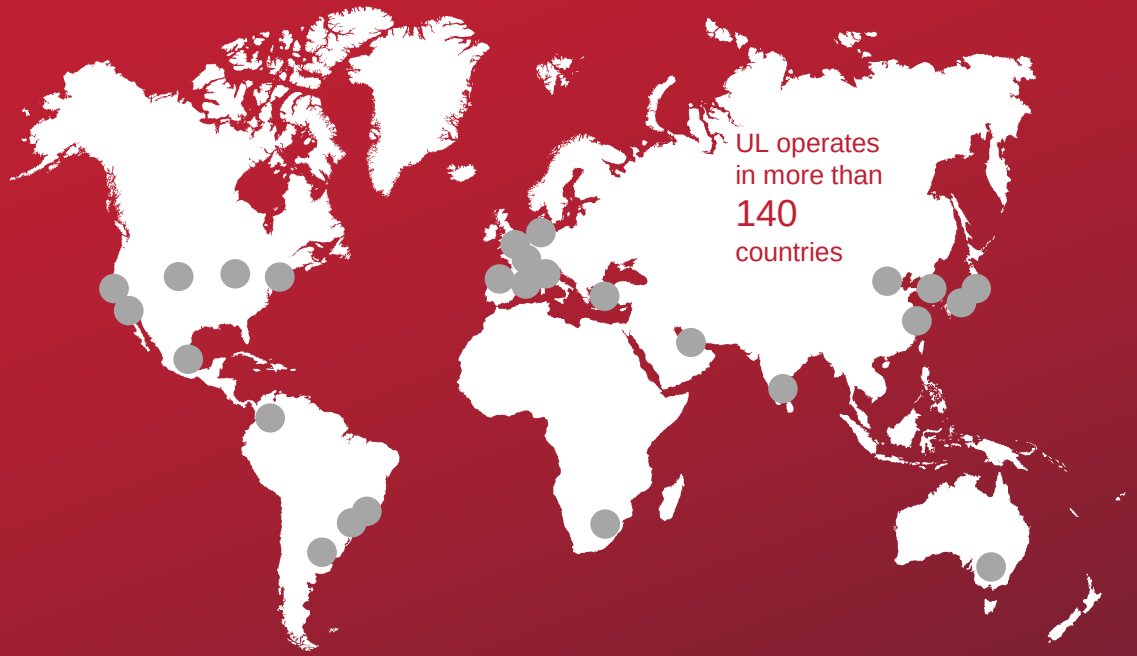
Improving PV plant operation through advanced data analysis

