

TotalEnergies

Improving Asset Management using AI

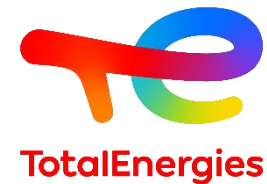
Intersolar – 6th May 2025

Etienne Drahi

Head of Solar R&D Program TotalEnergies



INTEGRATED POWER



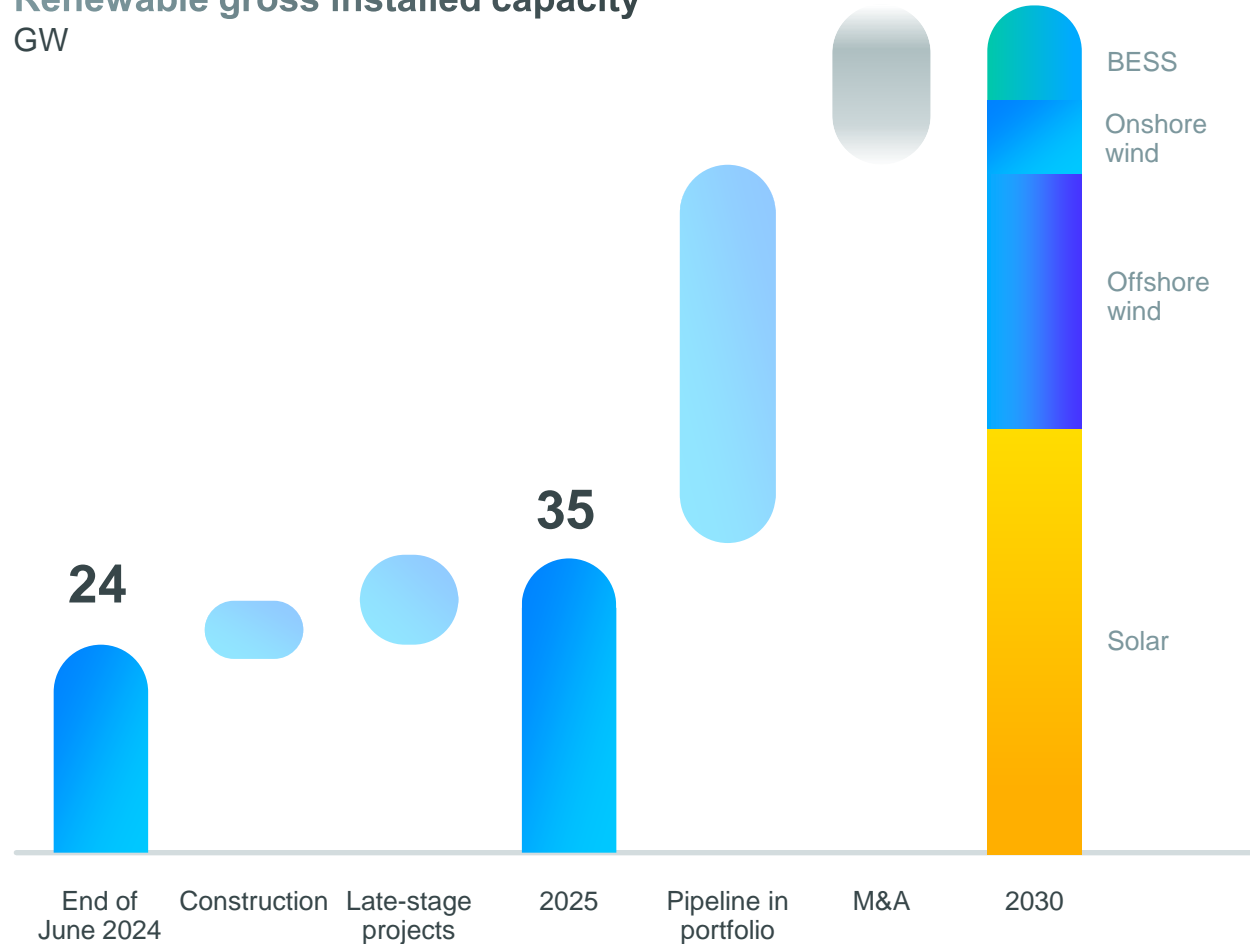
> 100 TWh power generation by 2030



ON TRACK TO DELIVER 100 GW RENEWABLES BY 2030



