WHEN TRUST MATTERS

CONTINGENCY FRAMEWORK AND RECOMMENDATIONS FOR RENEWABLE GENERATION OUTAGES

Modeling analysis of sudden weather-based outages as they relate to PRR 153

Christopher Hayes, Mohamed Awadalla, Elizabeth Traiger, Daran Rife, Ling Jiang, Mirko Del Hoyo

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Study Overview

- Proposed Reliability Rule (PRR 153): This PRR will require the NYISO to capture both the sudden loss of intermittent resources due to weather variability, along with electrical system faults, as design criteria contingency events. These contingencies would account for the loss of weather-driven generation such as Land-Based Wind (LBW), Offshore Wind (OSW) and solar (both utility scale and behind-the-meter as design criteria contingencies for the purpose of planning the NYCA system
- Analysis of wind and solar generation
  - Sub-hourly weather and renewable generation modeling
  - Coincident datasets to preserve the covariability across geographically and technologically diverse resources.
- Review of weather data for weather-based contingencies and regional dependencies to determine the parameters and metrics to define the contingency events.

Industry Review

Industry Review – Overview & Key Takeaways

- Limited efforts by jurisdictions (both U.S. and non-U.S.) to update planning guidelines and/or contingency planning specifically based on short-term weather-related generation losses
  - Those that have are mainly focused on extreme events (wildfire, extreme heat, etc.) not short-term solar PV and/or wind outage events
- All jurisdictions identified efforts to increase data granularity and modeling specificity (weather, resource generation assumptions, etc.) to supporting enhanced generation forecasting and resource adequacy planning
- Key metrics identified throughout benchmarking review
  - *Resource adequacy and general planning/forecasting*: Updated generator output and availability assumptions, derate factors, outage assumptions, etc. (for specific weather events, resiliency cases)
  - *Contingency classification*: Reclassification for extreme weather scenarios and specific generator outage types

U.S. Entities Evaluated

ISO New England	PJM	MISO
ERCOT	CAISO	SPP

Non-U.S. Entities Evaluated

IESO (Ontario)	Australia (AEMO)	Select European TSOs

Industry Review – AEMO Contingency Reclassification

- Australian Energy Market Commission's (AEMC) National Electricity Amendment (Enhancing operational resilience in relation to indistinct events) Rule 2022
  - Prompted Australian Energy Market Operator (AEMO) to revise the contingency event reclassification criteria under National Electricity Rules (NER) clause 4.2.3B
- AEMO can perform contingency reclassification from Non-credible to Credible Contingency Events
  - Reclassification can occur ("for the duration of a specified period in which the relevant power system conditions are considered likely to prevail") based on near-term forecast of sever weather conditions (and other unique system conditions)
    - Relevant conditions include: 1) Severe wind, 2) sudden or unexpected changes to solar generation
    - The majority of wind- and solar-related reclassifications since Rule 2022 revision (2023 onward) have been due to severe wind (>70), whereas only a small fraction have been due to changes in solar generation (<5)
- Historical reclassification of sets of transmission lines with multiple wind facilities (output constraint during high wind events) as Credible Contingency Event

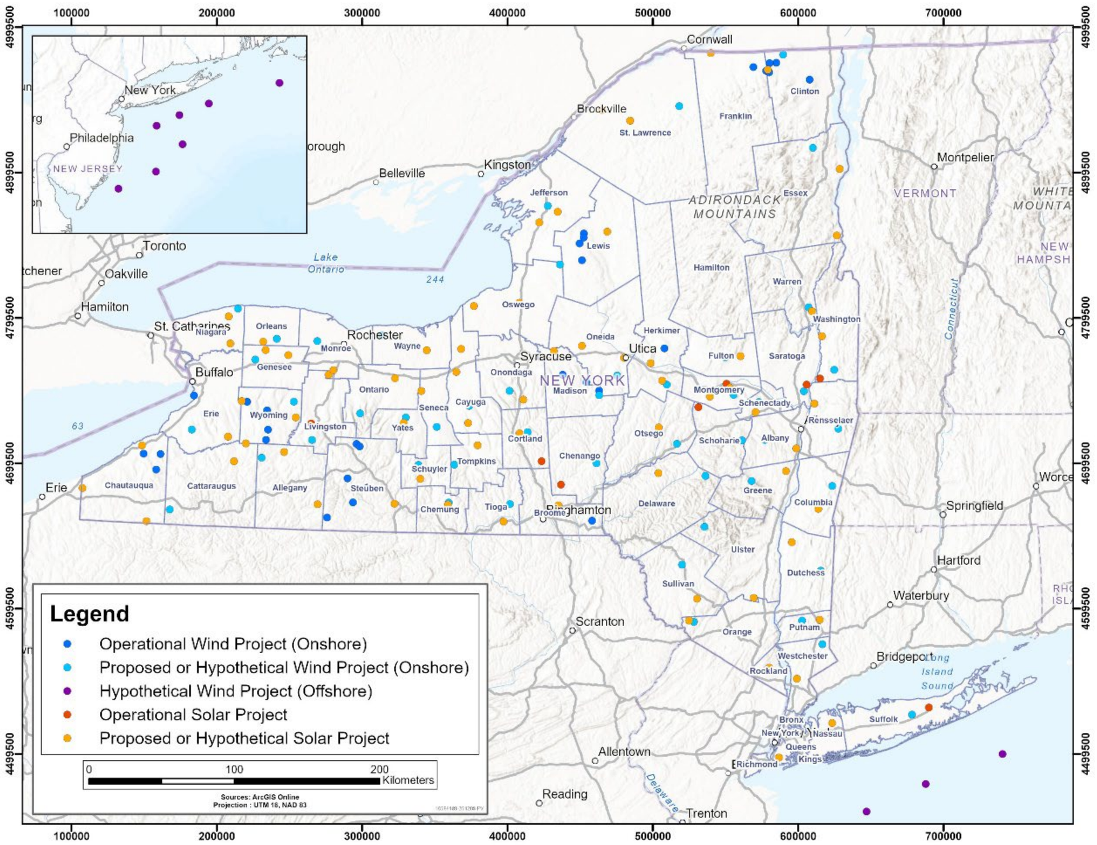
Analysis of impacts of sudden weather changes on renewable generation

