NERC standards, particularly those that govern the reliable operation of the Bulk Electric System
  - For example, EOP-005-3 governs system restoration from Black Start Resources. Part of NIPSCO's compliance plan relies on resources that currently exist within the portfolio and the NIPSCO TOP area
- Any resource decisions (retirement or replacement) will need to consider the implications for NIPSCO's ability to comply with NERC and MISO standards and procedures now and into future

An expanded scoring criteria can account for these additional considerations

ECONOMIC RELIABILITY ANALYSIS - REAL-TIME MARKET DYNAMICS & ANCILLARY SERVICES

Pat Augustine, Vice President, CRA

Goran Vojvodic, Principal, CRA

SUB-HOURLY ENERGY AND ANCILLARY SERVICES EVALUATION

- While most of NIPSCO's existing portfolio (including new renewables) realize nearly all value from energy and capacity contributions, highly flexible resources that do not provide a lot of energy to the portfolio may still provide value in the form of ancillary services and in their ability to respond to changing market conditions in real time at sub-hourly granularity:
  - The MISO market currently operates markets for spinning reserves and regulation
  - FERC Order 841 also requires ISOs to redesign markets to accommodate energy storage

- Long-term market developments are uncertain, and fundamental evaluation of sub-hourly ancillary services markets is challenging, but the 2021 IRP has performed an analysis, incorporating:
  - 5-minute granularity for energy and ancillary services based on historical data observations and future energy market scenario projections
  - Operational parameters for various storage and gas peaking options
  - ***Incremental value, above and beyond what is picked up in the Aurora-based hourly energy dispatch, is assessed and summarized on a portfolio level***

FERC ORDER 841

- The Federal Energy Regulatory Commission (“FERC”) issued Order No. 841 to boost competition in the storage sector and ensure that markets like MISO revise tariffs to establish participation models for storage resources, including:
  - Enablement of storage resources to provide energy and a variety of ancillary services
  - Allowance for storage resources to both receive and inject electric energy in a way that recognizes physical and operational characteristics and optimizes benefits to MISO through a single offer curve made up of both discharge segments and charge segments.
  - Ability of storage resources to participate and set prices in the Planning Reserve Auction (capacity market)
- MISO is responsible for implementing this order and has been granted an extension to June 6, 2022, to make its compliance filing
- NIPSCO will be involved in the MISO stakeholder process as the compliance filing is developed

ECONOMIC ANALYSIS OF REAL-TIME MARKET DYNAMICS + ANCILLARY SERVICES

- CRA's Energy Storage Operations (ESOP) model is an optimization program that estimates the value of storage and other flexible resources in the sub-hourly energy and ancillary services (A/S) markets, offering an estimate of the incremental value such resources offer beyond what can be estimated in the day-ahead hourly production cost framework of Aurora

Category	Aurora Portfolio Tool	ESOP
Market Coverage	Day-ahead energy	Energy plus ancillary services ("A/S") (frequency regulation and spinning reserves)
Time Granularity	Hourly, chronological	5-minute intervals, chronological
Time Horizon	20 years	Sample years (ie, 2025, 2030, 2035, 2040)
Pricing Inputs	MISO-wide fundamental analyses feed NIPSCO-specific portfolio dispatch	Historical data drives real-time and A/S pricing; specific asset types dispatched against price
Asset Parameters Used	Hourly ramp rate, storage cycle and depth of dispatch limits, storage efficiency	Sub-hourly ramp rate, storage cycle and depth of discharge limits, storage efficiency
Outputs	Portfolio-wide cost of service	Incremental value for specific asset type

RFP BID INFORMATION WAS USED FOR ASSET PARAMETERIZATION

- Generic Lithium-Ion storage and Natural Gas peaker operational parameters were developed from RFP bids
- Key parameters for sub-hourly modeling include ramp rates, cycle and state of charge limits for storage, and hours limits for the gas peaker

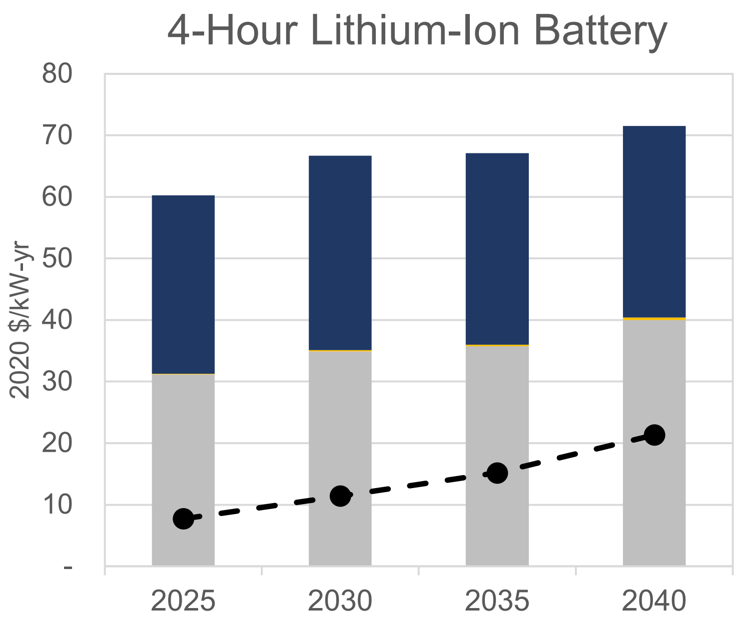
Lithium-Ion	Units	Value
Duration (Energy/Power Ratio)	hours	4
Roundtrip Efficiency	%	87%
Max Cycles per Year	#	365
Parasitic Load	%/hr	0.50%
Ramp Rate	%/min	100%
State of Charge Lower Bound*	%	0-20%
State of Charge Upper Bound*	%	80-100%
VOM	$/MWh	0

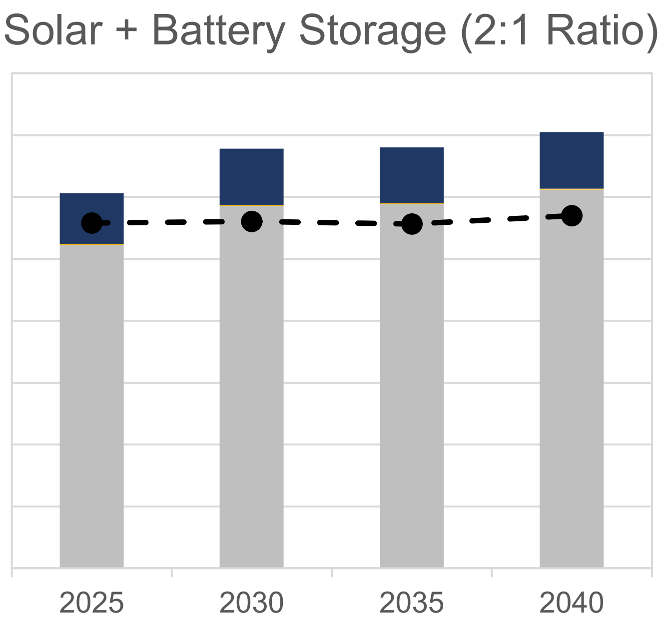
Note that ranges were tested, but this variable had modest impact on the overall conclusions

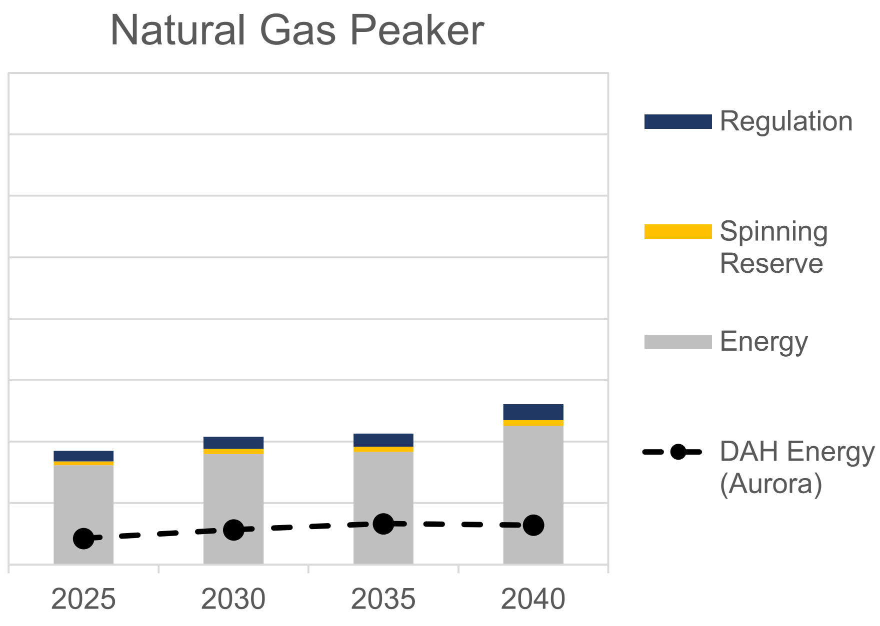
Gas Combustion Turbine	Units	Value
Heat Rate (Average Realized)	Btu/kWh	10,000
Ramp Rate	%/min	17%
Forced Outage	%	5.00%
Minimum Generation Percentage	%	50%
Max hours of operation / year	Hours/yr	3,000
Min Downtime	Hours	4
Min Runtime	Hours	2
Emission Rate	lb CO2/MMBtu	119
Start Costs	$/MW/start	18
VOM	$/MWh	2

SUB-HOURLY ANALYSIS INDICATES POTENTIAL UPSIDE FOR STORAGE ASSETS

Reference Case







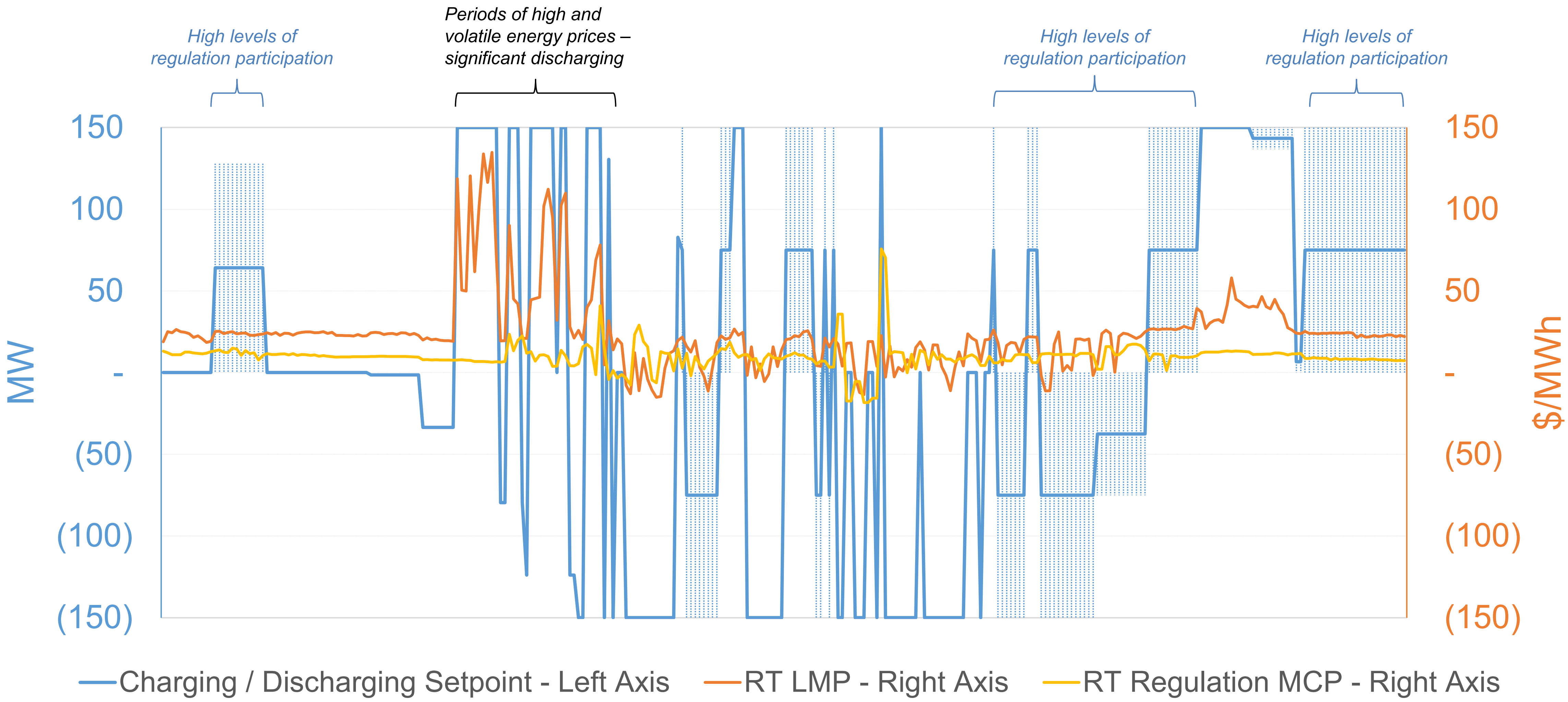
- Highly flexible battery able to respond in real time to changing price signals
- Can participate regularly in the regulation market (providing up and down service, given charging and discharging capabilities)

- Solar component provides significant energy value, which is also captured in fundamental modeling
- Investment tax credit rules limit the battery's flexibility and ability to take advantage of the regulation market (must charge predominantly from the solar)

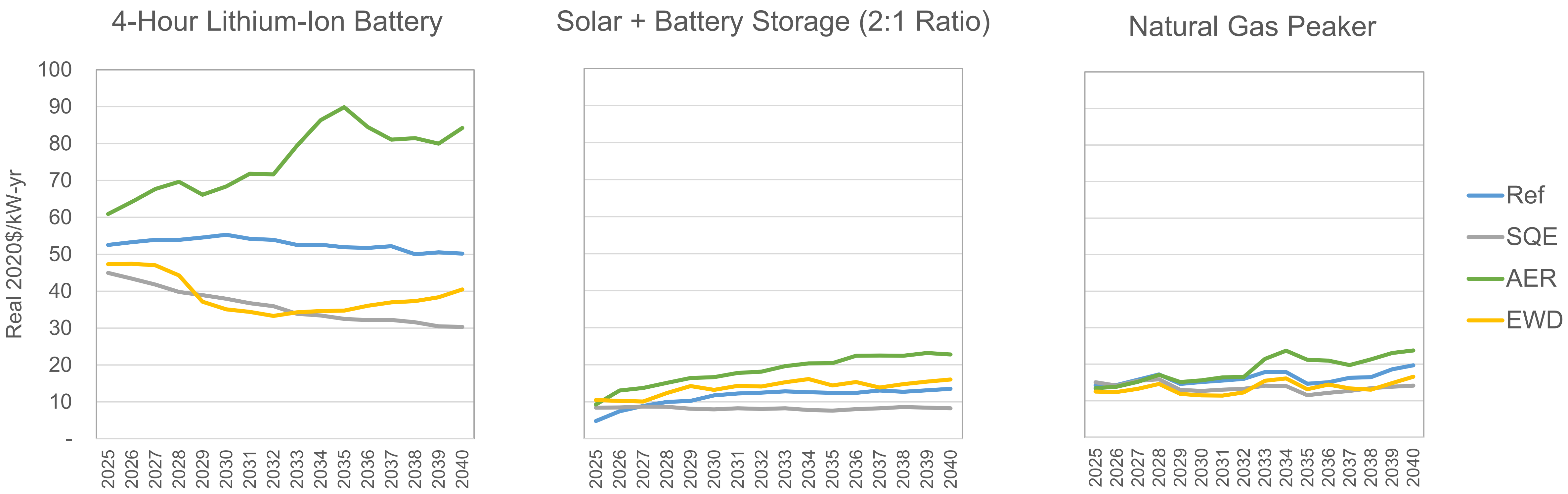
- Real-time volatility is greater than day ahead hourly dispatch value, providing value upside compared to Aurora modeling
- Regulation opportunities are only available when the unit is already operating for energy

ESOP DISPATCH EXAMPLE – SAMPLE 2025 SUMMER DAY

5-Minute Granularity across a Single Day – Reference Case



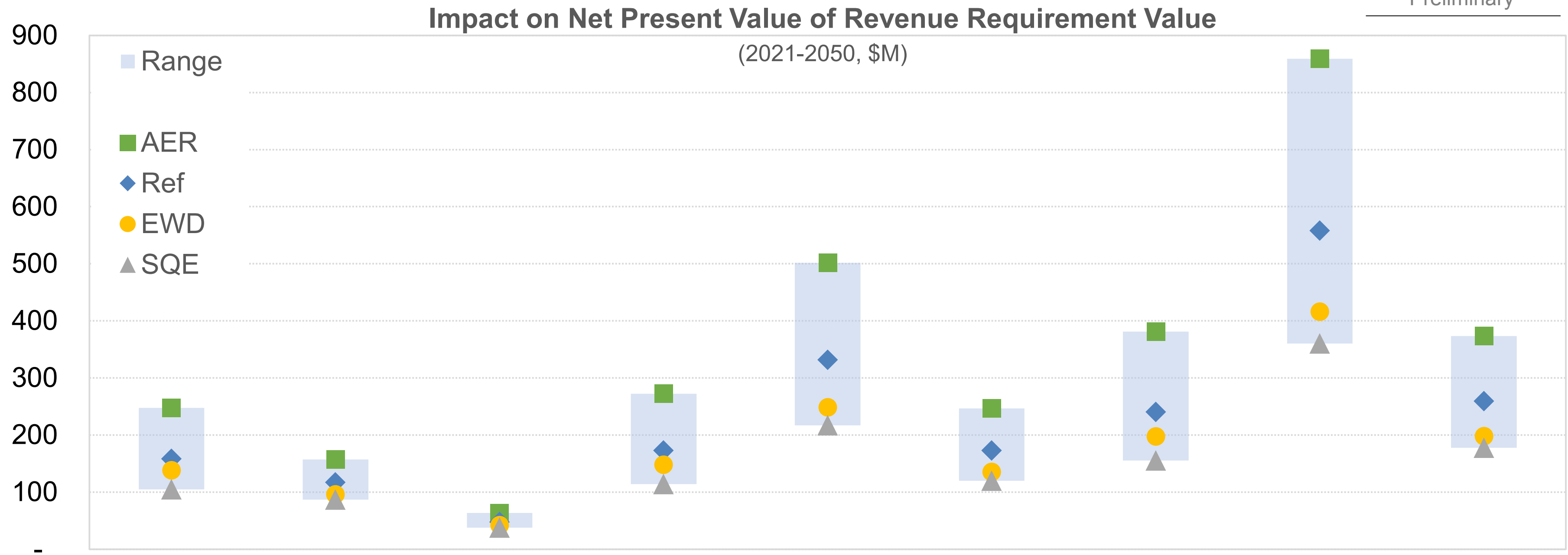
INCREMENTAL REAL TIME ENERGY AND ANCILLARY SERVICES VALUE ACROSS SCENARIOS



- Stand-alone storage resources have the largest upside opportunity in the sub-hourly energy and ancillary services markets
- The upside is greatest in the AER scenario, with highest prices and larger price spreads

RANGE OF ADDITIONAL VALUE OPPORTUNITY (NPVRR COST REDUCTION) BY PORTFOLIO

Preliminary



	A	B	C	D	E	F	G	H	I
Replacement Theme	**Thermal PPAs, solar and storage**	**Non-service territory gas peaking (no early storage)**	**Natural gas dominant (CC)**	**No new thermal resources; solar dominant w/ storage**	**Thermal PPAs plus storage and solar**	**Local gas peaker, plus solar and storage**	**Solar dominant w/ storage, plus retire Sugar Creek**	**All renewables and storage, plus retire Sugar Creek (Portfolio 7)**	**New H2-enabled peaker plus solar and storage, plus SC conversion to H2 (Portfolio 7H)**
Carbon Emissions	Higher	Higher	Higher	Mid	Mid	Mid	Low	Low	Low
Dispatchability	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Energy Duration)	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Energy Duration)	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Energy Duration)

Observations

- *Additional value is uncertain and dependent on market rules evolution, MISO generation mix changes, and market participant behavior*
- Portfolios with the largest amounts of storage (E and H) have the greatest potential to lower NPVRR by capturing flexibility value that may manifest in the sub-hourly energy and ancillary services markets
- A wide range of value is possible, with higher prices and price spreads in the AER scenario driving higher estimates
- Results will be incorporated into the final replacement analysis scorecard

BREAK

QUALITATIVE ASSESSMENT OF RELIABILITY ATTRIBUTES - SCORING CRITERIA & RESULTS

Fred Gomos, Director Strategy & Risk Integration, NiSource
Hisham Othman, VP, Transmission and Regulatory Consulting, Quanta Technology, LLC

RELIABILITY ASSESSMENT PROCESS OVERVIEW

1. **Define Initial Assessment Criteria**
2. **Obtain Stakeholder Feedback**
3. **Engage 3rd Party Reviewer**
4. **Incorporate into IRP Analysis Scorecard(s)**

Define Initial Assessment Criteria	Obtain Stakeholder Feedback	Engage 3rd Party Reviewer	Incorporate into IRP Analysis Scorecard(s)
Collaborated with NIPSCO transmission planning and system operations group to develop initial framework and criteria	We will seek feedback from interested stakeholders who want to learn more about the assessment criteria and provide input and feedback	Engage a qualified 3rd party expert to review the assessment criteria, develop the scoring methodology and score and rank the various resource technologies under consideration	Incorporate the scoring and ranking results of the assessment into the IRP Analysis Scorecard(s)
✔	✔	✔	✔

RELIABILITY ASSESSMENT GUIDING PRINCIPLES

Resources Modeled	▪ The resources modeled are based on the replacement portfolios constructed for the Replacement Analysis
Transmission Upgrades	▪ Analysis incorporates planned Transmission projects
Time Period	▪ Resources are evaluated in 2030 after the Michigan City Unit 12 retirement
Evaluation	▪ The analysis is conducted at a planning level and, therefore, further evaluation and granular studies will be required in the future ▪ Individual resources from the 9 replacement portfolios are assessed based on the established reliability criteria. The score of the individual resources drive portfolio score

Goal

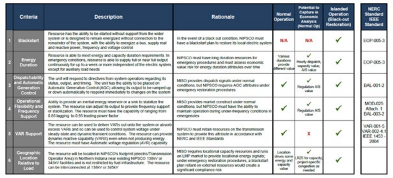
- **Understand potential reliability implications of potential resource additions to the NIPSCO portfolio**
- **Understand the range of potential mitigations required associated with different replacement portfolio strategies**

RELIABILITY ASSESSMENT AND RANKING

Assess NIPSCO's Reliability Needs

- Power Ramping
- Frequency Response
- Short Circuit Strength
- Flicker
- Black Start

