A Joint Granular Forecasting and Optimization Framework for Weather-Aware Grid Operations.

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Date: January 29, 2026

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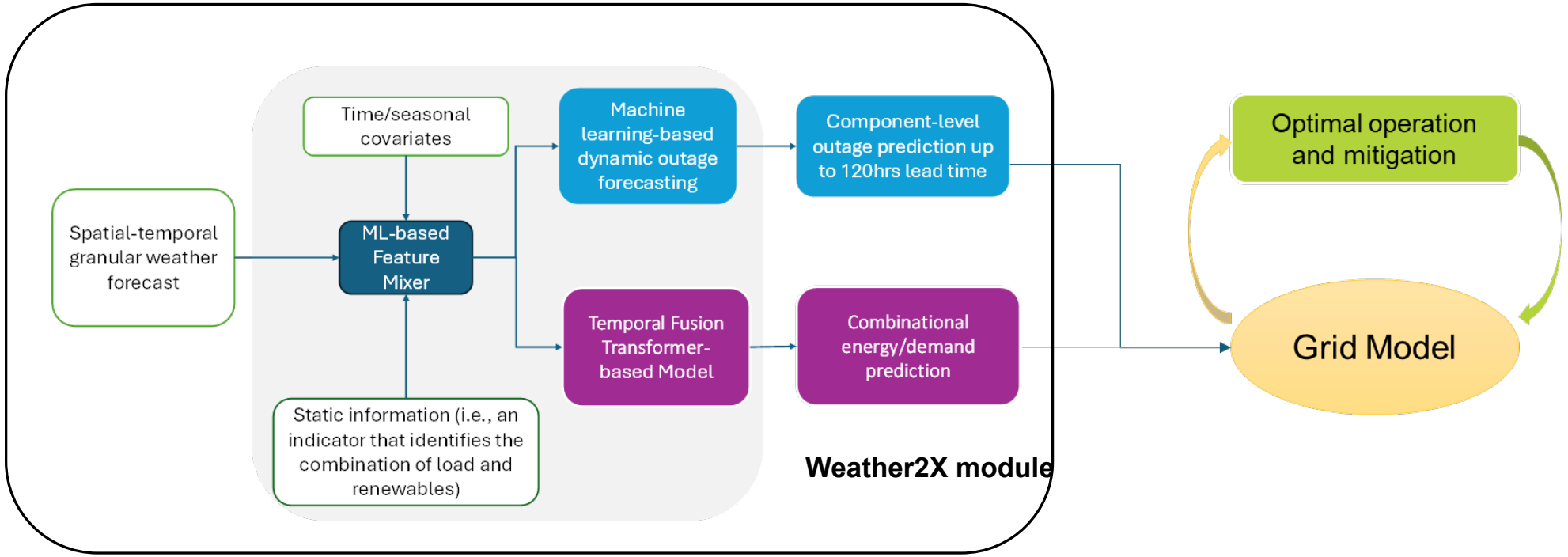
Background and Motivation

- Existing forecasting of demand, variable generation, and outages is performed at system level using siloed models
  - Lacks spatial resolutions and cannot be readily interfaced onto system planning and operation models
  - Cannot adapt to different resolutions of products of weather forecasts
  - Poorly handling of forecasting uncertainties
    - Driven by shared weather variables, forecast uncertainties are correlated
    - Currently uncertainties of siloed forecasts are propagated separately in reliability and resilience analyses

Objective

- To develop an AI/ML-based integrated joint forecasting framework, Weather2X, for
  - improved situational awareness and prediction with adaptive granularities to interface with planning models
  - more effective grid planning and operation under normal and extreme weather events

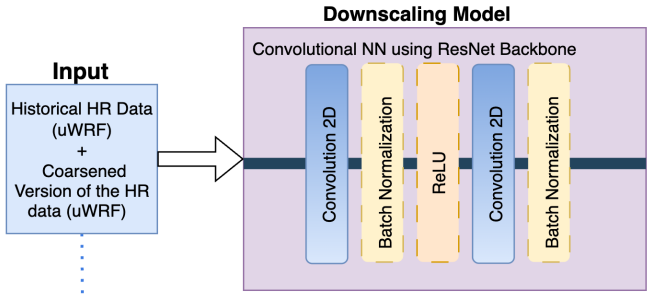
Combined with AI/ML, high-resolution data from advanced modeling and observations are readily used to improve forecasts and operation and recovery of energy systems.

