This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792059

goPV

Oct. 29th 2020

PV System: Operation & Maintenance

(14:30-16:30)

GLOBAL OPTIMIZATION OF
INTEGRATED PHOTOVOLTAIC SYSTEM
FOR LOW ELECTRICITY COST

PV System: Operation & Maintenance, ENEL GREEN POWER

Matteo Poletto, Tech. Supp O&M Solar Competence Center

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2. Maintenance: some definitions
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REN Operation & Maintenance global presence

2020 August

Technology	MW	Plants
Hydro	27.914	761
Geo	881	38
Wind	13.309	265
Solar	4.990	108
Biomass	61	11
Storage*	22	1
	47.155	1.184

1.184 plants **47,1 GW installed** **109,5 TWh produced(2019)** **23 Countries** **4.400 O&M people**

MAINTENANCE: some definitions

There are different kind of maintenance:

- **SCHEDULED maintenance**: actions and/or testing and/or measurements to ensure optimal operating conditions of equipment and of the entire PV plant and to prevent defects and failures

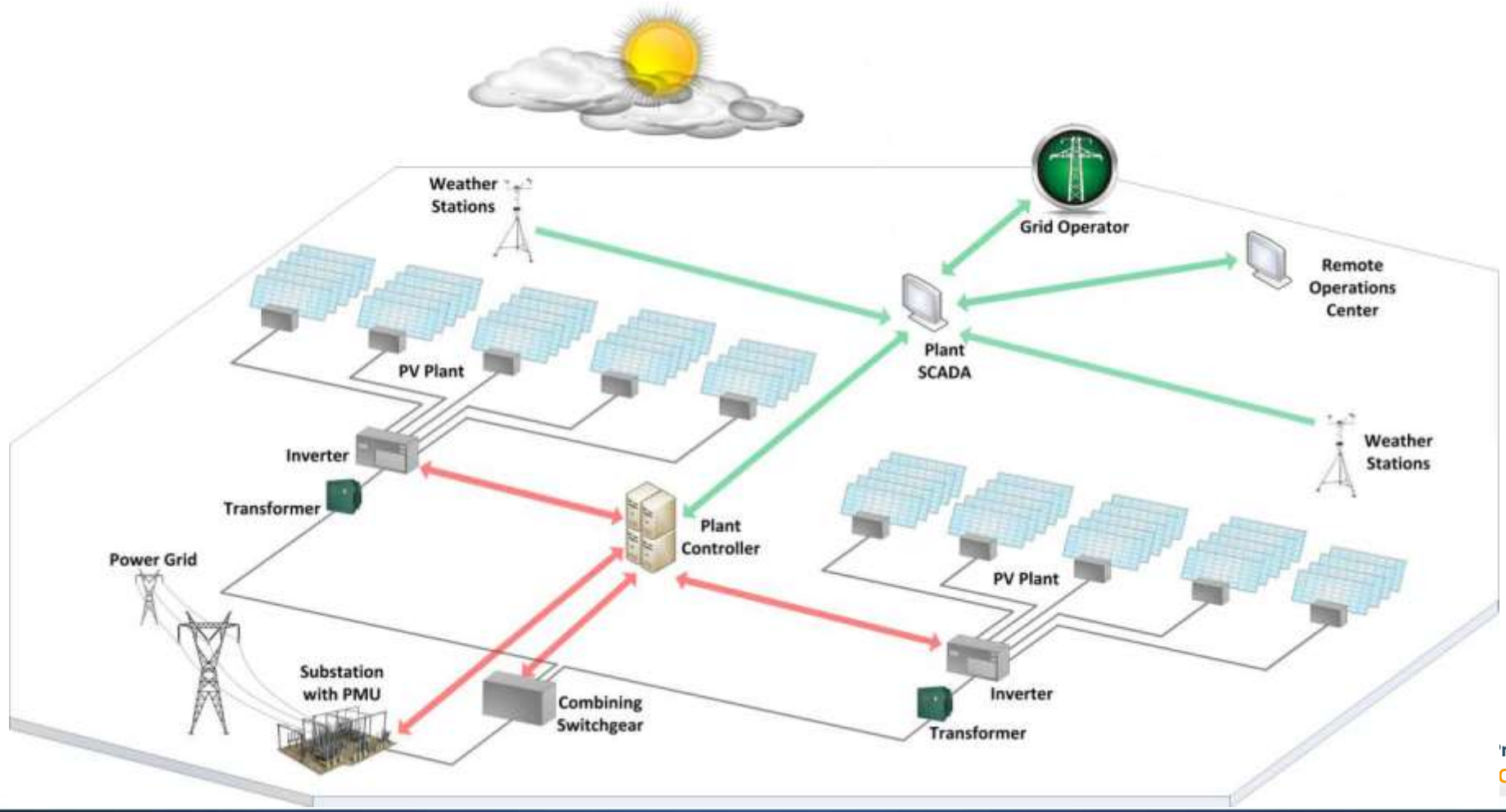
- **CORRECTIVE maintenance**: actions and/or techniques taken to correct failures, breakdowns, malfunctions, anomalies or damages detected during inspections, or through monitoring, alarming, or reporting or any other source

- **PREDICTIVE maintenance**: Set of activities that detect changes in the physical condition of equipment in order to predict and anticipate failures

- **EXTRAORDINARY maintenance**: actions and/or works performed in case of major unpredictable faults, such as serial defects, force majeure events, natural events, etc

MAINTENANCE: some definitions

The maintenance activities covers all the parts of a PV plant



MAINTENANCE: some definitions

The maintenance (Scheduled and Corrective) activities may be:

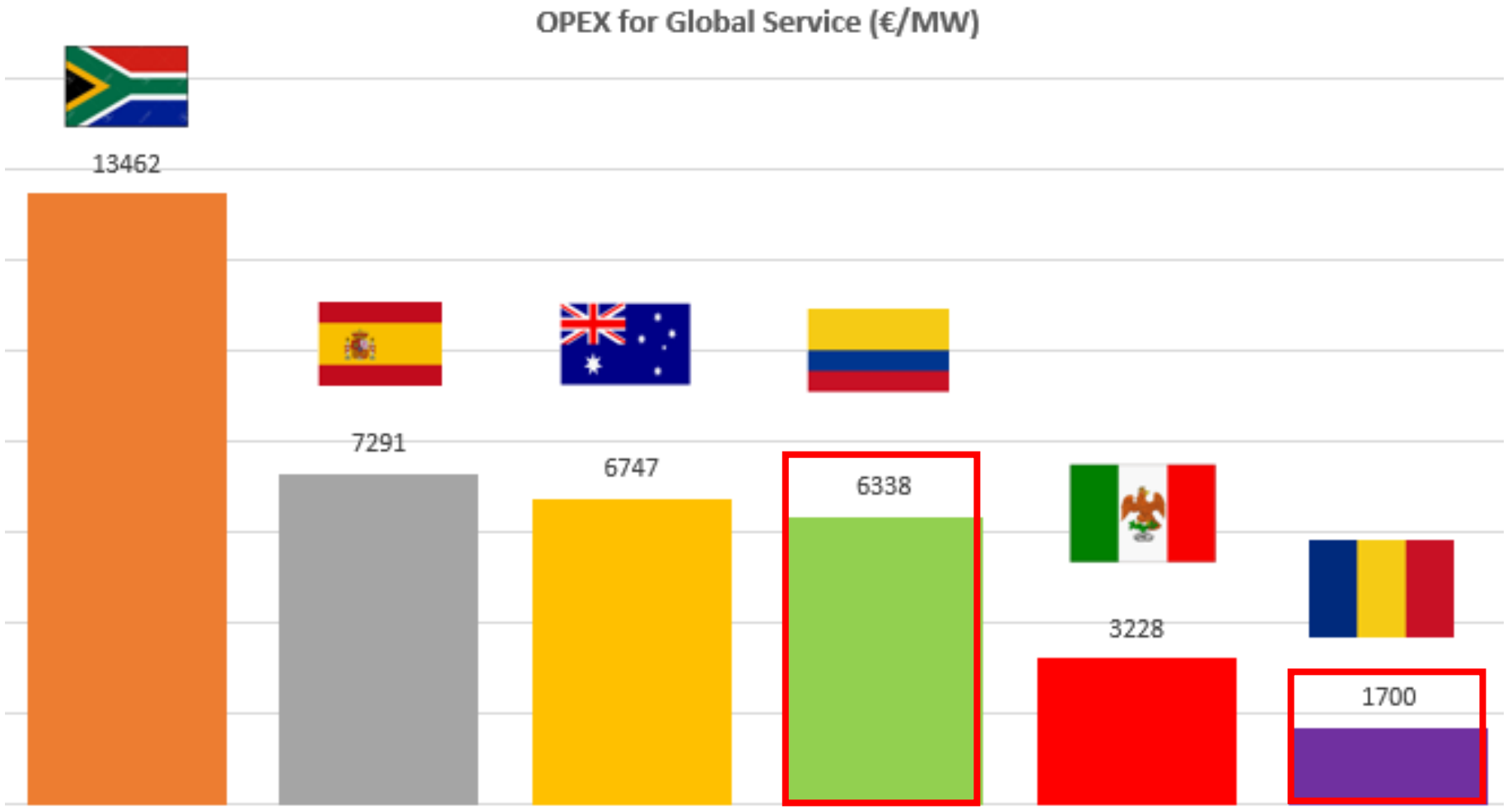
- **HARDWARE maintenance**: action carried out directly on field by operators with specialized or not specialized tools such as screwdrivers etc.
- **SOFTWARE maintenance**: actions carried out remotely or on field with computers and communication instruments

The Scheduled activities are:

- Inspections → Visual, Mechanical, Electrical, Software
- Measurements and Tests → Electrical, Mechanical, Software
- Substitution of components

Benchmark Costs for O&M Global Service

O&M Service Provider in EGP Solar Fleet

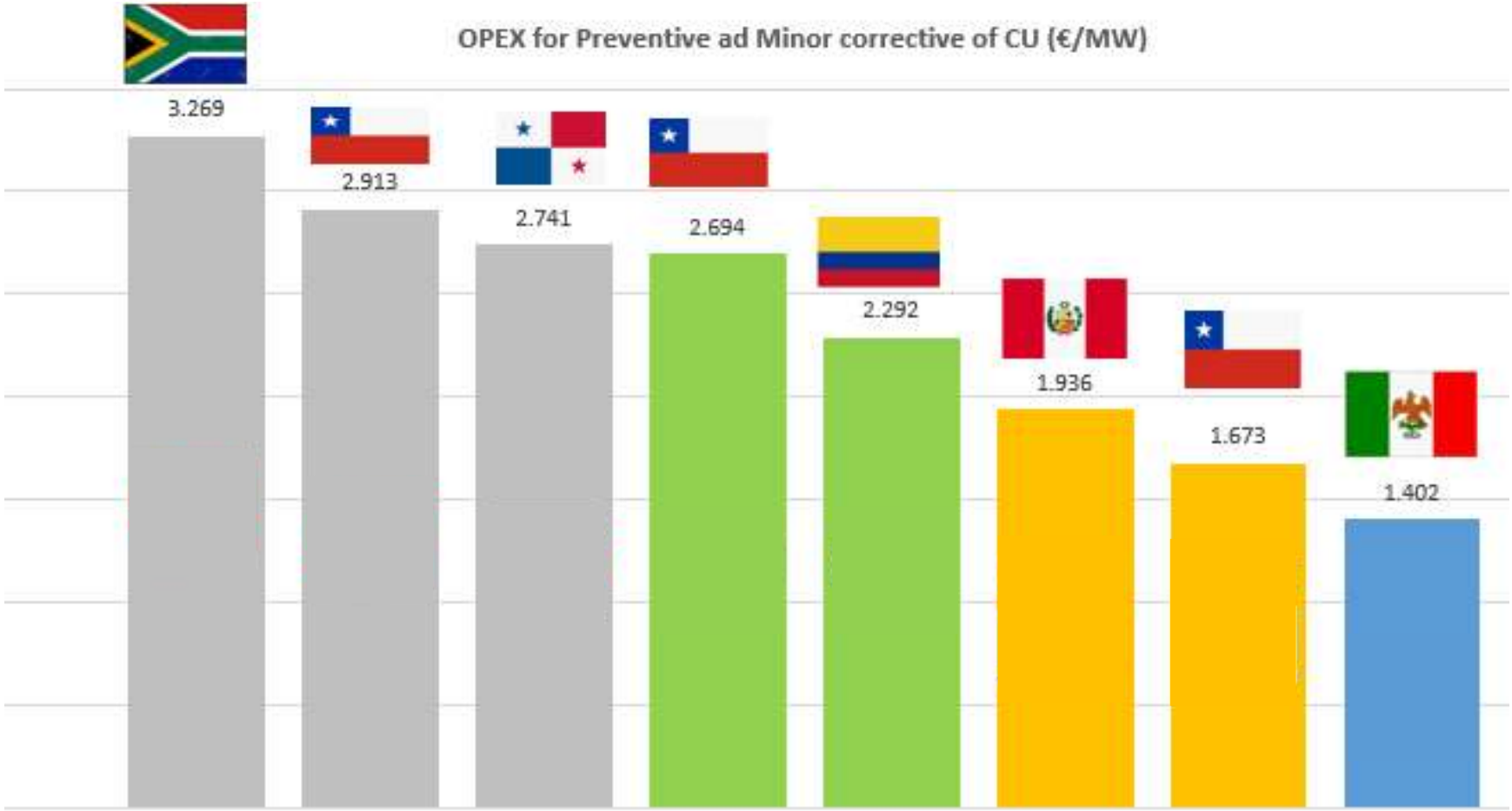


- Full-scope contracts are no longer the norm.