Review & Update Reliability Metrics

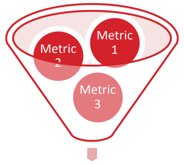


	Criteria	Description	Rationale	Normal Operation	Potential to Capture in Economic Analysis (Normal Op)	Islanded Operation (Black-out Restoration)	NERC Standard IEEE Standard
1	Blackstart	Resource has the ability to be started without support from the wider system or is designed to remain energized without connection to the remainder of the system, with the ability to energize a bus, supply real and reactive power, frequency and voltage control	In the event of a black out condition, NIPSCO must have a blackstart plan to restore its local electric system	N/A	N/A	✓	EOP-005-3
2	Energy Duration	Resource is able to meet energy and capacity duration requirements. In emergency conditions, resource is able to supply full or near full output continuously for up to a week or more independent of the electric system, except for auxiliary load needs	NIPSCO must have long duration resources for emergency procedures and must assess economic value risk for energy duration attributes over time	Various durations provide different value	✓ Hourly dispatch, capacity value, A/S value	✓	EOP-005-3
3	Dispatchability and Automatic Generation Control	The unit will respond to directives from system operators regarding its status, output, and timing. The unit has the ability to be placed on Automatic Generation Control (AGC) allowing its output to be ramped up or down automatically to respond immediately to changes on the system	MISO provides dispatch signals under normal conditions, but NIPSCO requires AGC attributes under emergency restoration procedures	✓	✓ Regulation A/S value	✓	BAL-001-2
4	Operational Flexibility and Frequency Support	Ability to provide an inertial energy reservoir or a sink to stabilize the system. The resource can adjust its output to provide frequency support or stabilization. The resource must have the capability of ranging from 0.85 lagging to 0.95 leading power factor	MISO provides market construct under normal conditions, but NIPSCO must have the ability to maintain operation during under-frequency conditions in emergencies	✓	✓ Regulation A/S value	✓	MOD-025 Attach. 1 BAL-003-2
5	VAR Support	The resource can be used to deliver VARs out onto the system or absorb excess VARs and so can be used to control system voltage under steady-state and dynamic/transient conditions. The resource can provide dynamic reactive capability (VARS) even when not producing energy. The resource must have Automatic voltage regulation (AVR) capability	NIPSCO must retain resources on the transmission system to provide this attribute in accordance with NERC and IEEE Standards	✓	X	✓	VAR-001-5 VAR-002-4.1 IEEE 1453 - 2004
6	Geographic Location Relative to Load	The resource will be located in NIPSCO's footprint (electric/Transmission Operator Area) in Northern Indiana near existing NIPSCO 138kV or 345kV facilities and is not restricted by fuel infrastructure. The resource can be interconnected at 138kV or 345kV	MISO requires locational capacity resources and runs an LMP market to provide locational energy signals; under emergency restoration procedures, a blackstart plan reliant on external resources would create a significant compliance risk	Location drives some energy and capacity value	✓ LRZ6 for capacity; project-specific congestion as needed	✓	

Apply a Series of Reliability Filters to IRP Portfolios

Scoring Criteria

Ranking Portfolios

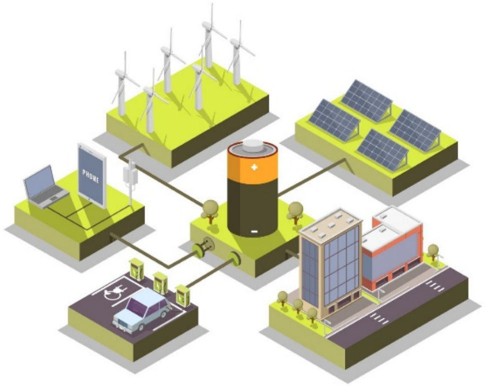


Preferred Portfolio

ESSENTIAL RELIABILITY SERVICES - OVERVIEW

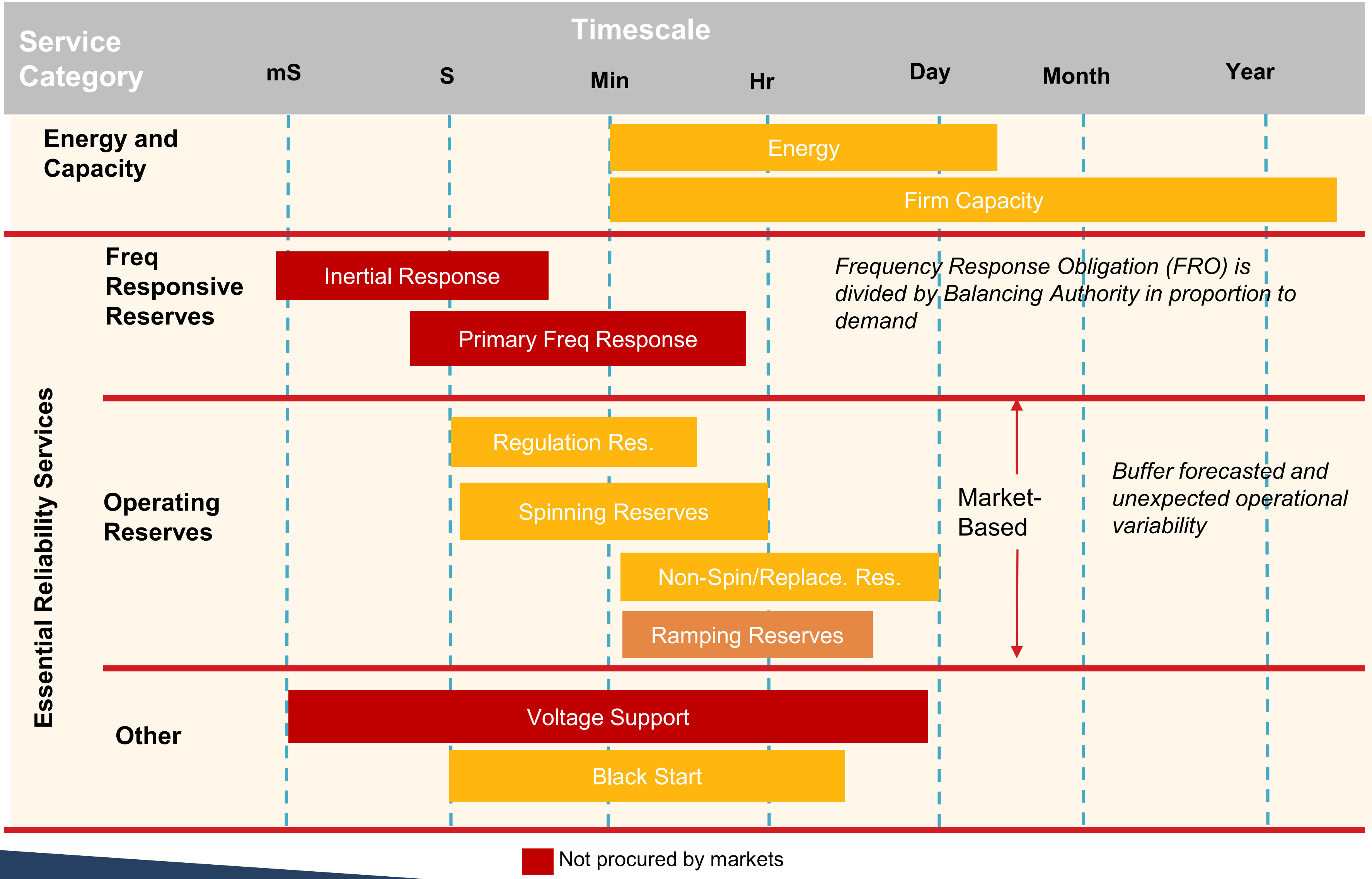
MODELING RESOURCE RELIABILITY ATTRIBUTES

- Resources have many attributes aside from energy and capacity that are critical to reliable operation.
  - Selecting a portfolio with the right attributes is crucial to ensure reliability and resilience.
  - Valuation and ranking resources should account for their reliability attributes.
  - System needs for reliability attributes increases with higher levels of inverter-based resources (IBRs).



- Reliability and Resilience Attributes/Metrics:
  - Dispatchability
  - Predictability
  - Dependability (e.g., Supply Resilience, firmness)
  - Performance Duration Limits
  - Flexibility (e.g., ramping speed, operating range)
  - Intermittency (e.g., intra-hr and multi-hr ramping)
  - Regulating Power
  - VAR support
  - Energy Profile (e.g., capacity value / ELCC)
  - Inertial Response
  - Primary Frequency Response
  - Minimum Short Circuit Ratio
  - Locational Characteristics (e.g., deliverability, resilience to grid outages)
  - Black start and system restoration support
  - Flicker
  - Harmonics
  - Sub-synchronous Resonance

ESSENTIAL RELIABILITY SERVICES



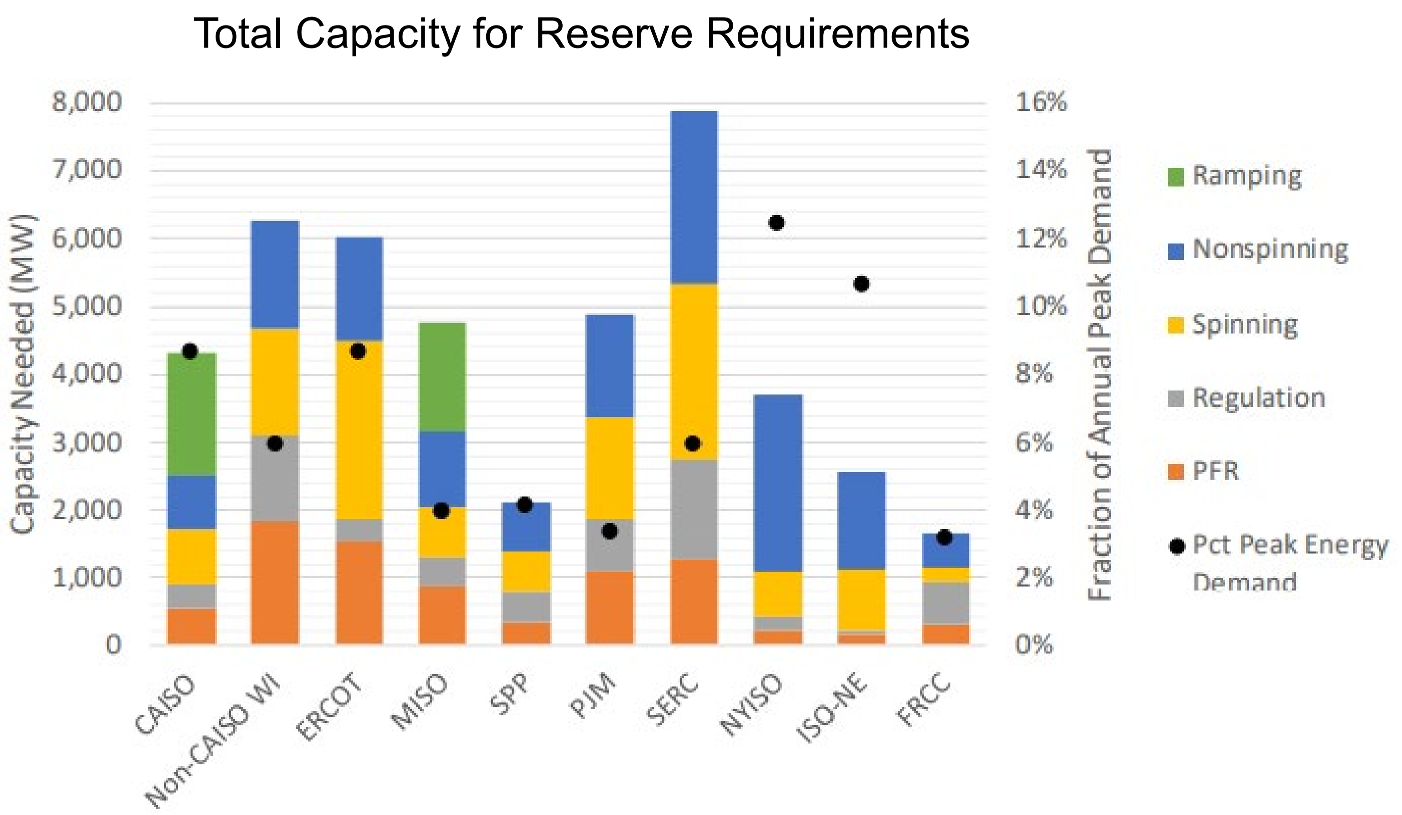
- Regulation Reserves:
  - Rapid response by generators used to help restore system frequency. These reserves may be deployed after an event and are also used to address normal random short-term fluctuations in load that can create imbalances in supply and demand.
- Ramping Reserves:
  - An emerging and evolving reserve product (also known as load following or flexibility reserves) that is used to address "slower" variations in net load and is increasingly considered to manage variability in net load from wind and solar energy. MISO sets the level based on the sum of the forecasted change in net load and an additional amount of ramp up/down (575 MW for now).

ESSENTIAL RELIABILITY SERVICES - RESERVE REQUIREMENTS ACROSS WHOLESALE MARKETS

2020	MISO	CAISO	PJM	ERCOT	ISO-NE	NYISO	SPP
Peak Demand	**121.4**	53.6	147.5	73.7	26.3	32.1	52.5
Reserve Margin %	**15.80%**	16.14%	16.60%	13.75%	16.90%	15%	12%
Peak Capacity Requirement GW	**140.6**	62.3	172	83.5	30.3	36.9	58.8
Primary Freq Response Obligation							
(MW/0.1Hz)	**210**	196.5	258.3	381	38.3	49.9	
MW	**882**	550	1085	1543	161	210	
% of Peak Load	**0.70%**	1.10%	0.70%	2.20%	0.70%	0.70%	
Regulating Reserve Requirement							
Up/Down %	**0.35%**	0.64%/0.72%	0.36% offpeak; 0.55% on-peak	0.48%/0.42%	0.25%	0.73%	0.92%/0.63%
Up/Down MW	**425**	320/360	525/800	318/295	60	217	470/325
Spinning Reserve							
%	**0.61%**	1.60%	1.03%	3.76%	3.75%	2.20%	1.14%
MW	**740**	800	1504.8	2626.8	900.00	655	585
Non-Spinning Reserve							
%	**0.92%**	1.60%	1.03%	2.21%	10min 5.98% ; 30min 3.33%	10min 4.41%, 30min 8.82%	1.43%
MW	**1110**	800	1053.2	1534.5	1435/800	1310/2620	730
Ramping Reserve Requirement							
5 min MW		-300/500					
15 min MW		-1200/1800					
Hourly MW	**-1614/1554**						

ESSENTIAL RELIABILITY SERVICES

- MISO's total capacity for reserves is around 4% of peak load. This is comparable to PJM and SPP. However, is less than half of CAISO, NYISO, ERCOT, and ISO-NE.
- MISO has a ramping product.



RELIABILITY CONCERNS OF HIGH PENETRATION INVERTER-BASED RESOURCES (IBRS)

Key Consideration	System Concern
Power Ramping	• High Up and Down Intermittent “un-forecasted” Power Ramps can affect Control Area performance
Low System Inertia	• High RoCoF following a large loss causes resources to trip due to reduced synchronizing torques • Under Frequency relays respond to low frequency (nadir) by tripping load • Speed of system events faster than ability of protection system
Low Short Circuit Ratio (Weakened Grid)	• Instability in inverter controls (PLL synchronization and inner current loop low frequency oscillations) • Challenges to inverter Ride-Through and Islanding • Voltage Flicker (especially in distribution feeders) • Difficulty of voltage control due to high voltage sensitivity dV/dQ • Difficulty in energizing large power transformers
Low Fault Current Levels	• Ability of protection systems to detect faults
Low damping of system oscillations	• Synchronous machines have rotor dampers. • Use of grid forming inverters and inverter control settings to mitigate
Low Reserves	• Renewables operate at max power tracking and do not leave a headroom for reserves
Flicker	• Intermittent renewables cause fluctuations is system voltages especially when the grid short circuit strength is low. Ensure compliance with IEEE 1453 standard for flicker.
Black Start	• Ability to restart a system with predominantly inverter-based resources.

IMPACT OF INVERTER BASED GENERATION ON SYSTEM PROTECTION

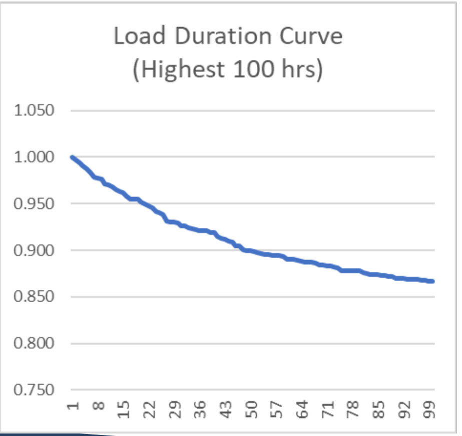
- **Declining Inertia of the power system**
  - The frequency change is important in regard to the stability of protective relays during power swing conditions.
  - In more extreme cases of system frequency changes, it may even impact the protection relay algorithms to a degree that an over or under frequency event can be erroneously caused.
  - The requirements onto maximum fault clearing time are a function of the system inertia
- **Reduced short circuit current (fault level)**
  - The inverter-based fault current contribution to short circuits is limited by the electronic controls of the inverters. The level may vary between control designs but would typically be in the order of 1.0 – 1.5 times nominal current. This will cause sensitivity issues for protective relays where they may fail to operate, or their operation will not be properly coordinated.
- **Different negative sequence fault current contribution**
  - Inverter contribution of negative- or zero-sequence current to a fault depend to inverter type and generation. Protection schemes that rely on negative sequence current are impacted. (directional elements, over current elements)
- **Changed source impedance characteristic**
  - The source impedance of an inverter-based generator during a fault is determined by the control algorithm of the inverter and does not need to be inductive. This may affect and challenge correct operation of the cross- or memory polarisation functions of protection relays.
- **Missing model of inverter-based generation**
  - The characteristic of inverters is mostly determined by the control algorithm selected and developed by the manufacturer. The behaviour of inverters from different manufacturers can be different in response to the fault current. the correct modelling of inverter-based generation inside of short circuit programs used for protection studies is challenging. This is even more a challenge for aggregated inverter-based generation that’s consist of different power sources like wind generation type 3, type 4 or solar panels.

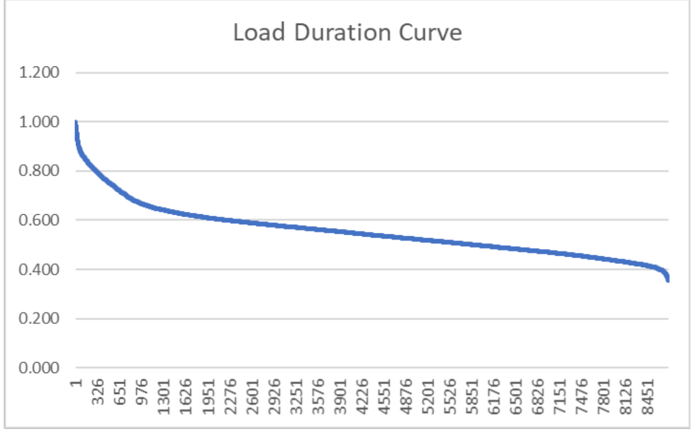
NIPSCO DEMAND AND RESOURCE DEVELOPMENT

DEMAND PROFILE

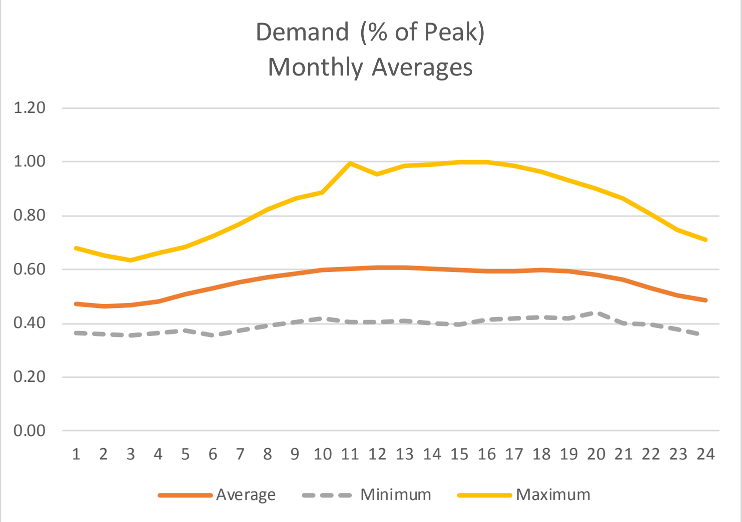
Month/Hr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.50	0.50	0.50	0.50	0.52	0.55	0.58	0.58	0.59	0.60	0.60	0.59	0.59	0.58	0.57	0.57	0.57	0.60	0.60	0.59	0.58	0.56	0.54	0.52
2	0.49	0.49	0.49	0.49	0.52	0.55	0.57	0.58	0.59	0.59	0.59	0.58	0.58	0.57	0.56	0.55	0.56	0.58	0.58	0.58	0.57	0.55	0.52	0.50
3	0.46	0.46	0.47	0.49	0.51	0.54	0.55	0.56	0.56	0.56	0.55	0.55	0.54	0.52	0.51	0.51	0.51	0.52	0.55	0.53	0.52	0.49	0.48	0.47
4	0.43	0.43	0.44	0.46	0.49	0.51	0.53	0.54	0.54	0.54	0.54	0.54	0.52	0.51	0.51	0.50	0.49	0.50	0.51	0.51	0.50	0.47	0.45	0.44
5	0.42	0.42	0.43	0.44	0.47	0.50	0.52	0.54	0.54	0.55	0.55	0.55	0.55	0.54	0.53	0.52	0.52	0.52	0.52	0.52	0.49	0.47	0.44	0.43
6	0.46	0.45	0.45	0.47	0.48	0.51	0.53	0.56	0.58	0.60	0.62	0.63	0.64	0.64	0.64	0.63	0.62	0.61	0.60	0.59	0.57	0.53	0.50	0.47
7	0.55	0.53	0.53	0.54	0.56	0.58	0.62	0.66	0.71	0.74	0.77	0.79	0.81	0.82	0.82	0.82	0.81	0.79	0.76	0.74	0.70	0.65	0.60	0.57
8	0.51	0.49	0.50	0.51	0.54	0.56	0.59	0.62	0.65	0.68	0.71	0.73	0.75	0.75	0.76	0.76	0.75	0.72	0.70	0.68	0.64	0.60	0.56	0.53
9	0.46	0.46	0.46	0.48	0.51	0.53	0.55	0.57	0.59	0.61	0.63	0.64	0.66	0.66	0.66	0.66	0.65	0.64	0.64	0.61	0.59	0.54	0.51	0.48
10	0.43	0.43	0.44	0.46	0.49	0.52	0.54	0.55	0.55	0.55	0.55	0.56	0.55	0.54	0.53	0.53	0.53	0.54	0.54	0.53	0.50	0.48	0.45	0.44
11	0.46	0.46	0.46	0.47	0.50	0.52	0.54	0.55	0.56	0.56	0.56	0.55	0.55	0.54	0.53	0.53	0.54	0.55	0.55	0.54	0.53	0.50	0.48	0.47
12	0.48	0.47	0.47	0.47	0.49	0.52	0.55	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.56	0.57	0.57	0.57	0.56	0.54	0.51	0.49
Average	*0.47*	*0.47*	*0.47*	*0.48*	*0.51*	*0.53*	*0.56*	*0.57*	*0.59*	*0.60*	*0.60*	*0.61*	*0.61*	*0.60*	*0.60*	*0.59*	*0.59*	*0.60*	*0.59*	*0.58*	*0.56*	*0.53*	*0.50*	*0.48*
Minimum	*0.36*	*0.36*	*0.35*	*0.36*	*0.37*	*0.36*	*0.37*	*0.39*	*0.41*	*0.42*	*0.40*	*0.40*	*0.41*	*0.40*	*0.40*	*0.41*	*0.42*	*0.42*	*0.42*	*0.44*	*0.40*	*0.40*	*0.38*	*0.36*
Maximum	*0.68*	*0.65*	*0.64*	*0.66*	*0.68*	*0.72*	*0.77*	*0.82*	*0.87*	*0.89*	*0.99*	*0.95*	*0.98*	*0.99*	*1.00*	*1.00*	*0.99*	*0.96*	*0.93*	*0.90*	*0.86*	*0.80*	*0.75*	*0.71*

- The demand is Summer peaking (July), and peak hours are mid day (11AM-4PM).
- Highest 15% of peak demand occurs in only 100 hours in a year.