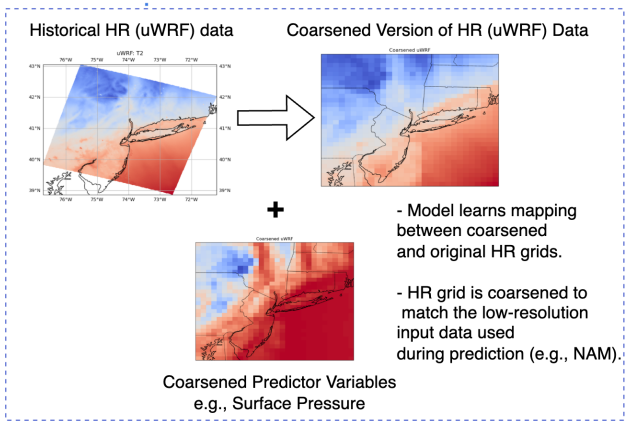


- Example applications
  - Unit commitment
  - Economic dispatch
  - Resource adequacy
  - Congestion relief
  - Restoration
  - Etc.

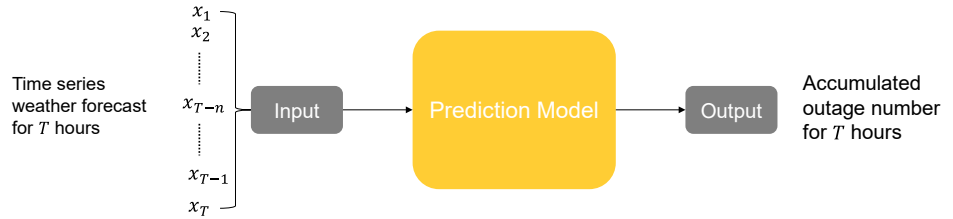
- Prediction of demand, renewable generation, and grid component outages in a single forecasting framework
- Adaptive granularities driven by AI/ML-based downscaling model
- Grid planning model ready outputs
- Joint forecasting of uncertainties enabling propagation and quantification of correlated uncertainties