Renewable gross installed capacity
GW



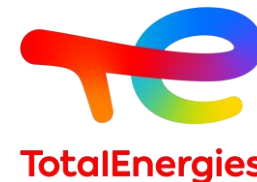
↑% **~80%**
already identified:
selectivity on a large pipeline
of projects (value over volume)

📄 **Balanced portfolio
of technologies**

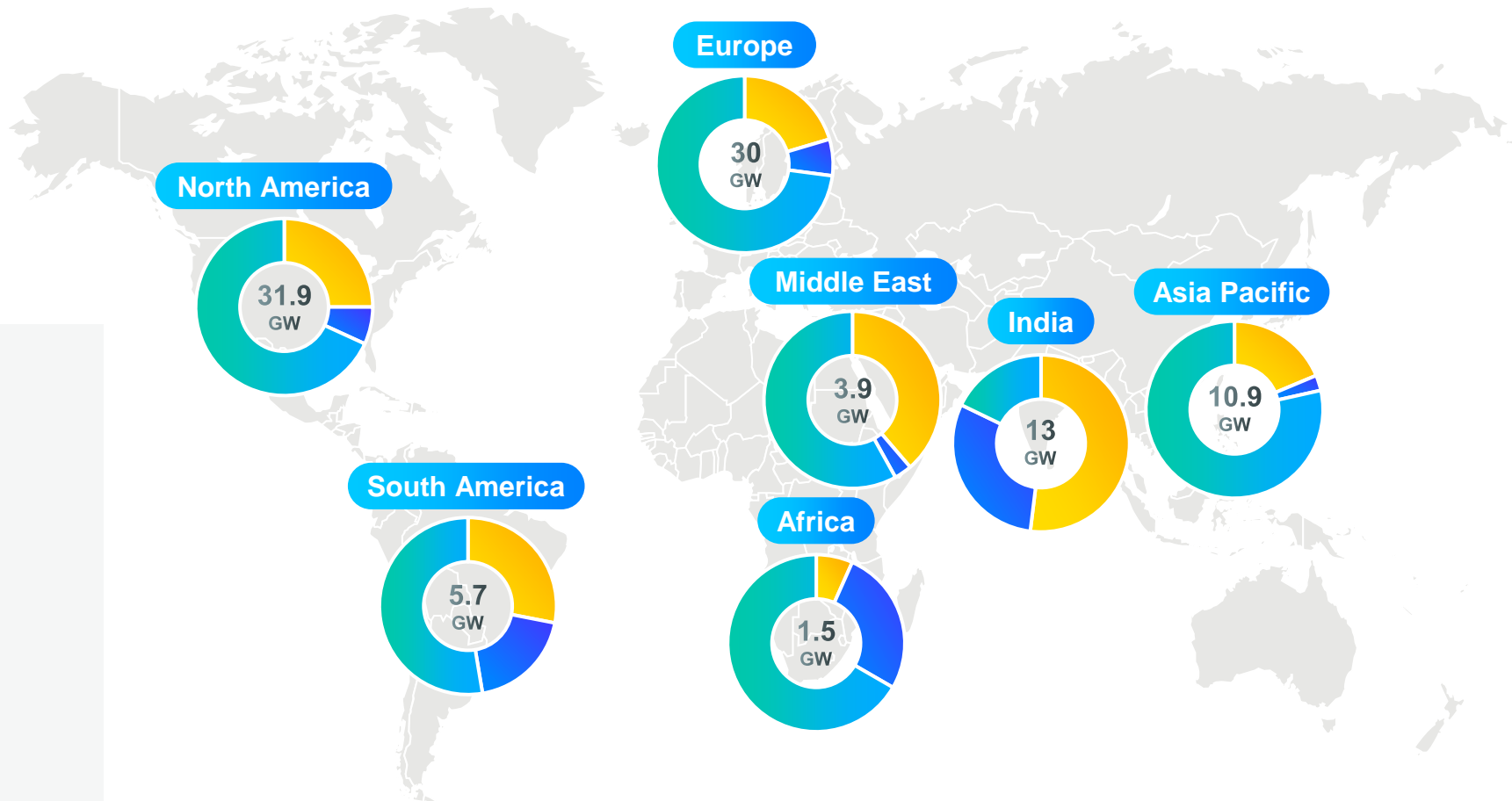
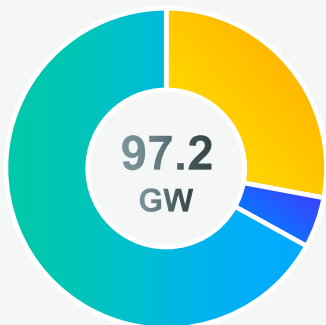
🔬 **~10%**
capacity in offshore
wind to 2030