Definitions

Abbreviation	Description	Modeling Information
LBW	Land Based Wind	All projects modeled with Class 2 turbine
OSW	Offshore Wind	All projects modeled with 15 MW offshore turbine
UPV	Utility Scale Solar PV	All projects modeled as single-axis tracker systems
BTM	Behind the Meter Solar	All projects modeled as fixed-tilt rooftop systems

Datasets and Modeling Methodology

- LBW (77), UPV (78) and OSW (7) project locations and configurations based on previous work
  - Addition of UPV (by county)
- LBW & OSW: 15-minute NOAA High-Resolution Rapid Refresh
  - LBW: Class 2 generic turbine
  - OSW: Generic 15 MW offshore turbine (full buildout)
- UPV & BTM: 15-minute Solcast Satellite Based Irradiance
  - UPV: Single-axis tracker with DC/AC ratio of 1.3
  - BTM: Fixed tilt panel (rooftop)
- 15-minute simulated production data
  - Wind-to-power model (LBW), WindFarmer (OSW), pvlib (UPV, BTM)



OSW: Lease areas can hold multiple projects

Sudden outage analysis overview

- What types of “weather or meteorological conditions” are considered?
  - Included: **Typical weather events (annual occurrence)**
    - Wind variability, clouds, snow (snowstorms), frontal systems, cold snaps, heat waves
  - Not included: **Extreme events**
    - Anything that can cause damage or failures
    - (Hurricanes, tornados, ice storms, lightning, fire, hail)
- What constitutes a “sudden” weather-based decrease?
  - A large, rapid decrease (between 15-minute records) of wind or solar generation.
- Single or multi-project basis
- Covariability of sudden decreases across projects

Weather Contingency "Event"

- Literature and industry review reveal no consensus on what specifically constitutes a sudden impactful drop in renewable generation
  - Past studies have assumed a ramp rate of 50% - 65% of the project capacity over a 1 - 4 hour period to be considered impactful.
  - ERCOT: 20% change over 30 minutes
- We have classified an "event" as a sudden drop of 25% of project capacity over 15-minute period. (**not a "lull"**)

Stats for All 15-minute Down Ramps

- LBW: 99.4% are < 25% capacity: (103 per yr / project)
- OFW: 98.9% are < 25% capacity: (190 per yr / project)
- UPV: 98.5% are < 25% capacity: (132 per yr / project)
- BTM: 99.6% are < 25% capacity: (32 per yr / county)

All Down Ramps

Percentile	LBW	OSW	UPV	BTM
0.00%	-97.5	-96.6	-97.9	-76.7
0.01%	-77.2	-95.7	-60.1	-48.2
0.05%	-56.1	-74.5	-50.5	-38.8
0.10%	-46.3	-61.8	-45.7	-34.6
0.50%	-26.3	-34.6	-33.9	-24.1
1.00%	-19.8	-26.3	-28.3	-19.6
5.00%	-9.4	-13.0	-14.8	-9.7
10.00%	-6.3	-8.9	-9.3	-6.1
20.00%	-3.8	-5.4	-4.9	-3.0
30.00%	-2.5	-3.5	-2.9	-1.8
40.00%	-1.7	-2.3	-1.8	-1.2
50.00%	-1.1	-1.5	-1.1	-0.8
60.00%	-0.7	-0.8	-0.6	-0.5
70.00%	-0.3	-0.4	-0.2	-0.3
80.00%	-0.1	-0.1	0.0	-0.2
90.00%	0.0	0.0	0.0	0.0
100.00%	0.0	0.0	0.0	0.0