Daniel Barandalla, solar advisory lead, Europe and Latin America

Empowering Trust®

Key office locations — renewables



500+
RENEWABLE ENERGY EXPERTS

35+ *years of*
EXPERIENCE IN RENEWABLE ENERGY

UL has assessed
100+
UTILITY-SCALE SOLAR PROJECTS SINCE 2013

HOMER Energy software is used in
190+
countries, with more than
250,000 users

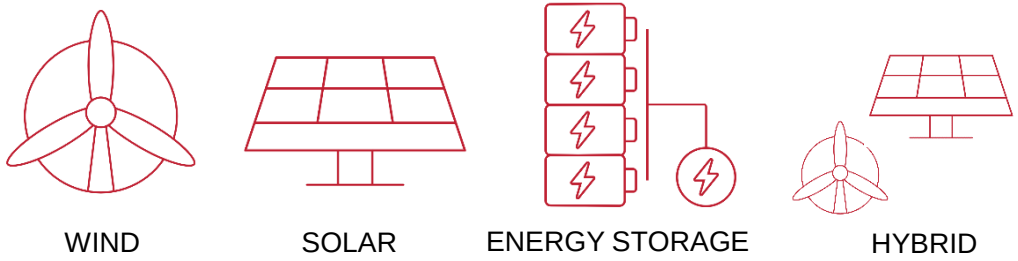
1000+
PV products evaluations annually

100,000+
HYBRID POWER PROJECTS MODELED SINCE 2014

Forecast provider for
100+ GIGAWATTS
OF INSTALLED RENEWABLE ENERGY PROJECTS

Independent/Owners Engineer for
1000+
WIND AND SOLAR PROJECTS SINCE 2012

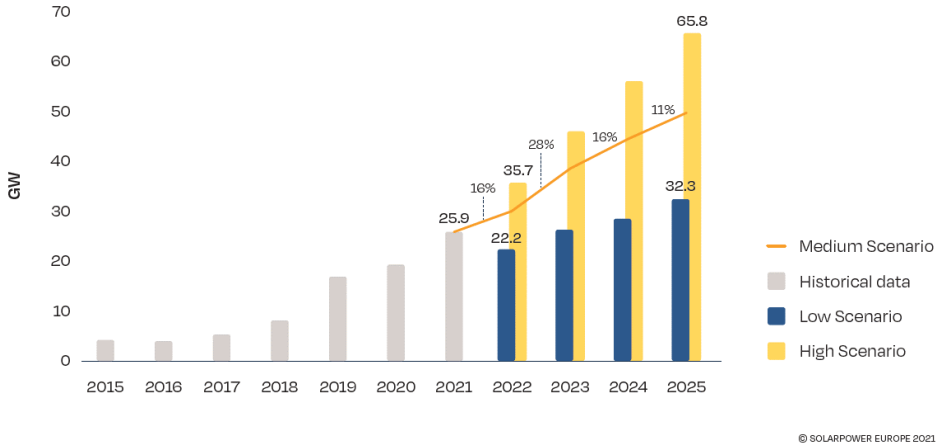
UL drives trust in renewables

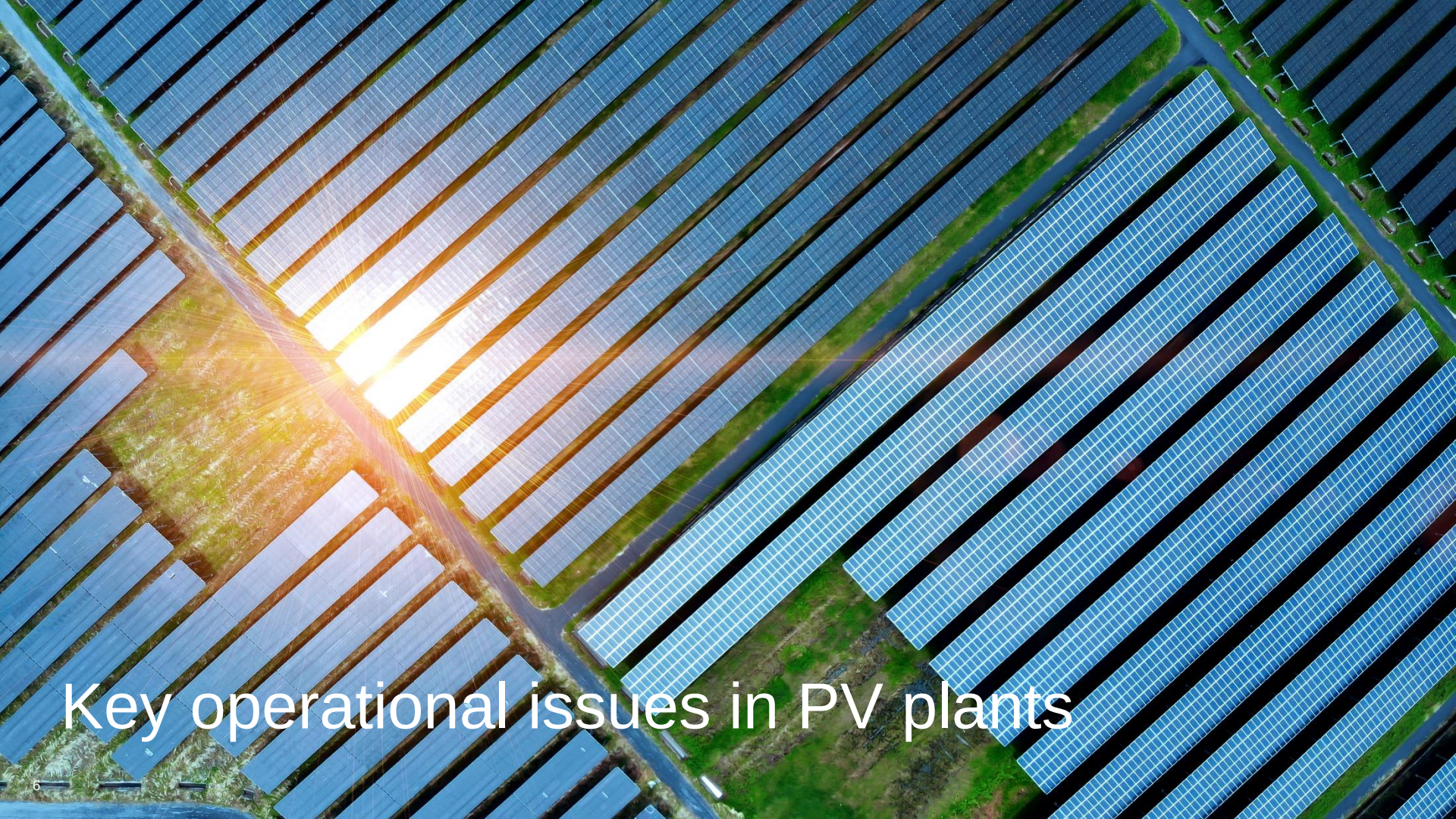


Solar PV operational portfolio: Europe

Operational PV portfolio in Europe

- 25.6 GW of new capacity was installed in Europe in 2021 (increase of 34% over the previous year), breaking records in terms of yearly installed capacity led by:
  - Germany with 5.3 GW of new installed capacity
  - Spain with 3.8 GW
  - The Netherlands with 3.3 GW
  - Poland with 3.2 GW
  - France with 2.5 GW
- The total solar PV installed capacity in the EU is of 165GW in 2021
- By 2030, SPE predicts having around 672 GW operational in the EU