A GLOBAL PORTFOLIO OF RENEWABLE ELECTRICITY GENERATION



2024 Gross portfolio*
in GW

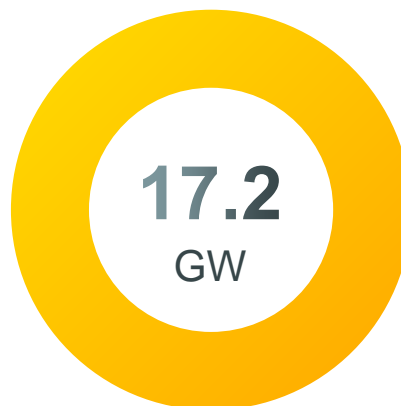




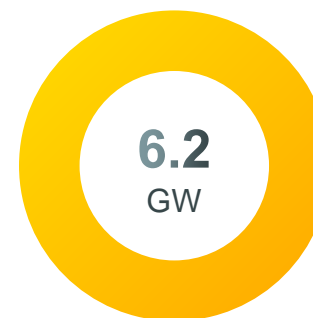
50 GW
OF SOLAR
POWER PROJECTS
INSTALLED, UNDER
CONSTRUCTION OR
IN DEVELOPMENT
WORLDWIDE



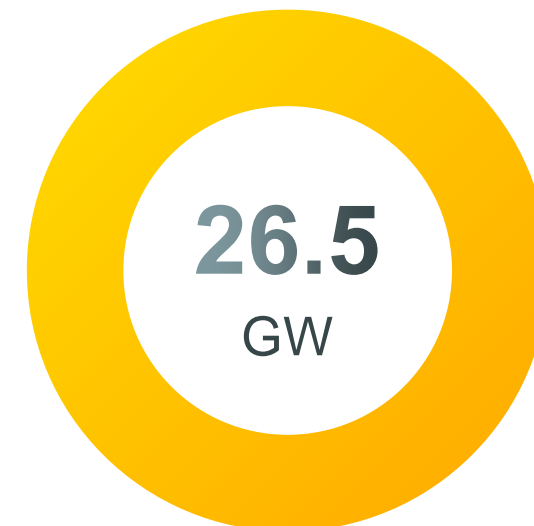
Solar portfolio
Q4 2024



Installed



Under construction

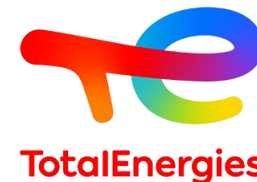


In development

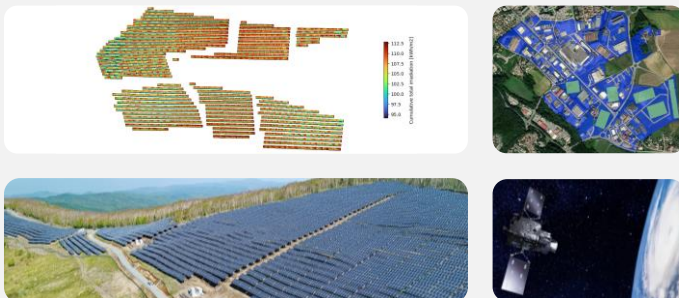


Solar R&D Program

Develop solutions to accelerate solar energy deployment, improve assets and cost efficiency in a sustainable way



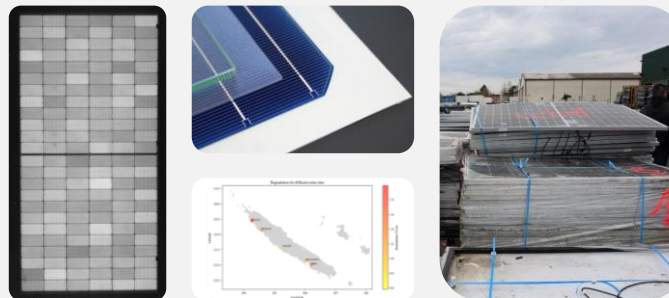
Better estimate resources



- **Predict** variability
- **Identify** sites
- **Estimate** yield
- **Anticipate** a changing climate



Select the best components



- **Explore** new technologies
- **Estimate** long term degradation
- **Manage** end of life of PV systems



Technical
