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# PERFORMANCE VALIDATION AND OPTIMIZATION OF UTILITY SCALE PV PLANT

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ASEF ASIA SOLAR ENERGY FORUM 2015  
Manila 15 June 2015

# M&P at a glance

## ABOUT US



MORE THAN  
**ONE GW**  
OF EXPERIENCE



**Moroni & Partners** is a consultant engineering company specialized in the renewable energy market, based in Ancona, established in 2007 by Mauro Moroni, PhD in Energetics at Politecnico delle Marche.

We provide engineering services consultancy to Investors, Banks, Lenders, Industrial customers and EPC Contractor in the field of Renewable Energies.

### A few numbers about us:

- More than 50 professionals
- 90% of staff graduated in Engineering
- More than 1.5 GW of experience in Renewable Energies

### Awards:



### Membership:



# M&P at a glance

## OUR DIVISIONS



MORE THAN  
**ONE GW**  
OF EXPERIENCE

### Engineering

- Environmental impact assessment and authorisations
- Design, engineering, urban and structural planning
- Detail Engineering
- Works Management
- Health & Safety
- Energy Efficiency for Industrial & Real Estate applications
- Re-Engineering

### Technical Due Diligence

- Preliminary evaluation and business plan
- Technical and Administrative Due Diligence
- Testing during and after construction
- Instrumental verifications
- Insurance appraisal
- Final & Provisional Acceptance Tests (FAC/PAC)

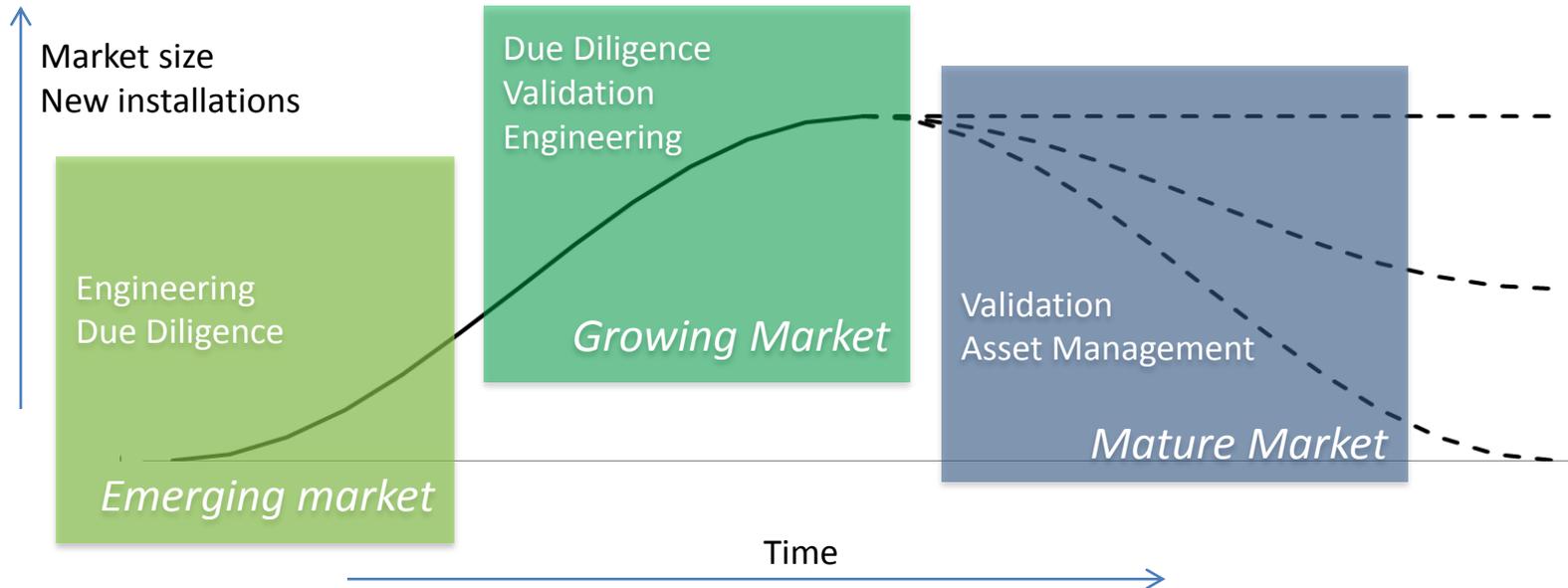
### Asset Management

- Service supply management
- Validation of Maintenance activities
- Remote monitoring of key performance parameters
- Assistance for administrative and accounting requirements
- Assistance in Customs Duty and GSE relations
- Tax and Legal assistance
- O&M supervision



# M&P at a glance

## OUR MARKET



*The value of M&P spreads along the whole lifespan of REN plants (from design to construction, validation and management), which makes us able to cover REN markets at any stage of development, from Emerging to Mature markets.*



M&P at a glance

## COMPANY CERTIFICATIONS



Moroni & Partners cares about services quality, environmental respect, energy rational use and workers' health and safety, obtaining these voluntary certifications:

**ISO 9001:2008** - Quality Management System

**ISO 14001:2004** - Environmental Management System

**ISO 50001:2011** - Energy Management System

**BS OHSAS 18001:2007** - Occupational Health and Safety Management System

**Multilateral Development Banks** are all the international financial banks whose goal is to provide financing opportunities to emerging markets.

Multilateral Development Banks are:

- WB World Bank through its 5 agencies:
  - IFC International Finance Corporation
  - IBRD International Bank of Reconstruction and Development
  - IDA International Development Association
  - MIGA Multilateral Investment Guarantee Agency (MIGA)
  - ICISD International Centre for Settlement of Investment Disputes
- ADB Asian Development Bank
- IADB Inter America Development Bank
- EIDR European Bank for Reconstruction and Development
- AfDB African Development Bank

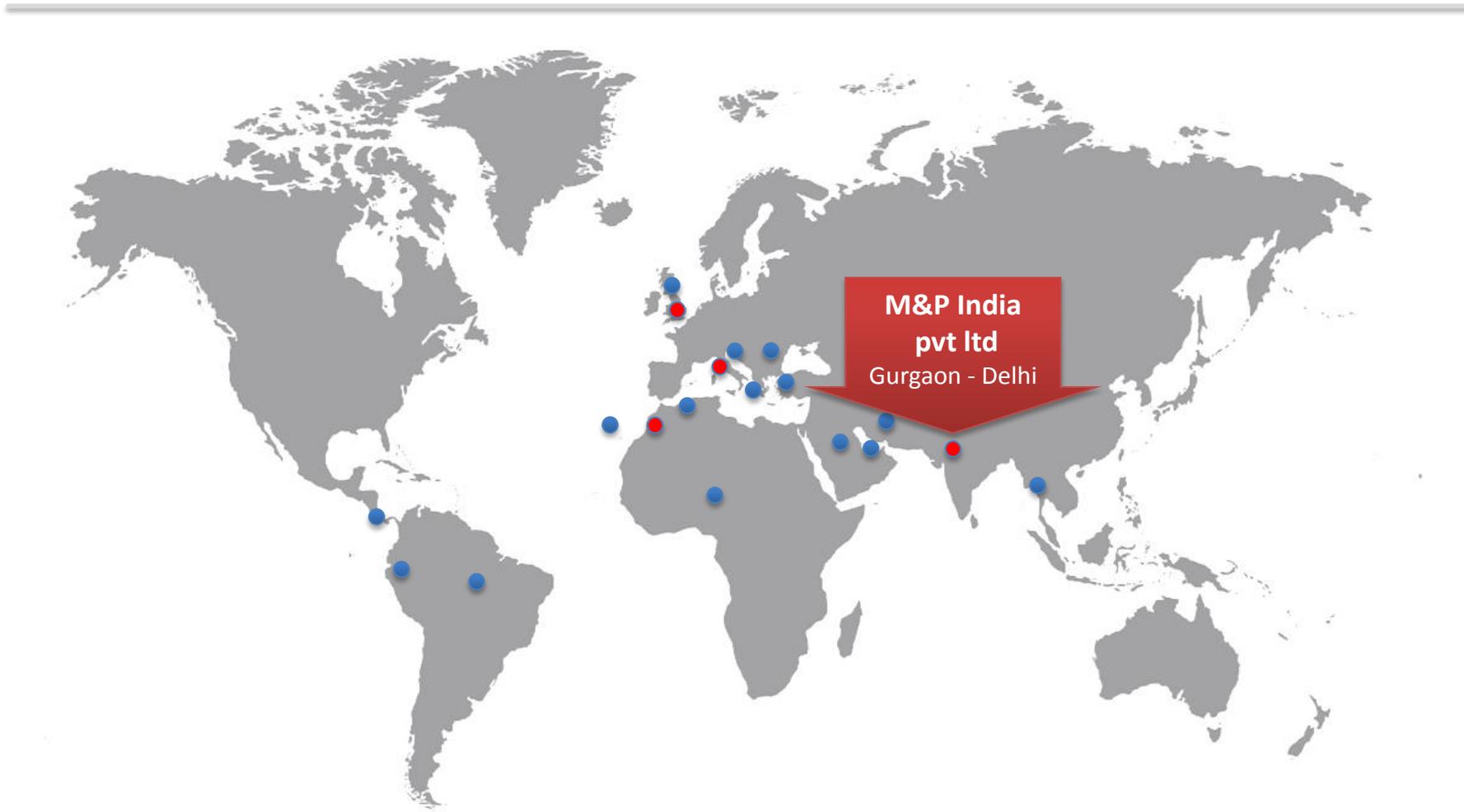
Since June 2014 M&P has been accredited by the **World Bank** and the other **Multilateral Development Banks (MDBs)** as advisor for engineering services and technical consultancy in the renewable energy market.