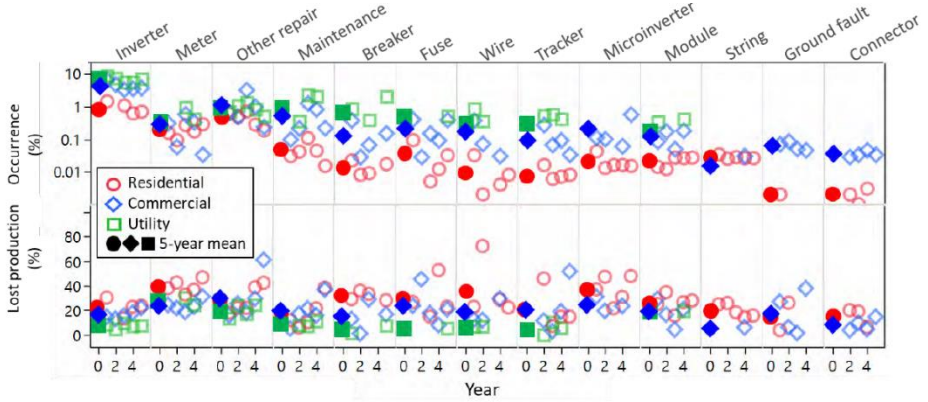
Key operational issues in PV plants

Key operational issues in PV plants

Most common failure: inverter failures — Are they properly installed/commissioned?

Installation quality can impact reliability (tracker configuration, strings, meters, connectors, fuses).

Tracker performance and adjusting backtracking and row-to-row tracking strategies are key to ensure proper performance.



Source: NREL – PV Reliability Workshop “PV Reliability of 100,000 Systems”

Detailed performance analytics for operational PV plants

The good news: Underperformance could be addressable

UL's performance analysis to identify and quantify sources of energy loss

Waterfall of losses to explain variance between proforma and actual output

Resource availability

Effect of actual insolation vs. proforma expectation

Other externalities

- Forced curtailment
- Grid outages
- Snow

As-built capacity and degradation

- Effect of as-built observed generation capacity vs. nameplate
- Effect of degradation over period of analysis
- Ongoing degradation

Addressable losses

- Inverter outages
- Other AC outages
- DC outages
- Tracker outages
- Soiling abatement
- Tracker setup
- Inverter setup

Advanced data analytics for performance evaluation

UL distills and interprets data from operational PV plants

Data curation

- Algorithms use physical models and statistical techniques to detect and repair data quality issues
- Handles random data issues such as time-shifts and data gaps
- Handles systematic issues such as sensor drift and mis-pointed irradiance sensors

Goes beyond filtering and backfilling; enables accurate and actionable analyses

Digital twin

- Comprehensive physical model of modules, inverters and circuitry
- Model for plane-of-array irradiance for fixed-tilt and tracker systems
- Generates expectation of energy and electrical parameters based on data from sensors for every 15-minute period

Captures the effect of continuously varying irradiance applied to the nonlinear responses of PV plants

Loss attribution

- Variance between actual and expected output is quantified for each 15-minute period
- Variance is algorithmically attributed and allocated to multiple loss categories
- Waterfall of losses accounts for variance between expected and actual output

Quantitative accounting of energy loss attribution to specific causes

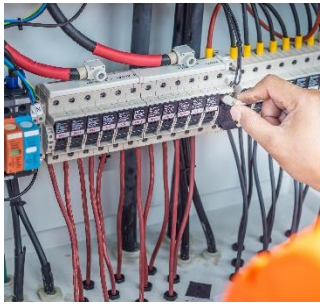
What is required

System design

- Location
- Modules and inverters
- Circuit
- Orientation
- Mounting
- Grid limits

SCADA data (15-min interval)

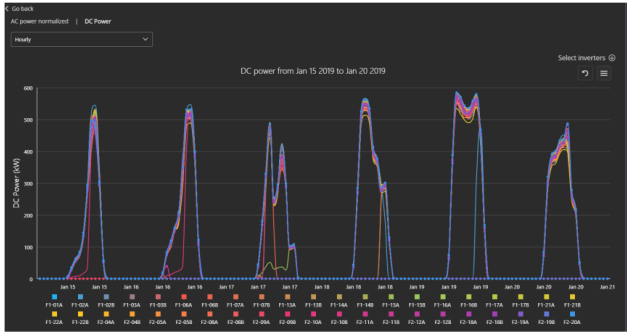
- Meter energy/power/pf
- Inverter AC power/DC power
- Inverter DC voltage/DC current
- Irradiance
- Temperature
- Wind speed
- Relative humidity
- Full historical period
- Data acquisition system (“DAS”) access or delivered files