Note: Global Service is an awarded service to an external contractor dealing with one or more maintenance services

Benchmark Costs for Solar Inverter Maintenance

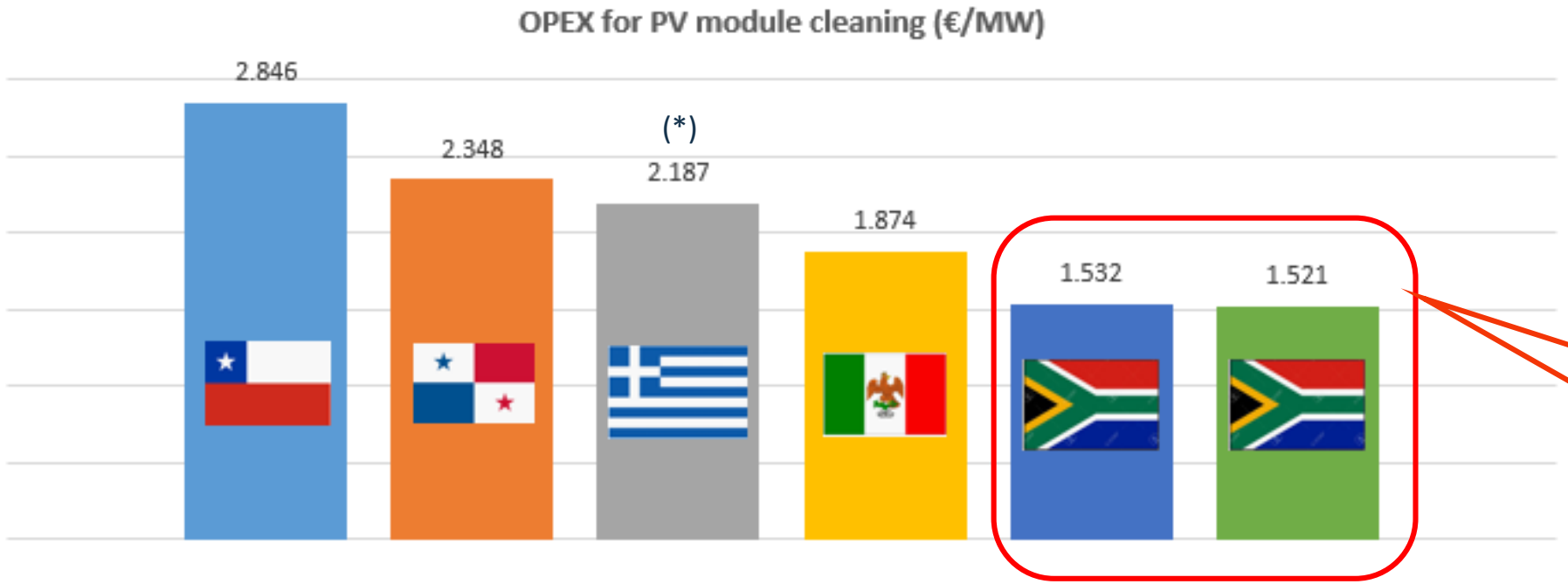
Inverter Scheduled Maintenance costs in EGP Countries



- **The O&M contracts are related to the Inverter centralized into the CU.**

Benchmark Costs for Module Cleaning

OPEX costs in EGP Countries

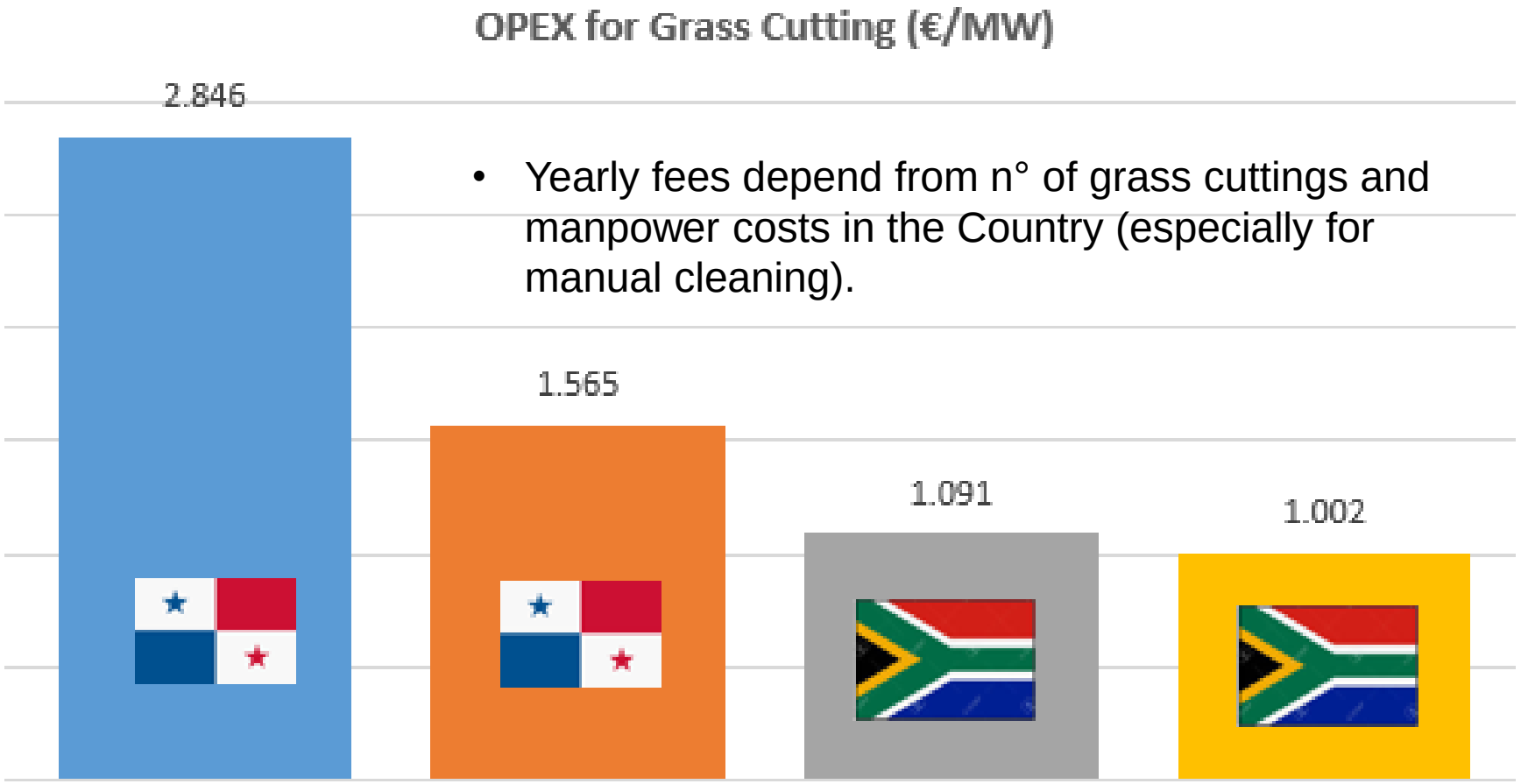


- Yearly fees depend from n° of cleanings and manpower costs in the Country (especially for manual cleaning).
- Local content obligations affect the service awarding.