Since November 2013 M&P participates in international events:

- 10-14 November 2013 - Solar PV Trade Mission: Saudi Arabia (Solar Plaza), Riyadh, **Saudi Arabia**
- 4-7 November 2013 - Saudi Build, Riyadh, **Saudi Arabia**
- 5 March 2014 - Italian Cleantech Showcase, Riyadh, **Saudi Arabia**
- 26-29 May 2013 - Saudi Energy, Riyadh, **Saudi Arabia**
- 11-13 April 2014 - Solarex, Istanbul, **Turkey**
- 15 May 2014 - Solar UK Finance and Investment (Solar Plaza), London, **United Kingdom**
- 3 July 2014 - Solar Secondary Markets Europe, (Solar Plaza), London, **United Kingdom**
- 4-6 November 2014 - Photovoltaica International Exhibition, Casablanca, **Marocco**
- 4-7 May 2015 - Private Sector Liaison Officers (PSLO) Energy Mission, Washington D.C. , **USA**

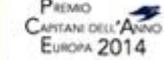
# Solar Breeder Morocco

## M&P WORLDWIDE

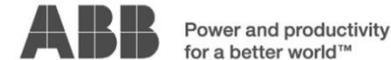
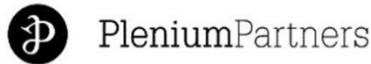


