



Future Energy System Outlook

Draft

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Appendix C

Synthetic Weather Year and
Renewable Generation
Forecasting Methodology



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Contents

Part 1: Synthetic weather year methodology 4

Weather year composition..... 5

Operational demand events..... 7

Renewable trough events 8

Climate change 10

Further development 11

Part 2: Renewable generation forecasting methodology..... 12

Wind generation 13

Solar generation 15

Reference generators 17

Further development 18



Part 1 | Synthetic weather year methodology

This document provides an overview of Western Power's methodology for synthetic weather year (SWY) development. A synthetic weather year is an alternative to the historical reference weather year (RWY) typically used for strategic planning studies. The SWY is intended to test the resilience of the system for a set of weather driven critical events and is applied to every year of the study horizon.

Applying a RWY set to strategic planning studies presents a number of challenges that the SWY is intended to overcome:

- A weather critical state that appears in one year of a 10 year RWY set will only be observed in simulations every 10 years
- Alignment of weather system impact on demand and generation for historical years lacks key data inputs.

The successful application of the SWY will address the issues noted above and ensure that for strategic planning studies, optimal solutions will be resilient to historically observed and future weather and customer demand events in every year in the study horizon.

The SWY is created as follows:

- Set a base weather year with a full generation and demand interval metered data set available – this covers temperature, solar irradiance and wind speed at turbine hub height.
- Analyse a set of RWY renewable generation and demand to determine timing, frequency and magnitude of system critical events e.g., High | Low operational demand and low renewable generation (renewable trough).
- Inject weather patterns for system critical states into base weather year – align to time of day and time of year (season).

Weather year composition

Data sources

The following data sources are used for historical RWY observations from 2016/17 – 2024/25:

- Temperature BOM Climate Data
- Wind BARRA – C2
- Irradiance Himawari – 8/9 surface global solar irradiance

Observation data is sampled at 60 minute intervals for spatial locations required to support demand and generation simulations. All observation data represents a single weather system that is spatially and temporally aligned to reflect real world observations.

Critical event injection

Critical events capture all observation data (temperature, wind and irradiance) for the duration of the event. Each critical event is injected as a full day time-series at the time of year as follows:

- Day of week – Weekend and weekday are preserved e.g. a critical event that starts on a Saturday in the RWY it occurs will be injected to start on a Saturday in the SWY.
- Month of year – Month of year is preserved e.g. a critical event that starts in August in the RWY it occurs will be injected to start in August in the SWY.

Base year

The most recent observation year is preferred as the base year as this captures current demand response to temperature. Wind and solar generation annual capacity factors are assessed for each RWY – if the base year diverges significantly from the RWY average a different base year may be selected.

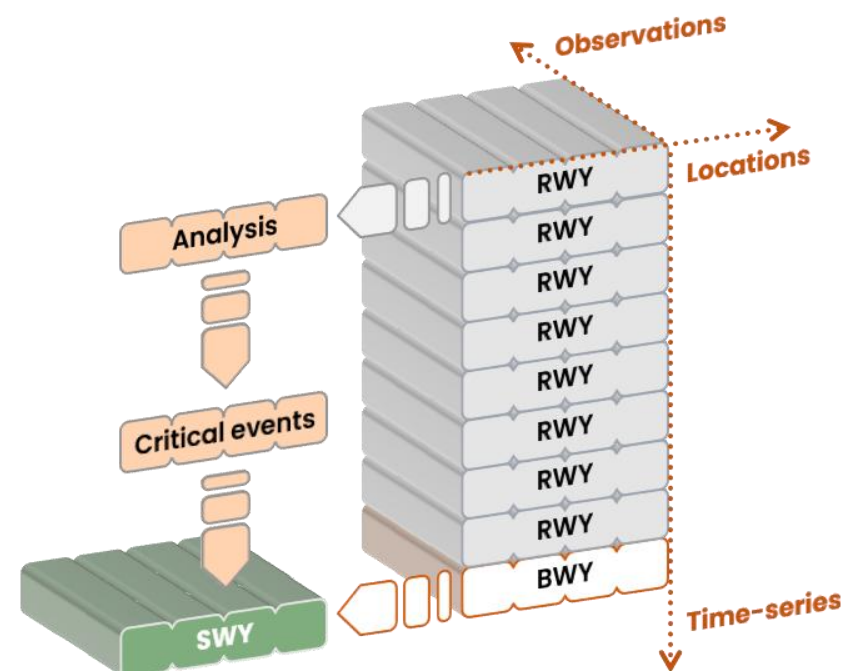


Figure 1. SWY composition

Distribution core weather zones

Temperature and solar irradiance traces are inputs to the distribution core modelling application (uSim) as both weather factors affect have a significant impact on demand patterns (see Appendix A for details on the distribution core demand modelling methodology).