Training for ML-based Temperature Downscaling Model

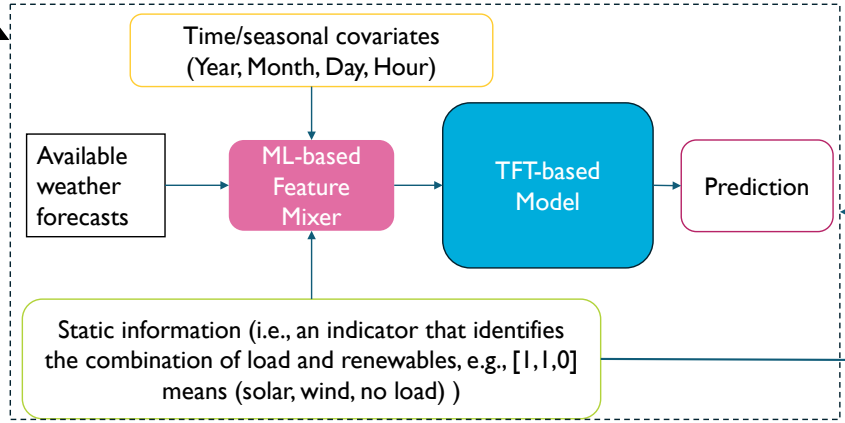


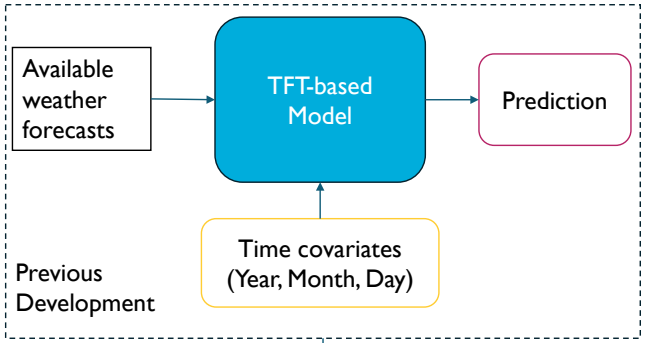


Outage Prediction



Joint forecasting



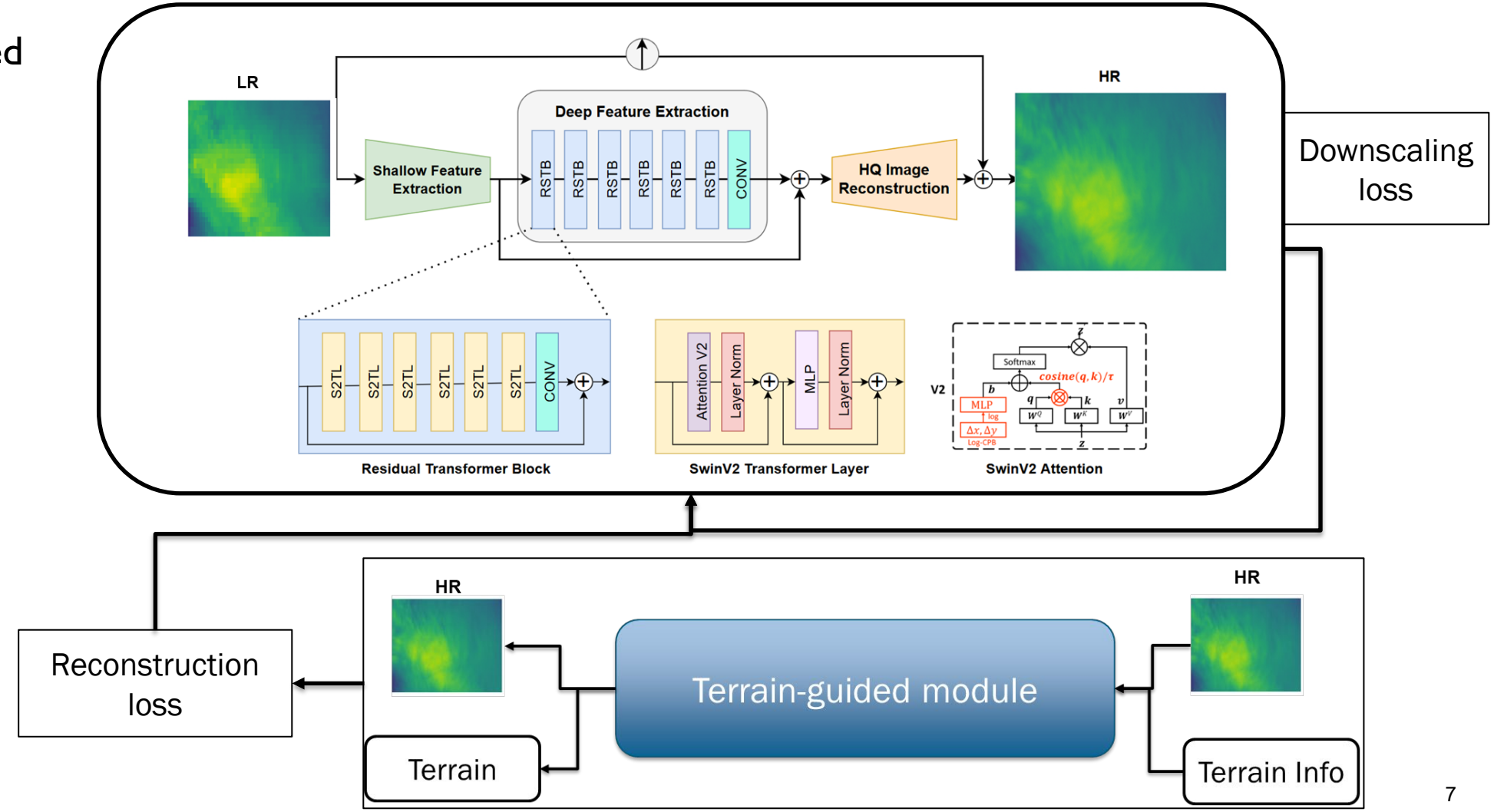


New development to consider the combination of renewables and load

Transferability

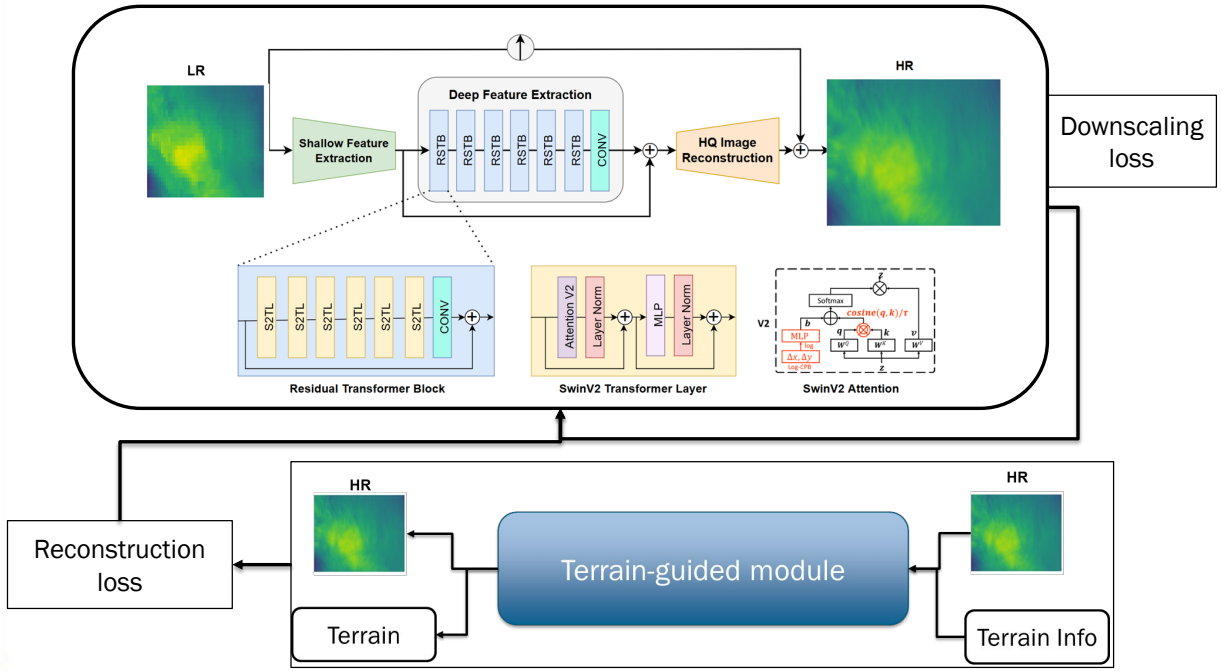
- Adaptive ML-based downscaling model
  - Transforms coarse-resolution forecast data into more localized, detailed forecasts
- Outage forecasting module
  - Multi-day granular, dynamic predictions of weather-induced outages
  - Linking multi-day weather forecasts and high-resolution damage data from utilities
- Demand + renewable forecasting module (TFT temporal mixer)
  - Jointly forecasts load and renewable availability using a Temporal Fusion Transformer (TFT)–based temporal mixer that integrates multi-source time series, weather profiles, and static context for accurate multi-horizon predictions
- Grid-model interface + optimization for decisions
  - Forecasts are generated at the spatial/temporal resolution required by grid planning models
  - Enabling a number of planning and operation studies

- An AI/ML-based downscaling model considering terrain feature
- Applicable to different seasons and regions