Month	Monthly Consumption (% of Max)
1	88%
2	80%
3	75%
4	72%
5	73%
6	81%
7	100%
8	93%
9	84%
10	74%
11	76%
12	78%



Annual Consumption pu-h	4,849
Load Factor	55.4%

EXISTING AND PLANNED GENERATION RESOURCES

- Existing Resources (2019)
  - Coal 1,995 MW
  - Combined Cycle 535 MW
  - Gas Peaker 155 MW
  - Hydro 10 MW

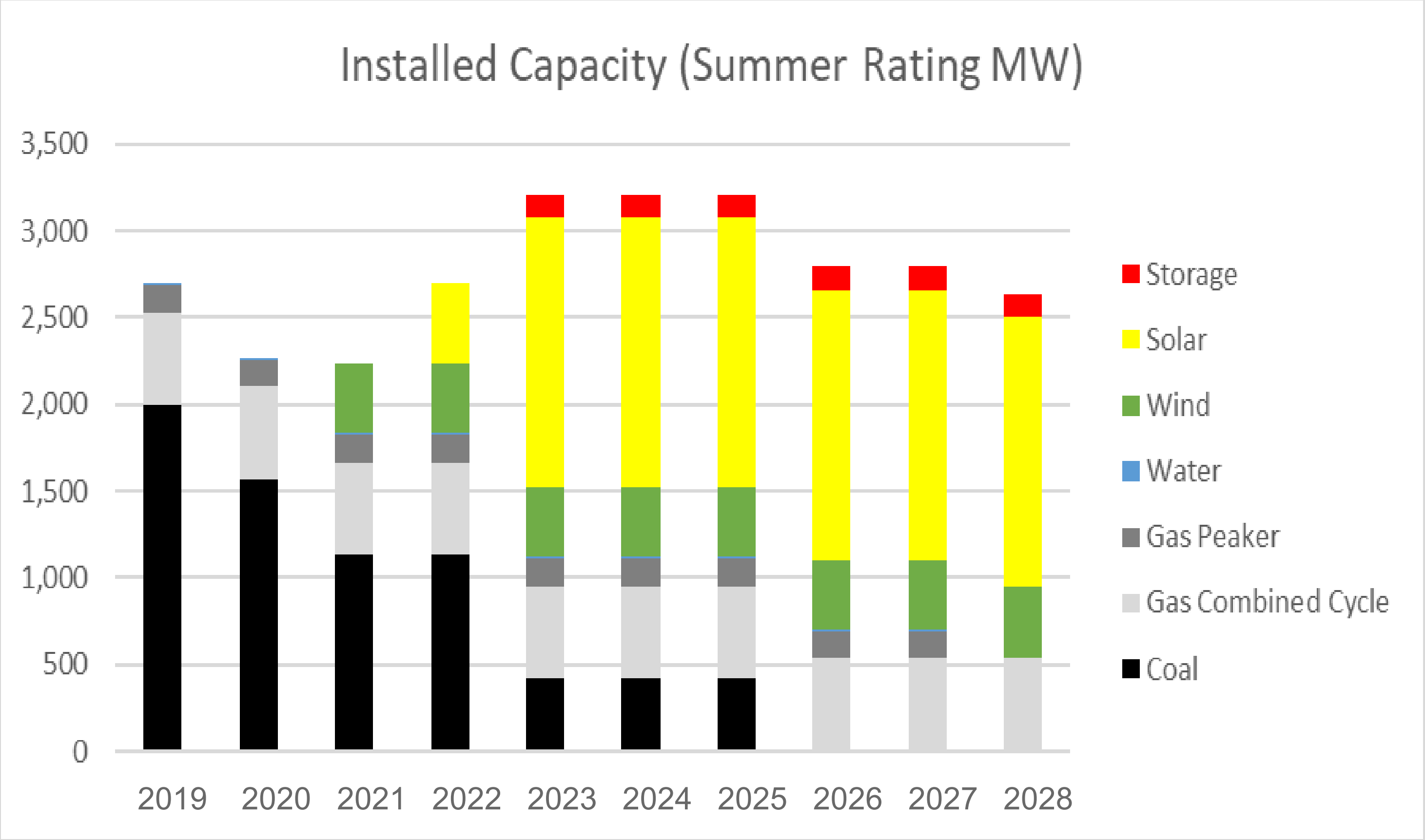
2,695 MW

- Planned Resource Additions (Owned Assets)
  - Wind (2021) 405 MW
  - Solar (2022/2023) 1,550 MW
  - Storage (2023) 135 MW

2,090 MW

- End of Life Schedule:

Coal	(2020)	425 MW
	(2021)	440 MW
	(2023)	710 MW
	(2026-2028)	420 MW
Gas Peaker	(2025-2028)	155 MW
		2,150 MW



- Significant changes in the resource mix are already planned prior to the 2021 IRP results, with a shift away from Coal towards Solar and Wind resources.

2021 IRP - CONSIDERED PORTFOLIOS

Replacement Resource Tranches

		A	B	C	D	E	F	G	H	I	Resource End Date
Sugar Creek Uprate	2027	53	53	53	53	53	53	-	-	53	
New DER	2026	10	10	10	10	10	10	10	10	10	
Wind P1	2026	-	-	-	-	-	-	-	200	200	
Solar P2	2026	250	100	-	400	250	100	450	250	250	
Solar+Storage P1	2026	450	-	-	450	-	-	450	-	-	
Storage P2	2025	-	-	-	-	-	-	-	100	100	
Storage P2	2026	-	-	-	-	100	-	-	100	-	
Storage P2	2027	-	-	-	-	100	-	-	100	-	
Storage A2	2025	-	-	-	-	135	-	-	135	135	
Storage A2	2026	-	-	-	-	-	-	-	-	-	
Storage A2	2027	135	-	-	135	135	135	135	135	135	
Gas Peaking P1	2026	-	443	-	-	-	-	-	-	-	
Gas Peaking A1	2026	-	-	-	-	-	300	-	-	-	
Gas CC A1	2026	-	-	650	-	-	-	-	-	-	
Other Thermal P1	2024	50	50	-	-	50	50	-	-	-	2034
Other Thermal P2	2026	100	100	-	-	100	100	-	-	-	2036
Hydrogen P1	2025	-	-	-	-	-	-	-	-	193	
Hydrogen P2	2026	-	-	-	-	-	-	-	-	20	

- Retirements:
  - Schahfer 17/18 - 2023
  - MC12 Retirement – Modeled as 2026; however, same resource mix as by 2028
- Other Thermal P1, P2:
  - Zonal resource contracts

	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Duration)
Higher Carbon Emissions	**A** NIPSCO DER 10MW SC Uprate 53MW Thermal PPA 150MW Storage 135MW Solar+Storage 450MW* Solar 250MW	**B** NIPSCO DER 10MW SC Uprate 53MW Gas Peaker** 443MW Thermal PPA 150MW Solar 250MW	**C** NIPSCO DER 10MW SC Uprate 53MW Gas CC 650MW
Mid Carbon Emissions	**D** NIPSCO DER 10MW SC Uprate 53MW Storage 135MW Solar+Storage 450MW* Solar 400MW	**E** NIPSCO DER 10MW SC Uprate 53MW Thermal PPA 150MW Storage 470MW Solar 250MW	**F** NIPSCO DER 10MW SC Uprate 53MW Gas Peaker** 300MW Thermal PPA 150MW Storage 135MW Solar 100MW
Low Carbon Emissions	**G** NIPSCO DER 10MW Storage 135MW Solar+Storage 450MW* Solar 450MW	**H** NIPSCO DER 10MW Wind 200MW Storage 570MW Solar 250MW	**I** NIPSCO DER 10MW SC H2 Electrolyzer 20MW SC Uprate 53MW H2 Enabled Peaker 193MW Wind 200MW Storage 370MW Solar 250MW

**Gas Peaker: Local to Service Territory in Portfolio F, while outside of territory in Portfolio B

2030 PORTFOLIO MIX

- 2,150 MW of conventional resources will be retired.
- 2,090 MW of IBR resources are planned to be added (owned assets).
- In addition, Portfolios A through I will provide additional resources. The total of all resources in 2030 are summarized below. The mix of IBRs ranges between 63% (C) to 85% (H).

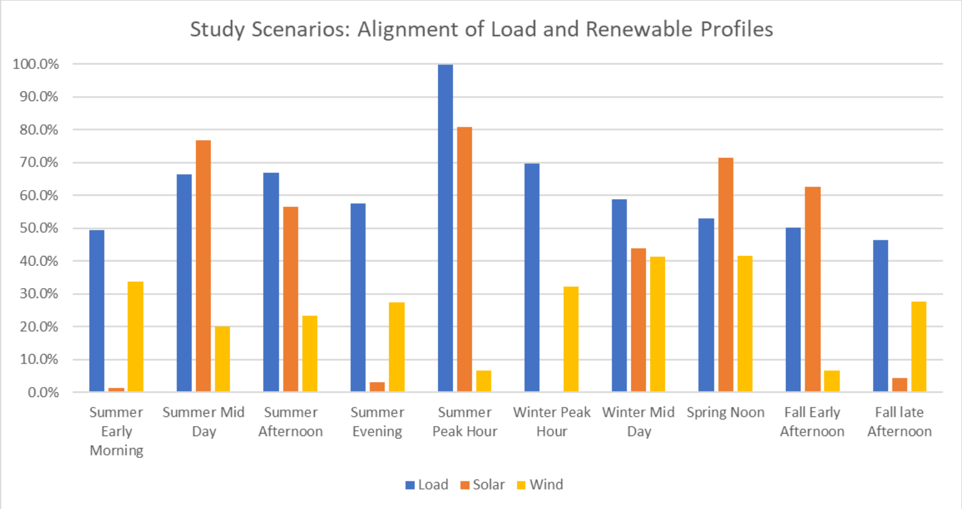
Portfolio	Solar PV MW	Wind MW	Energy Storage MW	Thermal Gen MW	Hydro MW	IBR %
A	2,100	405	420	738	10	80%
B	1,800	405	135	738	10	76%
C	1,550	405	135	1,238	10	63%
D	2,250	405	420	588	10	84%
E	1,800	405	605	738	10	79%
F	1,650	405	270	1,038	10	69%
G	2,000	405	270	535	10	83%
H	1,800	605	705	535	10	85%
I	1,800	605	505	781	10	79%

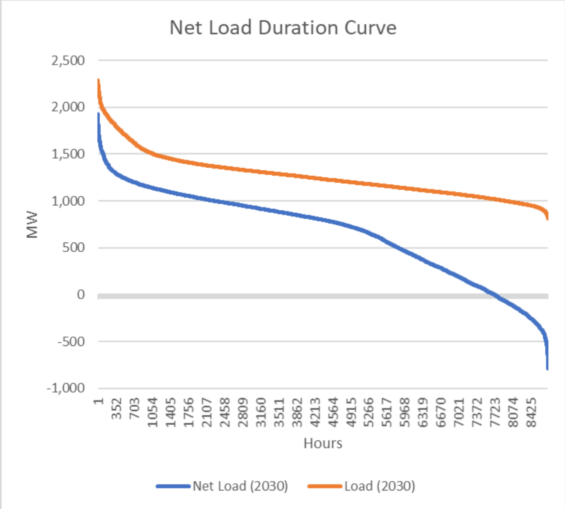
RESOURCE VARIABILITY ANALYSIS

RESOURCE VARIABILITY ANALYSIS - SUMMARY

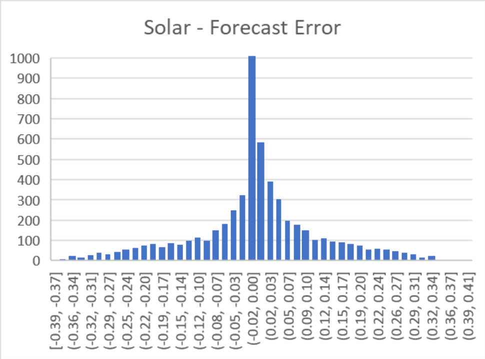
- The hourly profiles of Solar, Wind, and Solar plus Storage are characterized across two dimensions:
  - Forecast Error
  - Alignment with Load

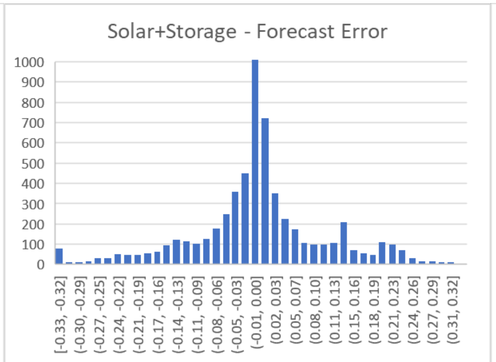
- This characterization is utilized in subsequent evaluation of portfolios of these resources.

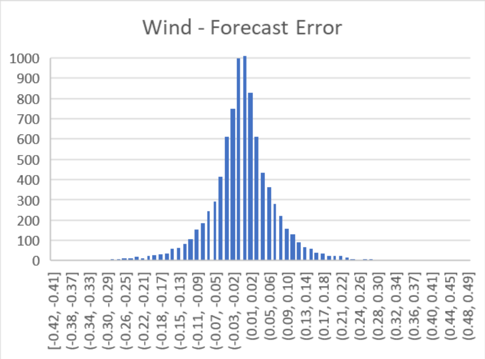




Forecast Error%	Solar	Wind	S+S
Standard Deviation	9.9%	7.5%	9.2%
min Error	-39%	-42%	-33%
max Error	39%	48%	33%
90% Percentile	19%	8%	12%







RELIABILITY CRITERIA & METRICS

RELIABILITY CRITERIA

	Criteria	Description	Rationale
1	Blackstart	Resource has the ability to be started without support from the wider system or is designed to remain energized without connection to the remainder of the system, with the ability to energize a bus, supply real and reactive power, frequency and voltage control	In the event of a black out condition, NIPSCO must have a blackstart plan to restore its local electric system.
2	Energy Duration	Resource is able to meet energy and capacity duration requirements. In emergency conditions, resource is able to supply the energy needs of critical loads.	NIPSCO must have long duration resources for emergency procedures and must assess economic value risk for energy duration attributes over time
3	Dispatchability and Automatic Generation Control	The unit will respond to directives from system operators regarding its status, output, and timing. The unit has the ability to be placed on Automatic Generation Control (AGC) allowing its output to be ramped up or down automatically to respond immediately to changes on the system.	MISO provides dispatch signals under normal conditions, but NIPSCO requires AGC attributes under emergency restoration procedures
4	Operational Flexibility and Frequency Support	Ability to provide inertial energy reservoir or a sink to stabilize the system. The resource can adjust its output to provide frequency support or stabilization in response to frequency deviations with a droop of 5% or better	MISO provides market construct under normal conditions, but NIPSCO must have the ability to maintain operation during under-frequency conditions in emergencies
5	VAR Support	The resource can be used to deliver VARs out onto the system or absorb excess VARs and so can be used to control system voltage under steady-state and dynamic/transient conditions. The resource can provide dynamic reactive capability (VARs) even when not producing energy. The resource must have Automatic voltage regulation (AVR) capability. The resource must have the capability ranging from 0.85 lagging to 0.95 leading power factor	NIPSCO must retain resources on the transmission system to provide this attribute in accordance with NERC and IEEE Standards
6	Geographic Location Relative to Load	The resource will be located in NIPSCO's footprint (electric Transmission Operator Area)in Northern Indiana near existing NIPSCO 138kV pr 345kV facilities and is not restricted by fuel infrastructure. The resource can be interconnected at 138kV or 345kV. Preferred locations are ones that have multiple power evacuation/deliverability paths, are close to major load centers, and do not deteriorate the transmission system's transfer capability headroom.	MISO requires location capacity resources and runs an LMP market to provide locational energy signals; under emergency restoration procedures, a blackstart plan reliant on external resources would create a significant risk. Location provides economic value in the form of reduced losses, congestion, curtailment risk, and address local capacity requirements. Additionally, from a reliability perspective, resources that are interconnected to buses with multiple power evacuation paths and those close to load centers are more resilient to transmission system outages and provide better assistance in the blackstart restoration process.
7	Predictability and Firmness of Supply	Ability to predict/forecast the output of resources and to counteract forecast errors.	Energy is scheduled with MISO in the day-ahead hourly market and in the real-time 5-minute market. Deviations from these schedules have financial consequences and thus the ability to accurately forecast the output of a resource up to 38 hours ahead of time for the day-ahead market and 30 minutes for the real time market is advantageous.
8	Short Circuit Strength Requirement	Ensure the strength of the system to enable the stable integration of all inverter-based resources (IBRs) within a portfolio.	The retirement of synchronous generators within NIPSCO footprint and also within MISO and replacements with increasing levels of inverter-based resources will lower the short circuit strength of the system. Resources than can operate at lower levels of SCR and those that provide higher short circuit current provide a better future proofing without the need for expensive mitigation measures.

RELIABILITY METRICS

	Criteria	Measurement Approach	Included in Minimum Interconnection Requirements	Quanta Analysis to Support Metric
1	**Blackstart**	• MWs with black start capability • **Qualitative Assessment of Risk of not Starting**	NO	• Blackstart Analysis ★
2	**Energy Duration**	• Percentage of NIPSCO's critical load (MW and Time) that can be supplied during emergencies	NO	• Energy Adequacy Analysis
3	**Dispatchability and Automatic Generation Control**	• MWs on AGC • Up Range / Down range • Ability for Fast Regulation • Duration of Up / Down Regulation	NO (except being on SCADA for monitoring and control)	• Increase of Regulation Requirements due to IBRs in each Portfolio • 10-min Ramp Capability of Portfolio
4	**Operational Flexibility and Frequency Support**	• Inertial Response Gap/Surplus • Primary Frequency Response Gap/Surplus	NO	• Inertial Repose • Primary Response
5	**VAR Support**	• Continuous VAR output range	YES	• Sum of VAR capability
6	**Geographic Location Relative to Load**	• MWs or % within NIPSCO footprint • Firmness of fuel supplies • MWs with POIs with multiple (2 or higher) secure power evacuation paths • Reduction in Existing Grid transfer capability headroom	NO	• Topology analysis
7	**Predictability and Firmness of Supply**	• Ability to mitigate Forecast Error of intermittent resources using fast ramping capability	NO	• Power Ramping ★
8	**Short Circuit Strength Requirement**	• MWs of IBRs potentially impacted by lack of short circuit strength • Need for synchronous condensers and/or grid forming inverters to ensure stable system integration	NO, 1547 and P2800 do not address	• Short Circuit Strength Analysis

★ Blackstart and Predictability and Firmness of Supply have been included as specific examples discussed on the following slides. Further details on the other criteria are found in the Appendix and will be detailed in the IRP report.

BLACKSTART

- The power industry does not have experience of black starting systems served mostly by inverter-based resources. Few success stories have been reported in news media over the past 5 years:

- **GE Completes First Battery Assisted Black Start of a GE Heavy Duty Gas Turbine**
  - Perryville Power Station, Entergy
  - GE 7F.03 150MW simple cycle
  - BESS 7.4MW
  - Feb 2020
- **Imperial Irrigation District**
  - El Centro Generating Station, Southern California
  - 44MW combined cycle
  - BESS 33MW/20MWh
  - Originally designed for grid stability and renewable smoothing
  - May 2017
- **Scottish Power**
  - Blackstart of wind power in world-first demonstration
  - Nov 2020
- **WEMAG German battery park demonstrates successful black start**
  - Schwerin, a city in northern Germany
  - Combined Cycle Plant
  - BESS 5MW/15MWh
  - Originally designed for frequency regulation and other grid balancing services
  - Feb 2017
- **Glendale Water & Power (GWP)**
  - BESS 2MW/950kWh
  - July 2017

BLACK START STRATEGY

- Observations:
  - Five portfolios (A, D, E, G, H) do not have synchronous machines.
  - 4 Portfolios have synchronous machines (B, C, F, I)
  - 3 Portfolios have large aggregate MW stand-alone storage capability (E, H, I)
  - 2 Portfolios do not have stand-alone storage systems
  - System needs short circuit strength and inertia to function before energizing solar/wind resources.
  - All portfolios have large aggregate MWs of Solar plus storage

ICAP MW

Inside NIPSCO	A	B	C	D	E	F	G	H	I
Gas Resource	0	0	650	0	0	300	0	0	193
Synch Cond.	986	986	986	986	986	986	986	986	986
Solar	350	350	100	500	100	200	550	350	350
Solar+Storage	1250	800	800	1250	800	800	1250	800	800
Wind	405	405	405	405	405	405	405	605	605
Storage	135	0	0	135	470	135	135	570	370

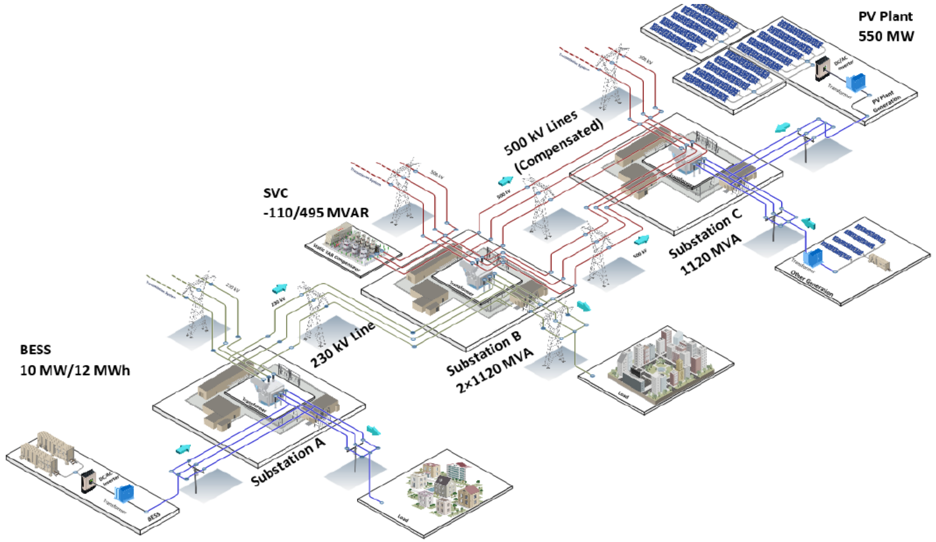
- Preliminary Black Start Strategy:
  - Energize standalone storage equipped with GFM inverters, if available
  - Portfolios C, F, and I should specify the gas resources to have black start capability
  - Find cranking paths to Synchronous Condensers and energize them.
  - Start with area around RMSGS, Babcock, Dune Acres, ..etc.
  - Energize solar plus storage sites, then solar, then wind

- Evaluation Metrics:
  - Adequacy of storage size to start the pony motors of synchronous condensers and supply the transformer inrush currents.
  - Ability of storage and synchronous condensers (real and reactive power) to black start other renewable resources (assume the auxiliary loads of these resources to be 5% of their rating, and that each farm is modular and can be started in steps).