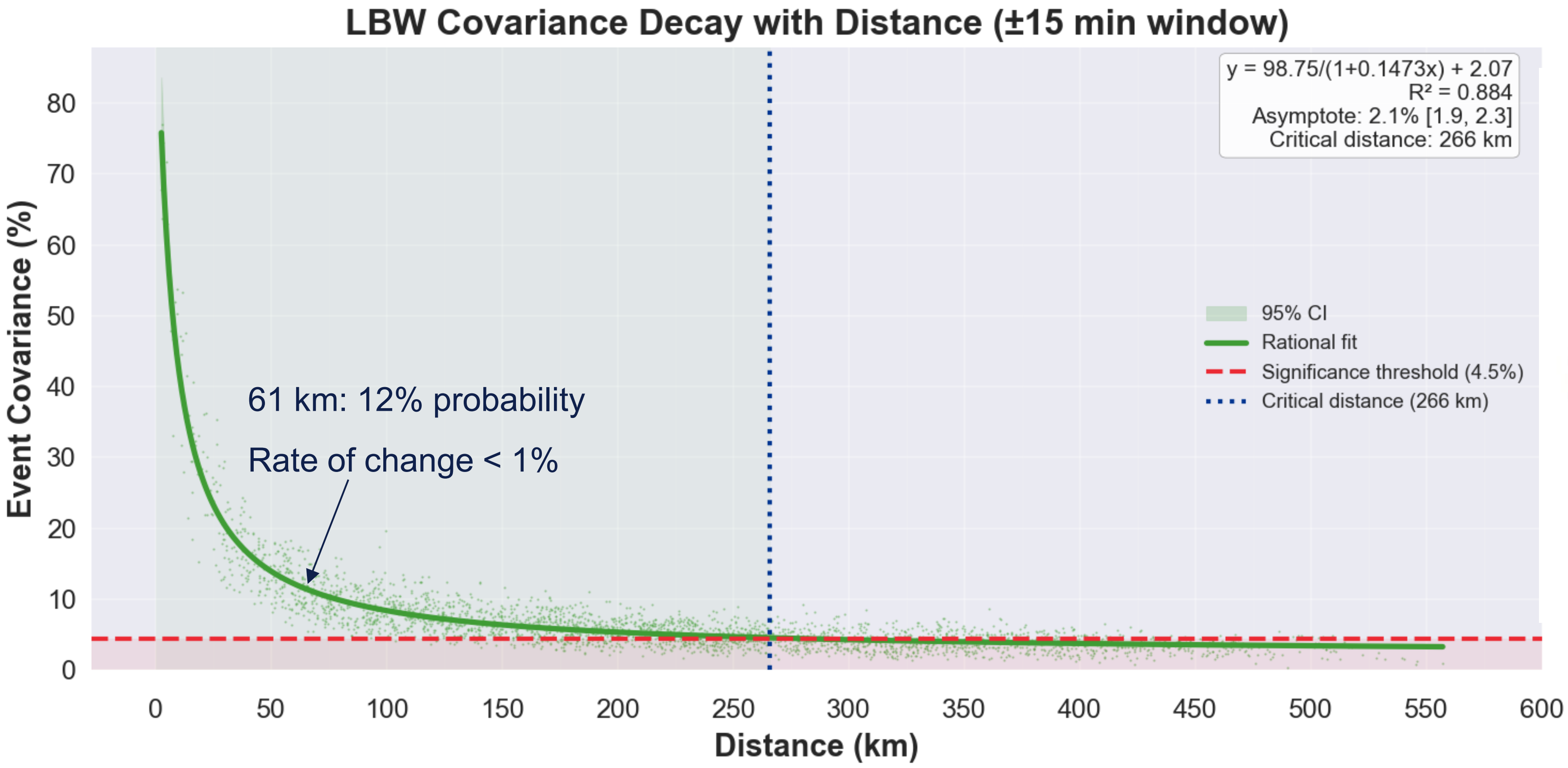
Down Ramps > 25% Capacity

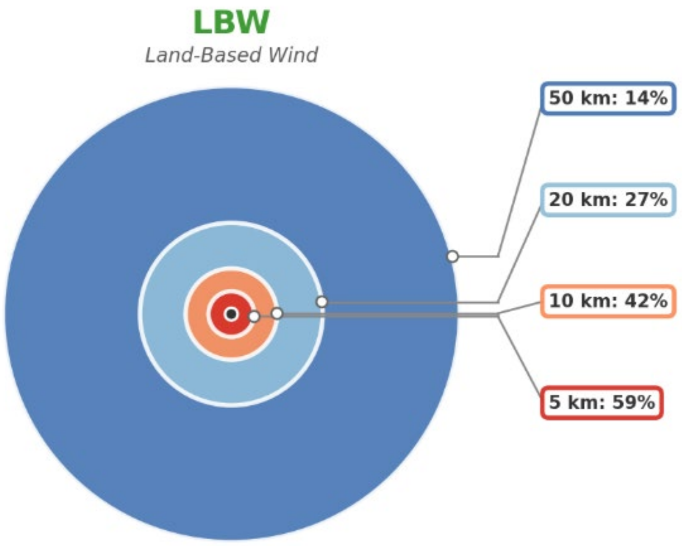
Resource Type	Median	Max
LBW	-31.4%	-97.5%
OFW	-32.7%	-96.6%
UPV	-30.9%	-97.9%
BTM	-29.4%	-76.7%

Spatial covariance of weather-driven production drops

- **Conditional probability** that when Project A experiences a ramp event, Project B also experiences one within ±15 minutes
  - Answers the question: *"How often do ramp events occur simultaneously at two locations?"*
- **Method**
  - **Ramp detection**: Identify instances where generation drops by ≥25% from recent levels within a specified time window (15-30 minutes)
  - **Temporal coincidence:** Events are considered coincident if they occur within ±15 minutes of each other, accounting for propagation time of weather systems
  - **Spatial analysis:** Coincidence frequency is calculated for all project pairs and analyzed as a function of inter-project distance
- **Interpretation**: *“When one project experiences a weather-driven drop in production, how likely is it that another project will experience the same drop at roughly the same time?”*