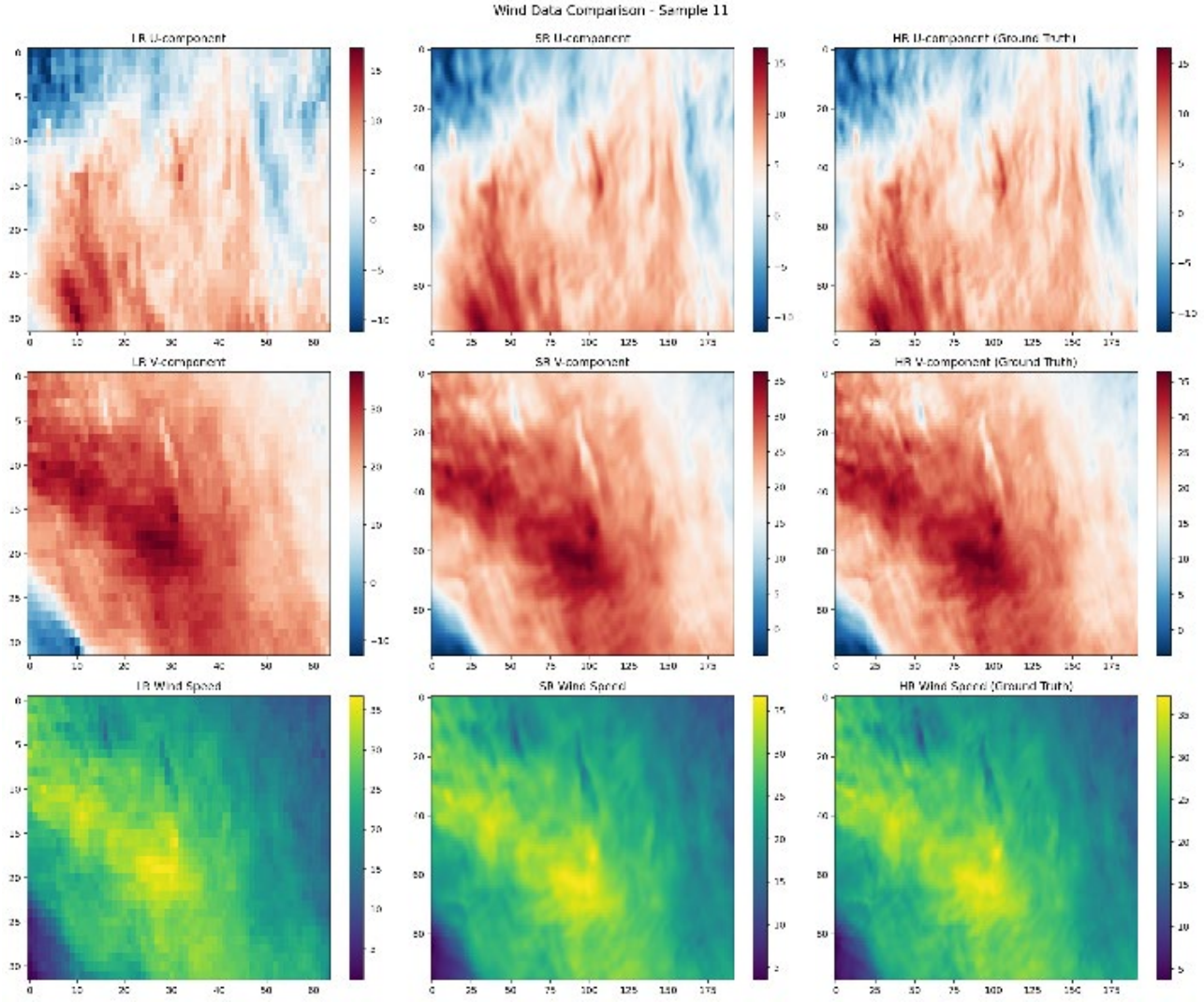


- Increasing computer power enables higher-resolution (time and space) weather models and data assimilation
  - Global Forecast System (GFS) data
    - ✓ 0.5 deg and 1.0 deg resolutions, up to 120 hours (operational model)
  - National Center Environmental Prediction (NCEP) North American Model (NAM) data
    - ✓ 12 km x 12 km, up to 84 hours (operational model)
  - NOAA High-Resolution Rapid Refresh (HRRR) model
    - ✓ 3 km x 3 km, every 15 minutes (operational model)
  - Weather Research and Forecasting (WRF) model
    - ✓ 1 km x 1 km, every 15 minutes (state-of-the-art research model)
- These are examples of of weather datasets we have used in our R&D efforts. Many other models and datasets are also available.

Architecture of the proposed downscaling model



Downscaled the wind direction, wind speed and temperature from 10 km to 2km resolution