(*) fee includes also grass cutting

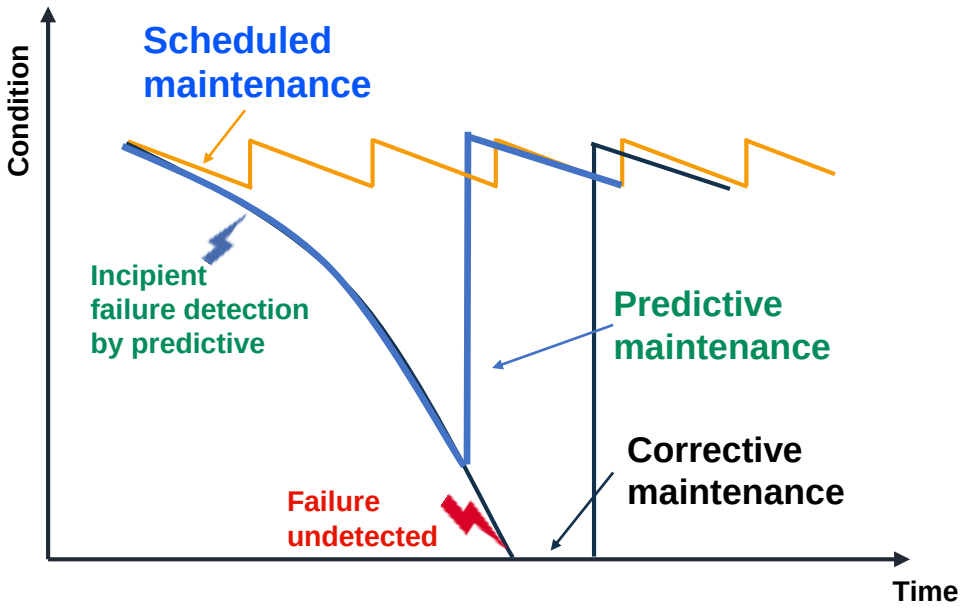
Benchmark Costs for Grass Cutting

OPEX costs in EGP Countries



- Yearly fees depend from n° of grass cuttings and manpower costs in the Country (especially for manual cleaning).

PREDICTIVE MAINTENANCE

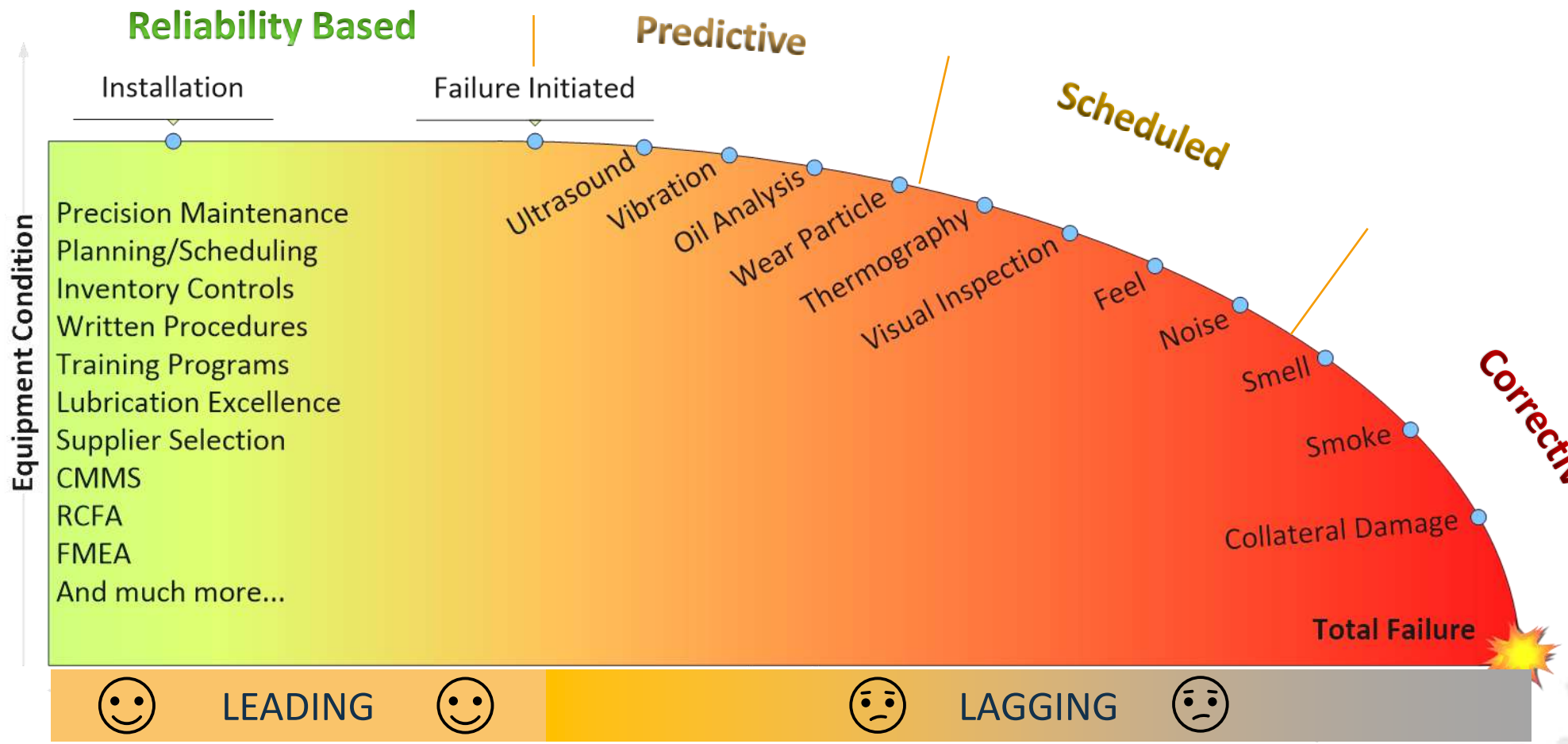


Benefits of Predictive Maintenance

- **Avoid severe damage** of equipment and **propagation** to other components
- In some cases **completely prevent** the occurrence of damage
- **Optimized maintenance planning**
- **Lower repair costs**
- **Reduced devices downtime** and relative **revenue loss, particularly for inverters**

IPF Curve

Installation, **P**oint of Defect, **F**ailure



Instrumentations and sensors on PV Field

Solar PV Field is almost totally composed from pure electronic components, only newest plant has one mechanical movement actuated by trackers who follow the sun. Most important sensors are electrical and environmental types.

Conversion Unit

INVERTER

- DC and AC Current Sensors
- NTC/PT100 sensors
- Voltage AC and DC Transductors

IDC	A	Analog	Input 1 Current (A)
VDC	V	Analog	DC Input Voltage (V)
IAC	A	Analog	Grid current (Average of phase 1,2,3)
VAC	V	Analog	Grid Voltage (Average of phase r,s,t)
PAC	kW	Analog	Inverter AC Power (Average of phase r,s,t)
T_IGBT	°C	Analog	IGBT Temperature Measure (°C)
FAN_SPEED	rpm	Analog	fan_speed (RPM)

ENVIRONMENTAL SENSORS

- PT 100
- Pyranometers (*Secondary Standard class*)

GTI	W/m2	Analog	Irradiance Tilted from pyranometer (or solar cell)
TEMP_M	°C	Analog	PV Module Temperature

Meteo Station

- Pyranometer *(Secondary Standard class)*
- PT100
- Humidity Sensor
- Rain Gouge
- Wind direction and intensity sensor
- Soiling sensor

GTI	W/m2	Analog	Irradiance Tilted from pyranometer (or solar cell)
GHI	W/m2	Analog	Irradiance Horizontal from pyranometer (or solar cell)
DHI	W/m2	Analog	Diffused Horizontal Irradiance
TEMP_AMB	°C	Analog	Enviroment Temperature
TEMP_M	°C	Analog	PV Module Temperature
WS	m/s	Analog	Wind Speed
WD	°	Analog	Wind Direction
RAIN	mm	Analog	Pluviometer
SNOW	mm	Analog	Snow
RH	kg/m3	Analog	Relative Humidity
PRESSURE	Pa	Analog	Atmospheric Pressure
Tilt	°	Analog	Tilt of the relative Sensor
Azimuth	°	Analog	Azimuth of the relative Sensor