Example spatial covariance

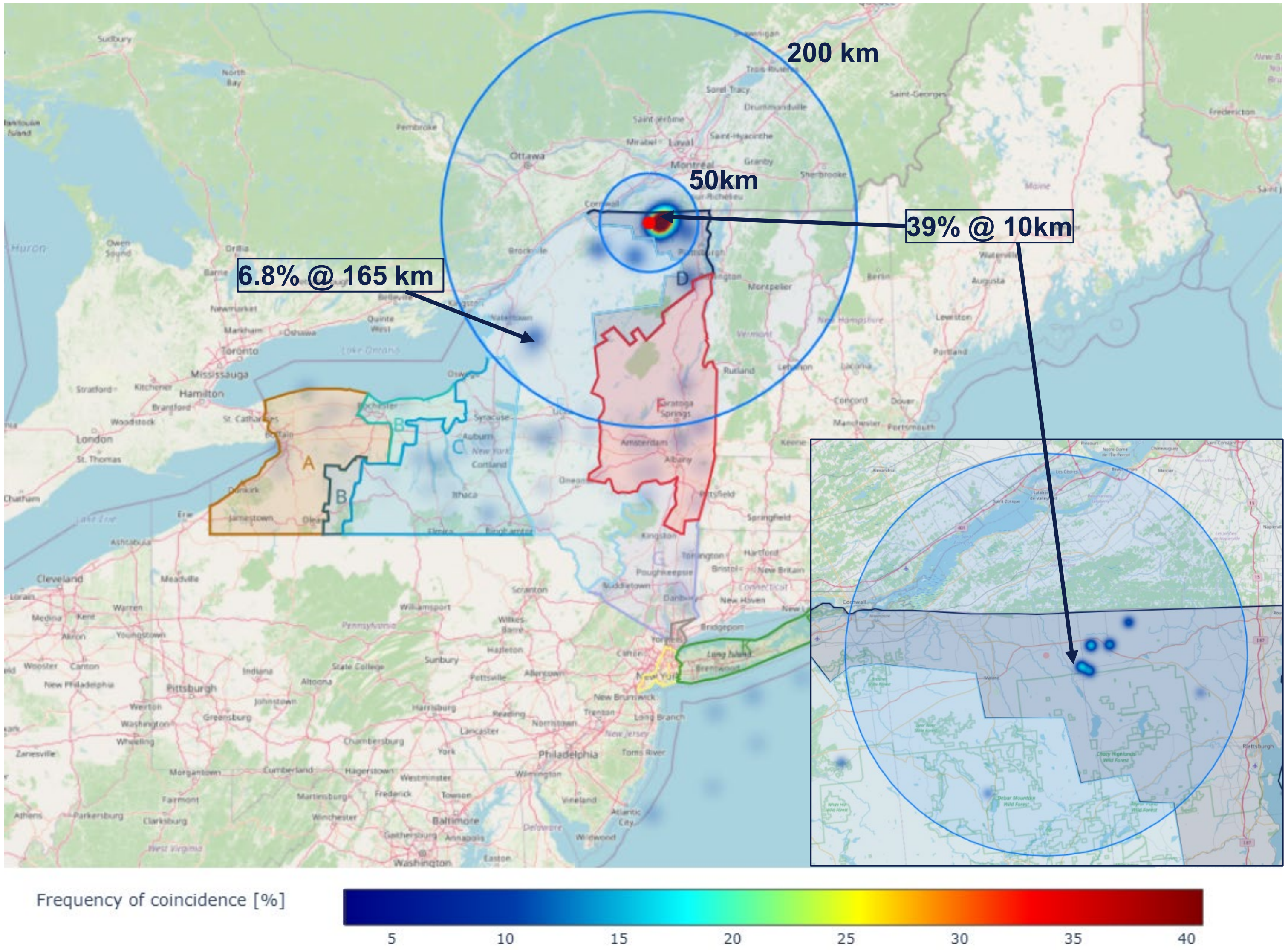




Note: Probability of coincident outage increases for ±30 min window

Example of Geographic Covariance LBW + OSW

- Probability of coincident sudden outage
  - Relative to WIND_0037
    - Clinton County
- Decreasing risk of simultaneous reductions (> 25% capacity):
  - 39% probability for projects within 10 km
  - ~15% probability at 50 km
  - Further reduction to 7% probability at 200 km
    - **Random chance ~ 5%**