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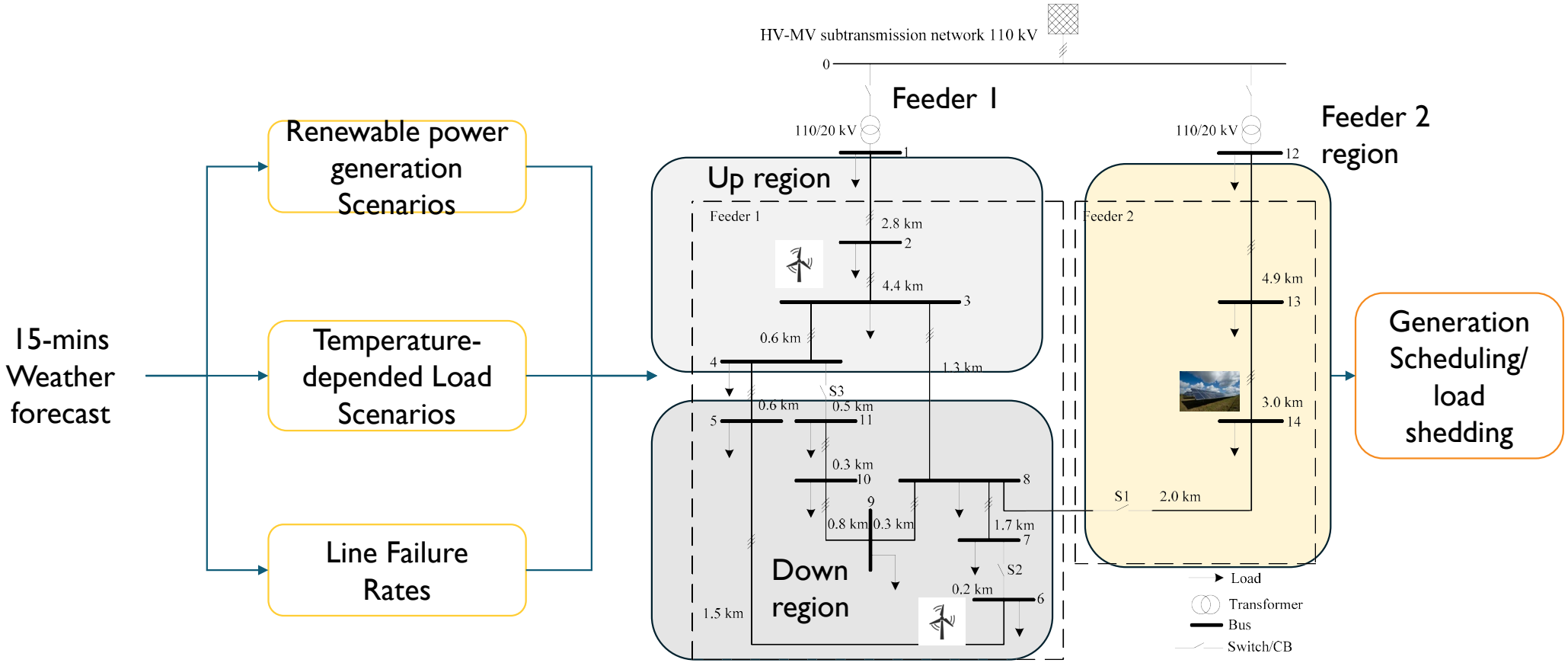
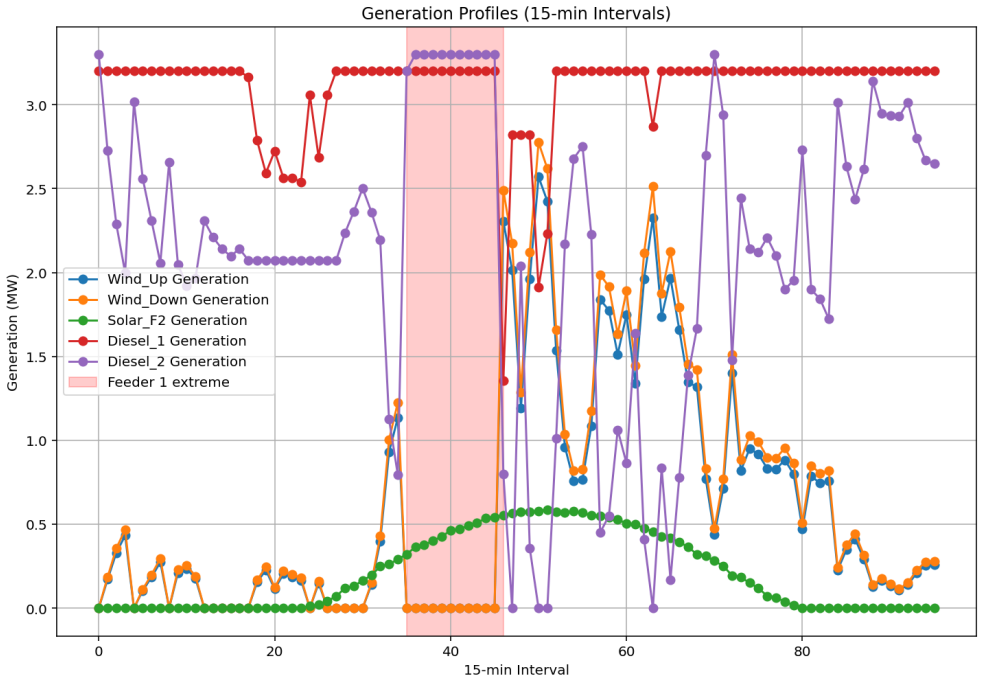
Interfacing Weather2X with the Grid with Distributed Energy Resources