M&P at a glance

# COMPANIES THAT HAVE CHOSEN US



Bluefield

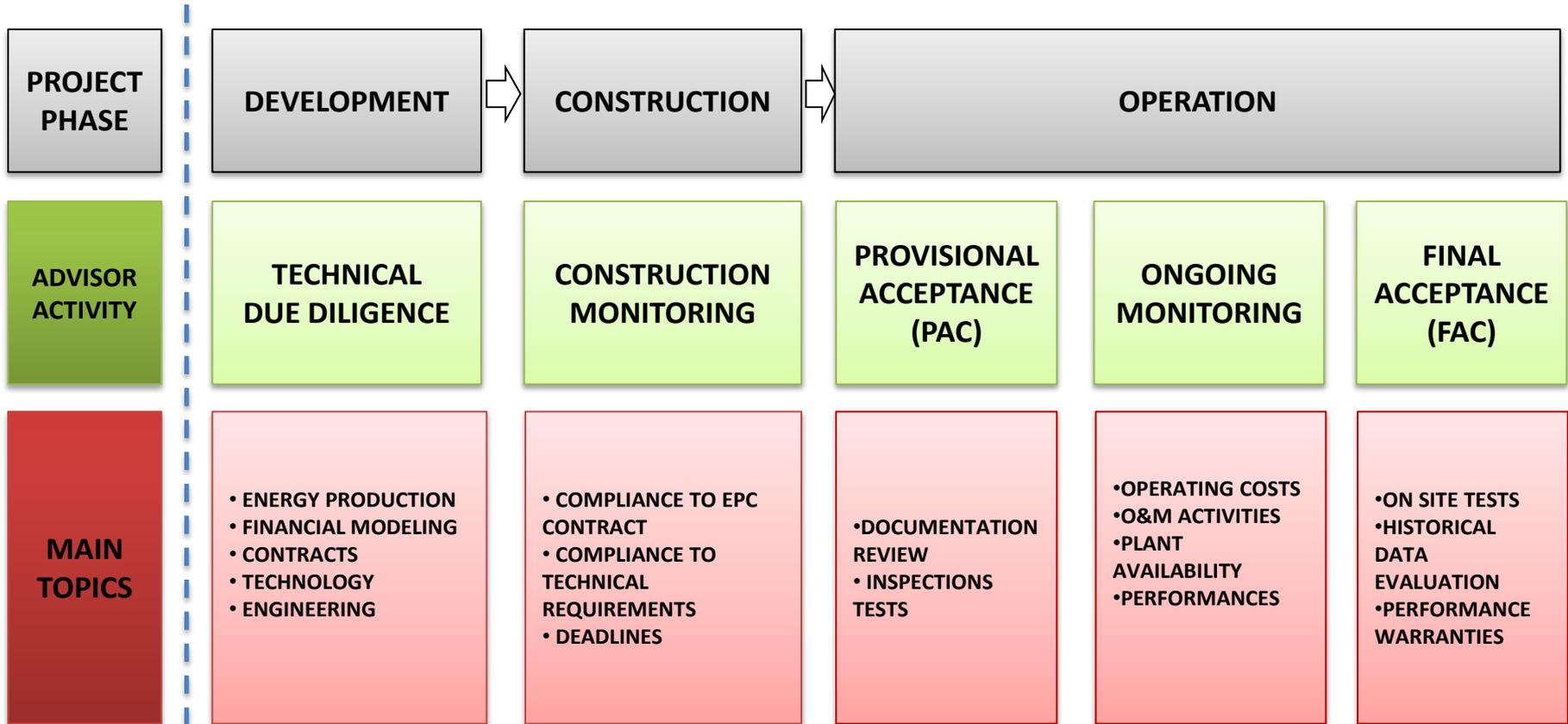


# PERFORMANCE VALIDATION



# Performance Validation

## THE TECHNICAL ADVISORY ROLE

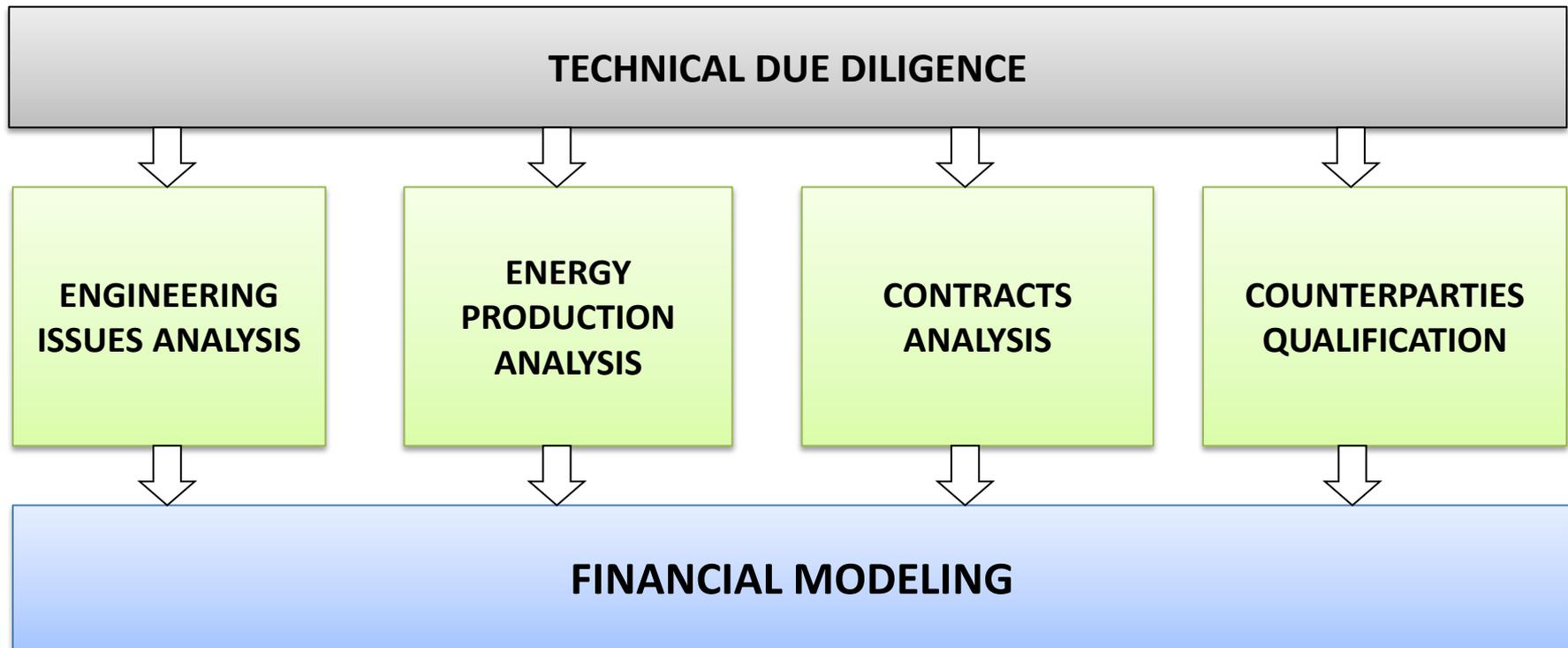


# Performance Validation - Development

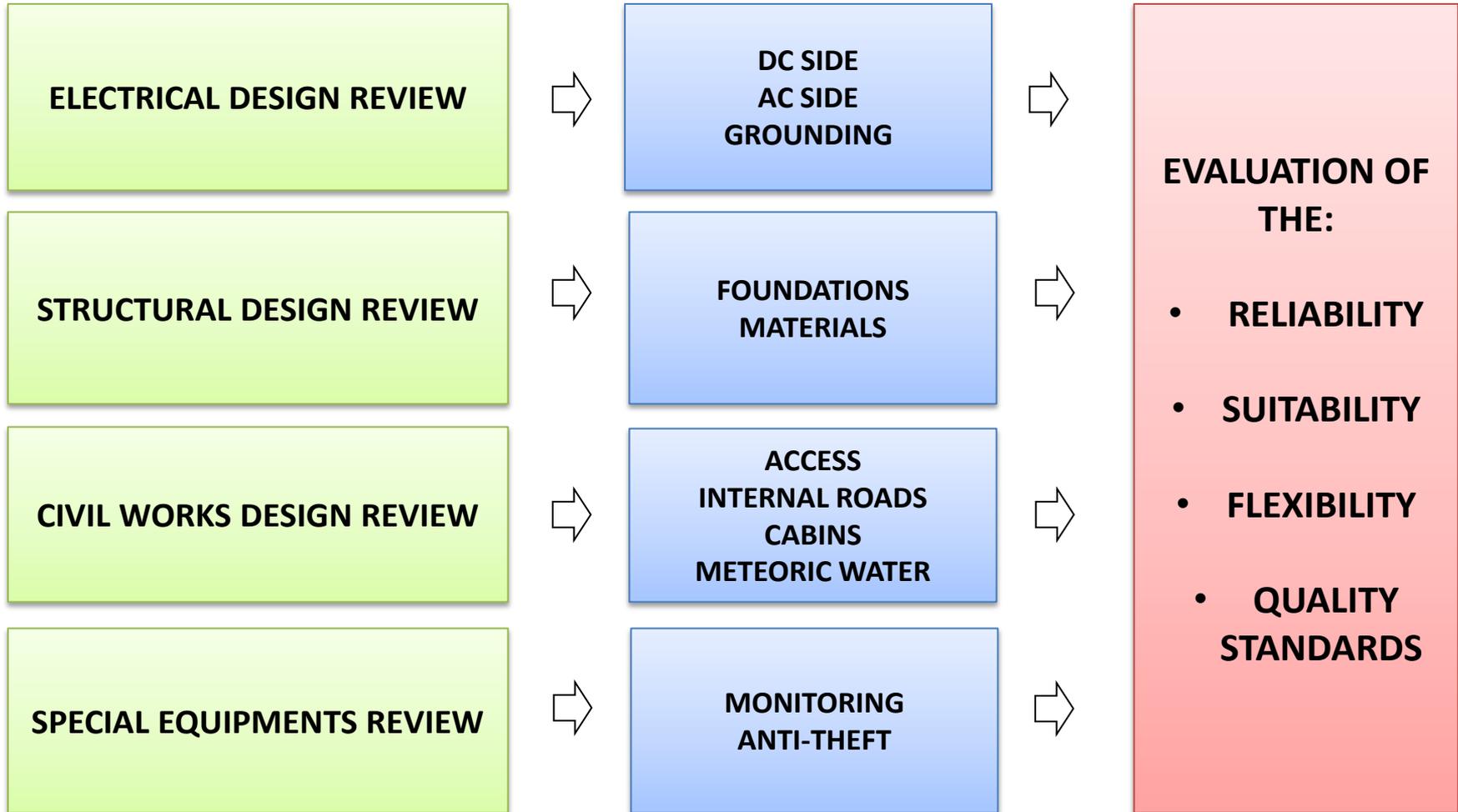
## TECHNICAL DUE DILIGENCE



The technical due diligence shall analyze technical issues with the aim of **verifying the technical and economical feasibility** of the Projects.



# Performance Validation - Development ENGINEERING ISSUE ANALYSIS



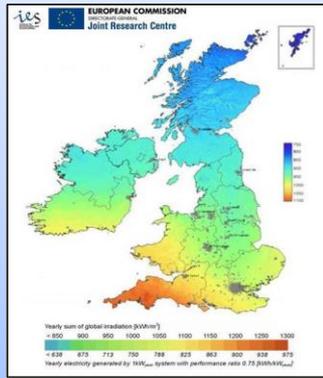
# Performance Validation - Development

## ENERGY PRODUCTION ANALYSIS

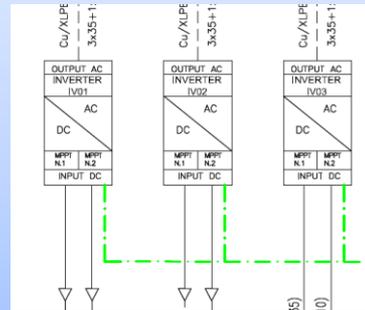


### INPUT DATA

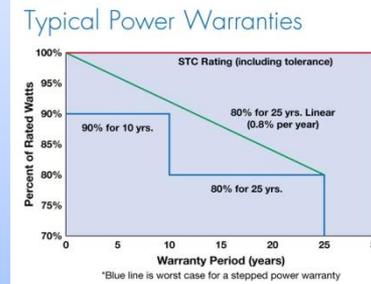
#### IRRADIATION



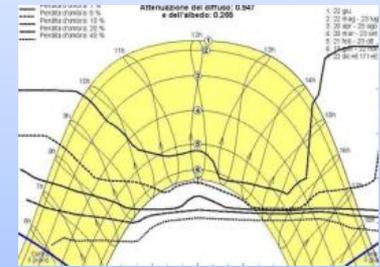
#### ELECTRICAL LOSSES



#### PV MODULES DEGRADATION



#### SHADING LOSSES



### DYNAMIC SIMULATION

## ESTIMATION OF THE ANNUAL ENERGY PRODUCTION OF THE PLANT

# Performance Validation - Development

## CONTRACT ANALYSIS



The technical advisor shall review and comment the following Commercial Contracts

### ENGINEERING CONSTRUCTION PROCUREMENT (EPC) CONTRACT

- SCOPE OF WORK
- COSTS, INCLUSIONS AND EXCLUSIONS
- PAYMENT METHODS
- DEADLINES
- PENALTIES
- WARRANTIES
- PERFORMANCES
- PROVISIONAL ACCEPTANCE PROCEDURES
- FINAL ACCEPTANCE PROCEDURES

### OPERATION AND MAINTENANCE (O&M) CONTRACT

- SCOPE OF WORK
- ORDINARY MAINTENANCE ACTIVITIES
- ROUTINE MAINTENANCE
- EMERGENCY MAINTENANCE
- DURATION
- COSTS, INCLUSIONS AND EXCLUSIONS
- PAYMENT METHODS
- PERFORMANCE WARRANTIES
- PENALTIES



# Performance Validation - Development

## COMPONENT QUALIFICATION



The technical advisor shall assess the quality and general capabilities of:

### MODULES MANUFACTURER



### INVERTER MANUFACTURER



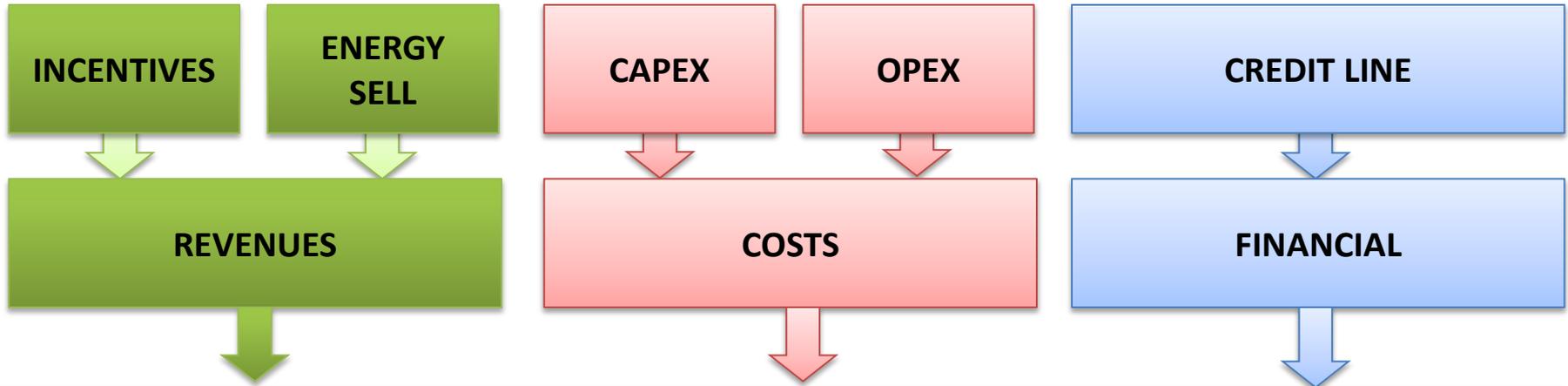
### SOLAR TRACKER MANUFACTURER



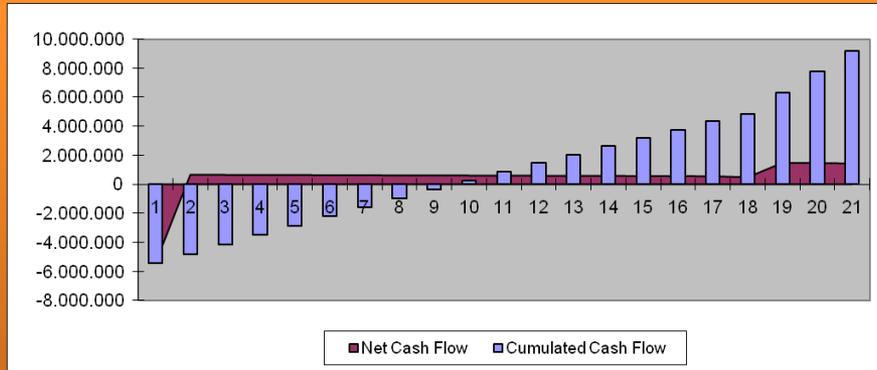
- **TECHNICAL QUALIFICATION** OF THE PRODUCT (TECHNOLOGY, COMPONENTS)
- QUALIFICATION OF **DOCUMENTATION** (CERTIFICATIONS, WARRANTIES, MANUALS)
- **MANUFACTURER TRACK RECORD** (INSTALLATIONS, CLAIMS, FAULTS)
- **FACTORY INSPECTION** (VISIT TO THE COMPANY PREMISES)

# Performance Validation - Development

## FINANCIAL MODELING



### BUSINESS PLAN EVALUATION



- NET PRESENT VALUE (NPV)
- INTERNAL RATE RETURN (IRR)
  - PAYBACK TIME
- DEBT SERVICE COVERAGE RATIO (DSCR)

# PERFORMANCE VALIDATION

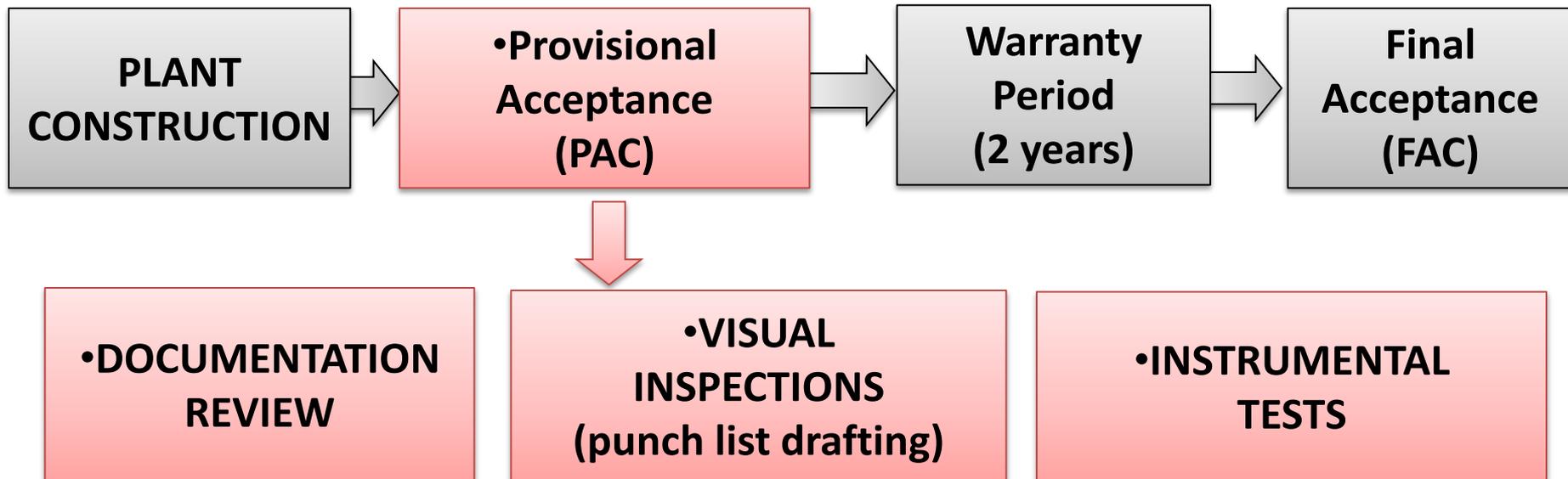


# Performance validation – Operation Phase

## PROVISIONAL ACCEPTANCE (PAC)



The advisor will take part to the **technical tests** for each plant, analyzing the global outcomes of Performance test/Technical tests according to the procedures defined in the EPC contract.



## Performance validation – Operation Phase

# VISUAL INSPECTION



Compliance of the **real condition and state of the plant with the “AS-BUILT” technical drawing** and documents.

**Equipment conservation conditions** including modules, inverters, electrical boards, structures, sensors, video cameras, control units.

Compliance of the **safety equipments** required by the standards and law

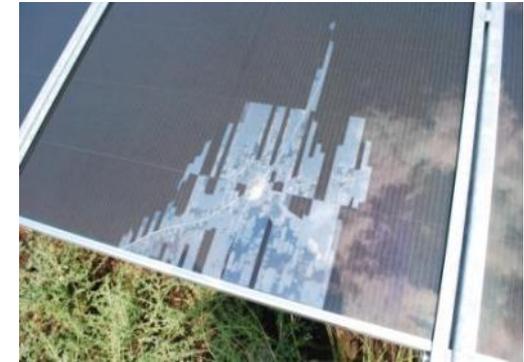
Compliance of the spare parts set to the **EPC contractual requirements**

# Performance validation – Operation Phase

## VISUAL INSPECTION



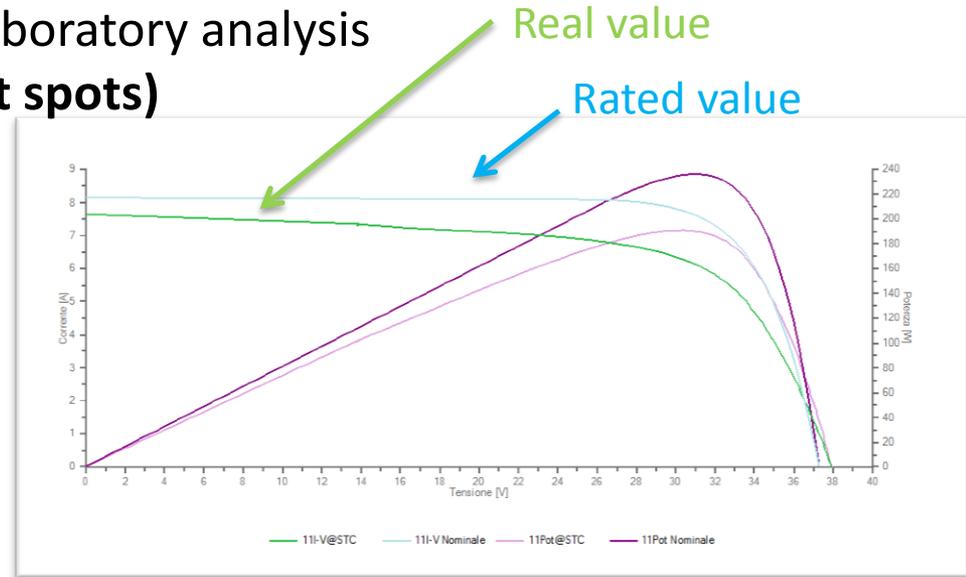
- Modules and structures
- Wiring
- Electrical Boards
- Transformers & Inverters



# Performance validation – Operation Phase INSTRUMENTAL TEST



- I-V measurement curves and / or laboratory analysis
- Measure of thermal anomalies (hot spots)



## Performance validation – Operation Phase

# PERFORMANCE RATIO AND CUF



The PR defines the ratio between the power (or energy) from the plant and the power (or energy) theoretically available.