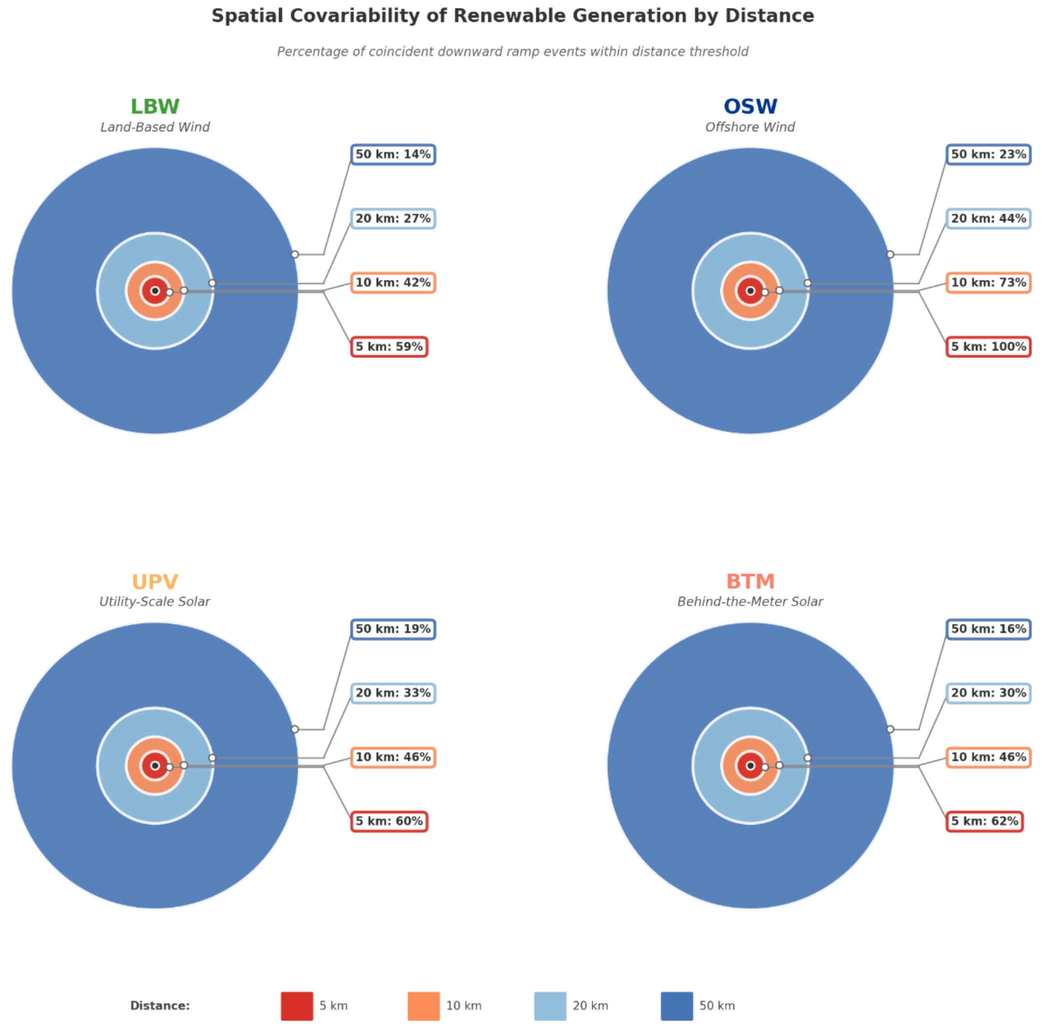


Probability of Simultaneous Outages

- Distance relationship applies everywhere
- No regional / zonal dependency
- Decay lengths influenced by model granularity
  - Likely conservative (longer)
- No wind to solar correlation at 15 or 30-min scale

	±15 Minutes						
Resource Type	1 km	3 km	5 km	10 km	20 km	50 km	100 km
LBW	88%	71%	59%	42%	27%	14%	8%
OSW	100%	100%	100%	73%	44%	23%	14%
UPV	80%	69%	60%	46%	33%	19%	13%
BTM	89%	73%	62%	46%	30%	16%	10%

Resource Type	Distance to Closest Neighbour
LBW	2.3 km
OSW	44.0 km
UPV	3.6 km
BTM	11.0 km



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Summary of findings: Outage Events

- Large changes over 15-minute periods are **rare**
  - Over 98% of LBW, OSW and UPV 15-minute down ramps are less than 25% of project capacity
  - Down ramps ≥ 90% capacity
    - LBW: ~ 1 per year / project
    - OSW: 4 per year / project
    - UPV: ~ 1 per year / project
    - BTM*: < 1 per year / county
  - Some OSW projects experienced complete outage:
    - Full capacity to zero in 15 minutes (high wind shutdown)

*70% reduction used for BTM (max is 76%)

- Types of Weather Events

  <u>LBW</u>
  - "Wind Gust" – Causes generation to go up and down quickly
  - "Sustained wind decrease" –Wind speeds quickly decrease and remain low for several records
  - "Strong Winds" –Turbines cut out due to wind speeds being too high

  <u>Solar</u>
  - "Cloud movement"
  - "Snow fall"

- Weather systems associated with largest decreases
  - Frontal Systems (cold front -> wind speed ↑ then ↓)
  - Bomb Cyclone (high wind shutdown)
  - Winter Storm / Snow (PV panel coverage)

Summary of findings: Covariability and Timing

- **Covariability (geographic dependence)**
  - Probability of near simultaneous sudden production decrease at more than 1 project
    - Exponential decrease in probability
    - > 60% probability for projects within 5 km drops to ~15% at 50 km
    - Reasonable distance: 61 km LBW, 88 km UPV, 70 km BTM, 97 km OSW
    - Statistically significant up to 178 km (UPV / BTM) and 266 km (LBW) (due in part to modeled data)
- **Timing**
  - Seasonally dependent event frequency (volatility)
  - LBW: Largest generation decreases (≥ 90% capacity) occur in late winter / spring (every year)
  - OSW: Largest generation decreases (≥ 90% capacity) spring / early summer (every year)
  - UPV & BTM: Most outage events ≥ 25% capacity occur in summer
    - Largest decreases (≥ 90% for UPV, ≥ 70% capacity for BTM) occurred in late winter / early spring due to snow (does not occur each year)

Recommendations for Defining Contingencies

Framework for Defining Contingencies

- Consideration for contingency definitions should include:
  - **Critical / Impactful Weather Events**
    - By resource type
  - **“Outage” thresholds / magnitude**
    - Partial reduction or near full loss
  - **Spatial covariance**
    - Geographic distribution of assets
    - Distances to correlated resources
  - **Time of the year and day**
  - **Availability of nearby “non-correlated” resources**
    - UPV – LBW, UPV – OSW, OSW – LBW

Figure 3: NYISO Load Zone Map

Recommendations for Land-Based Wind (LBW)