	SEL735-POI__Energy Active Export	INV-1-1__Active Power AC	INV-1-1__Current DC	PAD-3 WS 1 POA__Irradiance [W/m²]	PAD-1 WS 2 Ambient__Temperature [°C]
8/2/2018 6:20	897716	0	0	0	20.64588013
8/2/2018 6:25	897716	0	0	0	20.63936005
8/2/2018 6:30	897716	0	0	0	20.6705204
8/2/2018 6:35	897716	0	0	3.962786007	20.72523994
8/2/2018 6:40	897716	0	0	6.560245895	20.76051979
8/2/2018 6:45	897716	0	0	9.596014214	20.77788048
8/2/2018 6:50	897716	0	0	13.56284008	20.74504013
8/2/2018 6:55	897720.2	16.27999992	30.95999908	20.31204052	20.70550003
8/2/2018 7:00	897730.8	27.96000061	49.58000031	28.05443993	20.68139992
8/2/2018 7:05	897748.2	42.88000031	71.05999985	42.42925949	20.72477989
8/2/2018 7:10	897773.4	60.45999985	95.91999969	57.38941956	20.82753983
8/2/2018 7:15	897808.8	80.51999969	124.1999985	81.03688049	20.9424202

Source: UL

Data analytics



Source: UL RAMP

SCADA weather data
15-min resolution

Curated weather inputs

Project description
Components, configuration and layout distribution

PV plant digital twin

Expected output

Manual onboarding

SCADA production data
15-min resolution

Curated production data

Quantification variance/losses

Loss waterfall with quantified losses by cause for each device and each time period