Temperature

Demand is highly correlated to temperature at the interval level, largely driven by residential air conditioning. Temperature inputs are aligned to the SWY to ensure temperature driven demand patterns are correlated with weather driven wind and solar generation so that an internally consistent climatic system is being modelled.

uSim Weather zones

To manage computation load, the SWIS has been divided into six weather zones with a representative temperature and irradiance trace developed from historical observations at locations across zones. Each energy cell is mapped to a weather zone. To capture the large residential demand centre as well as high concentration of rooftop PV, Perth metro has been divided into three smaller zones for increased input granularity, with fewer larger zones in the regions to reduce computation time.

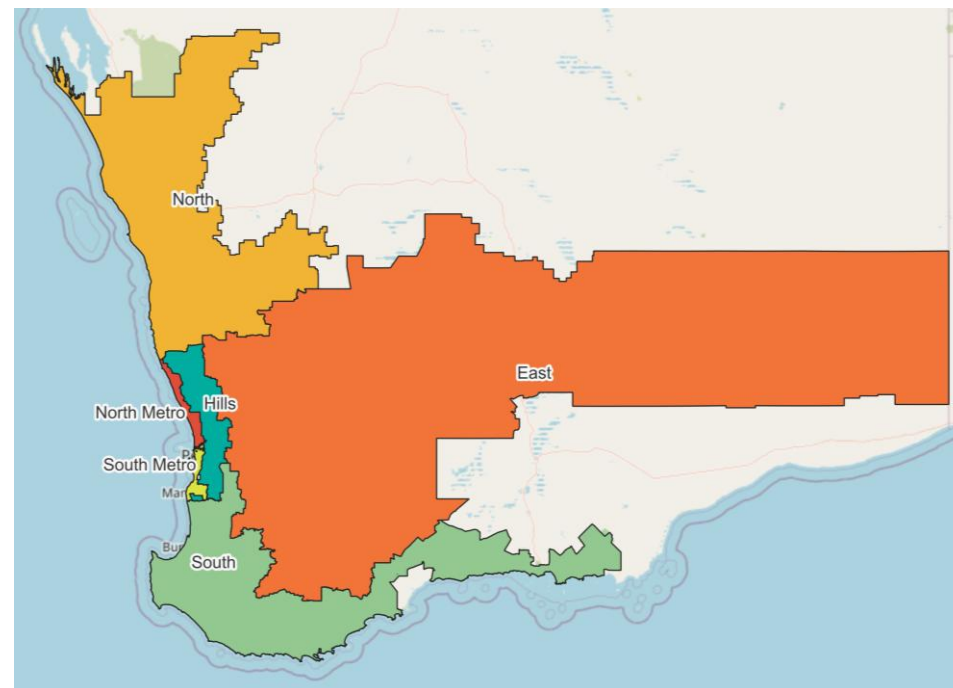


Figure 2. Distribution core weather zones

Operational demand events

An operational demand event is defined as one or more intervals where operational demand places significant stress on SWIS generation supply, network transfer or system stability. The following operational demand events are identified:

- Heat wave driven maximum demand, and
- Rooftop solar PV driven minimum demand (system low).

Heat wave

The primary focus of heat wave events is the potential to stress generation supply and network transfer. Typically SWIS peak demand during a heat wave is driven by distribution connected demand and does not see all network elements (e.g. transmission lines, power transformers, distribution feeders and LV networks) subject to maximum loading conditions at the same time. For this reason, a heat wave event defined at a single demand interval is represented as a full day time-series. This allows non-coincident demand on network elements to be captured.