- **Identify Impactful Weather Events**
  - ***High Wind Shutdown***
    - Wind speeds exceeding 22 m/s
  - ***Sustained wind speed decrease (most common)***
    - Decreases of 6 to 12 m/s
  - ***Wind Gust (Storm or Frontal System)***
    - Rapid increase and decrease in generation
- **Account for Spatial Covariance**
  - Account for exponential decay of multiple LBW outage probability by distance
    - High probability (>60%) of multiple outages for projects within 5 km
    - Low to moderate probability (~15%) at 50 km
    - Beyond **100 km** likely not a concern
- **Magnitude of Outage**
  - Partial reduction (≥ 25%)
  - Full or nearly complete loss (≥ 90%)
  - Consideration for duration of loss up to 2 hours
- **Time of Year**
  - Account for seasonality: Most common between March – June (volatile weather and storm systems)
- **Availability of nearby non-correlated resources**
  - Nearby solar outages not correlated with LBW outage
- **Prevailing Weather Conditions**
  - Account for frontal systems, bomb cyclones, winter storms

Recommendations for Offshore Wind (OSW)

- **Identify Impactful Weather Events**
  - ***High Wind Shutdown***
    - Wind speeds exceeding 25 m/s
  - ***Sustained wind speed decrease (most common)***
    - Decreases of 8 to 12 m/s
  - ***Wind Gust (Storm or Frontal System)***
    - Rapid increase and decrease in generation
- **Account for Spatial Covariance**
  - Account for exponential decay of multiple OSW outage probability by distance **and** single lease areas containing multiple projects (high risk)
    - High probability (>80%) of multiple outages for projects within 10 km (same lease area)
    - Moderate probability (~24%) at 50 km
    - Beyond **100 km** likely not a concern
- **Magnitude of Outage**
  - Partial reduction (≥ 25%)
  - Full or nearly complete loss (≥ 90%)
  - Consideration for duration of loss up to 2 hours
- **Time of Year**
  - Account for seasonality: Most common between October – April (winter storms)
- **Availability of nearby non-correlated resources**
  - Nearby LBW / Solar outages not correlated with OSW outage
- **Prevailing Weather Conditions**
  - Account for frontal systems, bomb cyclones, winter storms

Recommendations for Utility Scale PV (UPV)

- **Identify Impactful Weather Events**
  - ***Thick Cloud Shading (most common)***
    - Rapid passing of cloud bank (afternoon)
    - Fog (morning)
  - ***Snowfall***
    - Winter storms (account for duration)
- **Account for Spatial Covariance**
  - Account for exponential decay of multiple UPV outage probability by distance **and** single lease areas containing multiple projects (high risk)
    - High probability (>70%) of multiple outages for projects at 5 km
    - Moderate to low probability (~19%) at 50 km
    - Beyond **100 km** likely not a concern
- **Magnitude of Outage**
  - Partial reduction (≥ 25%)
  - Full or nearly complete loss (≥ 90%)
  - Consideration for duration of loss greater than 2 hours
- **Time of Year**
  - Account for seasonality:
    - Cloud impacts most common in Summer
    - Largest outages (snow) in Spring
- **Availability of nearby non-correlated resources**
  - Nearby wind outages not correlated with UPV outage
- **Prevailing Weather Conditions**
  - Account recent snow fall events

Recommendations for Behind the Meter PV (BTM)

- **Identify Impactful Weather Events**
  - ***Thick Cloud Shading (most common)***
    - Rapid passing of cloud bank (afternoon)
    - Fog (morning)
  - ***Snowfall***
    - Winter storms (account for duration)
- **Account for Spatial Covariance**
  - Account for correlation of UPV to BTM systems to be similar UPV – UPV relationship
    - Outage at UPV outage is likely to be accompanied by BTM outage for nearby homes
  - High probability (>60%) of multiple outages (BTM and UPV) for projects at 5 km
    - Moderate to low probability (~1%) at 50 km Beyond **100 km** likely not a concern
- **Magnitude of Outage**
  - Partial reduction (≥ 25%)
  - Full or nearly complete loss (≥ 70%)
  - Consideration for duration of snow induced loss greater than 2 hours
- **Time of Year**
  - Account for seasonality:
    - Largest outages (snow) in Winter
- **Availability of nearby non-correlated resources**
  - Nearby wind outages not correlated with BTM outage
- **Prevailing Weather Conditions**
  - Account recent snow fall events

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Additional Recommendations

- **Spatial Dependency**
  - Replace jurisdiction-based contingency rules with distance-based spatial covariance metrics to accurately assess backup capacity during weather events
- **Turbine technology considerations**
  - Get information from project operators (varying response to wind events)
- **Weather Systems**
  - Incorporate the **west-to-east progression of major winter weather systems** into outage modeling as well as consideration for strong winds to better anticipate correlated renewable generation losses
- **Winter Load Peaks and Cold Snaps**
  - Contingencies should be defined for potential winter peak or cold snap periods where both UPV and BTM may decrease due to snowfall and LBW may quickly decrease following the passage of a frontal system.

Contingencies for 2030 and 2040

Probabilistic Approach for Determining Contingencies

- **Purpose**: Quantity the likelihood and impact of weather-driven renewable loss events
- **Key Outputs**:
  - Event frequency (e.g., annual probability)
  - Expected magnitude of generation loss
  - Seasonal and geographic pattern

Why?

- Provides context for comparing renewable loss events to existing NERC contingencies.
- The outage scenarios data are probabilistic in nature, supporting expected-value–based loss metrics

Complementary to Security Criteria:

- Does not replace N-1/N-1-1 deterministic standards
- Helps assess whether these events are comparable in frequency to existing planning assumptions and whether they merit explicit consideration as contingencies.