POWER PLANT BLACK START STUDIES – KEY CONSIDERATIONS

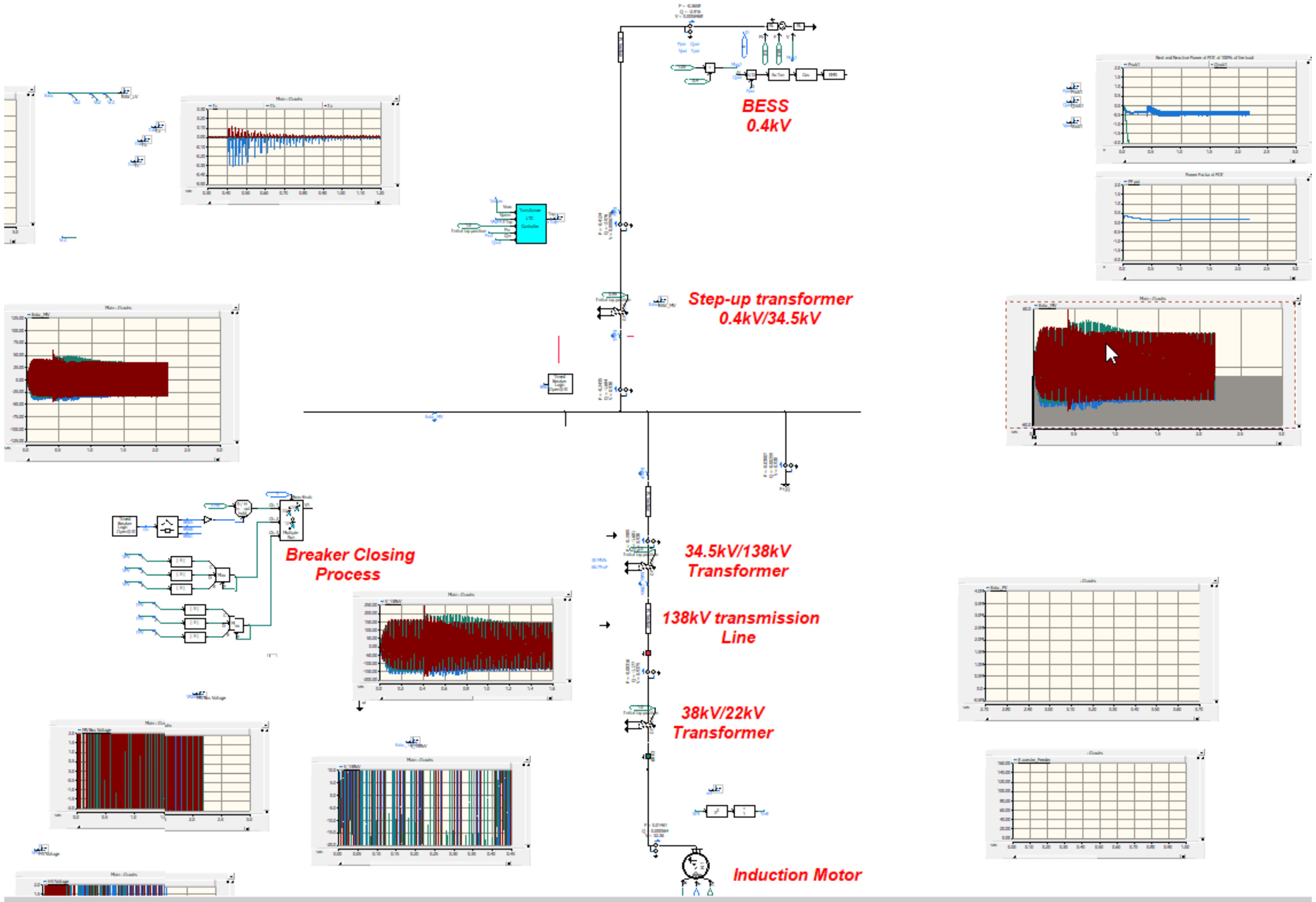
- Modeling:
  - Sequencing of Essential Motors (Startup and Shutdown)
  - Modeling of Induction Motors (dynamic characteristics)
  - Protection system Modeling
  - Fast bus transfer
  - Battery System
  - Transformers
- Analysis:
  - Transient and steady-state simulations
- Considerations:
  - Inverter short-circuit current limitations
  - Soft-start techniques
  - Dynamic interactions
  - Frequency and Voltage control
  - Protective relay operation in view of limited short circuit currents

- Results:
  - Inverter Size (MVA, PF)
  - BESS Size (MW, MWh)
  - BESS control and protection settings
  - Transformer tap settings
  - Protection setting adjustments



PORTFOLIO EVALUATION - BLACK START

- Using 135MW/150MVA battery to black start the pony motor of synchronous condensers:



BLACK START CAPABILITY - QUALITATIVE ASSESSMENT OF PORTFOLIOS

- The following are considerations for a qualitative assessment:
  - Portfolios that do not have energy storage systems with GFM inverters and do not have Peaker Plants with black start capability cannot be started. So, Portfolios B will fail.
  - Portfolios that have 135MW and higher of energy storage with GFM inverters appear (from the expedient cursory analysis) to have the capability to black start the synchronous condensers. This applies to portfolios (D-I). Portfolio C, if its peaker plant is equipped with black start capability should also be able to start.
  - Portfolios without peaker plants will have a limited time to energize the system (depending on the state of charge of the batteries). Larger batteries are better. During this period of time, they can attempt to start facilities with solar+storage first, and then solar, and then wind near the major load centers. The synch condensers provide the reactive power, and the battery stabilize the frequency.
  - From a risk perspective, it appears that the follow is the ranking of the Portfolios:
    - F and I are the best. They have both peaker plants and storage.
    - C next.
    - E, H next due their large storage size
    - G, D, A next
    - B fails to black start

Inside NIPSCO	A	B	C	D	E	F	G	H	I
Gas Resource	0	0	650	0	0	300	0	0	193
Synch Cond.	986	986	986	986	986	986	986	986	986
Solar	350	350	100	500	100	200	550	350	350
Solar+Storage	1250	800	800	1250	800	800	1250	800	800
Wind	405	405	405	405	405	405	405	605	605
Storage	135	0	0	135	470	135	135	570	370

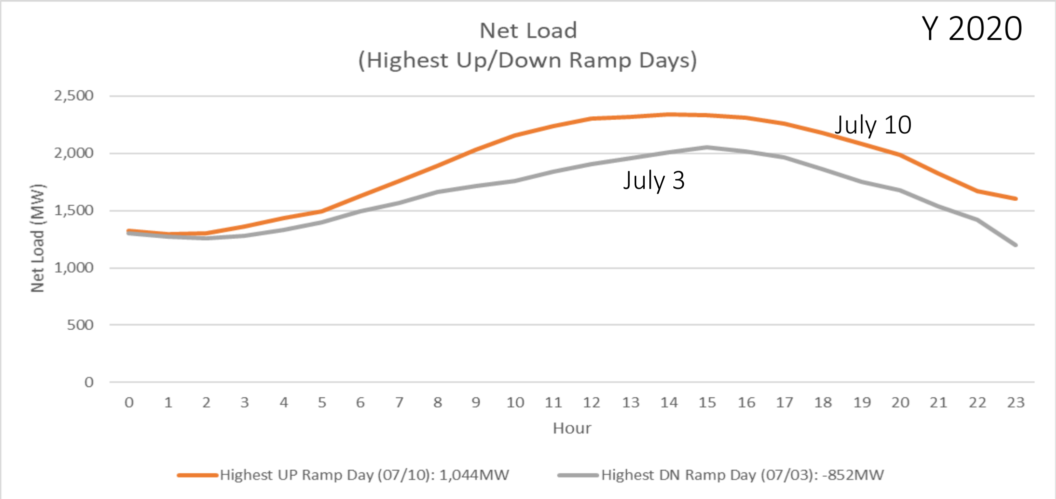
POWER RAMPS

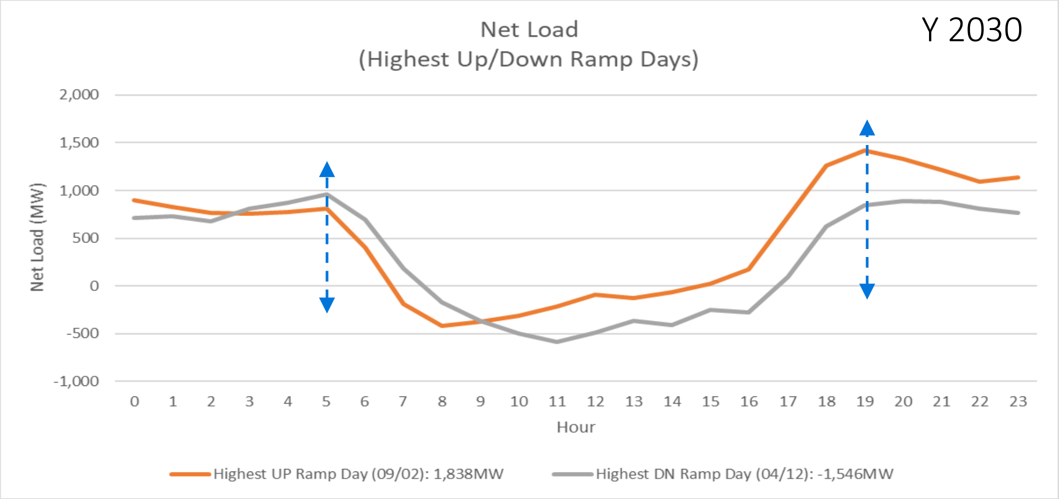
- The electric power industry has documented over the past decade an expected change in the hourly load profile as the intermittent renewable penetration of solar and wind resources increases. This has been dubbed the "Duck Curve".
- System operation is challenged during periods of high power ramp rates. This has prompted CAISO and later MISO to adopt a new ancillary service product called Ramping Product, with the objective of acquiring fast ramping resources that can be committed and dispatched rapidly to balance the system supply and demand during these periods of high power ramps.
- Power ramps can occur at different time scales:
  - Intra-hour ramping: intermittency of renewable resources due to cloud cover or wind bursts. These ramps can be quantified at a second, minute, 5-min, and 10-min basis. These ramps can be mitigated by procuring additional fast regulation reserves including energy storage.
  - Hour to hour: changes in power output between two consecutive hours.
  - Multi-Hour during a day: sustained increase or decrease in power output across multiple hours in a day.
- Hourly and daily power ramps can be partially mitigated by properly forecasting and scheduling these ramps in the day-ahead and real-time markets. However, any unscheduled hourly ramps will affect control area performance and have to be mitigated within the control area. Energy is scheduled with MISO in the day-ahead hourly market and in the real-time 5-minute market. Schedules are submitted up to 38 hours ahead of the actual hour time for the day-ahead market and 30 minutes for the real time market.

NET LOAD POWER RAMPS

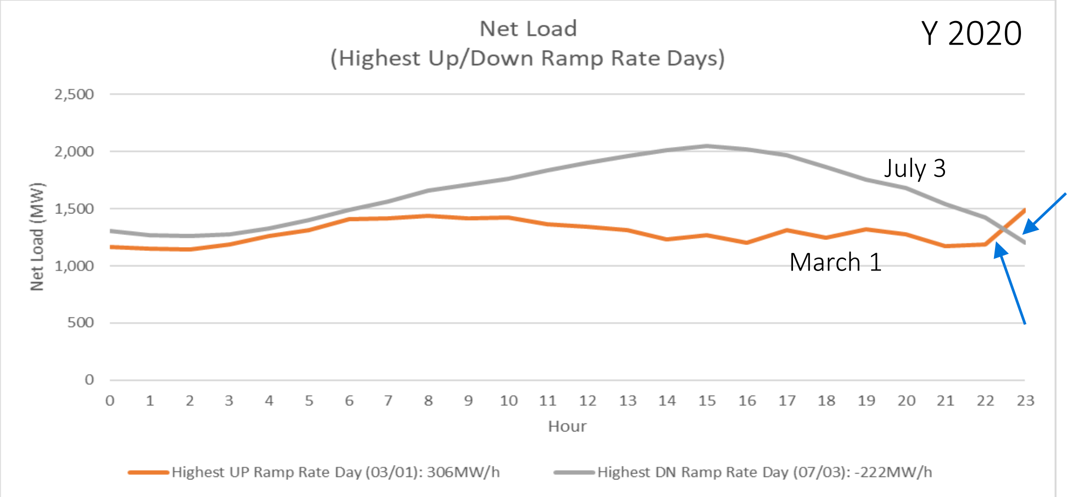
Portfolio E (without Storage/Peakers Dispatch)

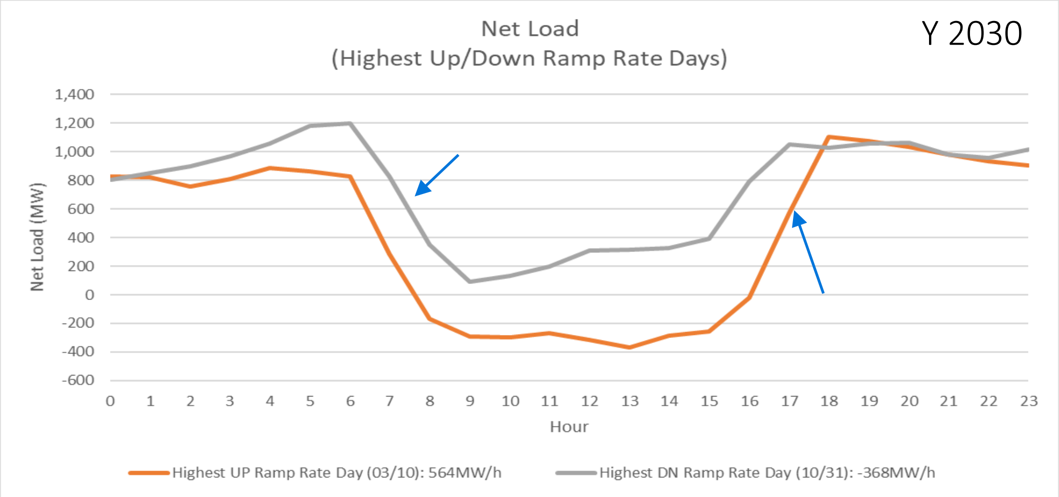
Highest Up/Down Ramp Days





Highest Up/Down Ramp Rate Hours



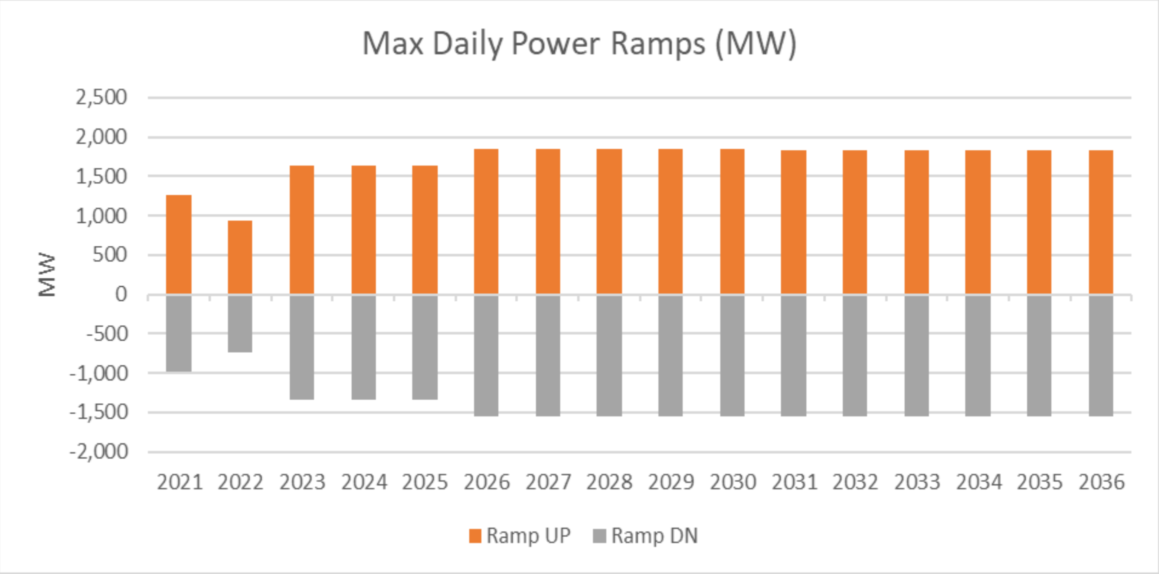


Significant change in Net Load profile from a conventional shape in 2020 to a "Duck Curve" in 2030

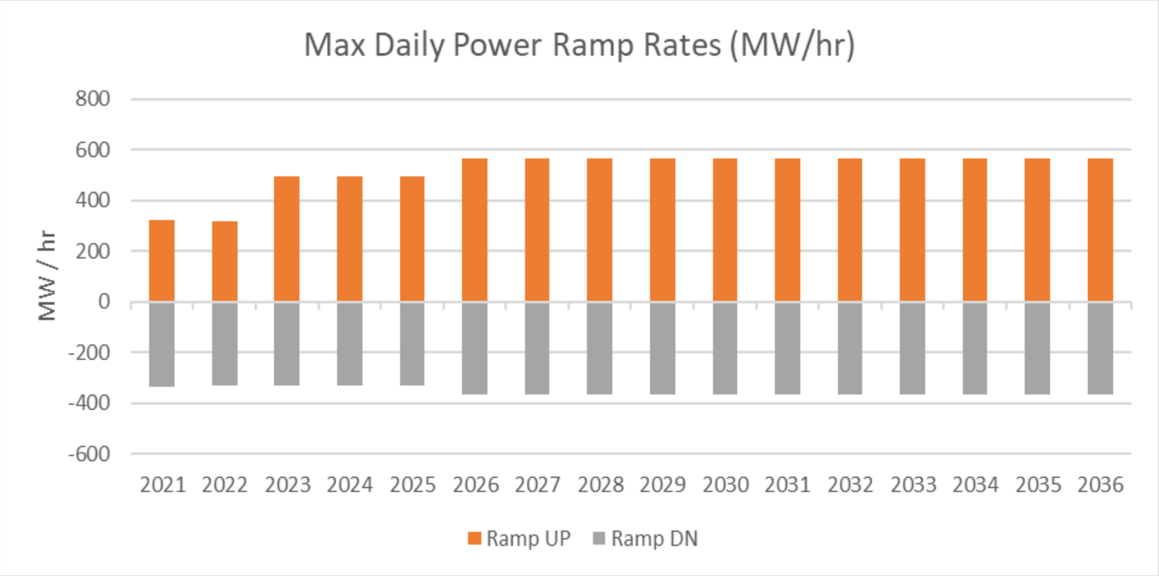
NET LOAD POWER RAMPS

Portfolio E (without Storage/Peakers Dispatch)

Year	Ramp UP	Ramp DN	Ramp Rate UP	Ramp Rate DN
2021	1,256	-982	322	-333
2022	930	-735	319	-331
2023	1,633	-1,347	494	-331
2024	1,632	-1,347	494	-330
2025	1,631	-1,347	494	-330
2026	1,839	-1,546	564	-368
2027	1,838	-1,546	564	-368
2028	1,838	-1,546	564	-368
2029	1,838	-1,546	564	-368
2030	1,838	-1,546	564	-368
2031	1,838	-1,546	564	-368
2032	1,837	-1,546	563	-368
2033	1,837	-1,546	563	-368
2034	1,837	-1,546	563	-368
2035	1,837	-1,546	563	-368
2036	1,837	-1,546	563	-368



Ramping Category	2020 MW	2020 %Peak	2030 MW	2030 %Peak	Increased MW 2030 vs 2020
1-hr Up	306	13.1%	564	24.7%	258
1-hr Down	-222	9.5%	-368	16.1%	146
Day Up	1,044	44.6%	1,838	80.5%	794
Day Down	-852	36.4%	-1,546	67.7%	694



QUANTA TECHNOLOGY

NET LOAD POWER RAMPS (Y2030 VS Y2020)

Portfolio	Solar	Wind	Solar + Storage	Day Ramping Up (MW)	Day Ramping Down (MW)	1hr Ramping Up (MW)	1hr Ramping Down (MW)	Peaker/Storage (MW)	Forecast Error 90th Percentile	Excess Ramping Capability (MW)
2020	**0**	**405**	**0**	**1,044**	**-852**	**306**	**-222**	**155**	**32**	**123**
A	1,800	405	450	1,863	-1,719	593	-397	135	428	-293
B	1,800	405	0	1,838	-1,546	564	-368	443	374	69
C	1,550	405	0	1,630	-1,346	493	-329	0	327	-327
D	1,950	405	450	1,988	-1,830	621	-426	135	457	-322
E	1,800	405	0	1,838	-1,546	564	-368	470	374	96
F	1,650	405	0	1,713	-1,426	521	-342	435	346	89
G	2,000	405	450	2,030	-1,870	630	-437	135	466	-331
H	1,800	605	0	1,844	-1,594	566	-413	570	390	180
I	1,800	605	0	1,844	-1,594	566	-413	563	390	173
90th Percentile	19%	8%	12%							

- Balancing areas are required per BAL-003 to comply with Control Performance Standard (CPS) 1 and CPS2. CPS2 is a monthly standard intended to limit unscheduled flows. It requires compliance better than 90% that the average Area Control Error (ACE) will remain below a threshold over all 10-min intervals in the month. For a balancing area with a peak load of 2500MW, the threshold is around 37MW. NIPSCO is a local balancing area under MISO but does not carry any ACE performance requirements currently.
- A small percentage (≈30%) of the hourly ramps in Net Load can be forecasted an hour ahead using a persistent forecast method and thus scheduled in the real time market. Example, Portfolio E has total 1-hour ramp up of 564MW while its forecast error is 374MW, or 66%.
- The unforecasted changes in renewable resource outputs should be mitigated using fast ramping resources.
- Portfolios ranked according to their ability to mitigate the unforecasted power ramps from best to worst: H, I, E, F, B. Other portfolios require additional flexible ramping resources to mitigate the impacts of the renewable power ramps.