University of
Denmark



Deliver high performance



- **Build** demonstrators and testing platforms
- **Evaluate** performance of new PV Systems
- **Reduce** O&M costs
- **Predictive** Maintenance

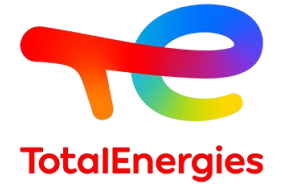


Université de
Sherbrooke



AI driven prediction in PV: from Resource to Power

Data-driven PV performance prediction

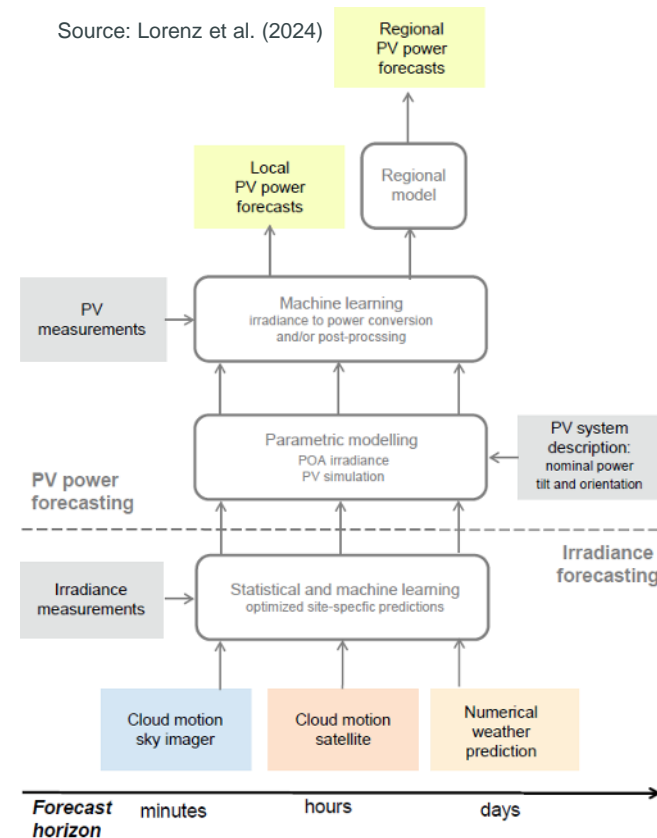


Project Operator Challenges:

- Meteo-to-PV conversion remains essential after plant commissioning for monitoring and forecasting performance.
- Operational data can be used to improve prediction by capturing degradation and plant-specific nuances

State of the art

- **Machine learning (ML) outperforms purely physics-based models** after a few months of operational data collection (e.g., Grzebyk et al. (2023)).
- Skill of PV power forecasting is driven by **the error of irradiance forecasting!**



What's next?