Contingency Definition Components

Different contingency scenarios are defined by project location and technology to reflect different weather-driven outage characteristics.

1. **Identify outage scenario event**
2. **Define outage scenario**
   - Full outage ≥ 90% capacity
   - Partial outage ≥ 25% capacity
3. **Determine Coincidence Probability**
   - Spatial correlation based on distance between projects
4. **Estimate expected loss (per project)**
   - $\text{Expected Loss} = \text{Probability} \times \text{MW Loss}$
5. **Aggregate Total expected Loss**

Remarks: NYISO applies probabilistic methods for resource adequacy, transmission security assessments remain deterministic. A similar probability-informed framework could be used to contextualize renewable loss events by defining their expected frequency, correlation and magnitude to established outages risk metrics.

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Contingencies for Severe Outage

Type of Weather Event	Technology Affected	Contingency Definition	Affected Generation Area	Applicable Season
High wind turbine shutdown	LBW	Loss of generation at an LBW project (>90%)	Other LBW, 88% at 1 km, dropping to 14% at 50 km	Winter/Spring
High wind turbine shutdown	OSW	Loss of generation at an OSW project (> 90%)	Increased spatial correlation (+18%) if outage is due to high wind shutdown (48% probability of coincidence at 50km)	Winter/Spring
Thick cloud passage	UPV, BTM	Loss of generation at UPV or BTM projects.	Other UPV and BTM 89–19% probability within 1–50 km.	Summer
Snow	UPV, BTM	Loss of generation at UPV or BTM projects	Other UPV and BTM 89–19% probability within 1–50 km.	Winter through Spring Late afternoon/early evening

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Contingencies for Partial Reductions in Wind

Type of Weather Event	Technology Affected	Contingency Definition	Affected Generation Area	Applicable Season
Rapid Wind Speed Decrease	LBW	Reduction of at least 25% in generation at a LBW project.	• 88–14% probability within 1–50 km • Beyond 266 km, the probability of losing production at another LBW is random chance	All seasons but most frequent April through July.
Rapid Wind Speed Decrease	OSW	Reduction of at least 25% in generation at a OSW project.	• 23 - 14% probability within 50–100 km • Beyond 200 km, the probability of losing another OSW is random chance. • LBW projects in Zone K are highly unlikely to be affected.	All seasons but most frequent April through July.

Contingencies for Partial Reductions in Solar

Type of Weather Event	Technology Affected	Contingency Definition	Affected Generation Area	Applicable Season
Thick cloud passage	UPV, BTM	Reduction of at least 25% in generation at a UPV/BTM project	Other UPV and BTM 89–19% probability within 1–50 km.	Summer
Snow	UPV, BTM	Reduction of at least 25% in generation at a UPV/BTM project	Other UPV and BTM 89–19% probability within 1–50 km.	Winter through Spring Late afternoon/early evening

OSW 2030 Contingency: High Wind Shutdown

- **High Wind Shutdown**
  - Strong winds: Projects generating at max capacity
  - Highest risk: **November – April**
    - overlaps light load periods
- **Full Outage (≥ 90% of capacity)**
  - **Single Project Loss**
    - Wind Farm 1: Loss of 1,890 MW
  - **Multi-Project Loss:** Within 60 km ➡ Windfarms 1, 2, 5
    - Possible Loss (90% cap): 3,375 MW
    - Total Expected Loss: 2,213 MW
- **Partial Outage (≥ 25% of capacity)**
  - **Single Project Loss**
    - Wind Farm 1: Loss of 525 MW
  - **Multi-Project Loss:** Within 60 km ➡ Windfarms 1, 2, 5
    - Possible Loss (25% cap): 938 MW
    - Total Expected Loss: 615 MW

OSW: 9,000 MW for 2030-2040

Project	2030 Capacity (MW)	Distance (km)	Probability of Coincidence	90% Loss (MW)	Expected Loss (MW)
WindFarm1	2,100	0	100%	1,890	1,890
WindFarm2	390	45	25%	351	87
WindFarm5	1260	57	21%	1,134	237
WindFarm7	5,250	82	16%	4,725	769

$$Expected\ Loss = probability\ of\ coincidence \times MW\ loss$$

$$Total\ Expected\ Loss = \sum Expected\ Loss$$

- **For each OSW project:**
  - ≥ 25% cap loss occurs average of 28 times per year
  - ≥ 90% loss occurs average of 3 times per year

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OSW 2030 Contingency: Rapid Wind Speed Decrease

- **Rapid Wind Speed Decrease**
  - Moderate to strong winds: Reduce by 6 to 12 m/s
  - Highest risk: **February – August**
    - overlaps spring light load period
- **Full Outage (≥ 90% of capacity)**
  - **Single Project Loss**
    - Wind Farm 1: Loss of 1,890 MW
  - **Multi-Project Loss:** Within 60 km ➡ Windfarms 1, 2, 5
    - Possible Loss (90% cap): 3,375 MW
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$$Expected\ Loss = probability\ of\ coincidence \times MW\ loss$$

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- **For each OSW project:**
  - ≥ 25% cap loss occurs average of 164 times per year
  - ≥ 90% loss occurs ~1 time per year

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LBW 2030 Contingency: High Wind Shutdown