ASSESSMENT RESULTS

RELIABILITY METRICS

	Criteria	Potential Measurement Approaches Considered	Included in Minimum Interconnection Requirements	Quanta Analysis to Develop Metric
1	**Blackstart**	• MWs with black start capability • **Qualitative Assessment of Risk of not Starting**	NO	• Blackstart Analysis
2	**Energy Duration**	• Percentage of NIPSCO's critical load (MW and Time) that can be supplied during emergencies	NO	• Energy Adequacy Analysis
3	**Dispatchability and Automatic Generation Control**	• MWs on AGC • Up Range / Down Range • Ability for Fast Regulation • Duration of Up / Down Regulation	NO (except being on SCADA for monitoring and control)	• Increase of Regulation Requirements due to IBRs in each Portfolio • 10-min Ramp Capability of Portfolio
4	**Operational Flexibility and Frequency Support**	• Inertial Response Gap/Surplus • Primary Frequency Response Gap/Surplus	NO	• Inertial Repose • Primary Response
5	**VAR Support**	• Continuous VAR output range	YES	• Sum of VAR capability
6	**Geographic Location Relative to Load**	• MWs or % within NIPSCO footprint • Firmness of fuel supplies • **MWs with POIs with multiple (2 or higher) secure power evacuation paths** • Reduction in Existing Grid transfer capability headroom	NO	• Topology analysis
7	**Predictability and Firmness of Supply**	• Ability to mitigate Forecast Error of intermittent resources using fast ramping capability	NO	• Power Ramping
8	**Short Circuit Strength Requirement**	• MWs of IBRs potentially impacted by lack of short circuit strength • Need for synchronous condensers and/or grid forming inverters to ensure stable system integration	NO, 1547 and P2800 do not address	• Short Circuit Strength Analysis

PORTFOLIO RELIABILITY METRICS

Preliminary

	Year 2030	Metric	A	B	C	D	E	F	G	H	I
1	Blackstart	Qualitative Assessment of Risk of not Starting	25%	0%	75%	25%	50%	100%	25%	50%	100%
2	Energy Adequacy	Energy Not Served when Islanded (Worst 1-week) %	76%	79%	32%	75%	79%	56%	75%	73%	58%
3	Dispatchability	Dispatchable (%CAP, unavoidable VER Penetration)	29%	17%	57%	28%	46%	47%	27%	48%	48%
			56%	49%	40%	61%	49%	44%	63%	50%	50%
		Increased Freq Regulation Requirements (MW)	60	47	40	64	47	43	66	53	53
		1-min Ramp Capability (MW)	346	211	261	331	681	397	326	761	599
		10-min Ramp Capability (MW)	649	514	764	574	984	859	548	983	944
4	Operational Flexibility and Frequency Support	Inertia MVA-s	3,200	6,004	6,711	3,200	3,218	5,099	2,914	2,914	4,379
		Inertial Gap FFR MW	148	276	177	180	0	72	192	0	0
		Primary Gap PFR MW	258	387	380	261	0	248	262	0	20
5	VAR Support	VAR Capability	364	109	283	429	314	233	451	445	442
6	Location	Average Number of Evacuation Paths	5	2.5	N/A	4.6	4.7	4.7	4.8	5.6	5.1
7	Predictability and Firmness	Ramping Capability to Mitigate Forecast Errors (+Excess/-Deficit) MW	-293	69	-327	-322	96	89	-331	180	173
8	Short Circuit Strength	Required Additional Synch Condensers MVA	805	64	0	1,017	779	68	1,070	948	599

CAP: the capacity value of the portfolio including the existing and planned resources
Solar capacity credit : 50% of installed capacity; Wind capacity credit : 16.3% (based on MISO published data on system wide capacity credits)

PORTFOLIO RELIABILITY METRICS (NORMALIZED)

Preliminary

	Year 2030	Metric	A	B	C	D	E	F	G	H	I
1	Blackstart	Qualitative Assessment of Risk of not Starting	25%	0%	75%	25%	50%	100%	25%	50%	100%
2	Energy Adequacy	Energy Not Served when Islanded (Worst 1-week) %	76%	79%	32%	75%	79%	56%	75%	73%	58%
3	Dispatchability	Dispatchable (%CAP, unavoidable VER penetration%)	29%	17%	57%	28%	46%	47%	27%	48%	48%
			56%	49%	40%	61%	49%	44%	63%	50%	50%
		Increased Freq Regulation Requirement (% Peak Load)	2.6%	2.1%	1.8%	2.8%	2.1%	1.9%	2.9%	2.3%	2.3%
		1-min Ramp Capability (%CAP)	26.0%	23.5%	18.4%	23.5%	49.9%	31.6%	22.8%	50.8%	40.2%
		10-min Ramp Capability (%CAP)	48.8%	57.4%	53.8%	40.8%	72.0%	68.4%	38.3%	65.6%	63.3%
4	Operational Flexibility and Frequency Support	Inertia (s)	2.19	6.09	4.29	2.07	2.14	3.69	1.85	1.77	2.67
		Inertial Gap FFR (%CAP)	11.1%	30.8%	12.5%	12.8%	0.0%	5.7%	13.4%	0.0%	0.0%
		Primary Gap PFR (%CAP)	19.4%	43.2%	26.7%	18.6%	0.0%	19.7%	18.3%	0.0%	1.3%
5	VAR Support	VAR Capability (%CAP)	63.9%	80.7%	42.9%	66.6%	51.9%	47.1%	67.3%	60.3%	60.4%
6	Location	Average Number of Evacuation Paths	5	2.5	N/A	4.6	4.7	4.7	4.8	5.6	5.1
7	Predictability and Firmness	Ramping Capability to Mitigate Forecast Errors (+Excess/-Deficit) (%VER MW)	-14.3%	3.9%	-21.7%	-14.6%	5.5%	5.5%	-14.7%	9.2%	8.8%
8	Short Circuit Strength	Required Additional Synch Condensers (%Peak Load)	35%	3%	0%	45%	34%	3%	47%	42%	26%

VER: Variable Energy Resources (e.g., solar, wind)
CAP: Capacity credit of all resources including existing, planned, and portfolio

SCORING CRITERIA THRESHOLDS

Preliminary

	Year 2030		1 (Pass)	1/2 (Caution)	0 (Potential Issue)	Rationale
1	**Blackstart**	Qualitative assessment of risk of not starting	>50%	25-50%	<25%	System requires real and reactive power sources with sufficient rating to start other resources. Higher rated resources lower the risk
2	**Energy Adequacy**	Energy Not Served when Islanded (Worst 1-week) %	<70%	70-85%	>85%	Ability of Resource to serve critical and essential part load for 1 week, estimated at 15% of total load. Adding other important load brings the total to 30%
3	**Dispatchability**	Dispatchable (VER Penetration %)	<50%	50-60%	>60%	Intermittent Power Penetration above 60% is problematic when islanded
		Increased Freq Regulation Requirements	<2% of peak load	2-3% of Peak Load	>3% of peak load	Regulation of Conventional Systems ≈1%
		1-min Ramp Capability	>15% of CAP	10-15% of CAP	<10% of CAP	10% per minute was the norm for conventional systems. Renewable portfolios require more ramping capability
		10-min Ramp Capability	>65% of CAP	50-65% of CAP	<50% of CAP	10% per minute was the norm for conventional systems. But with 50% min loading, that will be 50% in 10 min. Renewable portfolios require more ramping capability
4	**Operational Flexibility and Frequency Support**	Inertia (seconds)	>3xMVA rating	2-3xMVA rating	<2xMVA rating	Synchronous machine has inertia of 2-5xMVA rating.
		Inertial Gap FFR (assuming storage systems will have GFM inverters)	0	0-10% of CAP	>10% of CAP	System should have enough inertial response, so gap should be 0. Inertial response of synch machine ≈ 10% of CAP
		Primary Gap PFR MW	0	0 - 2% of CAP	2% of CAP	System should have enough primary response, so gap should be 0. Primary response of synch machine ≈ 3.3%of CAP/0.1Hz (Droop 5%)
5	**VAR Support**	VAR Capability	≥41% of ICAP	31-41% of ICAP	<31% of ICAP	Power factor higher than 95% (or VAR less than 31%) not acceptable. Less than 0.91 (or VAR greater than 41.5%) is good
6	**Location**	Average Number of Evacuation Paths	>3	2-3	<2	More power evacuation paths increases system resilience
7	**Predictability and Firmness**	Ramping Capability to Mitigate Forecast Errors (+Excess/-Deficit) MW	≥ 0	-10% - 0% of CAP	<-10% of CAP	Excess ramping capability to offset higher levels of intermittent resource output variability is desired
8	**Short Circuit Strength**	Required Additional Synch Condensers MVA	<5%	0-10% of CAP	>10% of CAP	Portfolio should not require additional synchronous condensers

PORTFOLIO RELIABILITY RANKING

Preliminary

	Year 2030		A	B	C	D	E	F	G	H	I
1	Blackstart	Qualitative assessment of risk of not starting	½	0	1	½	½	1	½	½	1
2	Energy Adequacy	Energy not served when islanded	½	½	1	½	½	1	½	½	1
3	Dispatchability	Dispatchable %	½	1	1	0	1	1	0	1	1
		Increased Freq Regulation Requirements	½	½	1	½	½	1	½	½	½
		1-min Ramp Capability	1	1	1	1	1	1	1	1	1
		10-Min Ramp Capability	0	½	½	0	1	1	0	1	½
4	Operational Flexibility and Frequency Support	Inertia	½	1	1	½	½	1	0	0	½
		Inertial Gap FFR	0	0	0	0	1	½	0	1	1
		Primary Gap PFR	0	0	0	0	1	0	0	1	½
5	VAR Support	VAR Capability	1	1	1	1	1	1	1	1	1
6	Location	Average Number of Evacuation Paths	1	½	1	1	1	1	1	1	1
7	Predictability and Firmness	Ramping Capability to Mitigate Forecast Errors (+Excess/-Deficit)	0	1	0	0	1	1	0	1	1
8	Short Circuit Strength	Required Additional Synch Condenser	0	1	1	0	0	1	0	0	0

		A	B	C	D	E	F	G	H	I
1	Blackstart	0.50	-	1.00	0.50	0.50	1.00	0.50	0.50	1.00
2	Energy Adequacy	0.50	0.50	1.00	0.50	0.50	1.00	0.50	0.50	1.00
3	Dispatchability	0.50	0.75	0.88	0.38	0.88	1.00	0.38	0.88	0.75
4	Operational Flexibility and Frequency Support	0.17	0.33	0.33	0.17	0.83	0.50	-	0.67	0.67
5	VAR Support	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	Location	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	Predictability and Firmness	-	1.00	-	-	1.00	1.00	-	1.00	1.00
8	Short Circuit Strength	-	1.00	1.00	-	-	1.00	-	-	-
	Cumulative Score	3.67	5.08	6.21	3.55	5.71	7.50	3.38	5.55	6.42
	Percent Score (out of 8 possible points)	46%	64%	78%	44%	71%	94%	42%	69%	80%

1	Portfolio passes the screening test
½	Portfolio requires minor to moderate mitigation measures
0	Portfolio requires significant mitigation measures

1. Every metric is scored based on the criteria in the legend at the top of the page

2. Then, for criteria where there is more than one metric, the scores are averaged to create a single score for each criteria

3. All criteria scores are added to get a final portfolio score out of 8 possible points

PORTFOLIO RELIABILITY RANKINGS

	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Duration)
Higher Carbon Emissions	A (7) NIPSCO DER 10MW SC Uprate 53MW Thermal PPA 150MW Storage 135MW Solar+Storage 450MW* Solar 250MW	B (6) NIPSCO DER 10MW SC Uprate 53MW Gas Peaker** 443MW Thermal PPA 150MW Solar 250MW	C (3) NIPSCO DER 10MW SC Uprate 53MW Gas CC 650MW
Mid Carbon Emissions	D (8) NIPSCO DER 10MW SC Uprate 53MW Storage 135MW Solar+Storage 450MW* Solar 400MW	E (4) NIPSCO DER 10MW SC Uprate 53MW Thermal PPA 150MW Storage 470MW Solar 250MW	F (1) NIPSCO DER 10MW SC Uprate 53MW Gas Peaker** 300MW Thermal PPA 150MW Storage 135MW Solar 100MW
Low Carbon Emissions	G (9) NIPSCO DER 10MW Storage 135MW Solar+Storage 450MW* Solar 450MW	H (5) NIPSCO DER 10MW Wind 200MW Storage 570MW Solar 250MW	I (2) NIPSCO DER 10MW SC H2 Electrolyzer 20MW SC Uprate 53MW H2 Enabled Peaker 193MW Wind 200MW Storage 370MW Solar 250MW

**Gas Peaker: Local to Service Territory in Portfolio F, while outside of territory in Portfolio B

RELIABILITY ASSESSMENT RESULTS WILL BE INCORPORATED INTO THE REPLACEMENT SCORECARD

	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Duration)
Higher Carbon Emissions	A 7 NIPSCO DER 10MW SC Uprate 53MW Thermal PPA 150MW Storage 135MW Solar+Storage 450MW* Solar 250MW	B 6 NIPSCO DER 10MW SC Uprate 53MW Gas Peaker** 443MW Thermal PPA 150MW Solar 250MW	C 3 NIPSCO DER 10MW SC Uprate 53MW Gas CC 650MW
Mid Carbon Emissions	D 8 NIPSCO DER 10MW SC Uprate 53MW Storage 135MW Solar+Storage 450MW* Solar 400MW	E 4 NIPSCO DER 10MW SC Uprate 53MW Thermal PPA 150MW Storage 470MW Solar 250MW	F 1 NIPSCO DER 10MW SC Uprate 53MW Gas Peaker** 300MW Thermal PPA 150MW Storage 135MW Solar 100MW
Low Carbon Emissions	G 9 NIPSCO DER 10MW Storage 135MW Solar+Storage 450MW* Solar 450MW	H 5 NIPSCO DER 10MW Wind 200MW Storage 570MW Solar 250MW	I 2 NIPSCO DER 10MW SC H2 Electrolyzer 20MW SC Uprate 53MW H2 Enabled Peaker 193MW Wind 200MW Storage 370MW Solar 250MW

**Gas Peaker: Local to Service Territory in Portfolio F, while outside of territory in Portfolio B

Preliminary	A	B	C	D	E	F	G	H	I
Replacement Theme	Thermal PPAs, solar and storage	Non-service territory gas peaking (no early storage)	Natural gas dominant (CC)	No new thermal resources; solar dominant w/ storage	Thermal PPAs plus storage and solar	Local gas peaker, plus solar and storage	Solar dominant w/ storage, plus retire Sugar Creek	All renewables and storage, plus retire Sugar Creek (Portfolio 7)	New H2-enabled peaker plus solar and storage, plus SC conversion to H2 (Portfolio 7H)
Carbon Emissions	Higher	Higher	Higher	Mid	Mid	Mid	Low	Low	Low
Dispatchability	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Energy Duration)	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Energy Duration)	Current Planning Reserve Margin	Winter & Summer Reserve Margin	Enhanced Reserve Margin (Local w/ Higher Energy Duration)
Cost To Customer 30-year NPV of revenue requirement (Ref Case) $M	$10,461 +$150	$10,332 +$21	$10,312 -	$10,438 +$126	$10,467 +$156	$10,426 +$115	$11,042 +$730	$11,090 +$778	$10,792 +$480
Cost Certainty Scenario Range (NPVRR) $M	$2,359 +$1,035	$2,782 +$1,458	$3,208 +1,885	$2,322 +$998	$2,538 +$1,215	$2,748 +$1,424	$1,324 -	$1,553 +$229	$1,855 +$531
Cost Risk Highest Scenario NPVRR $M	$12,015 +$207	$12,182 +$373	$12,518 +$709	$11,965 +$156	$12,126 +$317	$12,243 +$434	$11,809 -	$12,011 +$202	$11,848 +$39
Cost Risk Stochastic 95% CVAR – 50%	$104 +$21	$92 +$9	$83 -	$104 +$21	$98 +$15	$97 +$14	$123 +$40	$114 +$31	$87 +$4
Lower Cost Opp. Lowest Scenario NPVRR $M	$9,657 +$347	$9,400 +$91	$9,309 -	$9,644 +$334	$9,588 +$278	$9,495 +$186	$10,485 +$1,176	$10,458 +$1,149	$9,933 +$684
Carbon Emissions M of tons 2024-40 Cum. (Scenario Avg.)	27.3 +11.3	30.4 +14.4	47.2 +31.2	27.3 +11.3	27.3 +11.3	28.5 +12.4	16.1 -	16.1 -	25.2 +9.2
Reliability	*To be added in final scorecard*								
Resource Optionality MW-weighted duration of 2027 generation commitments (yrs.)	[illegible] +3.0	[illegible] +3.5	[illegible] +6.6	[illegible] +3.4	[illegible] +4.2	[illegible] +5.1	[illegible] -	[illegible] +1.2	[illegible] +4.5
Local Economy NPV of property taxes	$420 -$66	$388 -$98	$451 -$35	$417 -$69	$413 -$73	$416 -$70	$486 -	$477 -$9	$421 -$65

NEXT STEPS

Alison Becker, Manager Regulatory Policy, NIPSCO

NEXT STEPS

Scorecard Integration

- The scores from the reliability assessment will be integrated as a metric in the Replacement Analysis Scorecard

Seeking Feedback

- Seeking feedback regarding the assessment results presented today
- Reach out to Alison Becker (abecker@nisource.com) for 1x1 meetings

Final Stakeholder Meeting

- Final Public Stakeholder Advisory Meeting #5 is scheduled for **October 21st**

APPENDIX

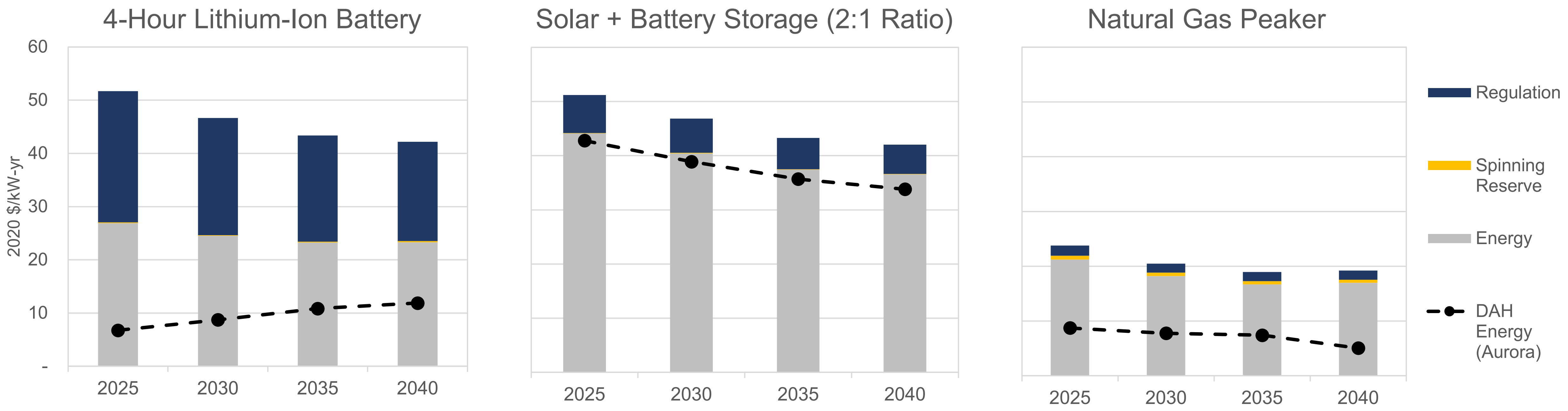
GLOSSARY

Acronym	Definition
A/S	Ancillary Services
ACE	Area Control Error
AER	Aggressive Environmental Regulation Scenario
AGC	Automatic Generation Control
BESS	Battery Energy Storage System
CRA	Charles River Associates
DER	Distributed Energy Resource
ELCC	Effective Load Carrying Capability
ESOP	Energy Storage Operations
EWD	Economy-Wide Decarbonization Scenario
FERC	Federal Energy Regulatory Commission
GFM	Grid Forming Inverters
IBR	Inverter-Based Resources
IRP	Integrated Resource Plan
MISO	Midcontinent Independent System Operator
MVA	Million Volt-Amps
NERC	North American Electric Reliability Corporation
NIPSCO	Northern Indiana Public Service Company
POI	Point of Interconnection
PPA	Purchase Power Agreement

Acronym	Definition
REF	Reference Case Scenario
RoCoF	Rate of Change of Frequency
SC	Sugar Creek
SQE	Status Quo Extended Scenario
TO	Transmission Owner
TOP	Transmission Operator
VAR	Volt-Ampere Reactive
VOM	Volt-Ohm-Meter

SUB-HOURLY ANALYSIS INDICATES POTENTIAL UPSIDE FOR STORAGE ASSETS

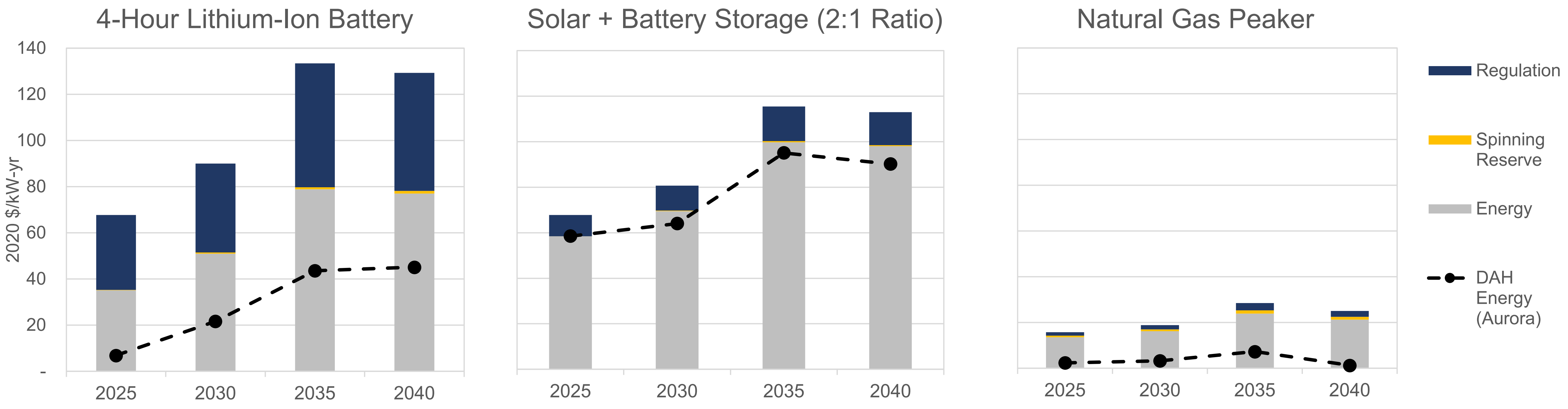
Status Quo Extended



- Lower overall power prices reduce margin expectations for all technologies, although premium between day ahead Aurora-based value and sub-hourly / ancillary services impact is comparable for solar + storage and gas peaker options
- Upside for stand-alone storage is mitigated over time as energy arbitrage opportunities are less valuable