- How can we **predict the performance of newly commissioned plants**?
→ Hybrid physics-data-driven forecasting through ML-based surrogates
- How can we **best estimate time-varying PV forecasting uncertainty**?
→ Shift from historical uncertainty estimates towards spatiotemporally aware real-time methods – potential for generative AI?
- How can we **predict the PV production outside our portfolio**?
→ Leverage our image segmentation expertise alongside existing regional PV forecasting methods.

AI driven prediction in PV: from Resource to Power

Intraday solar forecasting for trading and optimization

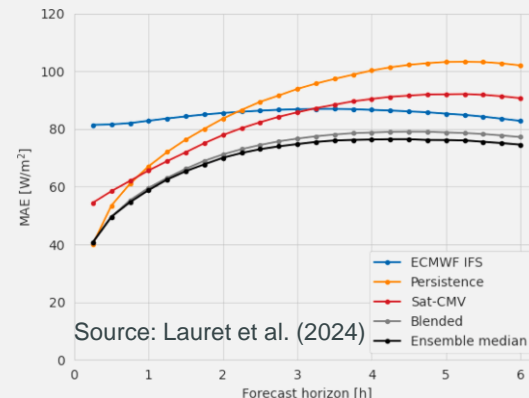
Project Operator Challenges:

- **Electricity is traded** down to 5 minutes before delivery in many markets (e.g., EPEX SPOT and Nord Pool)
- **Predictive control** can significantly improve PV plant operation (e.g., BESS charge control and PV tracking)

State of the art

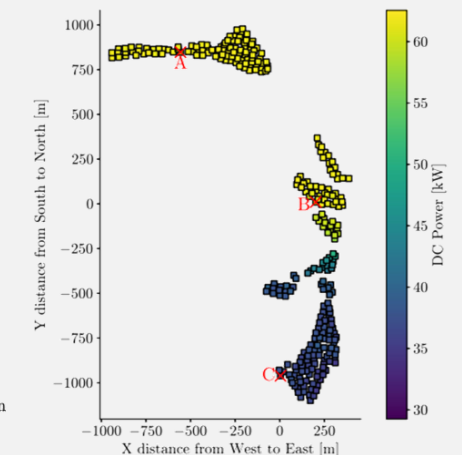
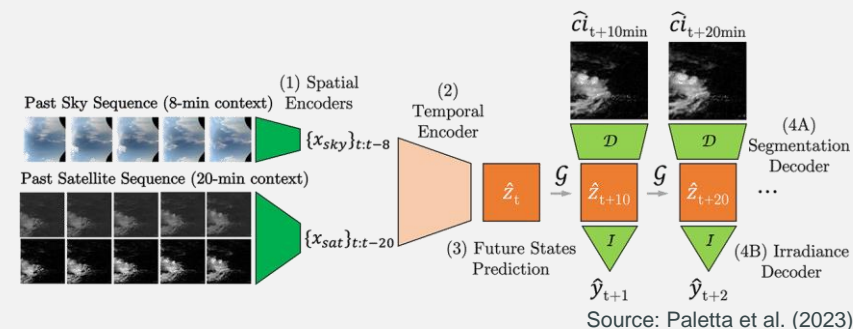
Intraday solar forecasting leverages diverse data: sky (<30 min) and satellite (<5 hours) images, numerical and deep-learning weather prediction, and real-time performance data
→ **Data fusion** is critical!

Statistical model blending is the current norm, but deep learning is gaining traction.