$$P.R. = \frac{Y_F}{Y_R} = \frac{E_{ca}}{P_n} \cdot \frac{G_{STC}}{H_i}$$

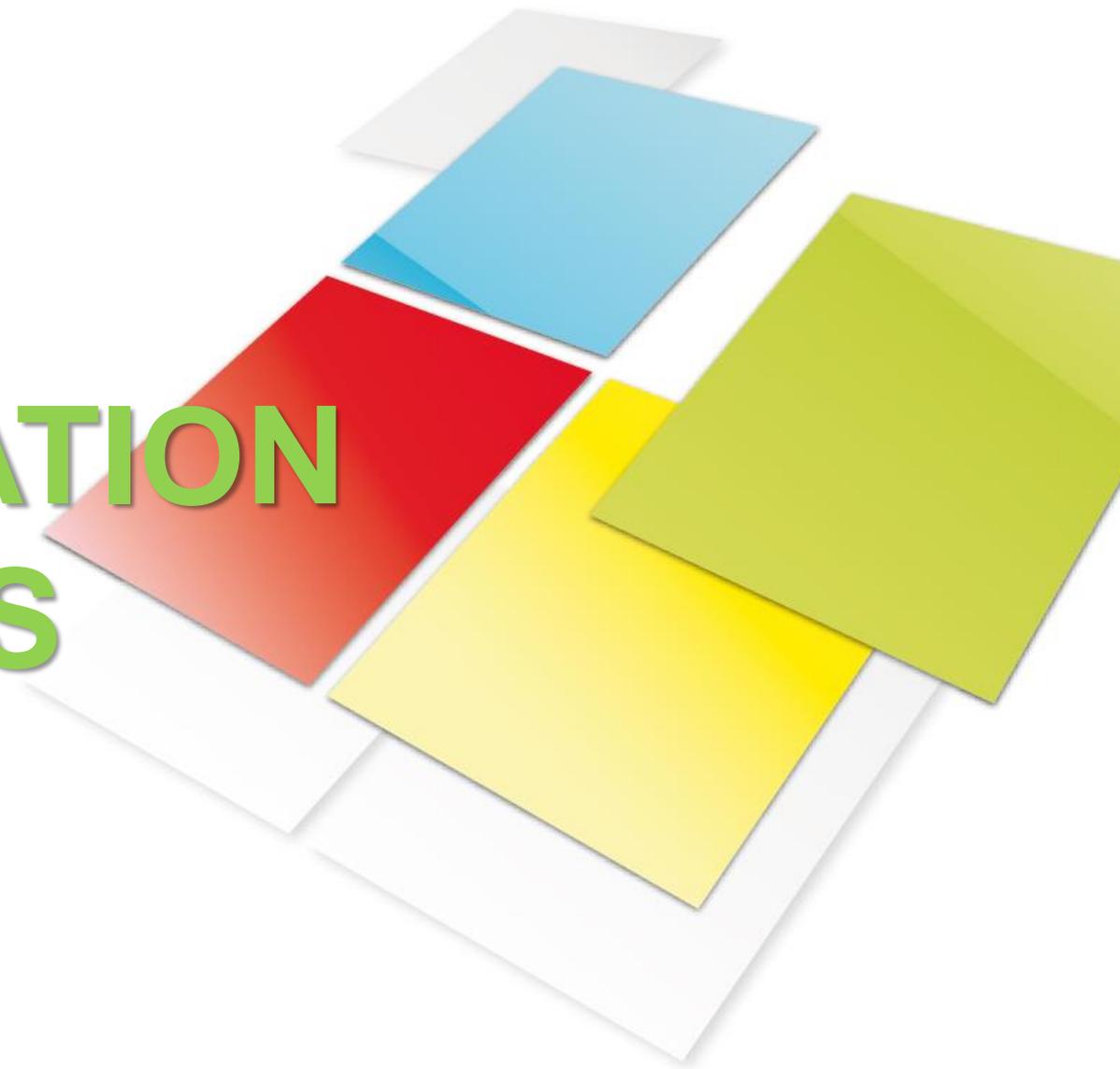
where:

- YF: Final yield (final energy index of the plant)
- YR: Reference yield (solar energy reference index)

The **correct calibration** of the irradiation sensors is fundamental to reach a reliable measure of the PR.

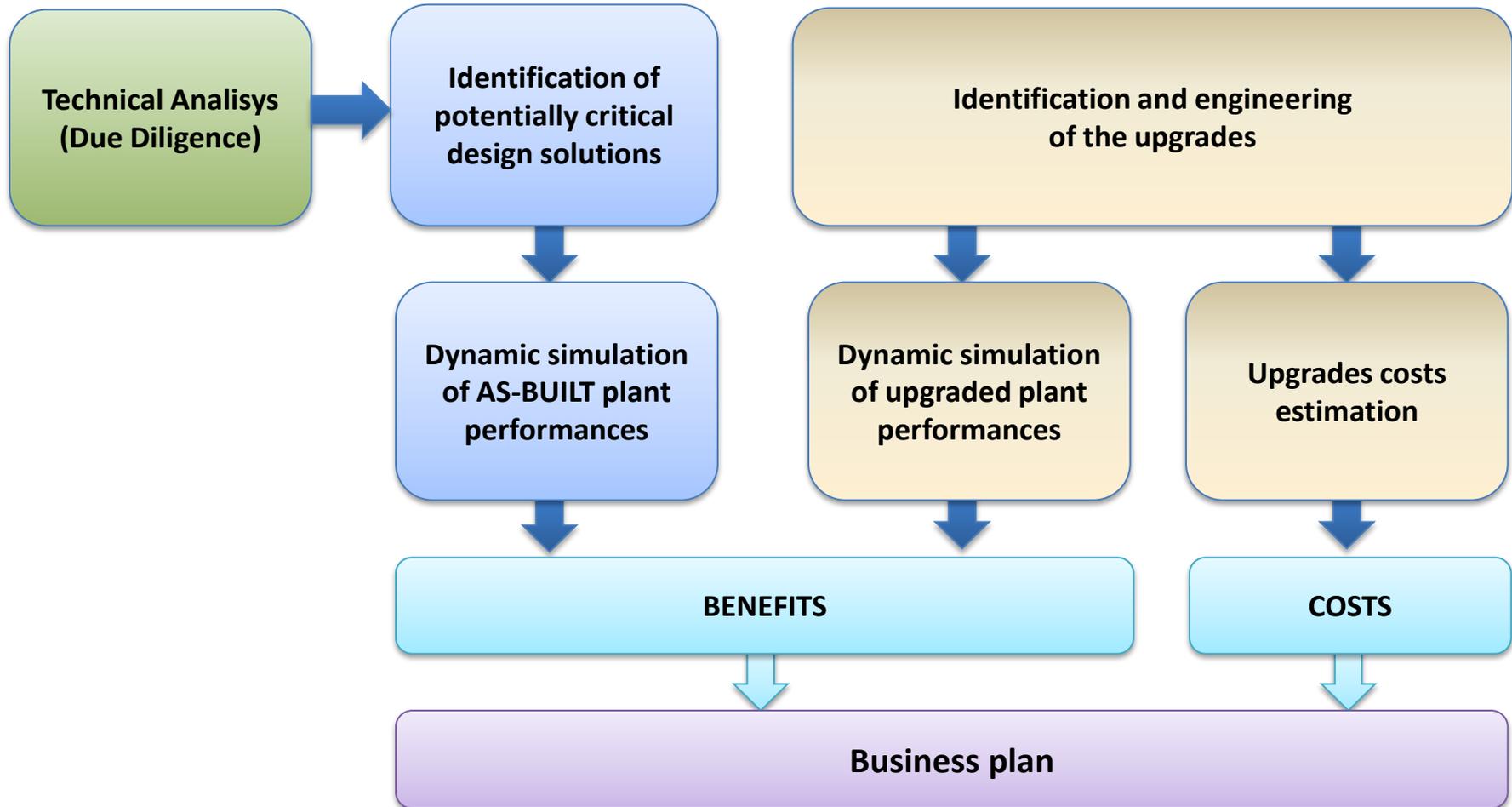


# OPTIMIZATION SERVICES



# Optimization Service

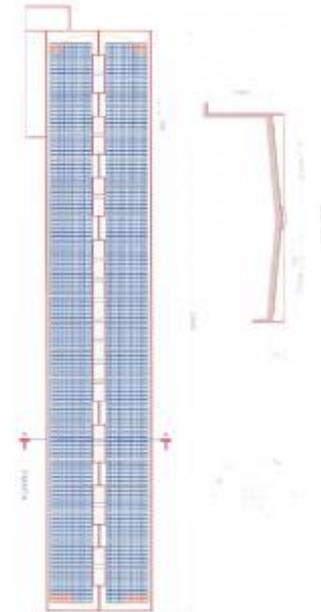
## THE PROCESS



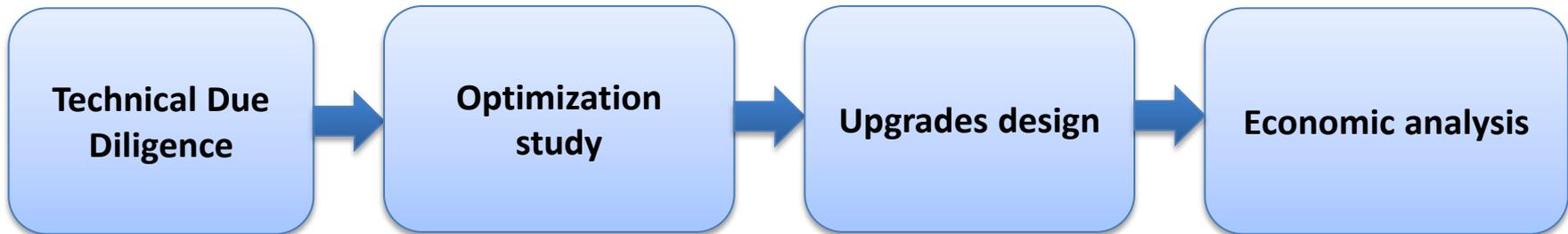
# Optimization Service BUSINESS CASE ANALYSIS (2)