SUB-HOURLY ANALYSIS INDICATES POTENTIAL UPSIDE FOR STORAGE ASSETS

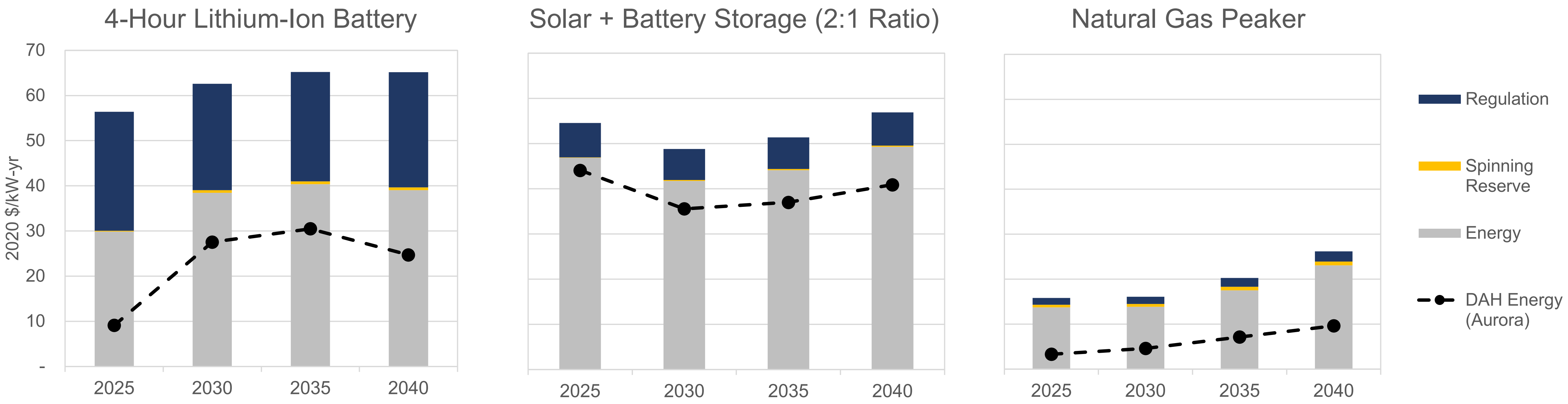
Aggressive Environmental Regulation



- Higher overall power prices increase margin opportunities, particularly for storage resources, which have significant upside potential with greater energy price spreads and higher ancillary services prices
- Natural gas peaker upside is more limited, given high carbon price and high natural gas price embedded in this scenario

SUB-HOURLY ANALYSIS INDICATES POTENTIAL UPSIDE FOR STORAGE ASSETS

Economy-Wide Decarbonization



- Prices in the EWD scenario are lower than the Reference Case, but renewable penetration is high, resulting in sustained upside opportunities for battery resources

FREQUENCY RESPONSE AND SIMPLIFIED MODEL

QUANTA TECHNOLOGY

- **Inertial Response**
  - $\frac{2H}{f_0}\frac{df}{dt} = \Delta P$
  - ΔP = Loss of power resources due to contingency event

    \+ Variability of intermittent resources solar+wind resources at 1s

    \- Virtual inertial contribution from online solar+wind resources

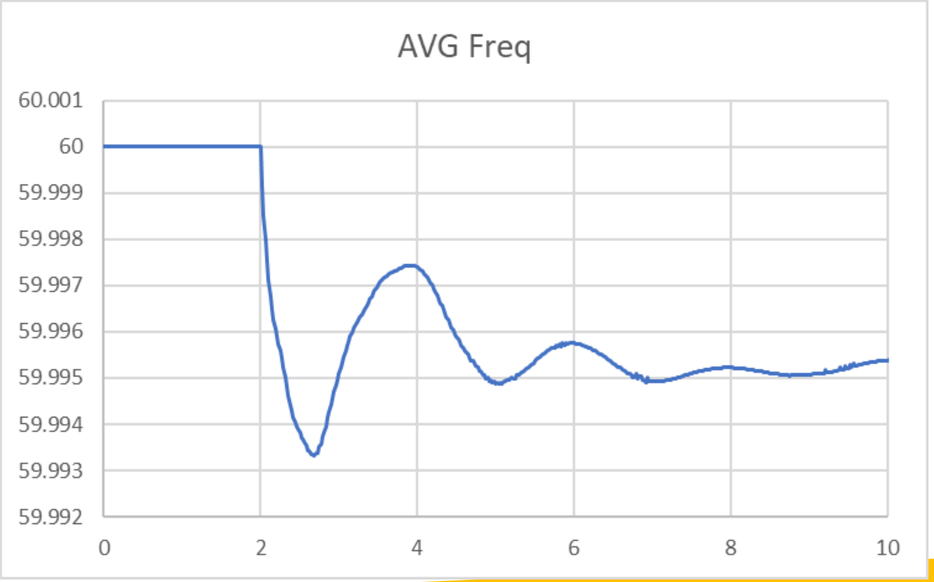
    \- Virtual inertial contribution from battery energy storage

    \- Inertial response contribution from outside areas over tie-lines

  - Inertia to limit RoCoF: H= ΔP/(2 x RoCoF Limit) f_0
  - Inertia to avoid triggering UFLS before the responsive reserves load: H=ΔP/(2 x UFLS speed) f_0 ;

    where UFLS speed = (pickup frequency – trip frequency)/delay

- **Primary Freq Response**
  - Δf(pu)= - (R .ΔP)/(D.R+1)
  - Where:
    - R is governor droop,
    - D is load damping,
    - ΔP is system disturbance, and all are in per unit using the same MW base value, such as system load level

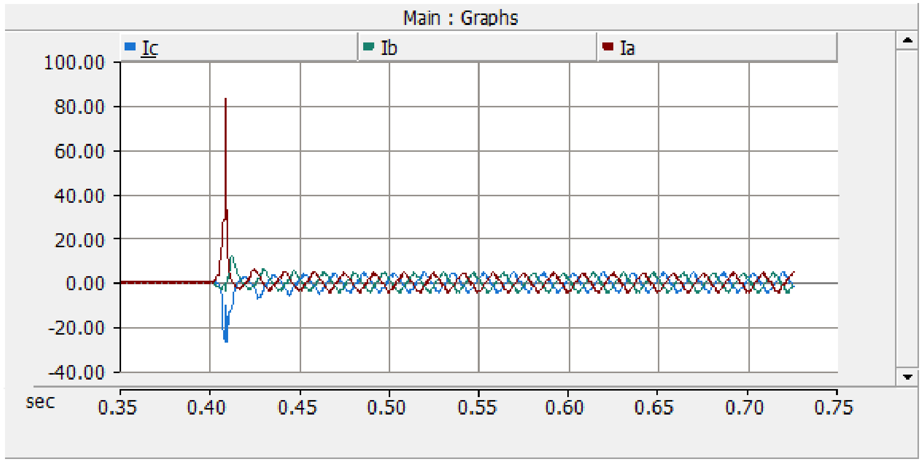


APPENDIX: MODELING THE PORTFOLIOS

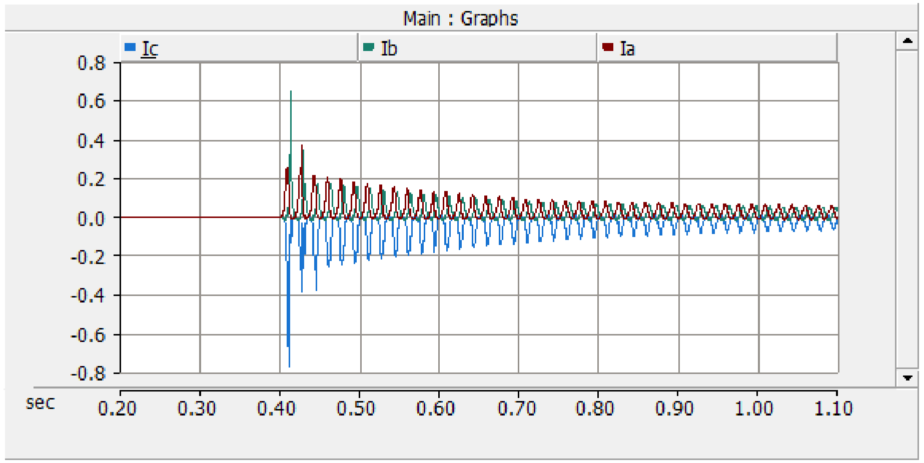
i. Energy Adequacy Analysis (Islanded Operation)
ii. Dispatchability
iii. Flexibility: Inertial Response
   Flexibility: Primary Frequency Response
iv. VAR Support
v. Predictability of Supply
vi. Short Circuit Strength
vii. Black Start
viii. Locational Attributes

INRUSH CURRENTS

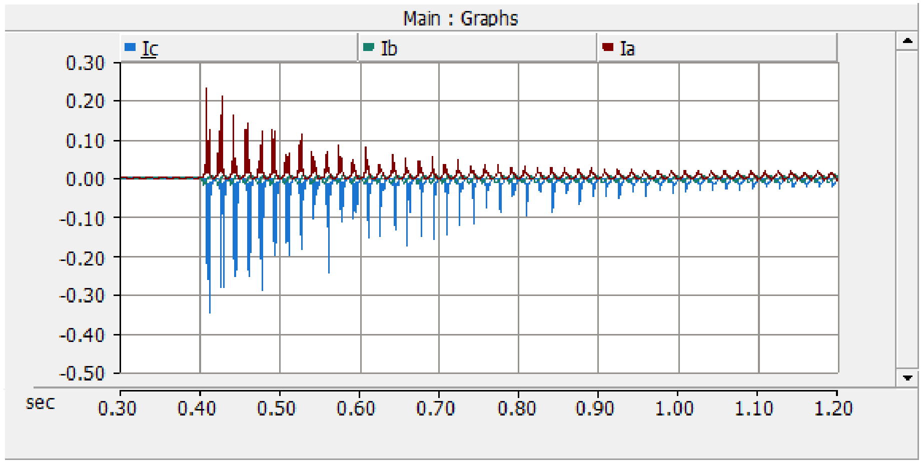
Step1: 0.4kV34.5kV XFO energization (0.4kV side)



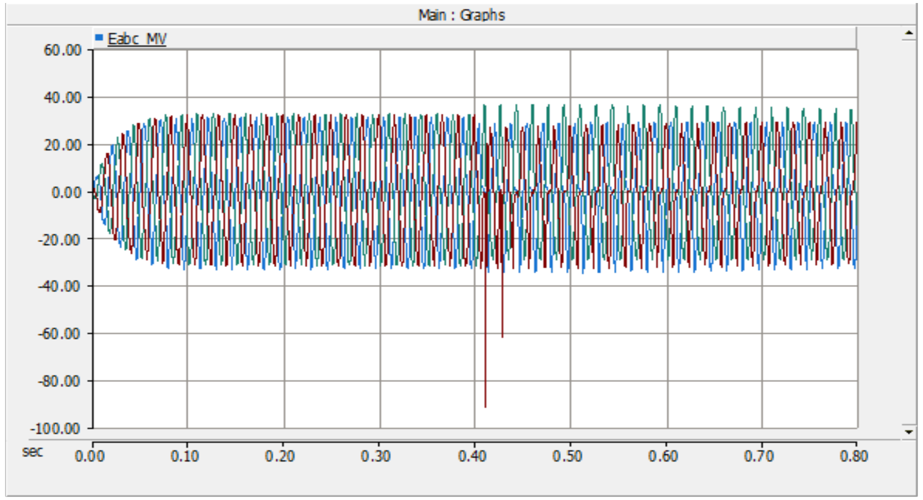
Step2 : 34.5kV/138kV XFO energization (34.5kV side)



Step3 : 138kV/22kV XFO energization (138kV side)

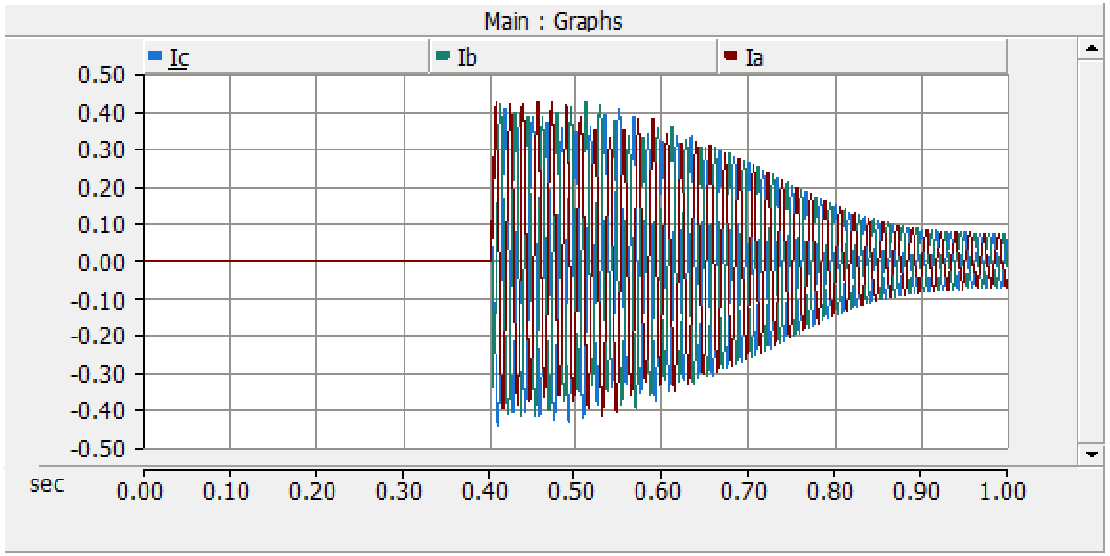


34.5kV Voltage side (TOV)

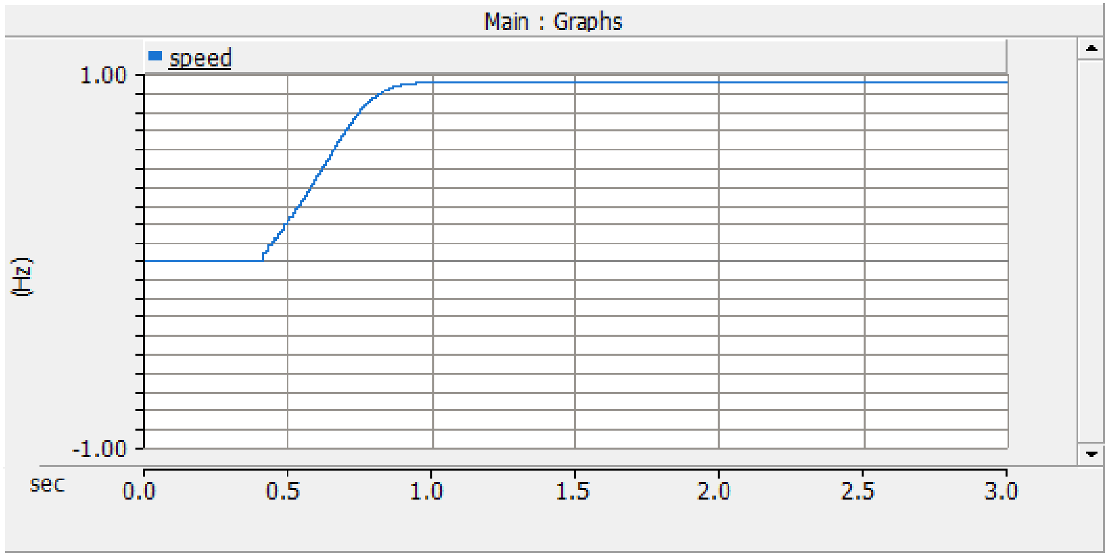


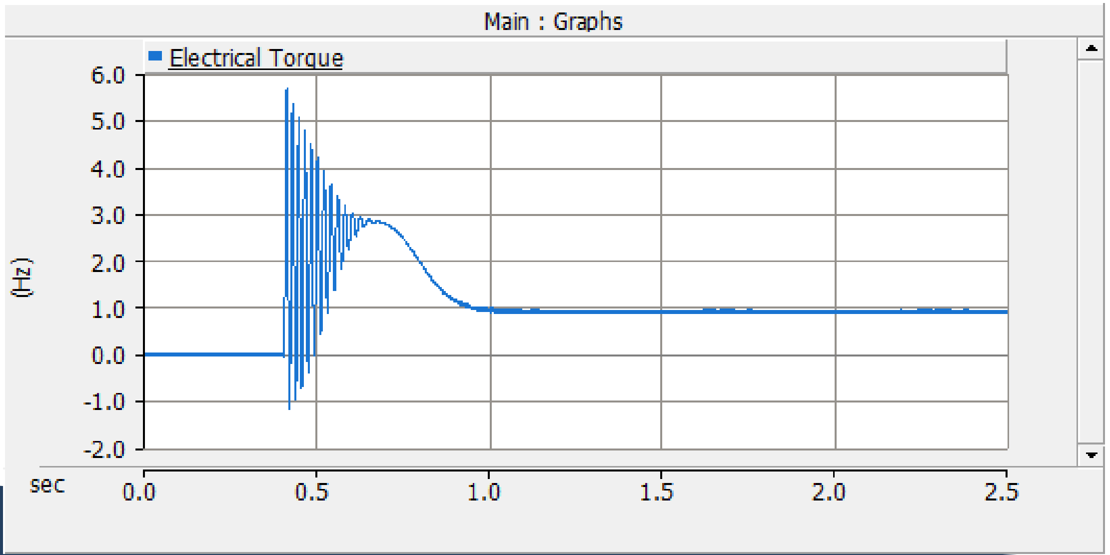
INDUCTION MOTOR (PONY)

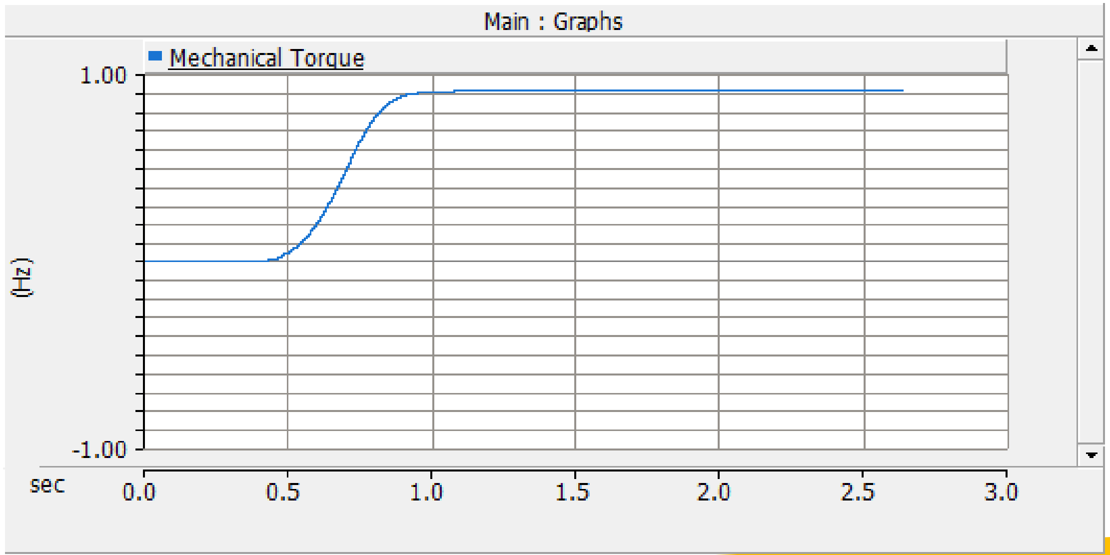
Step4 : Induction motor Inrush Current at 22kV (breaker closing)



Mechanical Speed

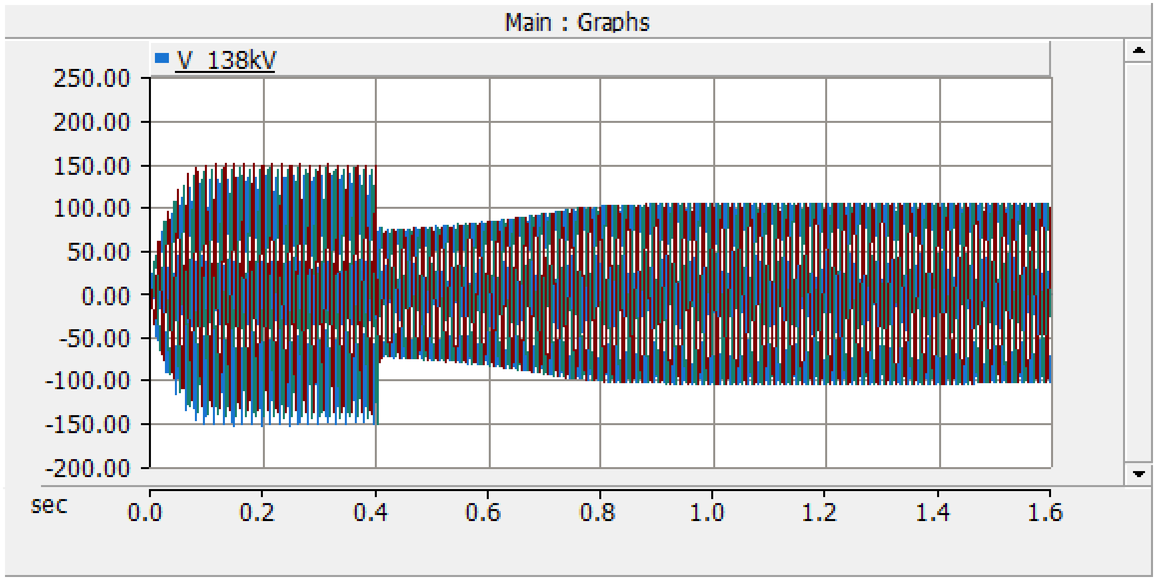






CHECK BATTERY RATINGS

- Upon closing the breaker between the battery and the 0.4/34.5k 150MVA transformer, the inrush current is around 80kA on the 0.4kV side which translate to a rating of 55MVArs from the inverters. This level of inrush current is within the capability of the system. Note that the inrush current will depend on the breaker closing time and strategy.
- The rating implications of energizing the 34.5/138kV transformer, the 18mile 138kV line, and the 138/22kV step down transformer is less, and are acceptable too.
- The motors started. There is a voltage drop on the 138kV bus.