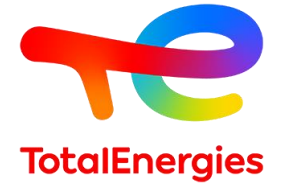
What's next?

- The coupled value of **sky and satellite images**
 - to nowcast and forecast plant **performance at inverter level**
 - to optimize **PV tracking** predictively
- Harnessing
 - **Generative AI** to do **probabilistic image forecasting**
 - **Graph neural networks** to utilize the “**PV fleet intelligence**”



AI driven prediction in PV: from Resource to Power

Day-ahead solar forecasting for trading and operations

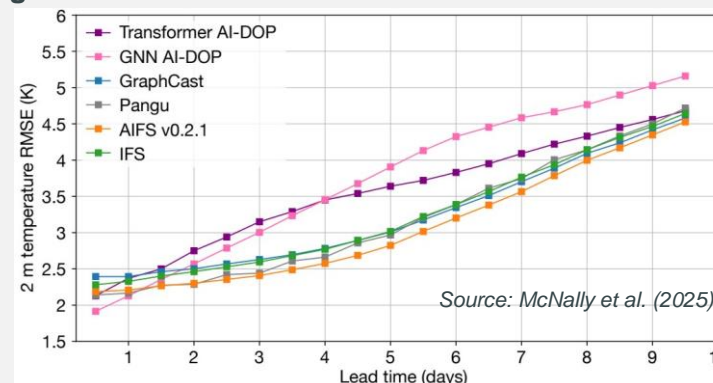
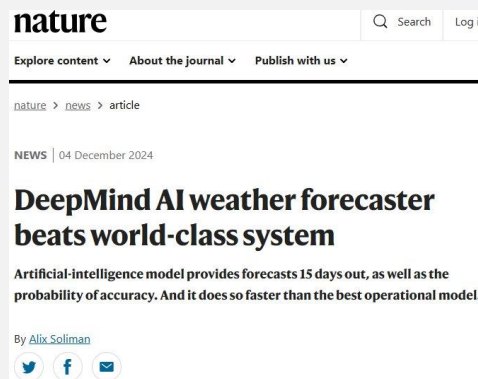


Project Operator Challenges:

- Day-ahead market serves as the baseline revenue stream for electricity trading.
- Limited in-house NWP expertise has led to reliance on external day-ahead solar forecasts.

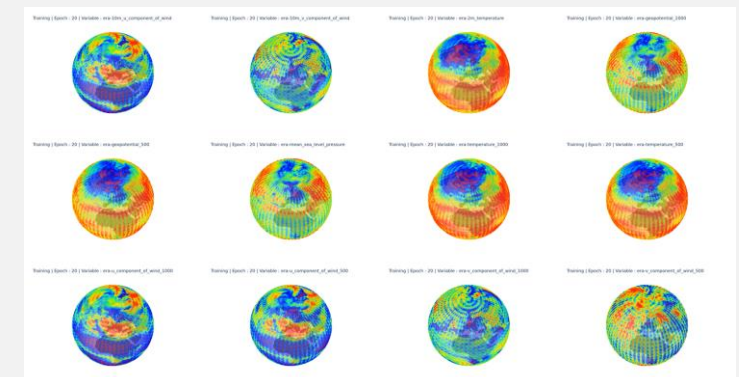
State of the art

- **Deep learning has quickly emerged** as a promising approach in weather prediction, offering potential advantages over classical NWP models.
- It enables companies with strong AI expertise to differentiate through in-house weather models, offering
 - **Design flexibility** in terms of region and horizon
 - **Accuracy** comparable to NWP
- Focus to date has been on **basic meteorological variables** rather than irradiance.



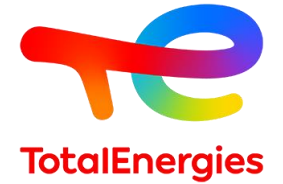
What's next?