- Rated Power: 980 kWp
- Plant type: Roof mounted photovoltaic



- Main services executed:

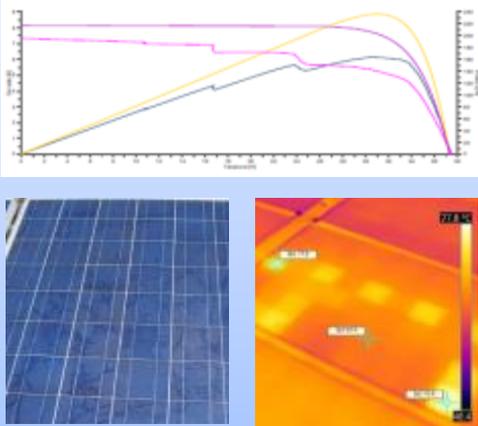


# Optimization Service BUSINESS CASE ANALYSIS (2)



## Main plant criticality detected

Defective PV modules  
(snail tracks)



Stringboxes and  
DC wires  
without sun  
protection



Shadows  
caused by  
internal objects



Unproper  
installation of  
monitoring  
system

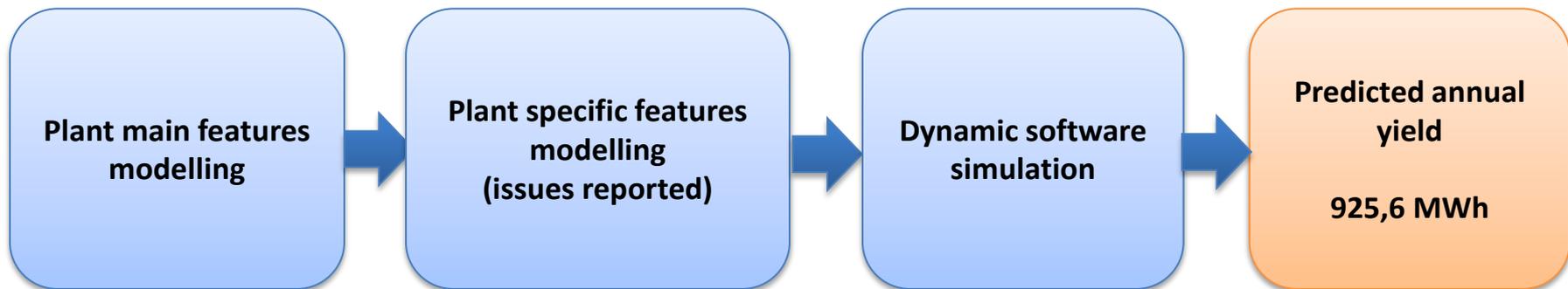
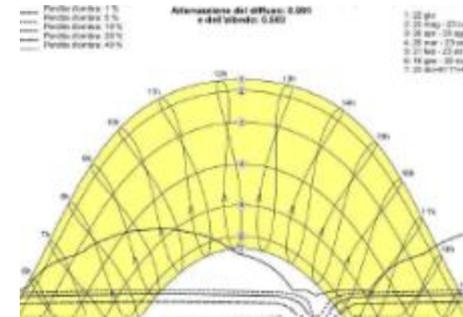
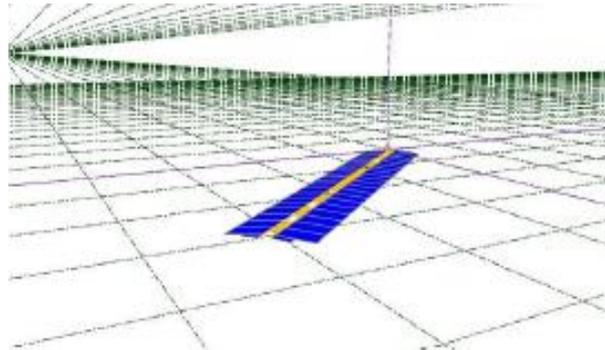
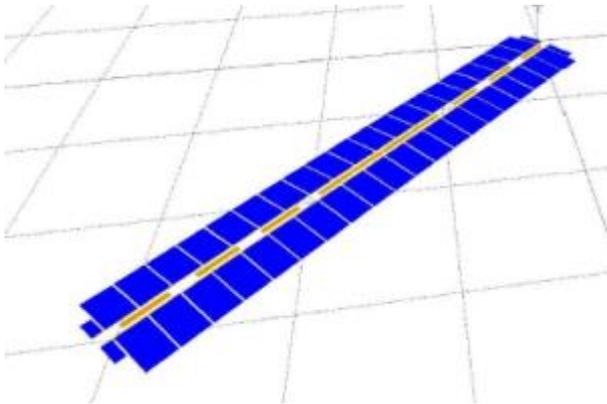


**Low Performance Ratio (67%)**

# Optimization Service BUSINESS CASE ANALYSIS (2)



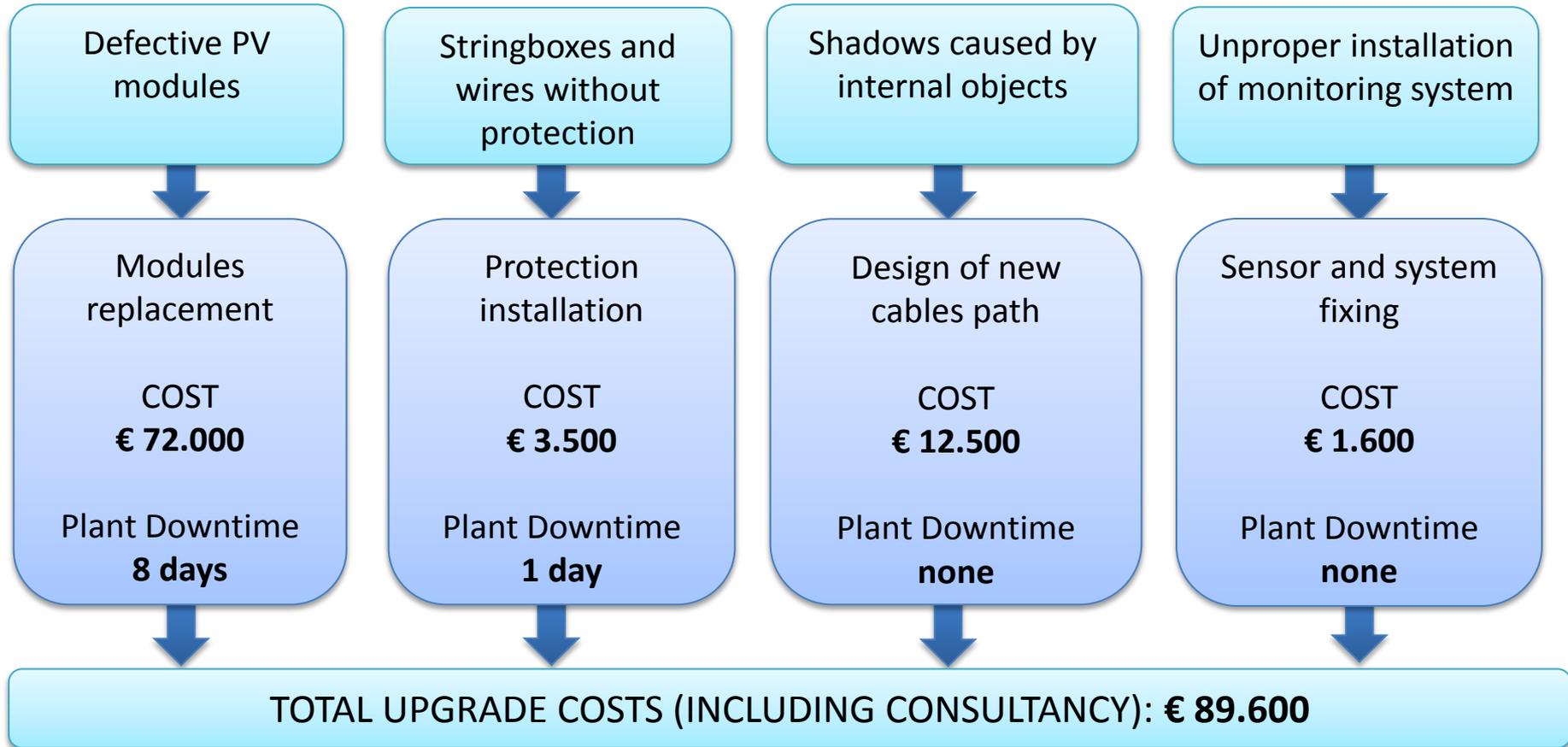
## PLANT MODELING AND SIMULATION – AS BUILT