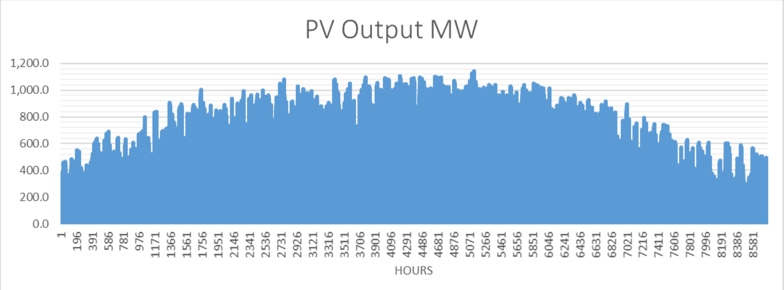
QUANTA TECHNOLOGY

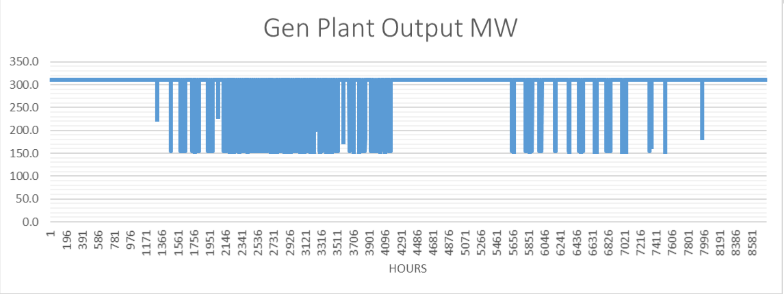
ENERGY ADEQUACY – ISLANDED OPERATION

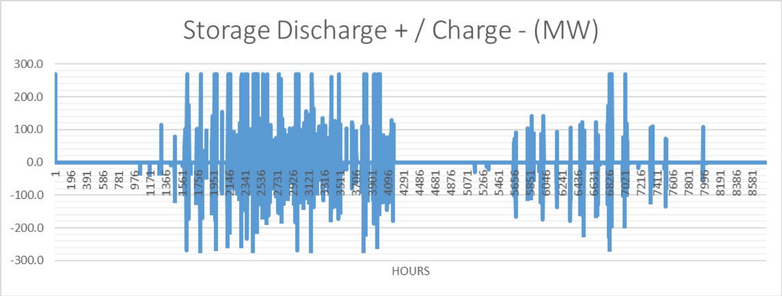
Portfolio	Solar PV MW	Wind MW	Energy Storage MW	Thermal Gen MW	Hyrdo	IBR %	Energy Not Served (GWh/Yr)	Energy Not Served 1-Yr (%)	ENS Worst 1-Week (%)	ENS Worst 1-hr (%)	Storage Avg Cycles/Day	Renewable Curtailment %
A	1,650	405	420	0	10	100%	6,079	54.8%	76.2%	99.0%	0.16	0.4%
B	1,350	405	135	0	10	99%	6,717	60.6%	78.5%	99.0%	0.06	0.2%
C	1,100	405	135	650	10	71%	2,054	18.5%	32.1%	63.2%	0.49	1.7%
D	1,800	405	420	0	10	100%	5,793	52.3%	75.0%	99.0%	0.26	1.3%
E	1,350	405	605	0	10	100%	6,711	60.5%	78.5%	99.0%	0.02	0.0%
F	1,200	405	270	300	10	86%	4,499	40.6%	55.9%	91.4%	0.11	0.2%
G	1,850	405	420	0	10	100%	5,705	51.5%	74.6%	99.0%	0.29	1.7%
H	1,350	605	705	0	10	100%	6,071	54.8%	73.4%	98.8%	0.04	0.0%
I	1,350	605	505	193	10	92%	4,476	40.4%	58.1%	88.1%	0.41	0.1%

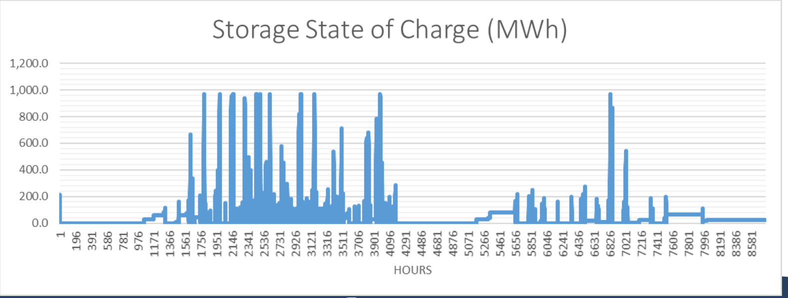
- The analysis is simulating resources (ICAP) inside the service territory (islanded operation). For additional context, the NIPSCO system has never been islanded. This analysis is testing a Black Swan event.
- The analysis simulates each portfolio in the year 2030 from an energy adequacy perspective when NIPSCO is operating in an islanded mode under emergency conditions and assesses its ability to meet the demand requirements across all 8760 hours of the year. The outcome of the simulations is the energy not served (GWh) if the system operates in islanded mode for 1 year, the worst energy not served if the islanded mode lasts for 1 week, and for 1 hour. Additional results are the average daily utilization of energy storage assets (cycles/day) and the level of renewable curtailment.
- The portfolios can be ranked as to their ability to serve the load as follows: C, I, F, G, D, H, A, E, B
- Note: All the resources in each portfolio in addition to all other existing and planned resources are assumed to continue serving NIPSCO load.

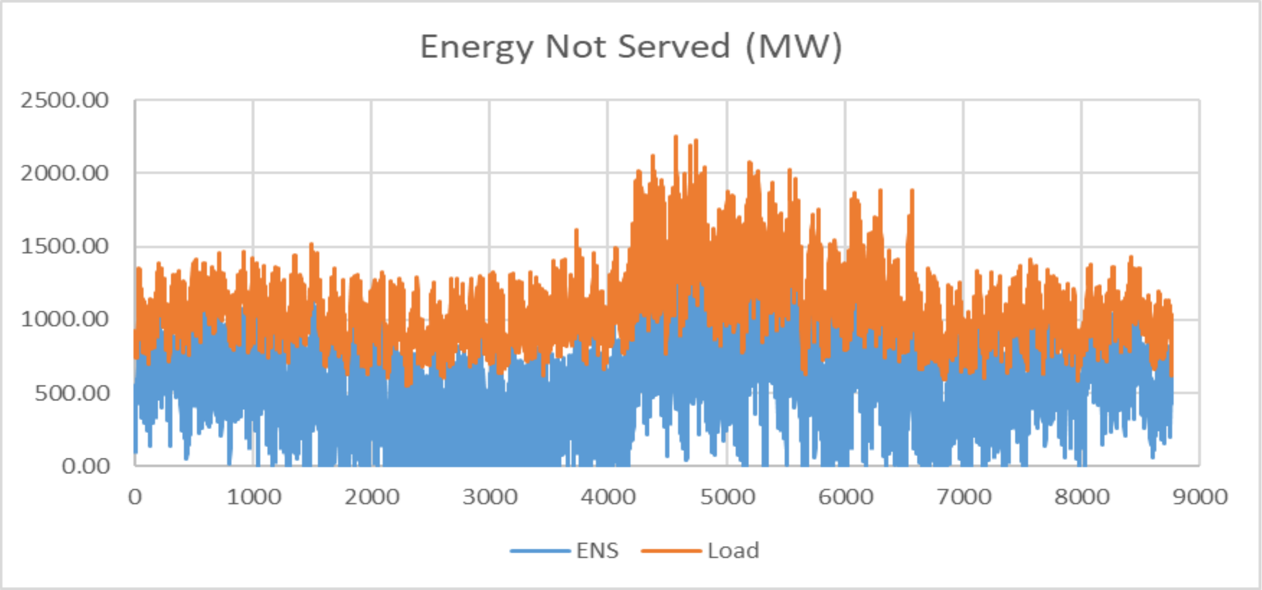
REPRESENTATIVE SIMULATION RESULTS – PORTFOLIO F











- The graph shows the hourly load profile and the energy-not-served (ENS) at each hour of the year 2030.
- The simulation dispatched the peaker plant and the energy storage assets against the net native load after deducting solar and wind outputs. Solar curtailment was enforced during periods when the storage was fully charged and the plant was at minimum output level.
- The peaker plant was assumed fully flexible (no ramp limits), but with a Pmin of 50% of its rating.
- The energy storage systems were assumed to have 4 hours of capacity, and round-trip-efficiency of 85%.

DISPATCHABILITY

Portfolio	Additional Installed Capacity (MWs) Total	Dispatchable	Non-Dispatchable	%Dispatchable	Renewable Penetration % Y2030
A	1,048	488	560	47%	53%
B	906	646	260	71%	48%
C	713	703	10	99%	43%
D	1,048	338	710	32%	56%
E	933	673	260	72%	48%
F	748	638	110	85%	45%
G	1,045	285	760	27%	57%
H	1,030	570	460	55%	53%
I	1,076	616	460	57%	53%

- Portfolios ranked by highest % of dispatchable resources: C, F, E, B, I, H, A, D, G
- Without additional resources, the renewable penetration from planned resources will reach 43% by 2030. However, adding one of the IRP portfolios will increase the penetration by as much as 14%.

INCREASE IN REGULATION REQUIREMENTS & POWER RAMPING CAPABILITY

QUANTA TECHNOLOGY

Portfolio	Increase in Freq Regulation Requirements (MW)
A	60
B	47
C	40
D	64
E	47
F	43
G	66
H	53
I	53

- The short-term intermittency of solar and wind resources increases the need for frequency regulation. This analysis quantifies the increased level of regulation services.

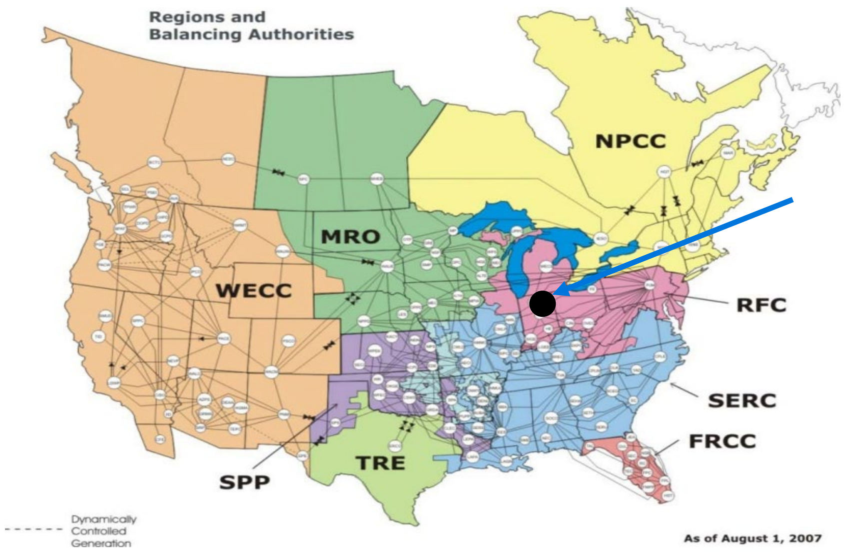
Y 2030

Portfolio	1-min Ramp Capability (MW)	10-min Ramp Capability (MW)
A	346	649
B	211	514
C	261	764
D	331	574
E	681	984
F	397	859
G	326	548
H	761	983
I	599	944

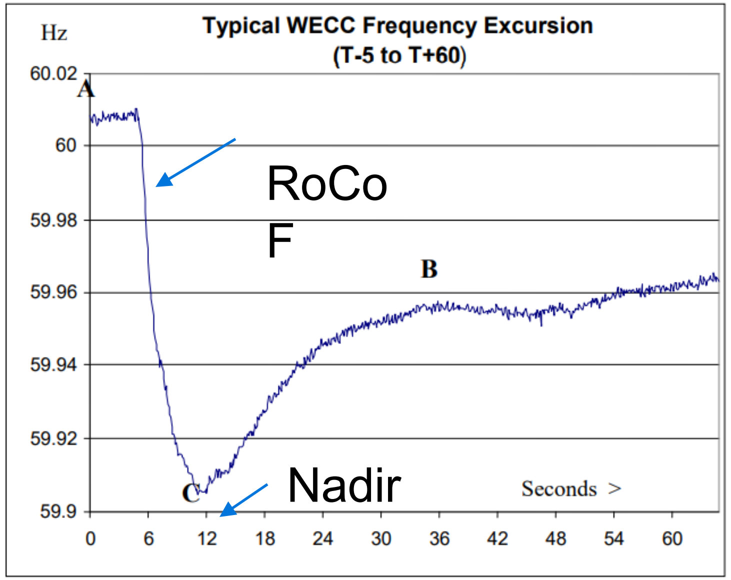
- The ramping capability of the system is measured at 1-min and 10-mins. The higher the ramping capability the better flexibility the system will have to respond to sudden disturbance.

FREQUENCY CONTROL - OVERVIEW

- NIPSCO operates a balancing control area, within the MISO balancing control area within the Eastern Interconnection.
- Dispatchers at each Balancing Authority fulfill their NERC obligations by monitoring ACE and keeping the value within limits that are generally proportional to Balancing Authority size.
- Generators contribute to the frequency response through Governors while loads contribute through their natural sensitivity to frequency. Frequency Response is measured as change in MW per 0.1Hz change in frequency. Governor's droop of 5% translates to a response of 3.3% while load response is typically 1-2%. Frequency Response is particularly important during disturbances and islanding situations. Per BAL-003, each balancing area should carry a frequency bias, whose monthly average is no less than 1% of peak load.
- Following the loss of a large generator, frequency drops initially at a rate (RoCoF) that depends on the level of inertia in the system. After few seconds, it will stabilize at a lower value (Nadir) due to the primary frequency response of generators and loads. Afterwards, AGC systems will inject regulation reserves that raise the frequency to within a settling range within a minute. Tertiary reserves are called upon if required to help.



Control	Ancillary Service/IOS	Timeframe	NERC Standard
Primary Control	Frequency Response	10-60 Seconds	FRS-CPS1
Secondary Control	Regulation	1-10 Minutes	CPS1– CPS2 – DCS - BAAL
Tertiary Control	Imbalance/Reserves	10 Minutes - Hours	BAAL - DCS
Time Control	Time Error Correction	Hours	TEC



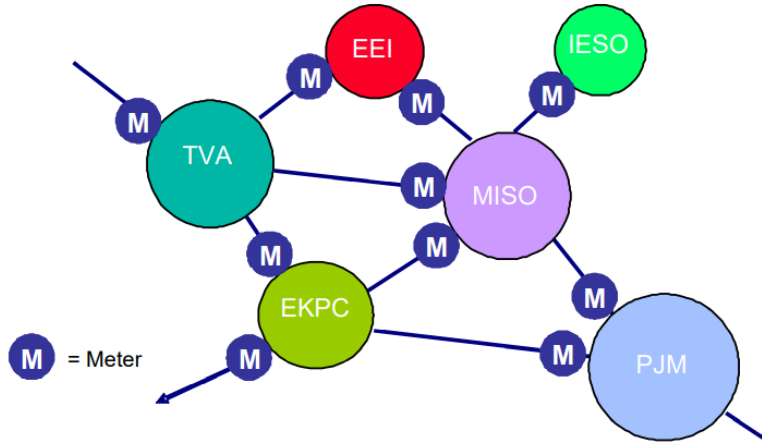
MODELING OVERVIEW

- The NIPSCO system is connected to neighboring utilities through 69-765kV lines with a total line ratings of 28GW. The simultaneous import capability is estimated at 2,650MW while the export capability is estimated at 2,350MW.

- Most of the conventional generation capacity within NIPSCO system is planned for retirement and thus the system inertia is expected to decline.

Portfolio	2021		2025		2030	
	Summer Rating MW	Inertia MVA-s	Summer Rating MW	Inertia MVA-s	Summer Rating MW	Inertia MVA-s
A	1,830	8,027	1,120	5,431	598	3,200
B	1,830	8,027	1,120	5,431	1,041	6,004
C	1,830	8,027	1,170	5,701	1,248	6,711
D	1,830	8,027	1,120	5,431	598	3,200
E	1,830	6,845	1,120	5,002	598	3,218
F	1,830	8,027	1,120	5,431	898	5,099
G	1,830	8,027	1,120	5,431	545	2,914
H	1,830	8,027	1,120	5,431	545	2,914
I	1,830	8,027	1,313	6,627	791	4,379

- The NIPSCO system will be assessed during normal operation when it is connected to the MISO system, and also under abnormal operation when it is isolated.



Sum of Tie Line Ratings	RTO	69	138	345	765	Total
Ameren Illinois	MISO		245			245
American Electric Power	PJM	94	927	12,819	2,669	16,509
Commonwealth Edison	PJM		766	7,967		8,733
Duke Energy Indiana	MISO	44	430	2,106		2,580
Michigan Electrical	MISO		215			215
Total MVA		**138**	**2,583**	**22,892**	**2,669**	**28,282**

INERTIAL RESPONSE (ROCOF)

Event	Loss of 420MW Gen									
Renewable Variability	Yes					No				
NIPSCO	Islanded					Connected				
Scenario	1	2	3	4	**5**	6	7	**8**	**9**	10

Summer Peak Hour
7/21 3PM

Load 100%; PV 81%; Wind 7%

Spring Noon
April 11-1PM

Load 53%; PV 63%%;Wind 42%

Fall Early Afternoon
10/18 1PM

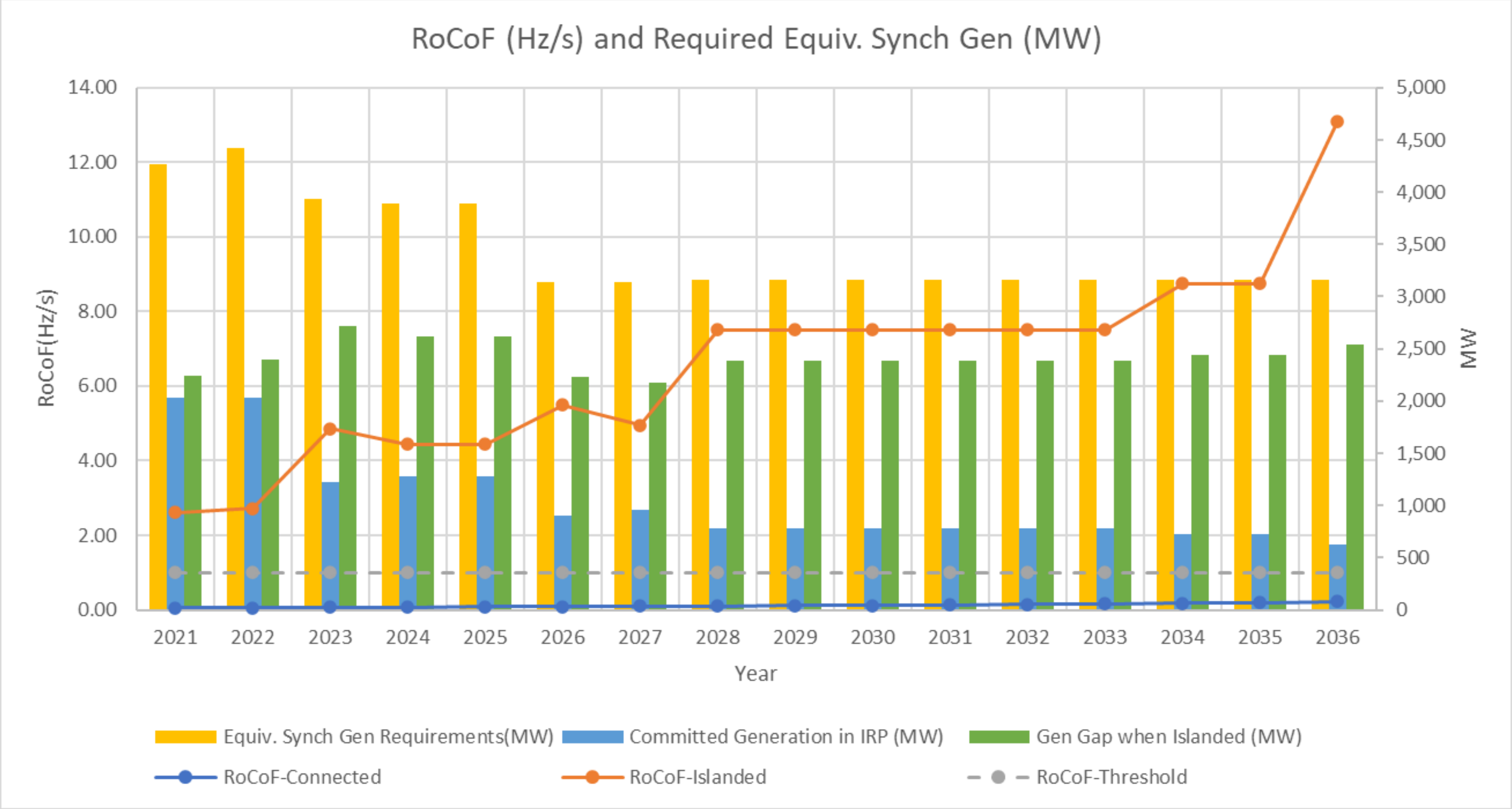
Load 50%; PV 63%%; Wind 7%

Assumptions:

- No storage systems in the IRP are fitted with grid-forming inverters capable of inertial response.
- Wind can provide inertial response level of 11% of their nameplate rating.
- IBR adoption in the rest of MISO starts at 20% in 2021 and increases by 2.5% each year reaching 42.5% in 2030.
- Tie-line import capability limit connecting NIPS area of 2650 MW.
- Solar and OSW variability (1-second) of 5% of nameplate rating.