Tracker

for each one

- Position transducer
- Wind sensors

ROLL_POSITION	ang.deg. (°)	Analog	Actual Position of Solar String
TARGET_POSITION	ang.deg. (°)	Analog	Target Position of Solar String
WS	m/s	Analog	Wind Speed

Operational Efficiency process strongly focused on inverter performances

4.000 Reference Power Curve for single MPPT of each Inverter created through fully in-house developed algorithms based on neural network approach and statistical analysis on historical data and updated on yearly bases

Up to 1-minute signals gathering from each plant

Inverter measurements
from gathering systems (WMR/SCADA)

- Voltage, Current, Power
- Both DC and AC side measurement

Environmental measurements
from field sensors

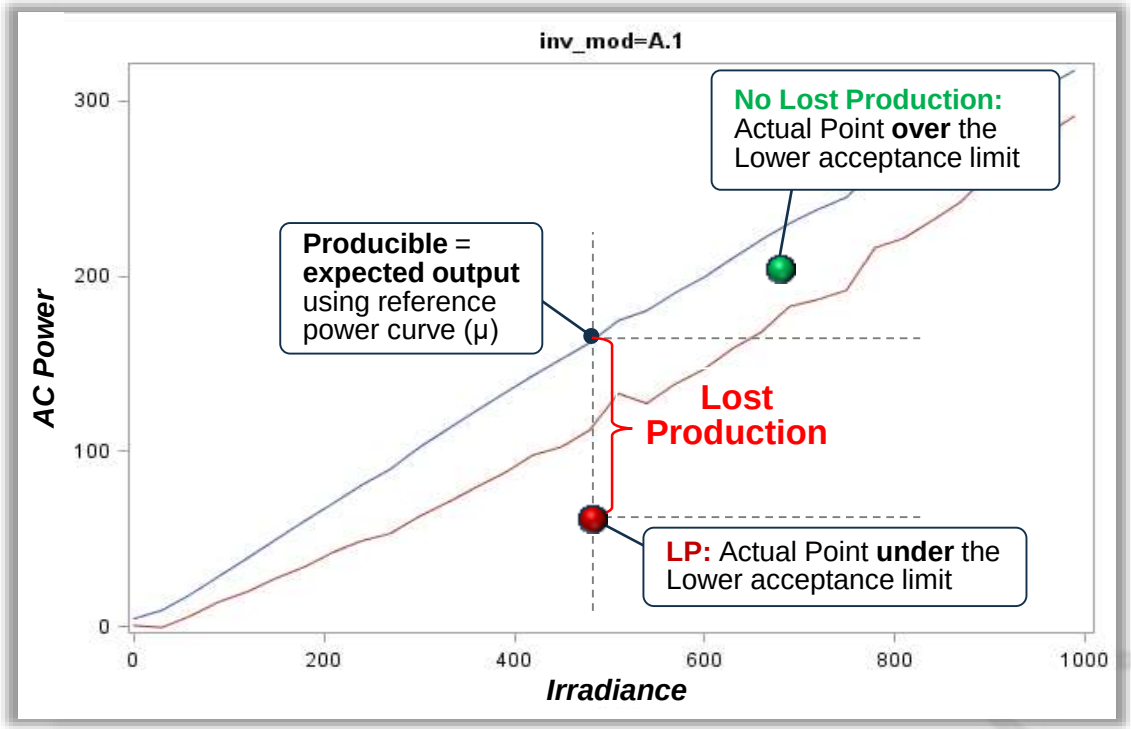
- Total irradiance in the plane of the array
- Ambient air temperature in a radiation shield
- Module temperature of the panel back-side

Solar Log Book
to detect and classify unavailability events

- Unavailability events log book
- Created on daily basis from SCADA alarms
- Editable by supervisor with undetected alarms

Lost production calculation at single MPPT level

Reference power curve vs 15minute actual point



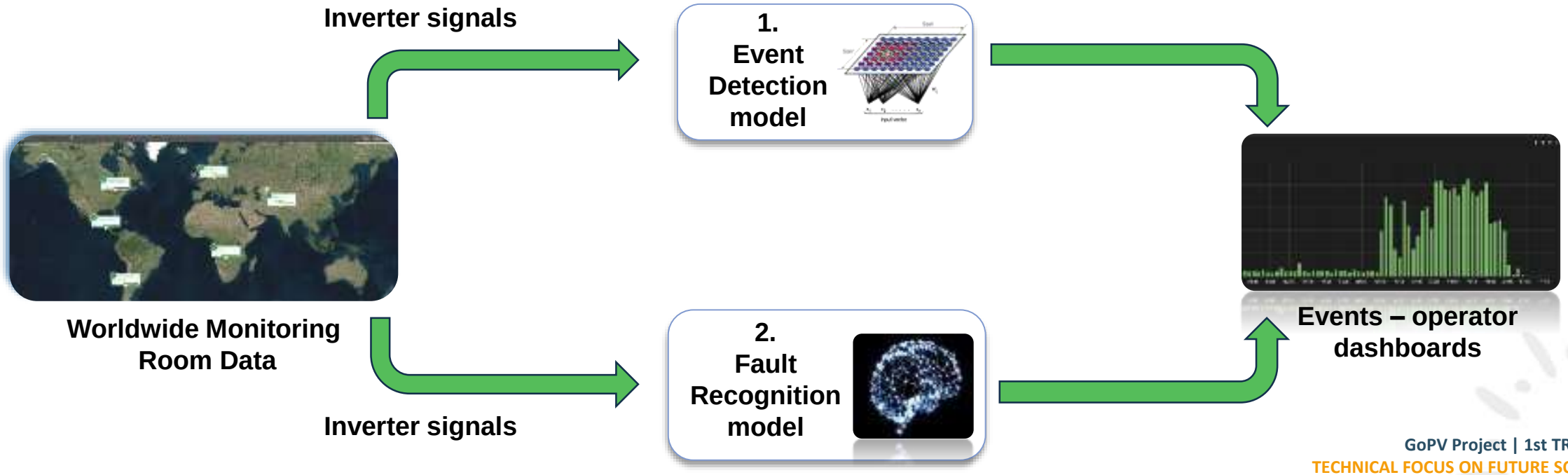
Dedicated algorithms developed in-house to detect underperformances for each inverter with specific focus on lost production caused by soiling and grid limitation

Solar Big Data Predictive: technical overview

Two approaches in parallel

Predictive models developed at Inverter level aimed to provide warnings for runtime operations. Two approaches have been investigated:

1. **Event Detection (Diagnosis Model):** predict inverter deviations from nominal behaviour
2. **Advanced Fault Recognition:** predict a specific class of faults (e.g. ground fault, bulk cap fail, ..)