- Building in-house expertise in deep learning for **day-ahead irradiance forecasting** by:
 - Assessing the performance of external **deep-learning weather prediction (DLWP)** products
 - **Developing and training** our own DLWP models



AI driven Operations of PV plants

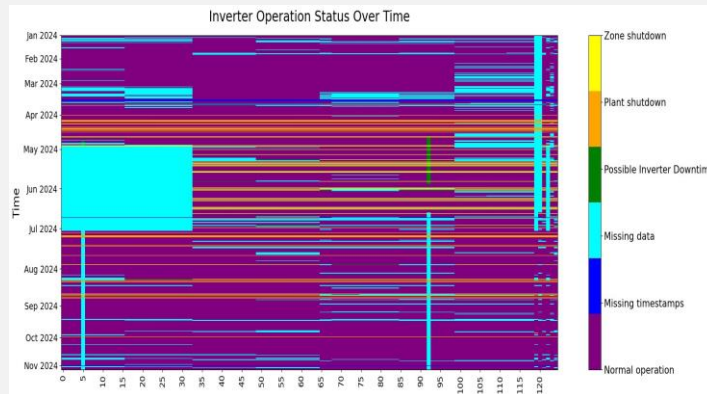
Data driven



Project Operator Challenges:

- Number of sites to operate (eg: TTE ~17-18 GW of solar sites in operation in 2025 on all continents. >500 sites)
- Lots of Merging & Acquisition → heterogeneity in and data acquisition systems and data quality

Data-driven KPIs

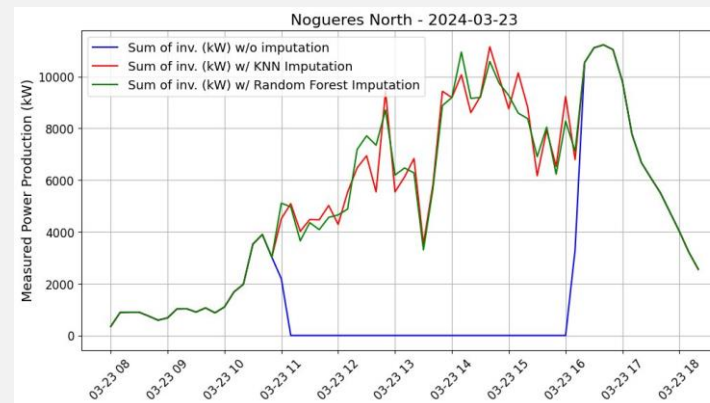


PV plant production data classification

- String level PV classification
- KPI's on Inverter downtime
- Inverter KPI's comparison
- Estimate the lost energy
- Availability calculations

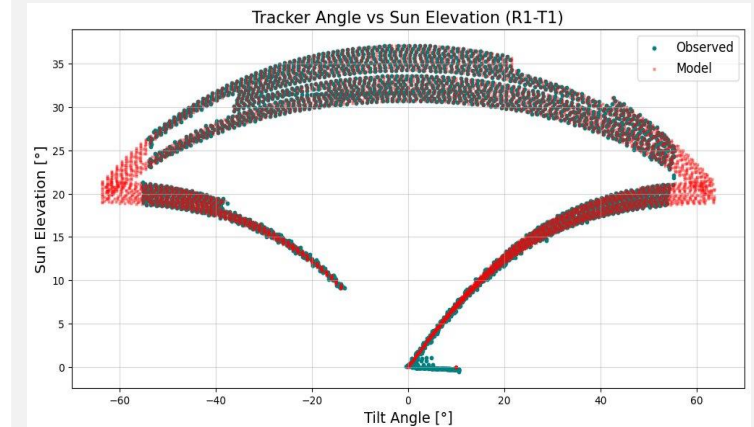
ML to represent PV production

- AI / ML models used to impute **missing data** and **quantify the lost energy***
- **Benchmarking Imputation methods** on synthetic data



Missing data imputation benchmarks

ML to detect anomalies



Single axis tracking issue detection

- ML algorithms for **tracking angle misalignment detection**
- **Lost energy** due to tracker issues **quantification**