The role of storage in lowering daily peak demand during heat waves is expected to increase. The potential for storage resource availability to be constrained by a reduced charging window is considered important to address – for this reason heat wave events are represented across a four day time period where the peak demand event occurs on day three.

System low

System low events are of interest due the dominant role that asynchronous generation has in meeting demand. During period where rooftop PV output is high, operational demand is reduced and inverter-based generation plays a greater role in meeting demand – this lowers inertia (historically provided by synchronous generators) which can impact system stability. Low operational demand periods overnight are currently not a concern due to synchronous generators contributing a high proportion of electricity generation at these times.

System low is determined as a single interval where operational demand is low and solar generation is high. As with other operational demand events; the entire day where the critical event occurs is injected into the SWY.

Renewable trough events

A renewable trough is defined as a multi-day period where aggregate production from wind and solar generators is below operational demand. The greater the energy gap the more significant the trough. A range of multi-day periods are assumed and a reference operational demand pattern and generation fleet is needed to enable this modelling (illustrated in Figure 3)

Wind & solar fleet

Defining the generation fleet for renewables trough analysis is a key initial step that may be iterative to determine representative critical events. It is necessary to validate changes to the renewable generation fleet by repeating the trough analysis; however, generation changes may not materially impact the critical events that are injected into the SWY.

Wind & solar forecast

A forecast is developed for each generator based on the generator size and location (latitude and longitude). For wind generators the input wind speed, wind turbine type and hub height are key parameters. For solar generation the input solar irradiance, panel orientation, panel tilt and tracking are key parameters. The renewable generation methodology provides more detail regarding this step.

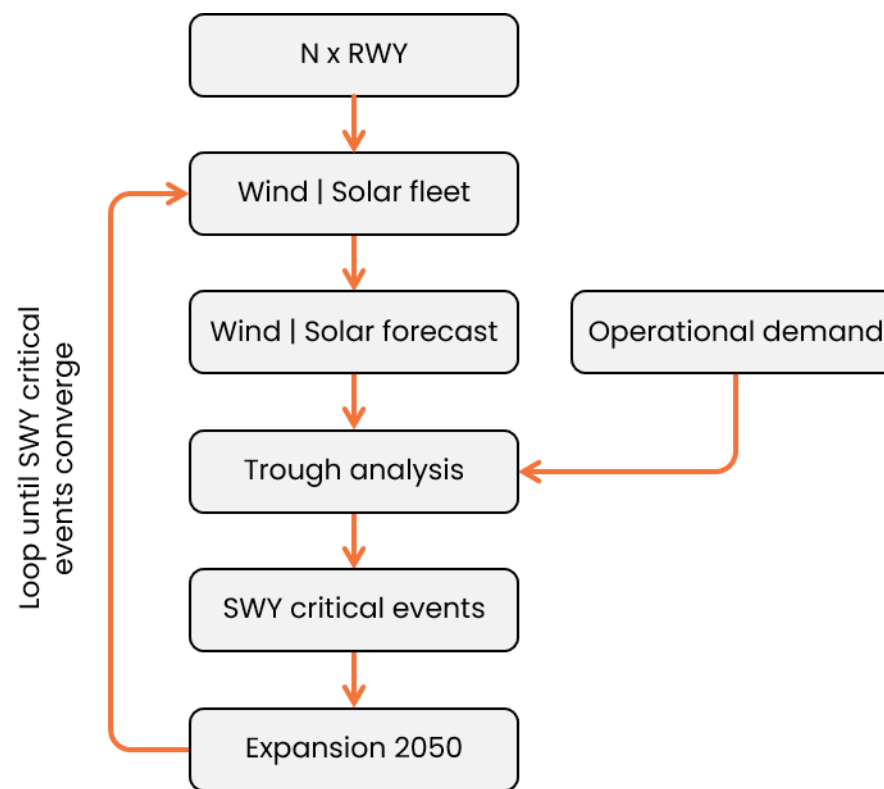


Figure 3. Renewable trough analysis

Trough analysis

Renewable trough analysis develops a 1-hour interval, rolling multi-day average of renewable generation production at the SWIS level and overlays a rolling multi-day average of operational demand. Periods where the absolute renewable generation production is lowest and periods where the gap between renewable generation production and operational demand is greatest are flagged for review as a renewable trough event.