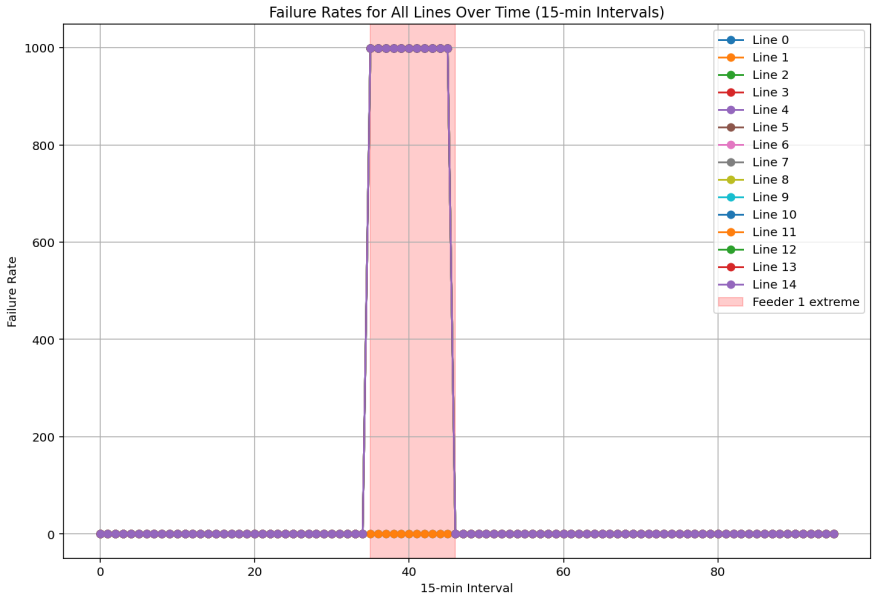


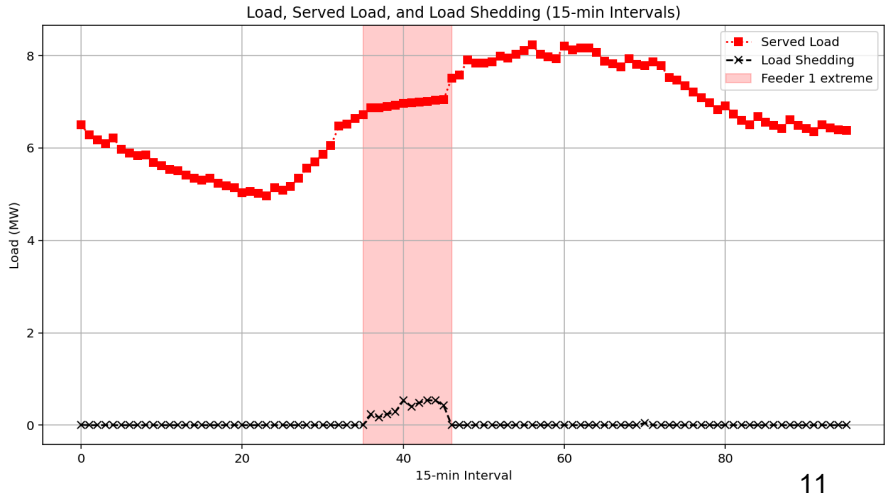
A distribution network with DERs to represent New York City

Case Study Results: Low Resolution Weather Data for High Wind Speed at Feeder 1

- Weather conditions (especially wind profiles) averaged over the three zones
  - All zones used the same profile
  - Load shedding: 4.14 MW