*(N. Hrelja et al. Quantification of Snow Losses using Limited PV Production Data)

Anderson et al. "Overcoming Communications Outages in Inverter Downtime Analysis." 47th IEEE Photovoltaic Specialists Conference (PVSC). IEEE, 2020

Livera et al. "Data processing and quality verification for improved photovoltaic performance and reliability analytics." PiPV 29.2 (2021): 143-158

AI driven Operations of PV plants

Advanced and Autonomous Inspections

Project Operator Challenges:

- O&M costs reduction and Improved O&M Decision-making process

Autonomous Inspection Robots & Drones



Drone in a box by DJI

- Unmanned aerial vehicle installed at a fixed location
- Drone can be programmed to conduct **inspections autonomously**
- Box houses the drone and serves as a charging station



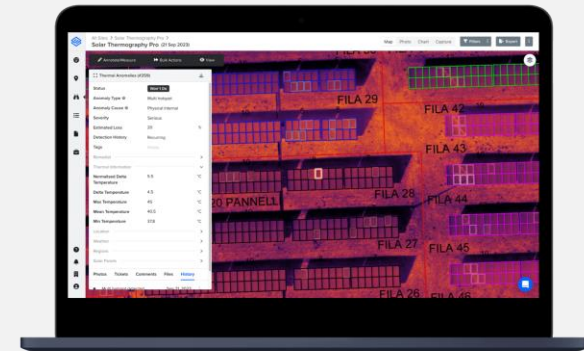
Ground robot by Onsite Technologies

- Unmanned ground vehicle installed at a fixed location
- Robot can be programmed to conduct **inspections autonomously**
- Robot docks at a charging station and charges using a wireless connection

Advanced Data Treatment & Analysis

- AI / ML models used to **detect anomalies in the thermal and visual images** captured during inspection
- Anomalies found are visualized on a **digital representation of the plant**
- Inspection reports can be generated from the **digital twin web application**

Digital twin software by Sitemark



AI driven Operations of PV plants

Advanced and Autonomous Maintenance

Project Operator Challenges:

- O&M costs reduction and Improved O&M Decision-making process
- Improved performance & safety

Autonomous Cleaning Robot



SolarBridge B1A by SolarCleano

- Smart obstacle crossing, Active posture adjustment
- Equipped with intelligent obstacle-crossing and proactive posture adjustment functions, **adapting to complex environments**, and prevent getting stuck



PR300 by Sunpure

- Fully automated solar cleaning robot
- With AI integration, it **adjusts to different heights and angles of solar installations**, maintaining **consistent pressure** on panels to prevent damage.

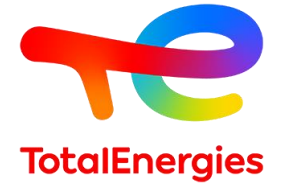
Autonomous Vegetation Management



Renubot by Renu Robotics

- Robot autonomously **navigates a solar plant and detects obstacles** using GPS RTK and lidar.
- AI enables **self-diagnostics and energy usage optimization**,
- Robot housing serves as a **charging station** (contact-based) and **GPS RTK base station**

Conclusions and Perspectives



- AI already **present in day-to-day** life of a solar plant operator but use still growing. **From resource to power, including operations and maintenance.**
- For project operators, **2 main areas for operations:**
 - **AI driven prediction of PV performance:** AI and machine learning are used to predict PV performance, transitioning from resource-based to data-driven approaches. Key areas include meteo-to-PV conversion, operational data usage, hybrid forecasting, and leveraging image segmentation for regional PV forecasting
 - **AI driven operations:** AI enhances PV plant operations through data-driven KPIs, anomaly detection, and autonomous inspections and maintenance. Technologies include drones, ground robots, and cleaning robots, improving O&M decision-making, performance, and safety.
- AI-centered operations boom with **promises of reduced O&M costs and enhanced performances/revenues**

THANK YOU

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