Expansion validation

The SWY is assembled critical events determined from the renewable trough analysis. System expansion modelling can be undertaken as an additional step to determine if the revised SWY has a material impact on the optimal generation fleet mix to 2050. Where there is a significant impact the renewable trough analysis can be repeated until the outcomes are convergent.

Climate change

Climate change adjustments to SWY temperature are planned based on climate change forecasts. Climate change is expected to be applied to studies as a sensitivity reflecting the ongoing uncertainty regarding the pace of global decarbonisation that has a strong influence on climate change trajectories. Solar irradiance and wind speed are not currently available as climate change adjustments.

The Coupled Model Intercomparison Project phase 5 (CMIP5) based Representative Concentration Pathways (RCP) that underpin the

Electricity Sector Climate Information (ESCI) data sets previously used for demand modelling for the SWIS are superseded by CMIP6 based Shared Socio-economic Pathways (SSP).

By 2050 under the high-emissions scenario SSP3-7.0 (see Table 1), Perth's average daily maximum temperatures are projected to increase by 1.1°C to 1.5°C above current baselines (with summer mean maximums expected to rise by up to 1.5°C to 1.9°C), translating to a doubling of summer days exceeding 35°C.

Perth	Annual (mean daily)			Summer (mean daily)			Winter (mean daily)		
	ANN mean	ANN max	ANN min	DJF mean	DJF max	DJF min	JJA mean	JJA max	JJA min
ERA5 (Current)	17.4	26.5	10.9	24.5	36.0	16.1	10.8	17.4	6.0
2030 SSP1 -2.6	17.9	27.0	11.2	25.0	36.6	16.5	11.1	17.9	6.3
2030 SSP3 -7.0	17.9	27.1	11.3	25.1	36.8	16.6	11.2	18.0	6.3
2030 SSP5 -8.5	18.0	27.2	11.4	25.1	36.7	16.6	11.3	18.0	6.4
2050 SSP1 -2.6	18.1	27.3	11.4	25.2	36.9	16.7	11.3	18.1	6.4
2050 SSP3 -7.0	18.5	27.8	11.8	25.7	37.5	17.2	11.7	18.5	6.7
2050 SSP5 -8.5	18.6	27.9	11.9	25.9	37.7	17.3	11.8	18.6	6.8

Table 1. Shared Socio-Economic Pathway climate projections for Perth, Western Australia

Further development

The following areas will be investigated to drive improvements in the SWY:

- Adjusting the SWY for climate change can be accommodated; however, climate projections currently available do not provide the required inputs (i.e. irradiance and wind) to support renewable generation forecasts that are adjusted for climate change.
- Critical event injection into a RWY set to support studies that require multiple RWY will be investigated.
- Holiday period critical events that address electric vehicle charging will be investigated.

Part 2 | Renewable generation forecasting methodology

This document provides an overview of Western Power's methodology for generation forecasting and reference generator selection.

Generation forecasting is applied to the following intermittent generation types;

- Solar PV
- Wind turbine

Other generation types may be added as they are introduced as candidate generators for the SWIS.

While generation forecasting inputs are aligned to the Synthetic Weather Year (SWY) the forecasting methodology can be applied to any Reference Weather Year (RWY).

Wind generation

Data inputs

Wind generation forecasting is developed using the SWY as the wind data input source. The SWY wind data is drawn from the Bureau of Meteorology Atmospheric Regional Reanalysis for Australia (BARRA) C2 data set. A 30 minute time-series wind speed trace is extracted for turbine hub heights at 50m, 100m and 150m. Meter interval data is sourced for existing wind generators – this is supplemented by meteorological mast data where available.

Wind farm modelling

Wind farms are modelled as a single aggregated facility – land form impact on wind resource and turbine airflow interactions are not modelled explicitly. Key model elements for each wind farm are:

- **Location.** Latitude and Longitude of the wind farm.
- **Wind speed.** Time-series wind speed at hub height – adjusted for locational factors such as surface roughness (BARRA-C2).
- **Turbine power curve.** A reference power curve (Figure 4) – can be replaced with a custom power curve where required.
- **Wind farm capacity.** Aggregated turbine peak rating.
- **Hub height.** Average turbine hub height for the wind farm.
- **Wake losses.** Cut in and Cut out wake losses for the wind farm – wake loss has directional dependence that is not addressed.
- **Electrical loss.** Electrical losses associated with cables, transformers and power electronics.