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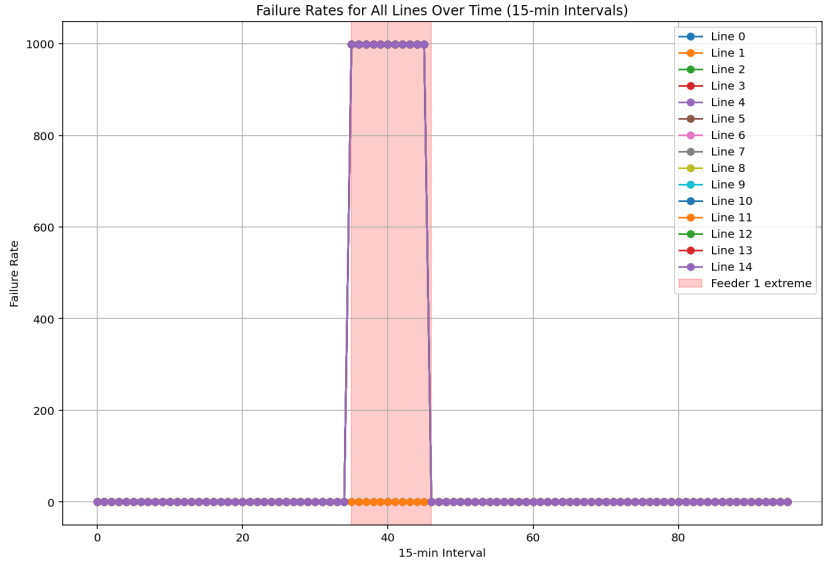
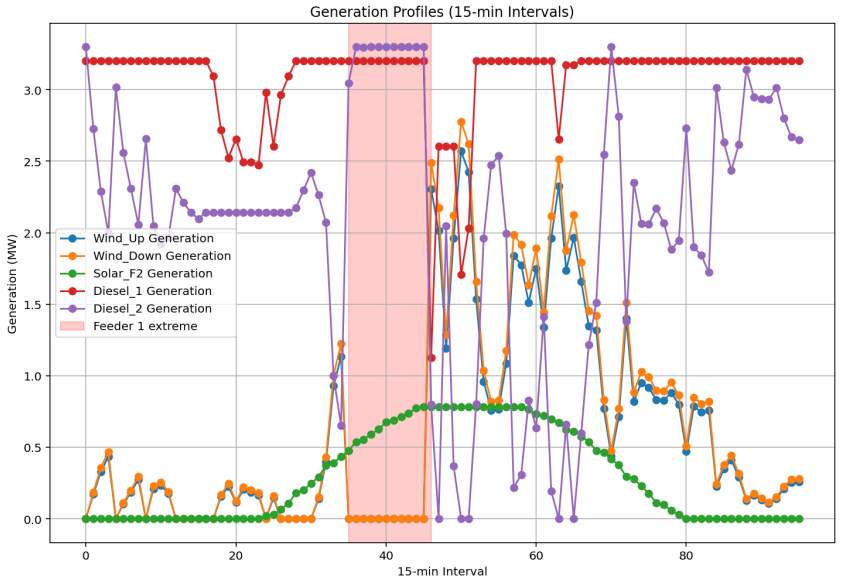
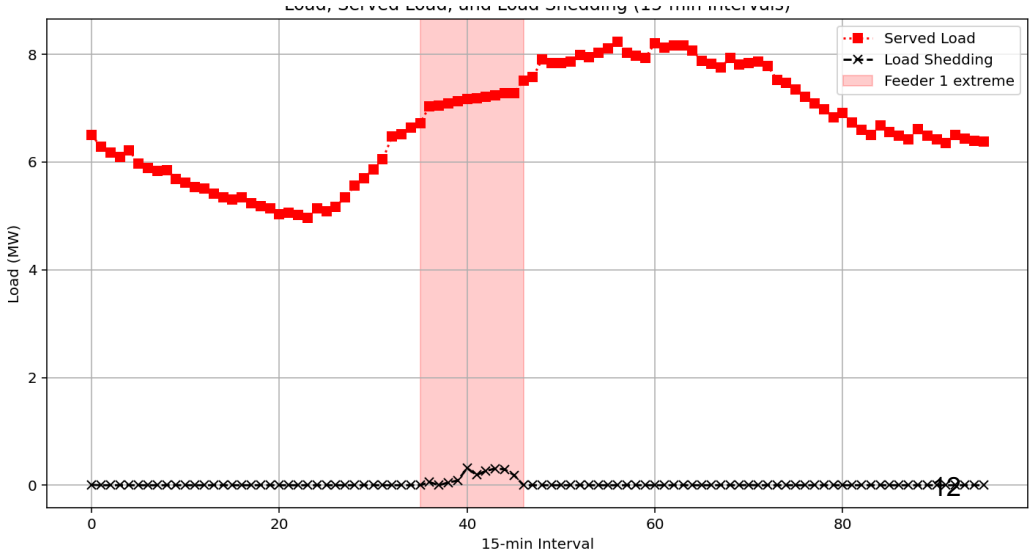
Case Study Results: High Resolution Weather Data for High Wind Speed at Feeder 1 (cont'd)

- Three zones used their individual weather profile
  - Load shedding: 1.76 MW
  - Reduced load shedding due to accurate solar generation forecast at Feeder 2







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Conclusions and Path Forward

- Integrated modeling
  - Unifies weather observations/forecasts, generation and demand forecasts, and dispatch into a single pipeline, closing the loop between predictions and operations
  - Demonstrates reliability benefits in high-renewable scenarios
  - Ready to interface with weather data of different resolutions
- Next steps
  - Uncertainty propagation and quantification of forecasts
  - Extend outage model to other grid components
  - Incorporate additional covariates
  - Expand model to various grid operation problems

Questions?

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