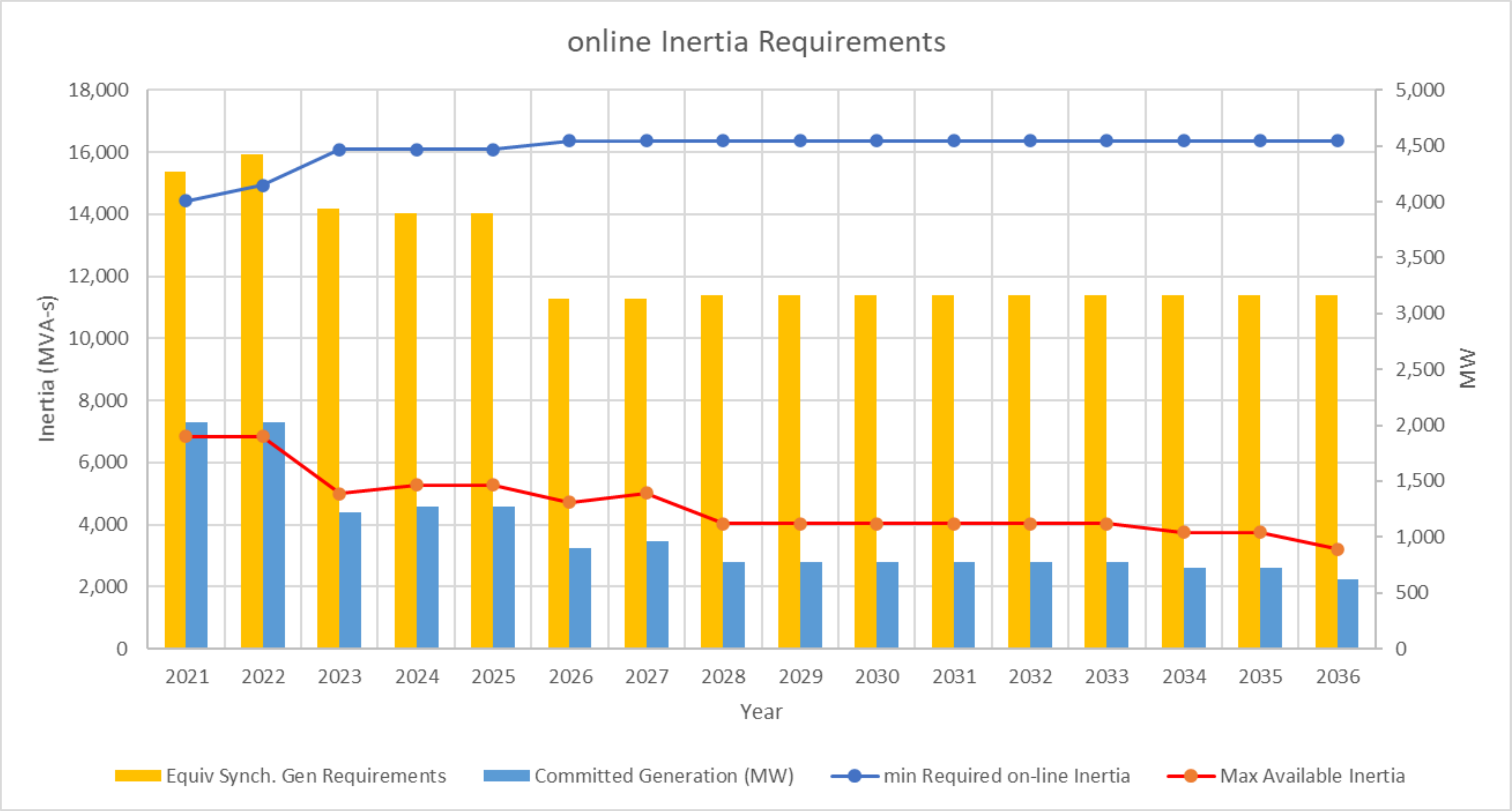
INERTIAL RESPONSE

- Using Portfolio E, the system inertial response was simulated during normal conditions when NIPSCO is connected to MISO and also during emergency conditions when it is islanded. The simulation is conducted assuming all available synchronous generation is committed.



- During normal operations when NIPSCO is connected to MISO system, RoCoF starts in 2021 at a small value of 0.05Hz/s and increases to 0.12Hz/s by 2030 and 0.38Hz/s by 2040. This increase is due to retirements of synchronous generation within NIPSCO system and also within MISO. However, it remains acceptable below 1.0Hz/s.
- When Islanded, RoCoF exceeds the acceptable threshold starting at 2.6Hz/s in 2021 and reaching 7.5Hz/s by 2028.

INERTIAL RESPONSE



- An equivalent inertia of 16,000MVA-s is required to be on-line to maintain RoCoF within 1Hz/s. This can be accomplished by either committing additional synchronous generation or synchronous condensers equipped with fly wheels reaching 2,383 MW or equipping energy storage with grid forming inverters capable of delivering a combined inertial response of 411MW.

INERTIAL RESPONSE –PORTFOLIO RANKING

Portfolio	On-Line Gen MVA (Y2021)	On-Line Gen MVA (Y2030)	On-Line Inertia MVA-s (Y2021)	On-Line Inertia MVA-s (Y2030)	Energy Storage MW (Y2030)	Fast Frequency Response (MW)	RoCoF Limit Hz/s
A	2,236	945	6,845	4,028	270	404	1.00
B	2,236	945	6,845	4,028	135	269	1.00
C	2,236	1,573	6,845	6,729	135	359	1.00
D	2,236	757	6,845	3,218	270	377	1.00
E	2,236	945	6,845	4,028	605	739	1.00
F	2,236	1,358	6,845	5,927	270	468	1.00
G	2,236	690	6,845	2,931	270	368	1.00
H	2,236	690	6,845	2,931	705	803	1.00
I	2,236	1,013	6,845	4,397	505	652	1.00

Normal System (Connected)

RoCoF Normal (Y2021)	RoCoF Normal (Y2030)	Gap Inertia (MVA-s)
0.04	0.08	0
0.04	0.08	0
0.04	0.07	0
0.04	0.08	0
0.05	0.12	0
0.04	0.08	0
0.04	0.08	0
0.04	0.08	0
0.04	0.08	0

Islanded System

RoCoF Islanded (Y2021)	RoCoF Islanded (Y2030)	Gap Inertia (MVA-s)	Required Mitigation BESS GFM[1] (MW)	Additional Required BESS GFM (MW)
2.61	7.61	16,568	418	148
2.61	7.51	16,361	411	276
2.61	3.04	16,093	312	177
2.61	13.45	16,729	450	180
2.61	7.51	16,361	411	0
2.61	3.71	16,200	342	72
2.61	18.33	16,783	462	192
2.61	17.61	16,211	443	0
2.61	6.22	16,211	394	0

[1]GFM : Battery Energy Storage equipped with Grid Forming Inverters

- The portfolios can be ranked based on the available fast frequency response capability within NIPSCO service territory: H, E, I, F, A, D, G, C, B
- All portfolios do not violate the inertial response threshold during normal interconnected operations
- During islanded operations:
  - Portfolios E, H, and I can meet the inertial threshold if 68%, 63%, and 78% of their storage is equipped with grid forming (GFM) inverters with inertial response functionality.
  - Other portfolios require additional storage in addition to equipping all their planned storage with GFIs.
- Ranking of Portfolios: I, E, H, F, A, C, D, G, B

PRIMARY FREQUENCY RESPONSE

Portfolio	Installed Generation MW (Y2021)	Installed Generation MW (Y2030)	Energy Storage MW (Y2030)	On-Line Reserves MW (Y2021)	On-Line Reserves MW Y2030)	Primary Freq Response (MW)	Freq Nadir Threshold (Hz)	Islanded System Freq Nadir Hz (Y2021)	Islanded System Freq Nadir Hz (Y2030)	Islanded System Required Gen Resources (MW)	Islanded System Requied Storage Resources (MW)	Islanded System Load Drop (MW)
A	1,830	748	270	-448	487	225	0.50	17.09	0.87	961	258	202
B	1,830	748	135	-448	151	113	0.50	17.09	1.64	1,608	387	404
C	1,830	1,248	135	-448	444	113	0.50	17.09	1.61	1,073	380	111
D	1,830	598	270	-448	461	225	0.50	17.09	0.87	1,125	261	228
E	1,830	748	605	-448	621	504	0.50	17.09	0.40	0	0	404
F	1,830	1,048	270	-448	461	225	0.50	17.09	0.87	612	248	228
G	1,830	545	270	-448	449	225	0.50	17.09	0.87	1,183	262	240
H	1,830	545	705	-448	549	588	0.50	17.09	0.35	0	0	576
I	1,830	791	505	-448	595	421	0.50	17.09	0.48	17	20	330

On-Line Reserves measured at peak load inside NIPSCO

Online Reserves include generation and energy storage resources in excess of net load inside NIPSCO area

- The portfolios were simulated to assess the level of frequency drop in response to the sudden loss of 420MW of generation. The simulations were conducted when the system was in normal interconnected modes and did not find any reliability issues with any portfolio. However, when the system was simulated under emergency operation in islanded mode, several portfolios experienced frequency violation of the nadir dropping by more than 0.5Hz potentially triggering under frequency load shedding schemes.
- The analysis continued to quantify the level of additional fast response requirements from storage systems to mitigate the reliability violations.
- Note: The analysis assumed a droop of 5% for conventional assets, and 1% for storage assets, all limited by the resource ramp rates.

DYNAMIC REACTIVE POWER CAPABILITY AND DISTANCE TO LOAD

Y 2030	
Portfolio	VAR Capability (MVAr)
A	444
B	385
C	603
D	378
E	590
F	575
G	355
H	545
I	565

- A large part of NIPSCO's baseload and industrial clients are clustered around the same area. NIPSCO provides the dynamic reactive power requirements of these customers.
- The resources within NIPSCO footprint can generate dynamic reactive power. However, the given the localized nature of reactive power, the closer "electrically" the generator VARs to the load centers, the more valuable they are to the system.
- The available dynamic VArs in the system are calculated assuming all resources have the capability to operate +/- 0.9 power factor.
- The electrical distance of each resource to each load center is calculated using the Zbus matrix in the form of electrical impedance.
- Each portfolio will be evaluated based on its VARs distance from the load centers as follows:
  - The VARs of each resource will be weighted by the inverse of its distance to all load points and by the relative weight of that load point among all load points. The shorter the distance, and the higher the load served at the load point, the higher the score.
  - The portfolio VARs will be normalized by the impedance per mile of 138kV lines to yield a metric of VARs/mile distance from load centers.

IMPORTANCE AND IMPACTS OF SHORT CIRCUIT STRENGTH

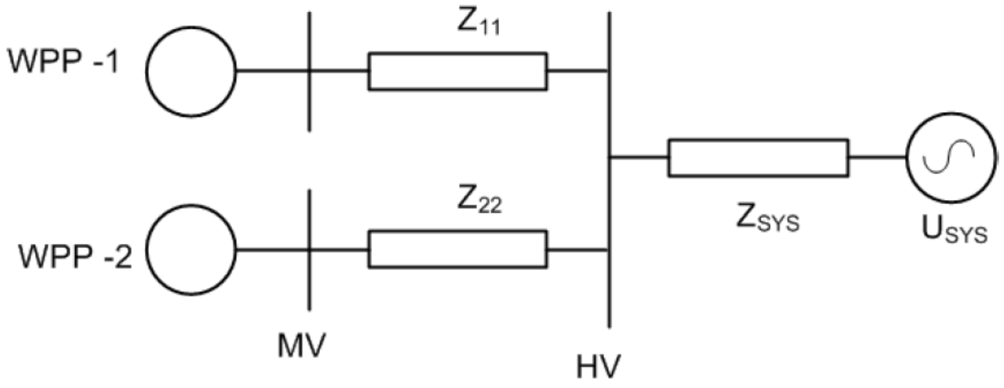
- Importance:

- Short Circuit MVA (SCMVA) is a measure of the strength of a bus in a system. The larger SCMVA, the stronger the bus. That indicates the bus is close to large voltage sources, and thus it will take large injections of real or reactive power to change its voltage. SCMVA changes depending on grid configuration and on-line resources. The lowest SCMVA is usually utilized for engineering calculations.
- When IBRs are interconnected to a system, it is desirable to maintain a stable bus voltage irrespective of the fluctuation of the IBR's output. Similarly, grid following (GFL) inverters rely on stable voltage and frequency to synchronize to the grid using their phase locked loops (PLL).
- The maximum allowable size of IBR desiring to interconnect to a bus is limited to a fraction of the bus's short circuit MVA, say less than 20-50%. This is expressed as Short Circuit Ratio (SCR) of the ratio of SCMVA to the rating of the IBR. This will translate to SCR of 2-5.
- When multiple IBRs are interconnected at a close electrical distance, their controls interact, and the impact of system voltages will increase. Thus, a modified measure was adopted to be ESCR (Effective SCR) to capture this interaction.

- Impact:

- When conventional power plants with synchronous generators are retired and/or the system tie-lines are severed, the short circuit currents will dramatically decline. IBRs are limited in their short circuit contribution and also the phase of their current (real) is not aligned with typical short circuit currents (reactive), and thus are not a substitute.
- Declining SCMVA and increasing IBRs will eventually violate the ESCR limits, requiring either a cessation of additional IBR interconnections, or provisioning additional mitigation measures.
- Mitigations can come in the form of optimal placement of IBRs to avoid clustering them in a manner that violates the ESCR limits, provisioning synchronous condensers, or requiring inverters to have grid-forming (GFM) capability.

SHORT CIRCUIT STRENGTH – EQUIVALENT SHORT CIRCUIT RATIO



$$ESCR_i = \frac{S_i}{P_i + \sum_j IF_{ji} * P_j}$$

where $IF_{ji} = \frac{\Delta V_j}{\Delta V_i}$ is the interaction factor between buses i and j and can be calculated using Zbus.

Pi and Pj are the inverter ratings at buses i and j respectively, while Si is the minimum short circuit MVA at bus i.

Optimal Placement of IBRs from Short Circuit perspective to avoid ESCR limitation:

$$MAXIMIZE \ \sum_{j \in buses} P_j$$

Subject to $\sum_j IF_{ji} * P_j \leq \frac{S_i}{ESCR\ Threshold}$

$$P_j \geq 0$$

PLACEMENT OF IBRS IN PORTFOLIOS A TO I

- NIPSCO provided a list of locations of the planned IBRs as follows:
  - 1305MW within NIPSCO territory in addition to 450MW in Duke/Vectren territory. These 1755MW were modeled in this analysis as planned resources and thus excluded from the relative evaluation of Portfolios A-I.
  - 930MW of resources are outside of NIPSCO territory (Duke, IPL, Big Rivers, Ameren) and were not modeled.
  - The resources in each portfolio (A-I) are located at buses with Queued projects and POIs. The study distributed them among these POIs while respecting the ICAP MW to the extent possible (next slide).
  - The Sugar Creek combined cycle plant is assumed within the service territory and is modeled connected to the Reynolds 345kV bus.
  - Islanded NIPSCO system was modeled.

Portfolio	Solar PV MW	Wind MW	Energy Storage MW	Thermal Gen MW	Hyrdo MW	IBR %
A	2,100	405	420	738	10	80%
B	1,800	405	135	738	10	76%
C	1,550	405	135	1,238	10	63%
D	2,250	405	420	588	10	84%
E	1,800	405	605	738	10	79%
F	1,650	405	270	1,038	10	69%
G	2,000	405	270	535	10	83%
H	1,800	605	705	535	10	85%
I	1,800	605	505	781	10	79%

SHORT CIRCUIT STUDY PROCEDURE

- An islanded NIPSCO system is modeled including Sugar Creek and 2 synchronous condensers.
- System Zbus matrix is calculated, and the Interaction Factor matrix is derived.
- The Effective Short Circuit Ratio (ESCR) is calculated at each bus to assess the strength of the system to integrate the combined planned and Portfolio IBRs.
- If the ESCR is above 3, the Portfolio is deemed satisfactory from a short circuit strength perspective.
- Otherwise, additional synchronous condensers are placed in the system and their sizes optimized to enable full integration of the Portfolio resources (not withstanding potential violations of other planned resources outside of the portfolio).
- The portfolios are compared based on the total MVA of the synchronous condensers that will be required to mitigate short circuit strength violations.
- Three sites for synchronous condensers were selected based on the system topology:
    - 17REYNOLDS, 17SCHAHFER, and 17BURR_OAK
- NOTE: This is a screening level analysis and is indicative. Detailed system studies should be conducted by NIPSCO to assess the selected Portfolio in detail.

ESCR ANALYSIS – WITHOUT MITIGATION

- Using the an ESCR threshold of 3, the analysis shows that ESCR is violated at each bus for all Portfolios. Therefore, all portfolios will require mitigation. This analysis did not consider the combined cycle plant or Hydrogen plants in Portfolios B, C, F, and I.
- Portfolio C does not introduce additional IBRs to those already planned and thus is excluded from this comparative analysis.
- Each Portfolio is evaluated using %Pass (percentage of IBR resources) that will pass the ESCR test. The analysis is provided for all resources and again for only those introduced by the Portfolio.

Bus	Bus Name	A	B	C	D	E	F	G	H	I
255504	17J837_INXRD	F	F	F	F	F	F	F	F	F
255506	17J838_INXRD	F	F	F	F	F	F	F	F	F
3	TAP1	F	F	F	F	F	F	F	F	F
255490	17J643-	F	F	F	F	F	F	F	F	F
255510	17J847-	F	F	F	F	F	F	F	F	F
255110	17SCHAHFER	F	F	F	F	F	F	F	F	F
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
255106	17LEESBURG	F	F	F	F	F	F	F	F	F
255106	17LEESBURG	F	F	F	F	F	F	F	F	F
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
255130	17GREEN_ACR	F			F	F	F	F	F	F
255180	17STILLWELL	F	F		F	F		F	F	F
255151	17LUCHTMAN	F	F		F	F		F	F	F
255149	17LK_GEORGE					F		F	F	
255159	17MORRISON									
255205	17REYNOLDS	F	F	F	F	F	F	F	F	F
	Total									
	Pass (MW)	0	0	0	0	0	0	0	0	0
	Fail (MW)	2,590	2,005	1,755	2,740	2,474	1,990	2,790	2,774	2,575
	% Pass	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Portfolio Only									
	Pass (MW)	0	0	0	0	0	0	0	0	0
	Fail (MW)	835	250	0	985	719	235	1,035	1,019	820
	% Pass	0%	0%	N/A	0%	0%	0%	0%	0%	0%

ESCR ANALYSIS – WITH SC MITIGATION

- The analysis is repeated by optimizing the mitigation using 3 potential synchronous condensers (SC) to enable each Portfolio to pass the test. For Portfolios B, C, F, I, the total SC MVA will be reduced by the planned synchronous generation assets (assuming they are located at places that provide similar short circuit strength as the assumed combined 3 sites in this study).
- Portfolio C does not introduce IBRs.
- The ranking of portfolios from lowest need for mitigation are:
  - C, B, F, I, E, A, H, D, G

Portfolio	SC (Gross) MVA	Synch. Gen (MW)	SC (Net) MVA
A	805		805
B	507	443	64
C	0	650	0
D	1017		1017
E	779		779
F	368	300	68
G	1070		1070
H	948		948
I	792	193	599

ESCR ANALYSIS – WITH SC MITIGATION AND GRID FORMING ESS INVERTERS

- The analysis is repeated by assuming all storage systems will be equipped with grid forming inverters, and then optimizing the mitigation using 3 potential synchronous condensers (SC) to enable each Portfolio to pass the test. For Portfolios B, C, F, I, the total SC MVA will be reduced by the planned synchronous generation assets (assuming they are located at places that provide similar short circuit strength as the assumed combined 3 sites in this study).
- Portfolio C does not introduce IBRs.
- The ranking of portfolios from lowest need for mitigation are:
  - C, F, B, I, E, H, A, D, G

With Grid Forming Inverters for Energy Storage

Portfolio	SC (Gross) MVA	Synch. Gen (MW)	SC (Net) MVA
A	706		706
B	507	443	64
C	0	650	0
D	906		906
E	287		287
F	208	300	-92
G	947		947
H	430		430
I	393	193	200

ESCR ANALYSIS – WITH MITIGATION (CAUTION)

- The analysis reveals potential issues with planned projects that should be investigated in detail at a level deeper than this screening study level.
- These correspond to the following projects:

Bus	Bus Name	kV	Project	Type	ICAP(MW) - Power flow
255504	17J837_INXRD	0.7	Indiana Crossroads	Wind	200
255506	17J838_INXRD	0.7	Indiana Crossroads	Wind	100
255490	17J643-DUNNS	0.7	Dunn's Bridge 1	S+S	165
255510	17J847-DUNNS	0.7	Dunn's Bridge 1	Solar	100

Bus	Bus Name	A	B	C	D	E	F	G	H	I
255504	17J837_INXRD	F	F	F	F	F	F	F	F	F
255506	17J838_INXRD	F	F	F	F	F	F	F	F	F
3	TAP1	P	P	P	P	P	P	P	P	P
255490	17J643-	F	F	F	F	F	F	F	F	F
255510	17J847-	F	F	F	F	F	F	F	F	F
255110	17SCHAHFER	P	P	P	P	P	P	P	P	P
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
255106	17LEESBURG	P	P	P	P	P	P	P	P	P
255106	17LEESBURG	P	P	P	P	P	P	P	P	P
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
255130	17GREEN_ACR	P			P	P	P	P	P	P
255180	17STILLWELL	P	P		P	P		P	P	P
255151	17LUCHTMAN	P	P		P	P		P	P	P
255149	17LK_GEORGE					P		P	P	
255159	17MORRISON									
255205	17REYNOLDS	P	P	P	P	P	P	P	P	P
	Total									
	Pass (MW)	2,025	1,440	1,190	2,175	1,909	1,425	2,225	2,209	2,010
	Fail (MW)	565	565	565	565	565	565	565	565	565
	% Pass	78%	72%	68%	79%	77%	72%	80%	80%	78%
	Portfolio Only									
	Pass (MW)	835	250	0	985	719	235	1,035	1,019	820
	Fail (MW)	0	0	0	0	0	0	0	0	0
	% Pass	100%	100%	N/A	100%	100%	100%	100%	100%	100%

QUANTA TECHNOLOGY

LOCATIONAL ATTRIBUTES – NUMBER OF EVACUATION PATHS

- The evacuation paths from each site are tabulated based on the grid topology.
- For each site, the number of viable paths based on the site ICAP (MW) are calculated.
- Next step is to assess the average paths for each portfolio and rank them
- For each portfolio, a metric of the average number of paths to evacuate the portfolio resources is calculated. Only resources in each portfolio are considered and not the previously planned resources.
- Portfolio A has an average of 5 evacuation paths while Portfolio B has 2.5.
- The ranking from highest evacuation paths to lowest is:
  - H, I, A, G, E/F, D, B

Evac Paths	A	B	C	D	E	F	G	H	I
7	300	300	300	300	300	300	300	300	300
2	200	200	200	200	200	200	200	200	200
2	265	265	265	265	265	265	265	265	265
6	435	435	435	435	435	435	435	435	435
8									
4									
4									
8									
7	105	105	105	105	105	105	105	105	105
7	200			200	250	100	200	250	250
5	250	250	250	250	250	250	250	250	250
3	200	200	200	200	200	200	200	200	200
7	250			250			250	200	200
3	135			135	150	135	135	150	135
3	131	131		200	131		200	131	131
2	119	119		200	125		200	125	104
9					62.5		50	162.5	
3									
2									
	Gas Peaker	CC	Solar	S+S	ESS	Wind	Sync Con.	Planned	Outside
MW-Path	4,186	631	0	4,555	3,406	1,105	5,005	5,706	4,156
Avg Paths	5.0	2.5	N/A	4.6	4.7	4.7	4.8	5.6	5.1

EXISTING/PLANNED RENEWABLE PROJECTS – POWER PURCHASE AGREEMENTS (PPAS) ONLY

Project	Technology	ICAP (MW)	Battery Capacity (MW)	Expected In-Service	Structure	In/Out of Service Territory
Barton	Wind	50	-	Existing	PPA	Out of Service Territory
Buffalo Ridge	Wind	50	-	Existing	PPA	Out of Service Territory
Jordan Creek	Wind	400	-	Existing	PPA	In Service Territory
Indiana Crossroads II	Wind	200	-	2023	PPA	Out of Service Territory
Greensboro	Solar + Storage	100	30	2022	PPA	Out of Service Territory
Brickyard	Solar	200	-	2022	PPA	Out of Service Territory
Green River	Solar	200	-	2023	PPA	Out of Service Territory
Gibson	Solar	280	-	2023	PPA	Out of Service Territory
		1,480	30			