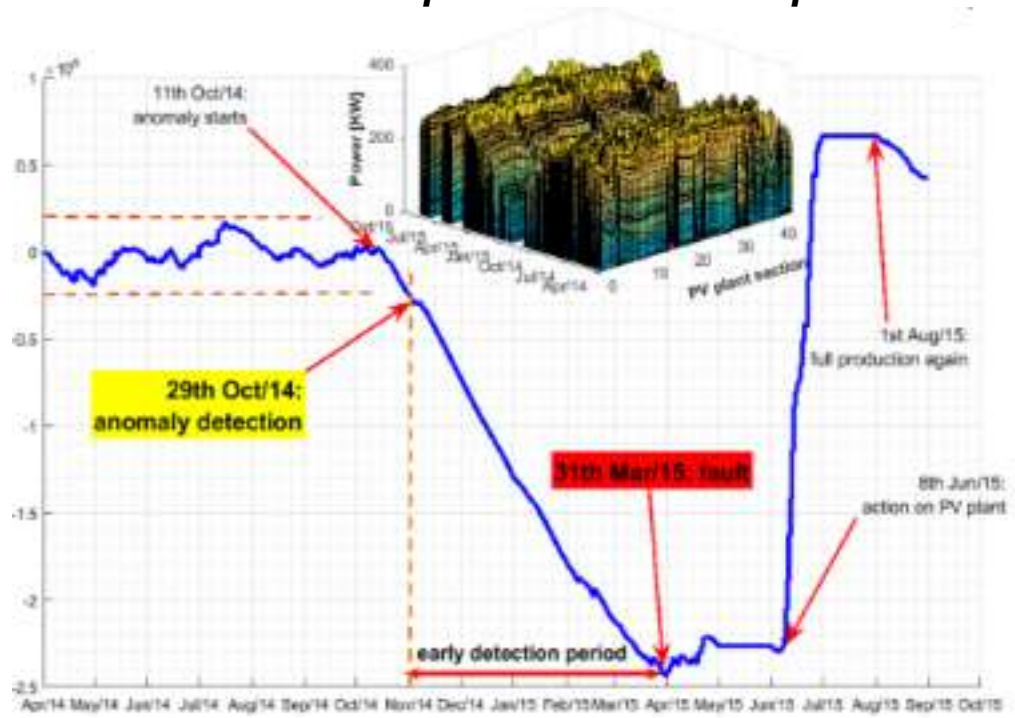


Solar Big data Predictive

Plant 1 (Romania) business case

Advanced modeling for inverter anomalies early detection

Deviation of expected vs real AC power



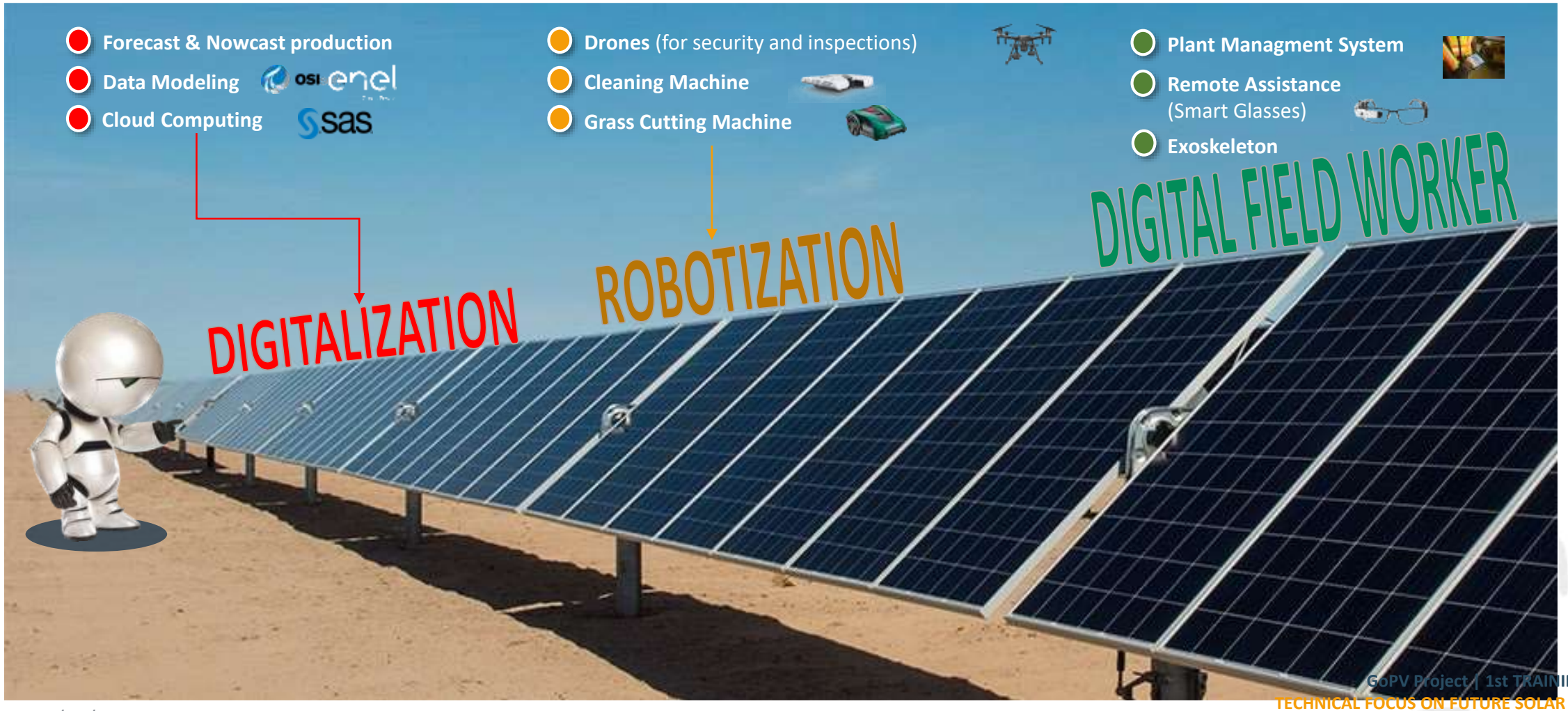
- The draining-off of the thermal paste due to heat caused **overheating and breakage of the IGBT** (Insulated Gate Bipolar Transistor) of the inverter

- **Predictive model** of expected vs real AC power could have allowed **inverter fault early detection** and repair, **avoiding 2 months of lost production**

~55k€ of potential avoided lost revenues thanks to predictive model implementation