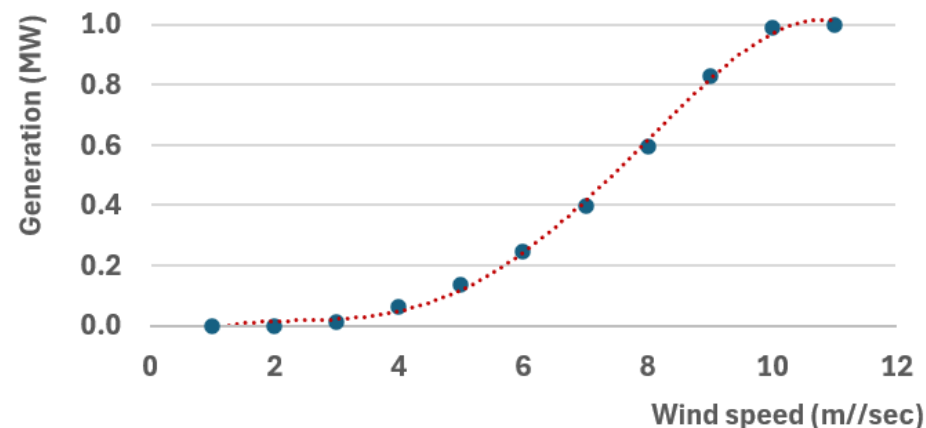


Figure 4. Reference power curve

Calibration & performance

The wind farm model is calibrated using existing wind farm meter data and meteorological mast data where available. Each wind farm is simulated with BARRA wind speed inputs – the simulated energy production is calculated for each month and compared to metered energy production. A wind speed calibration factor is calculated for each month that adjusts the wind speed so that the simulated and metered energy production aligns. Calibration is intended to adjust for BARRA simulation error and other factors that the wind farm simulation does not adequately address e.g. parasitic load.

14 | Wind generation

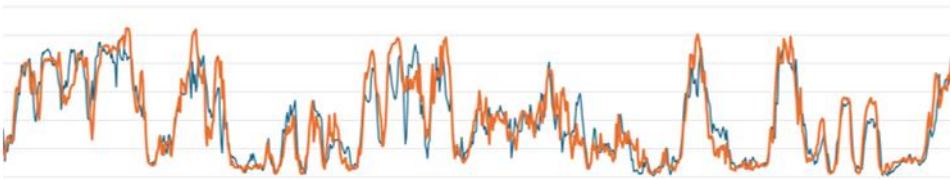
Calibration factors are applied to both existing and candidate wind farms for which no meter data is available to derive calibration factors. Calibration factors are developed regionally to ensure that regional variations in BARRA simulations are addressed. SWIS average calibration factors for existing wind farms are outlined in Table 2.

MONTH	J	F	M	A	M	J	J	A	S	O	N	D
FACTOR (%)	10.8	12.2	16.9	15.7	14.4	12.7	11.5	12.7	12.7	13.8	12.4	8.9

Table 2. SWIS existing wind farm calibration factors

Wind farm modelling performance is evaluated by calculating correlation coefficients of multi-hour rolling average wind farm energy production (metered vs simulated). The multi-hour average addresses the inherent variability of wind resources at the hourly interval – these variations are expected to be moderated through resource diversity and energy storage. A sample of the aggregated wind generation trace for existing wind farms connected to the SWIS is provided in Figure 5. Rolling average views are also used to support qualitative assessment of trace pattern alignment for existing wind farms.