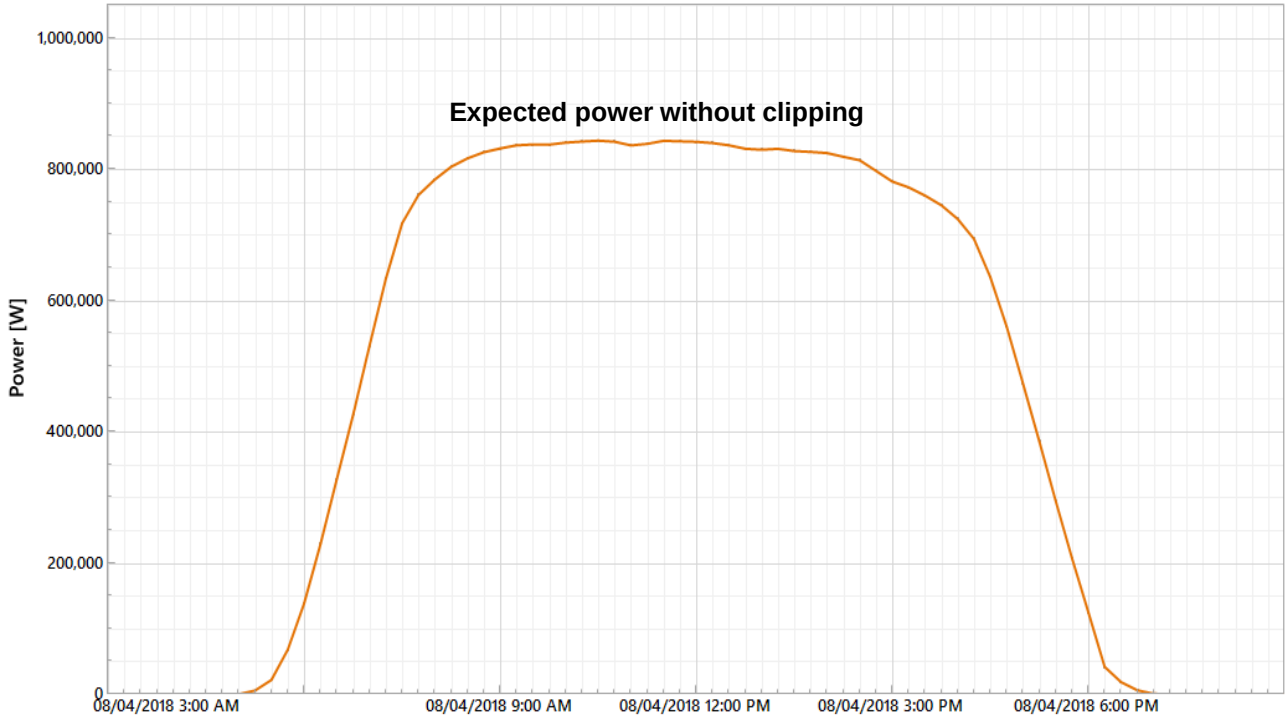
Customer input

Manual

UL's solar performance analytics

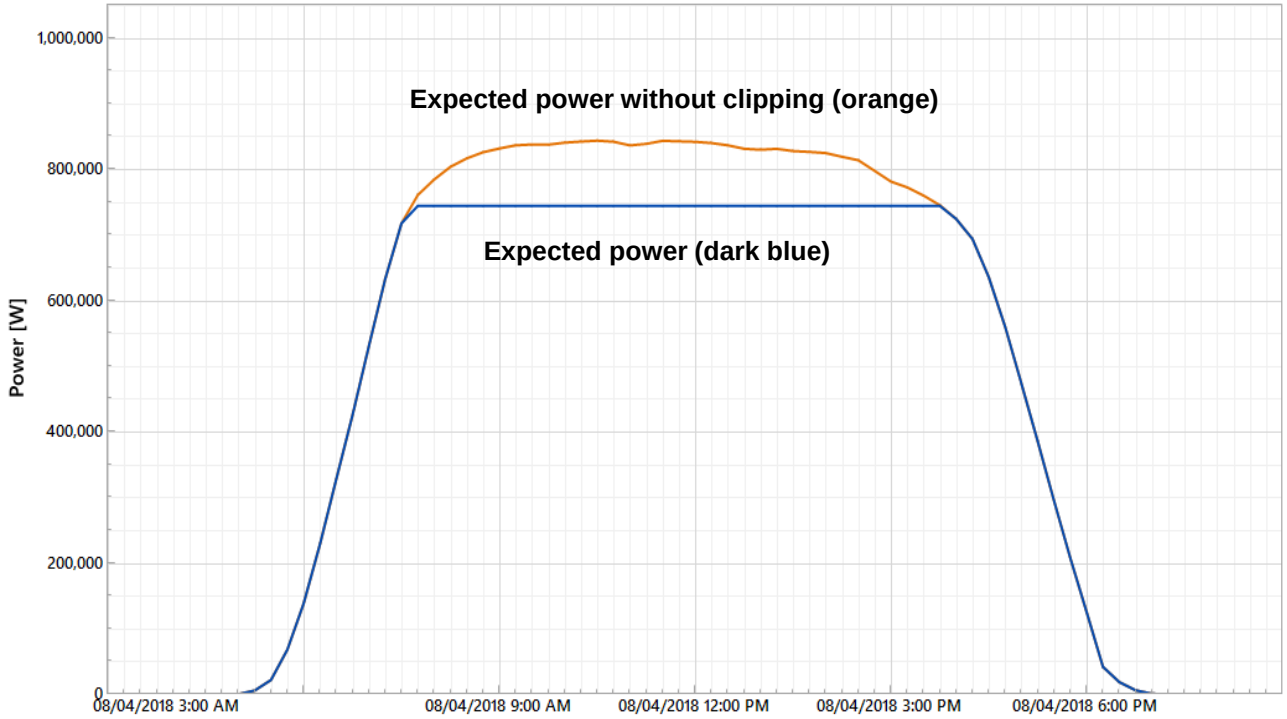
Case examples and conclusions

Modelling expected generation



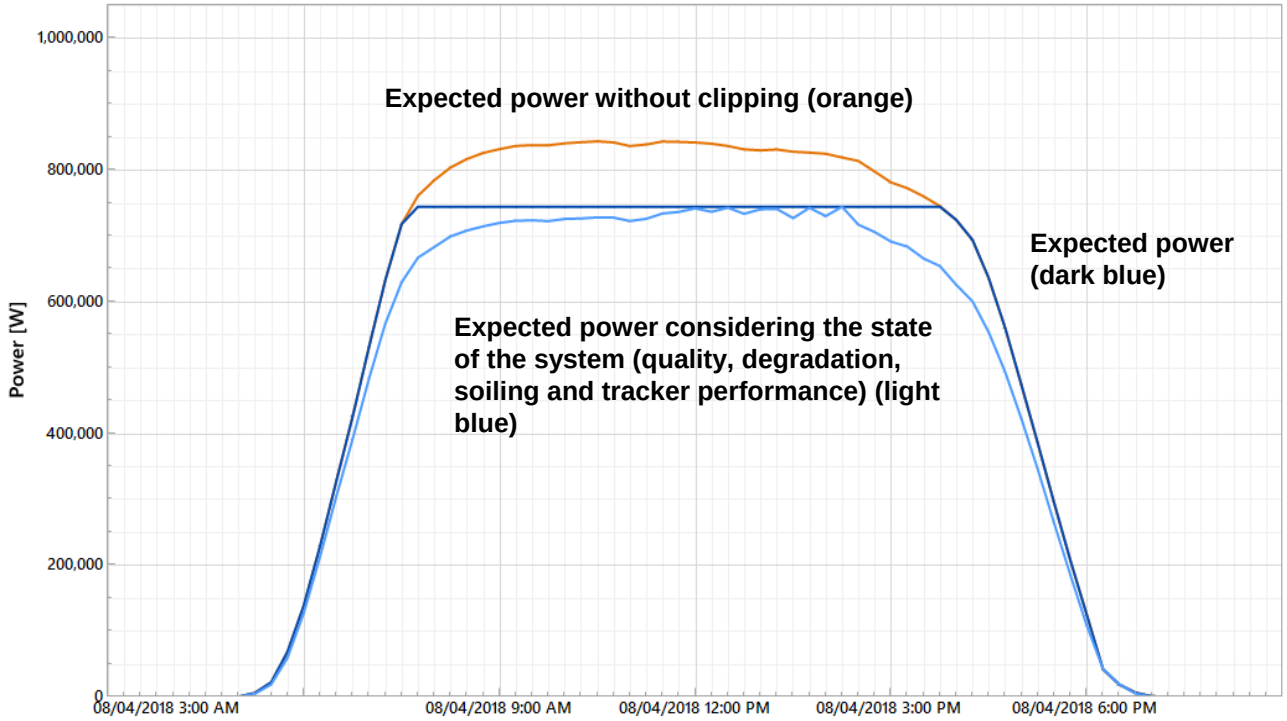
Source: UL

Modelling expected generation



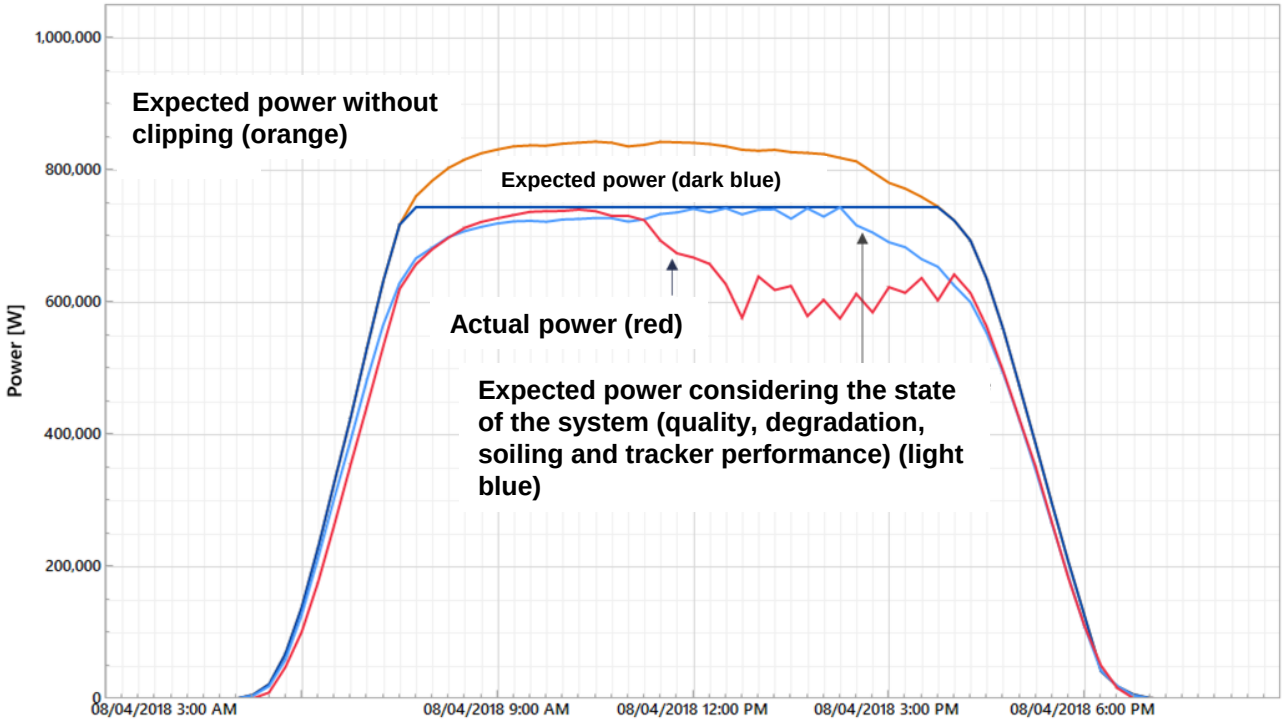
Source: UL

Modelling expected generation



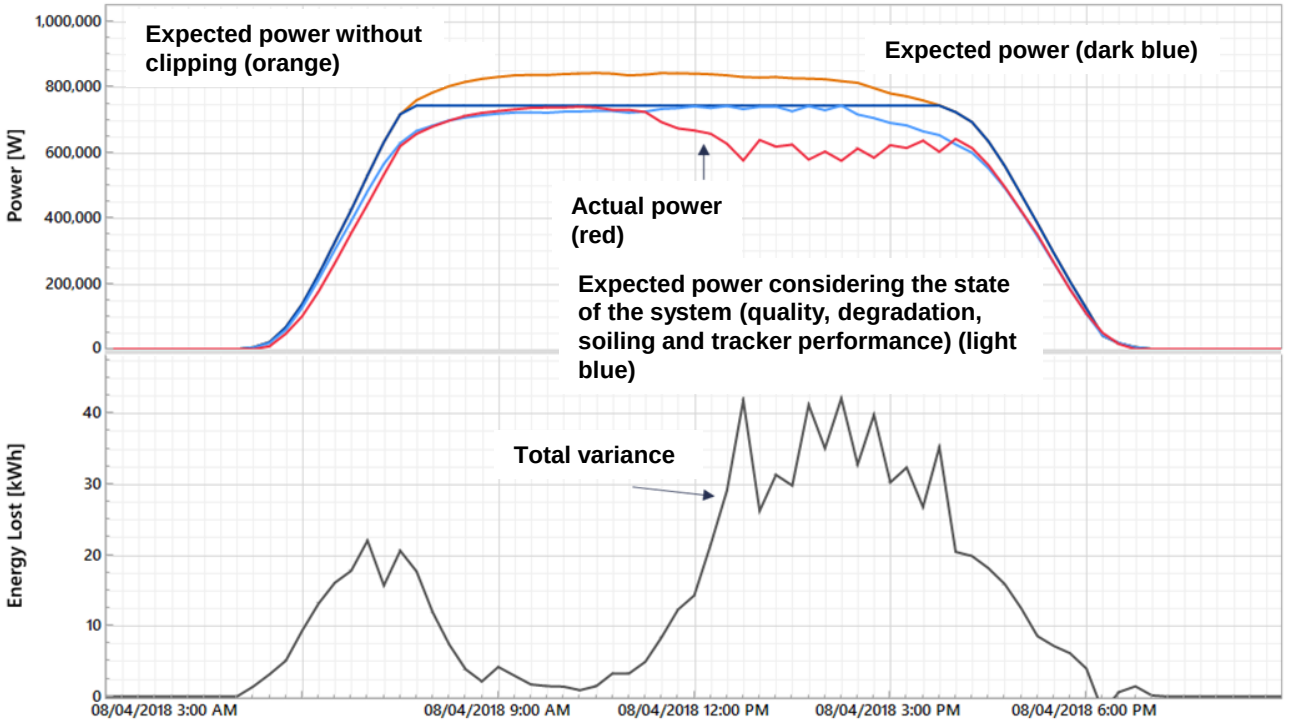
Source: UL

Modelling expected generation



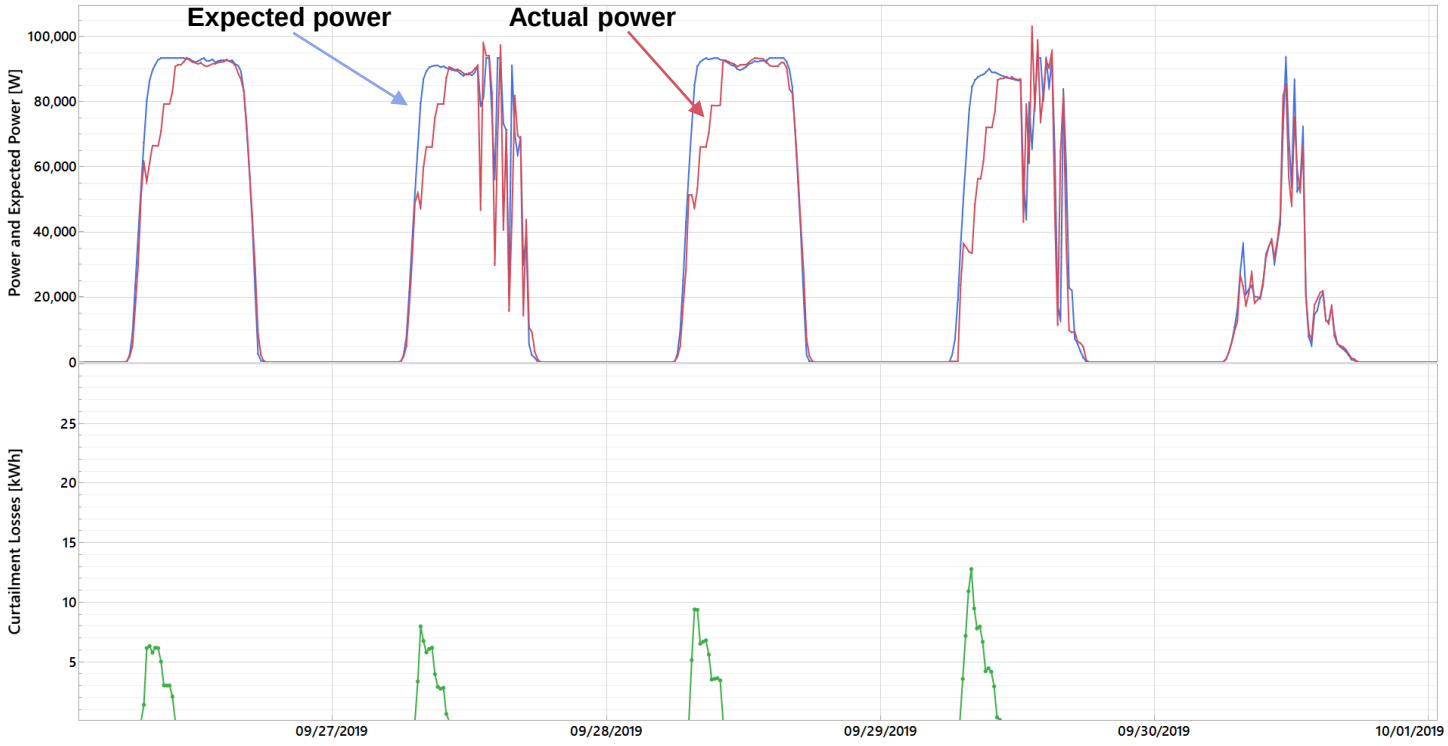
Source: UL

Quantifying variance



Source: UL

Variance attribution — curtailment



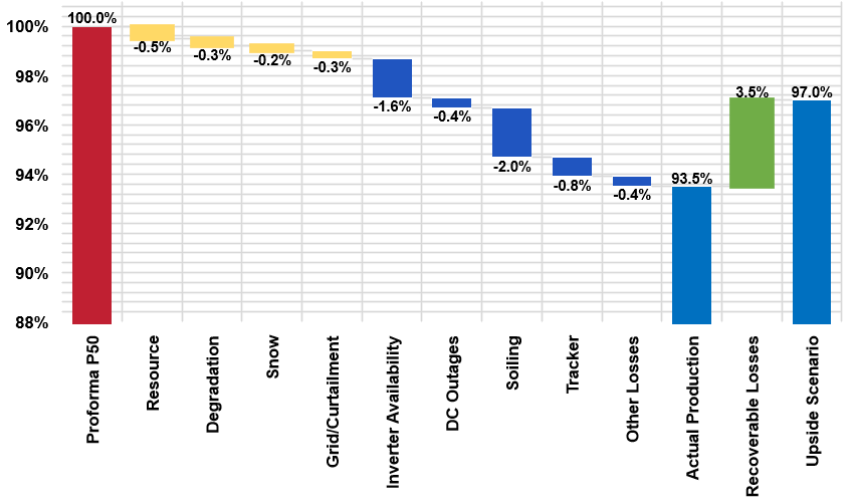
Source: UL