Innovative Solutions in the Solar Technology

PV Field key features



Solar Digitalization

Data Model

Objective

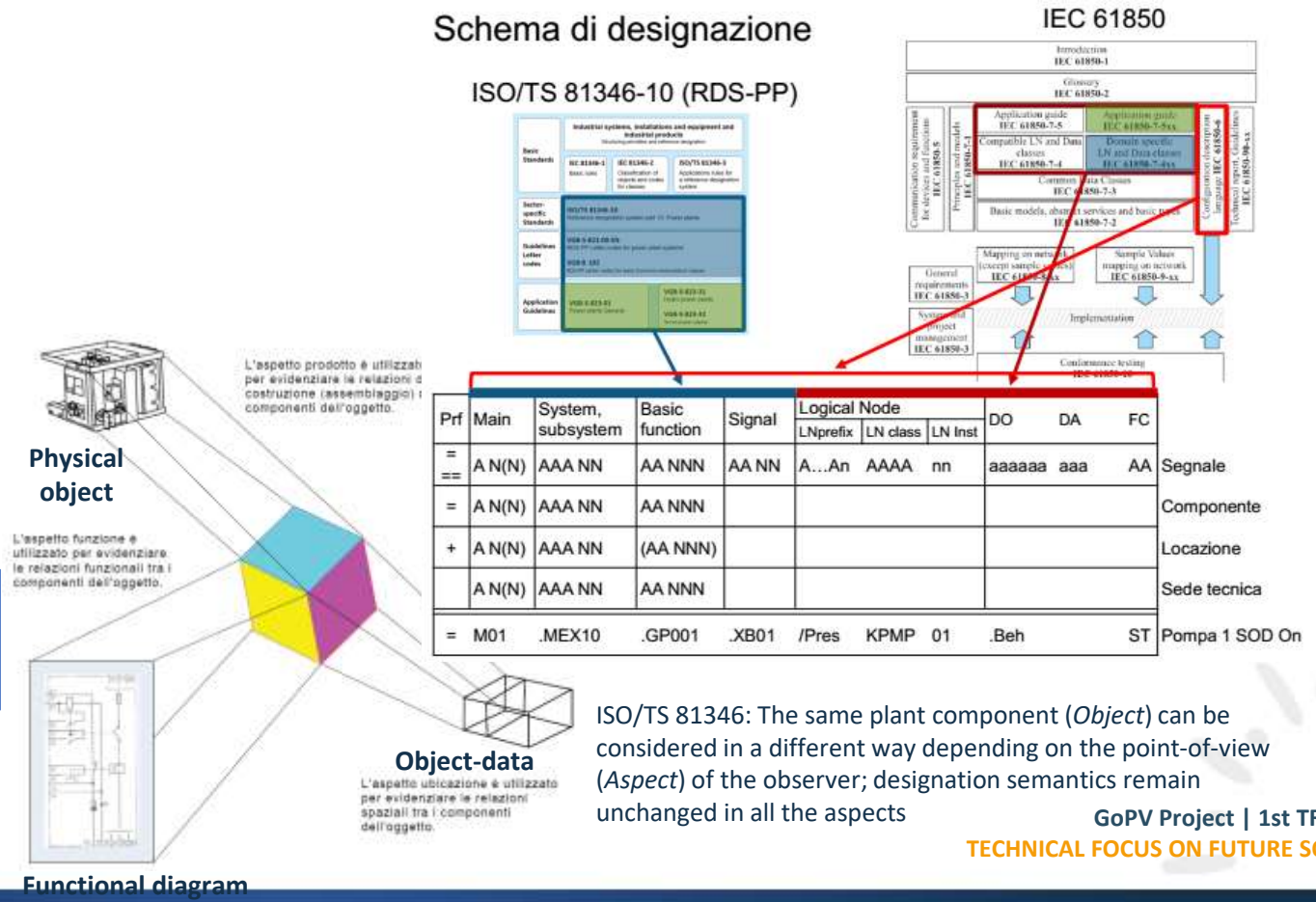
The Data Model is a Cross Technology project, started from Hydro Tech, suitable to achieve a new structure of information (tags) gathered from existing, and new, power plants with an object oriented language. This new way to structure data is made follow two main innovative international standard regulations.

1st STEP

The first part of the activity is to **convert the original Tag list of each Inverter Manufacturer to the new EGP Data Model**. The choosen model is streghtly related to the Hydro DM, compliant with **RDS-PP and IEC61850**. After deeper analisys we knew that there aren't any **IEC Standard law for Solar Tech**; but an Alliance of many inverter supplier built a Technical Documentation called **sunSPEC** who define also Data Modelling.

2nd STEP

Apply the Data Modelled Tag to the as-built tag list for each plant of all over the world. The activity will carry out a tag renaming in the Pi Archive.



Prf	Main	System, subsystem	Basic function	Signal	Logical Node			DO	DA	FC	
					LNprefix	LN class	LN Inst				
= ==	A N(N)	AAA NN	AA NNN	AA NN	A…An	AAAA	nn	aaaaaa	aaa	AA	Segnale
=	A N(N)	AAA NN	AA NNN								Componente
+	A N(N)	AAA NN	(AA NNN)								Locazione
	A N(N)	AAA NN	AA NNN								Sede tecnica
=	M01	.MEX10	.GP001	.XB01	/Pres	KPMP	01	.Beh		ST	Pompa 1 SOD On

ISO/TS 81346: The same plant component (*Object*) can be considered in a different way depending on the point-of-view (*Aspect*) of the observer; designation semantics remain unchanged in all the aspects

Solar Digitalization

Cloud Computing* - Zone Monitoring: «EYE»

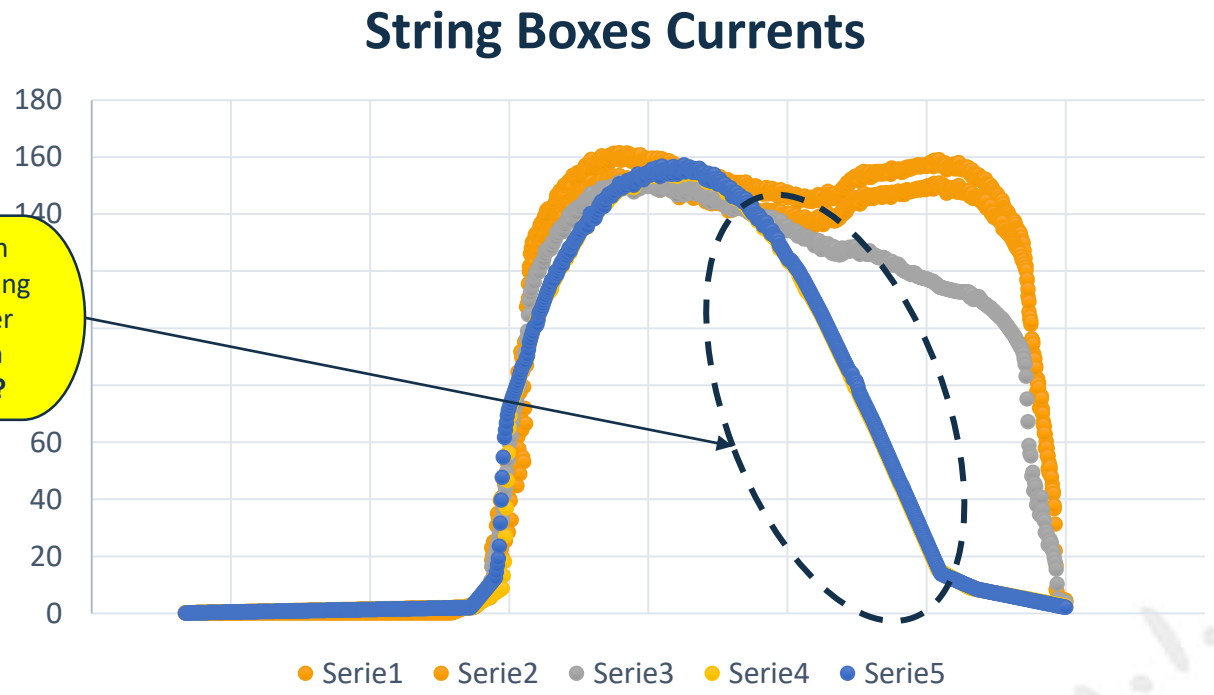
Objective

The Conversion Unit supplier doesn't give us a well performing Zone Monitoring Algorithm, so thanks to O&M experience in graphical analysis of current behavior, we have choosen the idea to build an internal algorithm.

Problem: O&M Local team cannot find underperformance strings due to passive string boxes.

- **Centralization of Zone Monitoring**, this adaptive algorithm is standard and unique
- **Easy and friendly analysis** on the data
- **Home made without additional costs** using company software (SAS) and without external consulting (saving CAPEX/OPEX)

How to translate an underperforming string boxes due to tracker unavailability **in an algorithm or code?**



*Cloud computing :The term is generally used to describe data centers available to many users over the Internet.