Project Cluster in Clinton County

- **High Wind Shutdown**
  - Strong winds: Projects generating at max capacity
  - Highest risk: **April – August**
    - overlaps light load periods
- **Full Outage (≥ 90% of capacity)**
  - **Single Project Loss**
    - WIND_0025: Loss of 73 MW
  - **Multi-Project Loss:** Within 60 km
    - Possible Loss (90% cap): 1,242 MW
    - Total Expected Loss: 477 MW
- **Partial Outage (≥ 25% of capacity)**
  - **Single Project Loss**
    - WIND_0025: Loss of 20 MW
  - **Multi-Project Loss:** Within 60 km
    - Possible Loss (25% cap): 345 MW
    - Total Expected Loss: 132 MW

Total LBW: 4,169 MW for 2030-2040

Project	2030 Capacity (MW)	Distance (km)	Probability of Coincidence	90% Loss (MW)	Expected Loss (MW)
WIND_0025	81	0	100%	73	73
WIND_0014	107	2	78%	96	75
WIND_0016	101	6	54%	90	49
WIND_0043	215	8	47%	194	92
WIND_0037	78	11	40%	70	28
WIND_0012	304	16	31%	274	86
WIND_0005	98	28	21%	88	19
WIND_0048	298	40	16%	268	44
WIND_0027	100	60	12%	90	11
WIND_0049	100	66	11%	90	10

- **For each LBW project:**
  - ≥ 25% cap loss occurs ~1 time per year
  - ≥ 90% loss occurs ~1 time per year

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LBW 2030 Contingency: Wind Speed Decrease

Project Cluster in Clinton County

- **Rapid Wind Speed Decrease**
  - Moderate to strong winds: Reduce by 6 – 12 m/s
  - Highest risk: **April – August**
    - overlaps light load periods
- **Full Outage (≥ 90% of capacity)**
  - **Single Project Loss**
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WIND_0037	78	11	40%	70	28
WIND_0012	304	16	31%	274	86
WIND_0005	98	28	21%	88	19
WIND_0048	298	40	16%	268	44
WIND_0027	100	60	12%	90	11
WIND_0049	100	66	11%	90	10

- **For each LBW project:**
  - ≥ 25% cap loss occurs average of 98 times per year
  - ≥ 90% loss occurs average of 1 times per year

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UPV 2030 Contingency: Snow

<u>Project Cluster in Montgomery County</u>

- **Rapid Production Decrease Due to Snow**
  - Snow accumulates on PV panels
  - Highest risk: **November – April**

- **Full Outage (≥ 90% of capacity)**
  - **Single Project Loss**
    - SOLAR_0056: Loss of 18 MW
  - **Multi-Project Loss:** Within 60 km
    - Possible Loss:1,278 MW
    - Total Expected Loss: 402 MW
- **Partial Outage (≥ 25% of capacity)**
  - **Single Project Loss**
    - SOLAR_0056: Loss of 5 MW
  - **Multi-Project Loss:** Within 60 km
    - Possible Loss (25% cap): 355 MW
    - Total Expected Loss: 112 MW

Total UPV: 10,440 MW for 2030-2040

Project	2030 Capacity (MW)	Distance (km)	Probability of Coincidence	90% Loss (MW)	Expected Loss (MW)
SOLAR_0056	20	0	88%	18	16
SOLAR_0048	250	4	64%	225	144
SOLAR_0031	200	15	38%	180	69
SOLAR_0032	40	21	32%	36	11
SOLAR_0025	50	25	29%	45	13
SOLAR_0064	20	28	27%	18	5
SOLAR_0072	300	44	21%	270	56
SOLAR_0020	500	54	18%	450	82
SOLAR_0022	20	55	18%	18	3
SOLAR_0009	20	55	18%	18	3
SOLAR_0040	20	62	17%	18	3

- **For each UPV project:**
  - ≥ 25% cap loss occurs average of 1.3 times per year
  - ≥ 90% loss occurs ~ 1 time per year

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Limitations and Caveats

- **Dataset Limitations**
  - Mesoscale data unable to capture small-scale turbulent eddies
    - Unable to determine weather changes at finer than 15 minutes
  - Mesoscale modeled wind datasets tend to have longer correlation length scales than real “point” observations made by met towers. – covariability distances may be longer as a result.
  - Wind and solar production models assume wind speed or irradiance changes occur at every turbine or every solar panel at the same time.
    - Hysteresis effects are not modeled on a time series basis (ramps may be amplified)
  - Model resolution (3 km) –increase to covariability distance
  - May not be sufficient resolution for N-1-1 analysis
  - Snowfall dataset only available hourly resolution and interpolated to 15 minute
    - Snow loss model likely conservative (does not account for panel cleaning, impacts of panel movement)
  - **Recommendation**:
    - Higher resolution Large Eddy Simulation (LES) weather modeling for specific weather scenarios
    - Higher-resolution (spatial and temporal) wind and solar production models that capture changes across portions of projects.

Conclusions

- Analysis Limitations
  - Given a 30-minute window within which a contingency plan can be implemented the 15-minute dataset cannot capture the additional risk of an N-1-1 event occurring at any minute during that window.
- Locational or transmission-based contingency metrics should be considered for high-wind events
- Large outages are uncommon but do occur as part of the natural variability in production each year. Unlike traditional outages, weather-based outage risk can be mitigated by forecasting and project control mechanisms
- OSW wind within same lease area at high risk of coincident outages. OSW windfarms in modeled dataset are only for each lease area.
- Project specific wind turbines may respond differently to high wind events or sudden decreases in generation. Suggest communication with project operators to determine behaviour characteristics
- Outages at offshore wind farms within same lease area could be very impactful

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Thank You

Chris Hayes chris.hayes@dnv.com
Elizabeth Traiger Elizabeth.traiger@dnv.com

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