Variance attribution — DC outage losses

Source: UL

Solar performance is addressable

Loss waterfall and potential for upside



Addressable factors drive the majority of underperformance.

UL estimates that 3-4% of energy lost to underperformance is recoverable.

Attribution categories

- Resource
- As-built quality
- Degradation
- Soiling
- Snow
- Curtailment
- AC availability
- Inverter efficiency
- DC availability
- Stalled trackers
- Tracker retro-tracking shading
- Shading (above modeled loss)
- Plant controller (gain)
- Not attributed

Case example

Customer

A large global owner-operator of utility-scale and distributed generation projects

Challenge

Assets were underperforming and operator couldn't fully identify underlying causes; suspected degraded solar panels based on limited data

Engagement

UL assessed data from COD (2014) to date to evaluate module degradation and other causes of underperformance. Operational issues including inverter performance and soiling played bigger roles than degradation.

Value proposition

Addressing clogged inverter filters (nominal cost) rather than replacing modules would lead to substantial improvement.

UL's recommendations saved the customer from €100M+ capital investment as they had contemplated replacing more than 3 million modules.

Attribution of losses — cumulative		
Initial quality	12,111 MWh	0.41 %
Inverter DC/AC	-8,361 MWh	-0.26 %
Degradation	44,087 MWh	1.39 %
Seasonal and soiling	37,281 MWh	4.31 %
Tracker outages	2,461 MWh	0.08 %
Retro-tracking loss	3,671 MWh	0.12 %
Curtailment	168,116 MWh	5.28 %
AC availability (inverter)	72,913 MWh	2.29 %
Dynamic inverter recov.	-5,214 MWh	-0.56 %
Inverter to meter loss	38,835 MWh	1.22 %
Not attributed/other	3,851 MWh	1.09 %

Data-driven recommendation saved substantial unwarranted capital investment

Questions?

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Thank you

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