1 hour intervals – 87.4% correlation



6 hour rolling average – 91.7% correlation

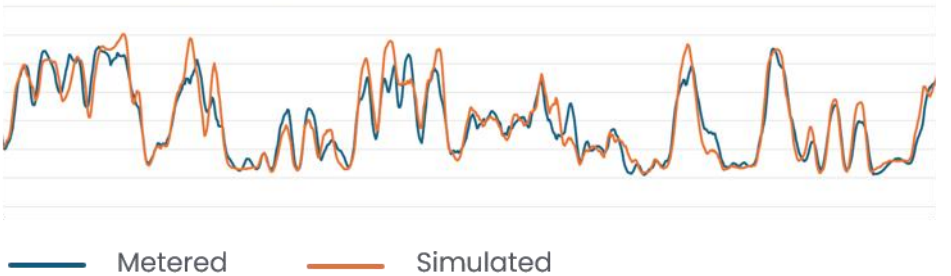


Figure 5. SWIS existing wind farm trace sample

Solar generation

Data inputs

Solar generation forecasting is developed using the SWY as the irradiance data input source. The SWY irradiance data is drawn from the Bureau of Meteorology Atmospheric Himawari-9 BOM IDE00346 and IDE00347 data sets. A 60 minute time-series irradiance data set is extracted for surface global irradiance, direct normal irradiance and surface diffuse irradiance. Meter interval data is sourced for existing solar generators.

Solar farm modelling

Solar farms are modelled as a single aggregated facility. Key model elements for each solar farm are:

- **Location.** Latitude and Longitude of the solar farm.
- **Irradiance.** Time-series irradiance (Himawari-9).
- **Panel efficiency.** Reference panel efficiency (default 25%) – can be replaced with a custom panel efficiency where required.
- **Solar farm capacity.** Aggregated panel peak rating.
- **Panel tilt.** Vertical panel tilt angle (default 30 degrees).
- **Panel temperature.** Temperature adjusted efficiency.
- **Panel orientation.** Orientation relative to North (default 0°C).
- **Panel tracking.** Default panel horizontal tracking applied.
- **Electrical loss.** Electrical losses associated with cables, transformers and power electronics.
- **Export limit.** Downstream network and connection export limits.

Calibration & performance

The solar farm model is calibrated using existing solar farm meter data. Each solar farm is simulated with Himawari satellite observation inputs – the simulated energy production is calculated for each month and compared to metered energy production. A solar irradiance calibration factor is calculated for each month that adjusts the solar irradiance so that the simulated and metered energy production aligns. Calibration is intended to adjust for simulation error and other factors that the solar farm simulation does not adequately address e.g. parasitic load.

Calibration factors are applied to both existing and candidate wind farms for which no meter data is available to derive calibration factors. Calibration factors are developed regionally to ensure that regional variations in Himawari observations are addressed. SWIS average calibration factors for existing solar farms are outlined in Table 3.

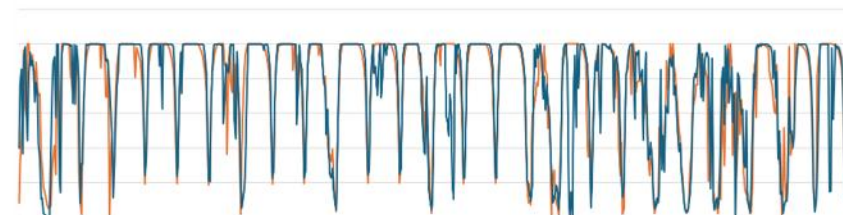
MONTH	J	F	M	A	M	J	J	A	S	O	N	D
FACTOR (%)	1.3	0.0	-2.2	7.3	3.7	5.2	7.5	3.7	3.7	3.7	3.7	6.6

Table 3. SWIS existing solar farm calibration factors

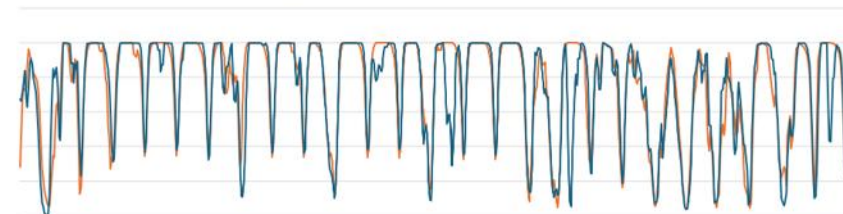
Solar farm modelling performance is evaluated by calculating correlation coefficients of multi-hour rolling average solar farm energy production (metered vs simulated). The multi-hour average addresses the inherent variability of solar resources at the hourly interval – these variations are expected to be moderated through resource diversity and energy storage. A sample of the aggregated solar generation trace for existing solar farms connected to the SWIS is provided in Figure 6. Rolling average views are also used to support qualitative assessment of trace pattern alignment for existing solar farms.