Solar ROBOTIZATION

Actual PV panels Cleaning

Chile	Romania, Greece	Mexico	South Africa	Peru	Brazil

BPMetalmeccanica Truck
(Carrera Pinto, Finis Terrae)

SunBrush Tractor
(Pampa Norte)

Roboklin25 Tractor

SunBrush Tractor

Manual
(Diego de Almagro, Chanares, La Silla, Lalackama I and II)

Manual

Robot (dry, under test)

Manual dry and wet

SunBrush Tractor (dry)

Alexil semi robotic (under test)

Solar ROBOTIZATION

Robot for module cleaning - Activities' status

Goal

- Solution for fully **automatic** cleaning of photovoltaic modules
- Dry cleaning for **sustainability** solar power plant
- Reduce up to **90%** of soiling impact
- Increase Annual **Energy** yield (kWh**)**

Activities

- **Use Case 1:** Test for technical KPI evaluation and cleaning performance of first prototypes:
  → **Done** in Passo Martino Lab -Catania
- **Use Case 2:** Test for golden sample approval:
  → **Done** in Passo Martino Lab -Catania
- **Use Case 3:** Test in real field: using a sub-field (1 MW) inside Pampa Norte, Chile, 80 MW photovoltaic power plant:
  → **Planned** to be confermed.

First Results

3 distinct prototypes developed and tested according with GPG technical specification:

- **Excellent** results in **cleaning performance** for all the samples;
- **WashPanel**: difficulties when 2 consecutive trackers are not aligned;
- **Crel**: high Robot weight;
- **Reiwa**: compliant with all the examinated KPIs.

Next Steps

- Analysing the result of the test in real field, GPG'll evaluate the real benefits of this solution and its application during the design of new PV plants and to be applied for some existing pv plants .

Solar ROBOTIZATION

Drones and Solar thermal analysis with AI (Roboost)

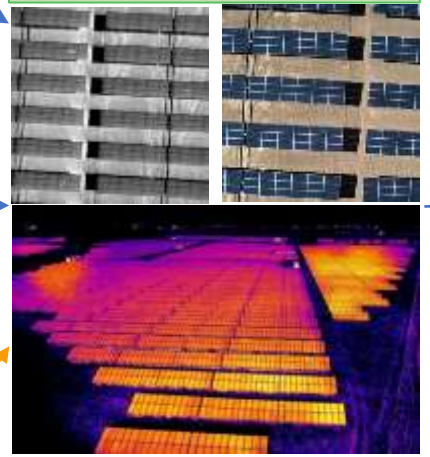
Aerial thermography is the practice of assessing and monitoring photovoltaic (PV) system condition using data captured via an aircraft equipped with a thermal camera.

Case1
EGP's drone
EGP's pilot

Case2
Fly drone by
Ext. Contractor

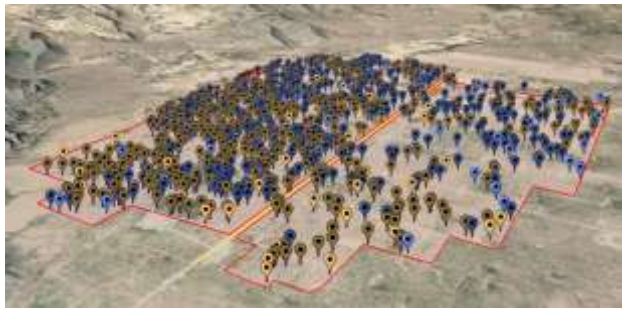
Case3
EGP
autonomous
drone

Thermographic and RGB images



Analysis of the images through a AI Software

RAPTOR MAPS



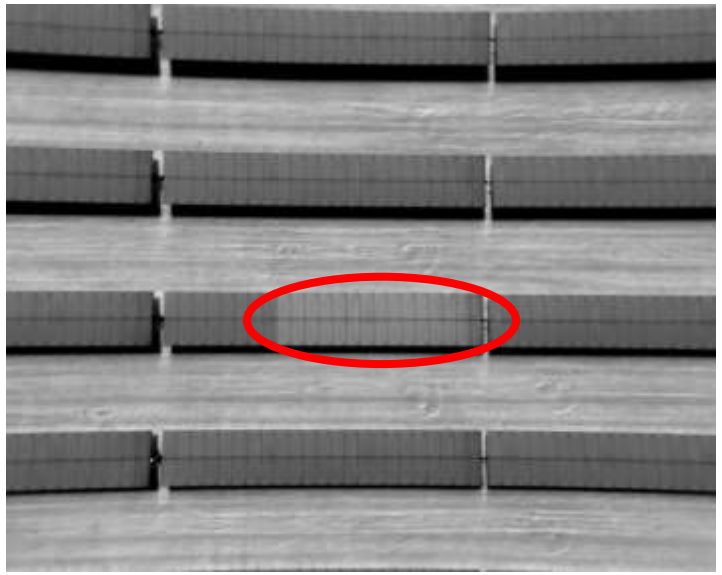
- **Increase Safety of O&M activities on site**
- **More hours on high-added-value activities**
- **Operational O&M Costs reduction**
- **Lost Production decrease**

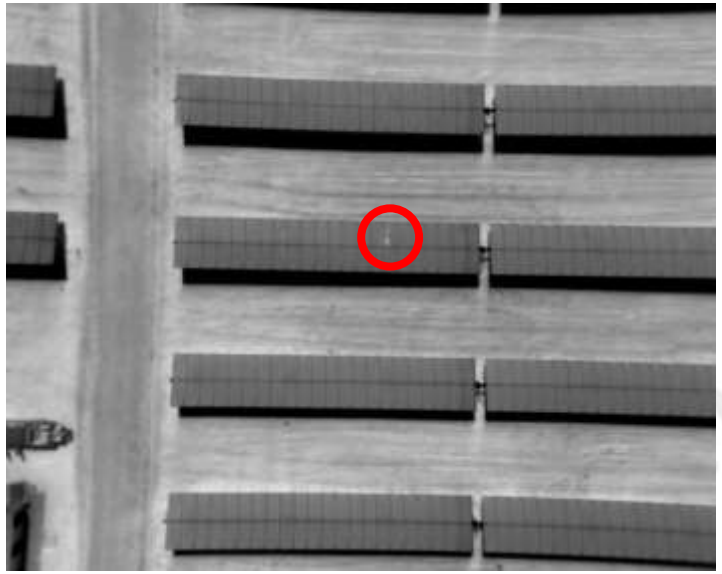
For each inspected MW*
600€ costs saving
* Purchased drones + Framework Agreement Raptor Maps

Level I	Level II	Level III
Module,String-level outages	Diode & hot spots	Individual cell

Solar ROBOTIZATION

Drones and Solar thermal analysis with AI (Roboost)





Solar - Pills

Other initiatives

Smart Glasses

Global Framework Agreement for Smart Glasses devices and Augmented Reality solutions closed with Brochesia company

Functionality

- Remote assistance & «Hands-free» maintenance support
- Training «on the job»
- Checklists & Safety procedures

COMAU MATE exoskeletal device for shoulder support

Support the operator during the panel positioning, fixing on Tracker structure and PV panel's cleaning activities, in which the shoulder joint reaches large elevation angles reducing muscular fatigue and articulation overload.

Autonomous Grass Cutting

Project ongoing in **Greece** with the goal to **build autonomous customized grass cutting systems** with related management software algorithms.

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Thank you for your attention!

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