The number of solar farms available for calibration has been reduced for this modelling cycle. Significant outage / curtailment activity across some months for the meter data inputs to the solar farm model is being investigated to determine how best to reflect in simulated solar farm generation traces.

1 hour intervals – 84.6% correlation



3 hour rolling average – 89.4% correlation



— Metered — Simulated

Figure 6. SWIS existing solar farm trace sample

Reference generators

Reference generators are used as candidates for expansion modelling; they are developed for each network zone reflecting:

- Active generation connection projects in Western Power's connections queue
- Industry consultation e.g. Registration of Interest (ROI) process.
- Land use restrictions and zoning (e.g. national park, off-shore wind precincts).
- Availability of fuel supply e.g. gas pipeline proximity and capacity.

Reference generation locations are illustrated in Figure 7. Note that gas generation candidates are not currently shown.

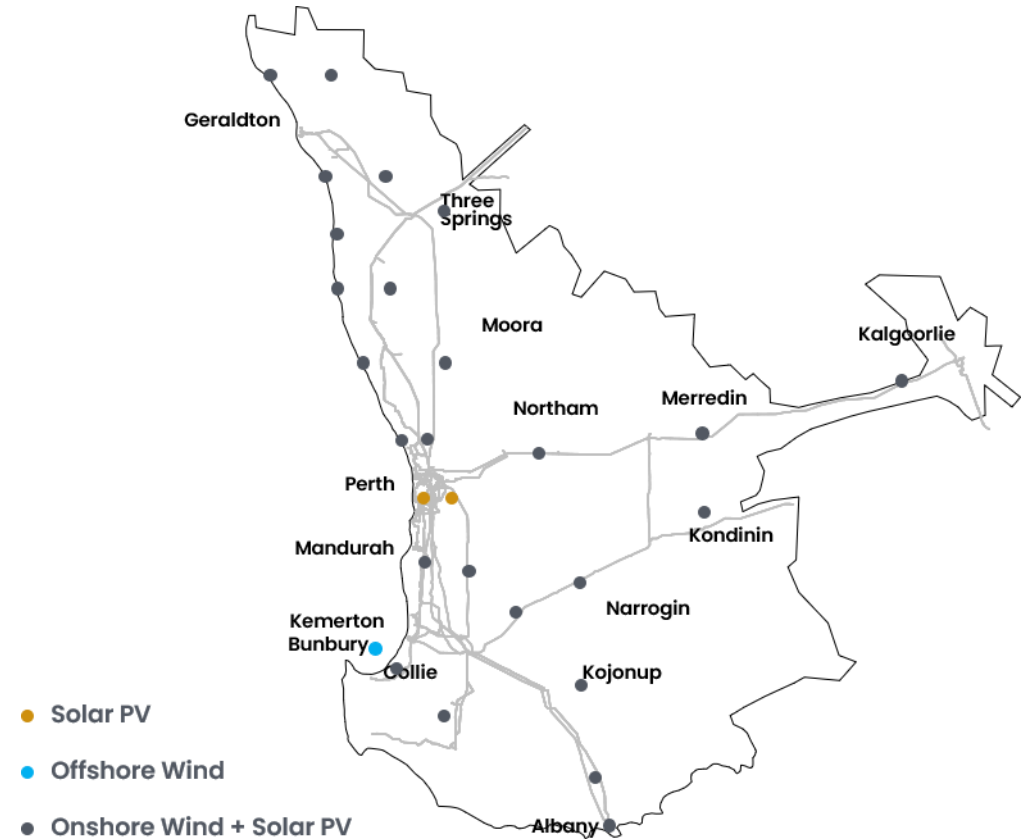


Figure 7. SWIS reference candidate generator locations

Further development

The following areas will be investigated to drive improvements in generation forecasting:

- Wind farm wake loss variability with wind direction.
- Air density impact on wind farm production.
- Curtailment, planned and unplanned outage treatment for both wind and solar generation.
- Solar simulation midday production dip.