# Optimization Service BUSINESS CASE ANALYSIS (2)

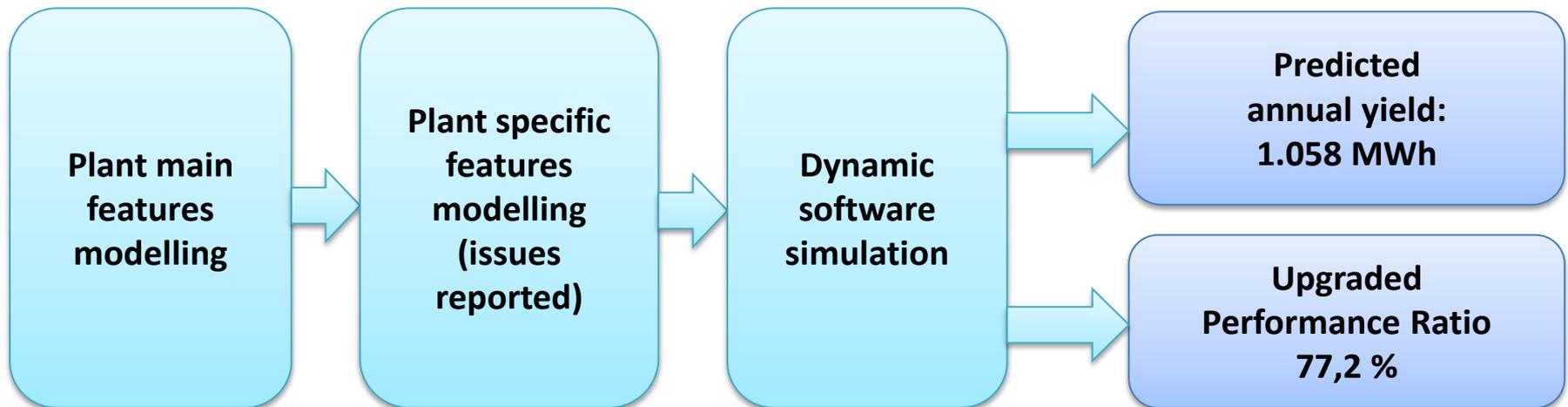


## Proposed upgrades after re-engineering study

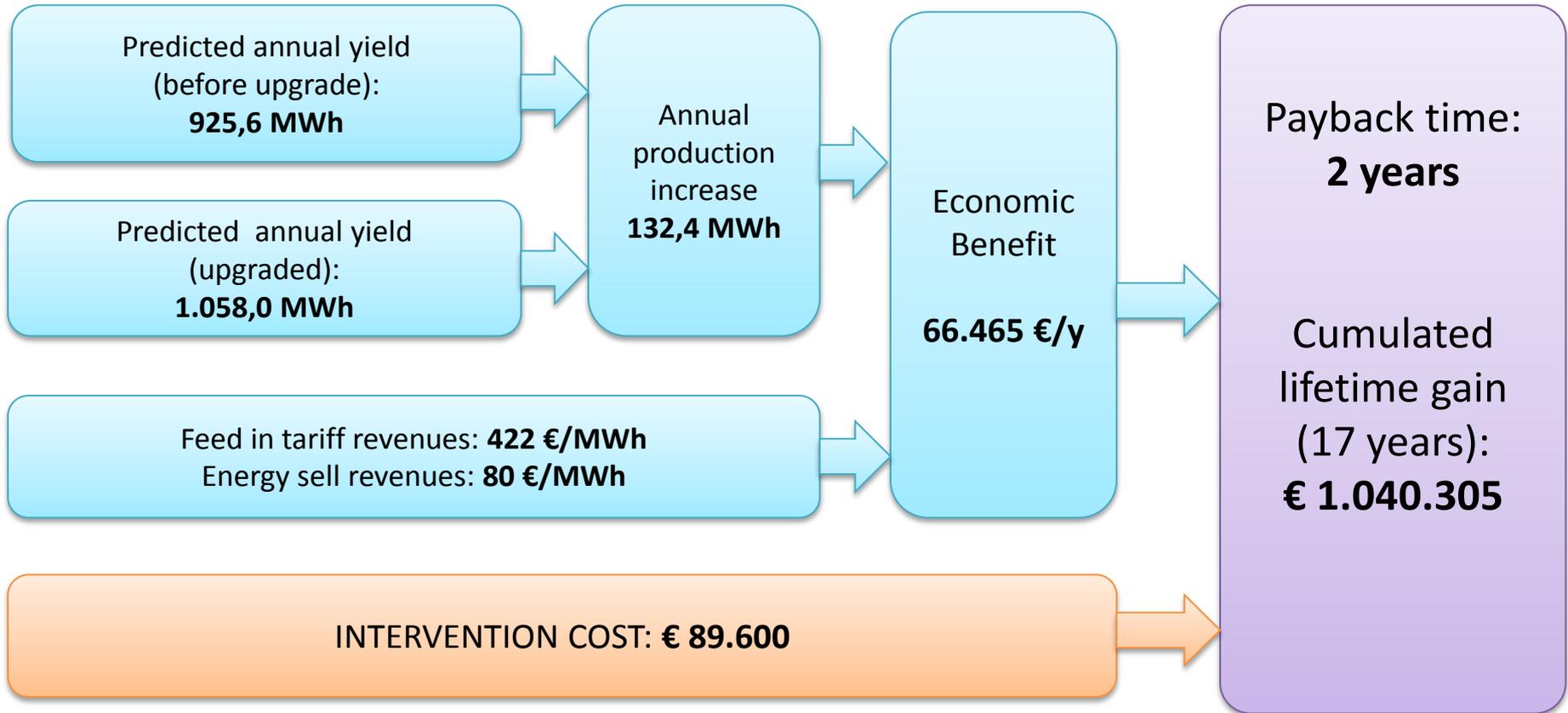




## PLANT MODELING AND SIMULATION – UPGRADED



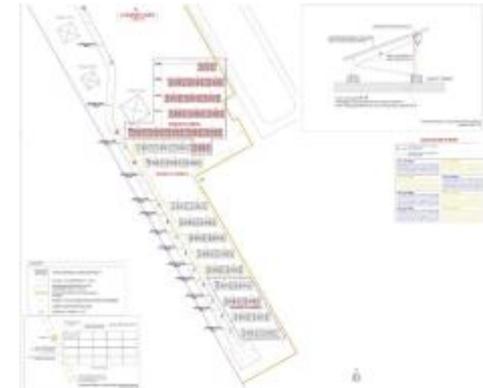
## ECONOMIC ANALYSIS



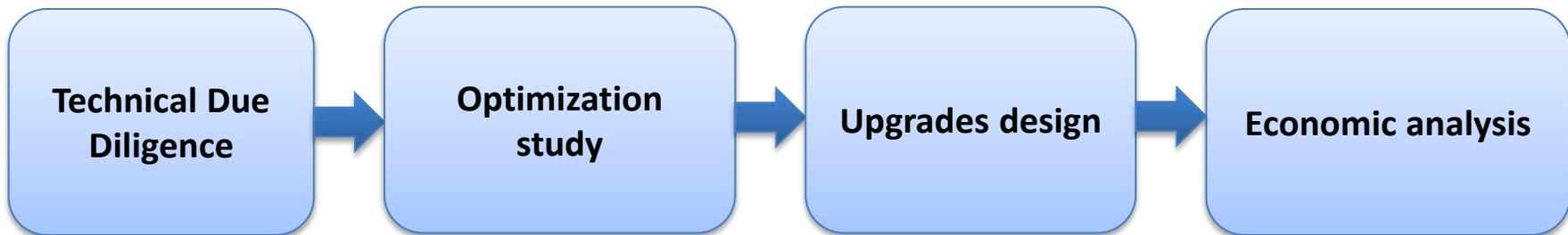
# Optimization Service BUSINESS CASE ANALYSIS (1)



- Plant type: Ground mounted photovoltaic



- Main services executed:

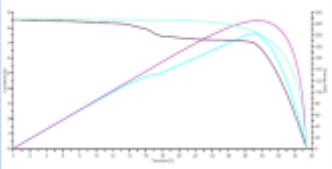


# Optimization Service BUSINESS CASE ANALYSIS (1)

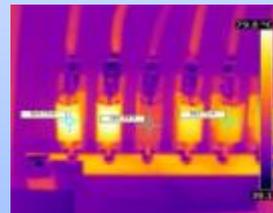


## Main plant criticality detected

Defective PV modules



Defective fuse and wires connections



Shadows caused by internal objects



Shadows caused by external objects

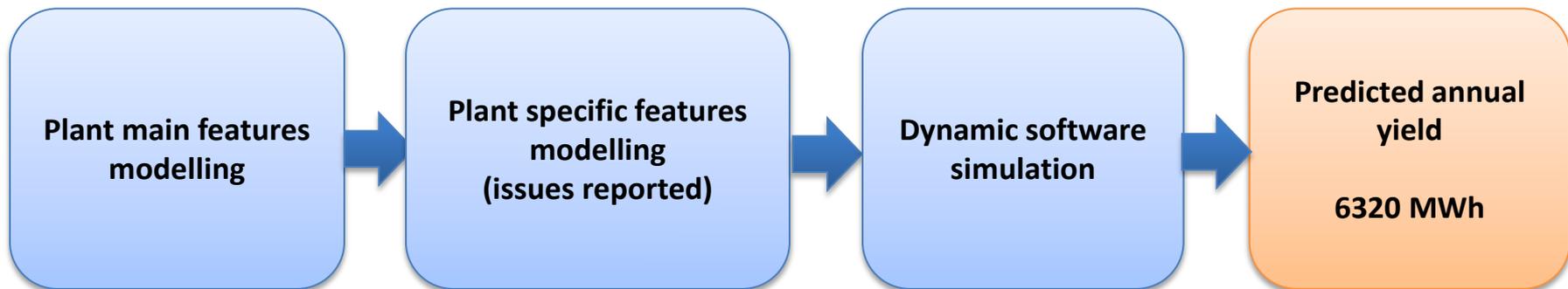
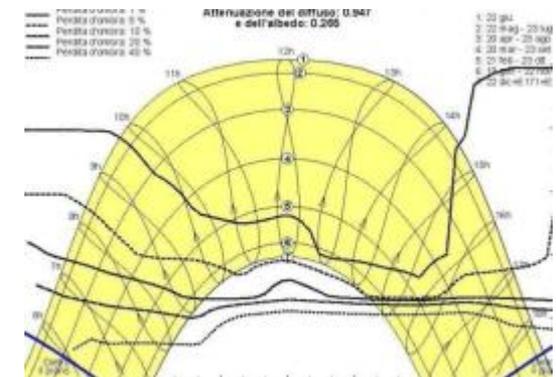
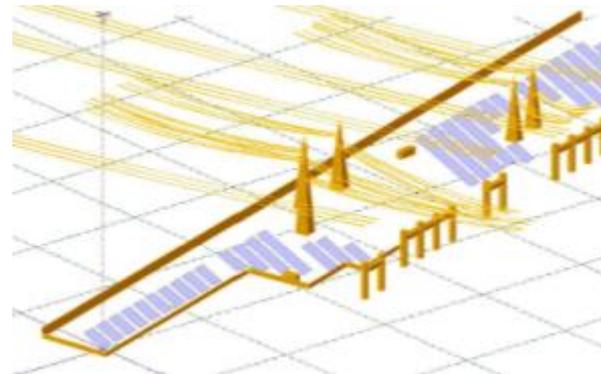
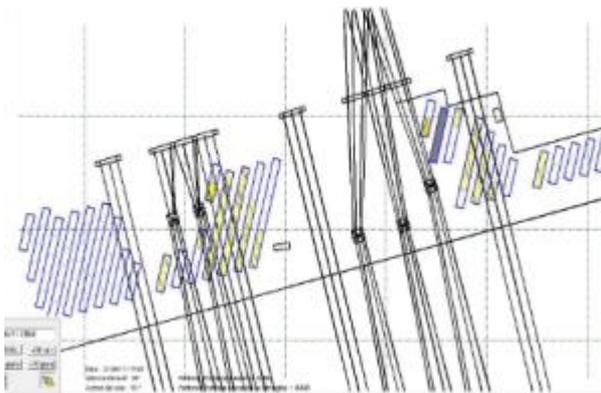


**Low Performance Ratio (65%)**

# Optimization Service BUSINESS CASE ANALYSIS (1)



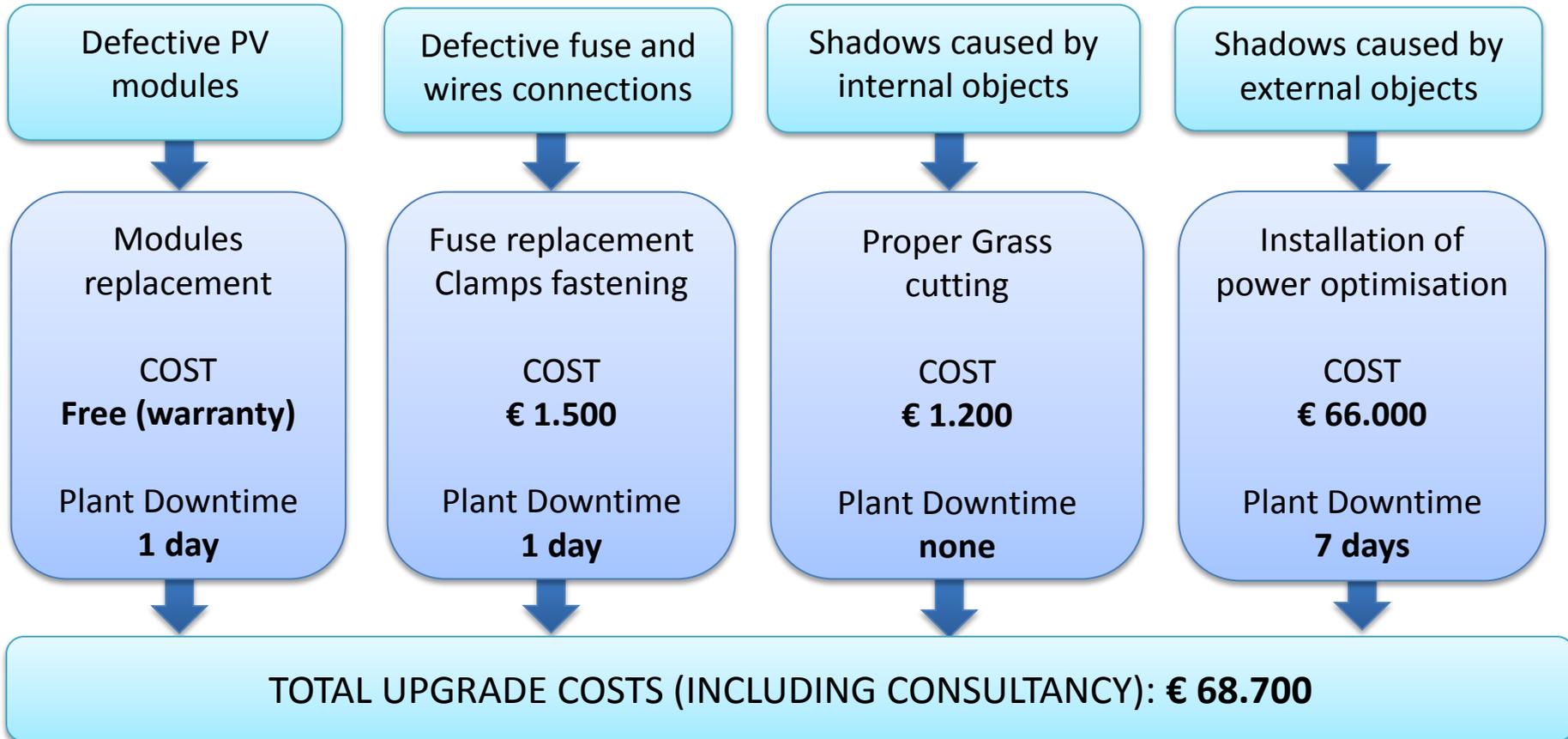
## PLANT MODELING AND SIMULATION – AS BUILT



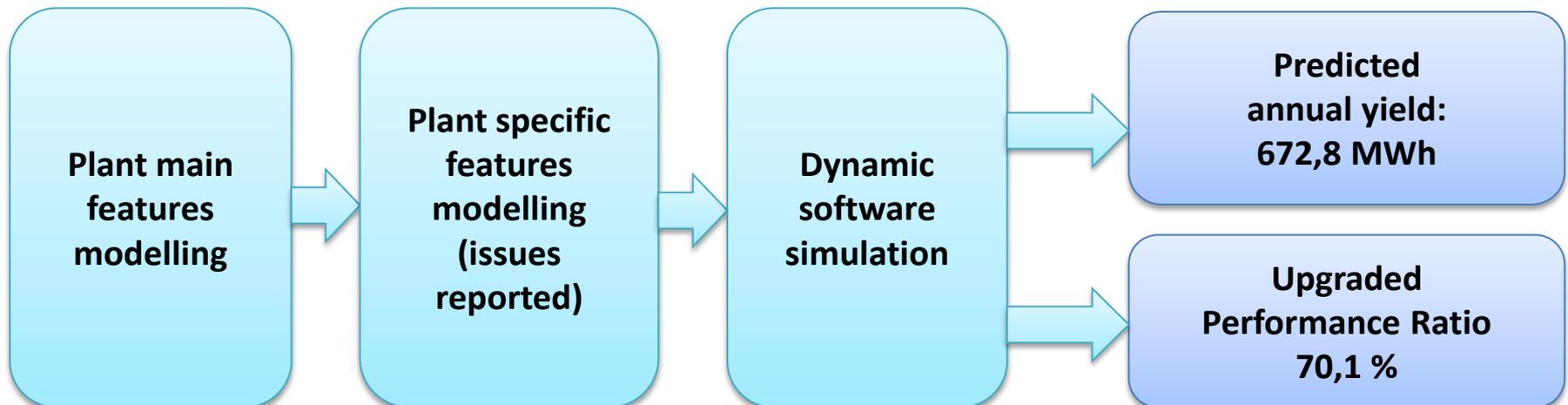
# Optimization Service BUSINESS CASE ANALYSIS (1)



## Proposed upgrades after re-engineering study



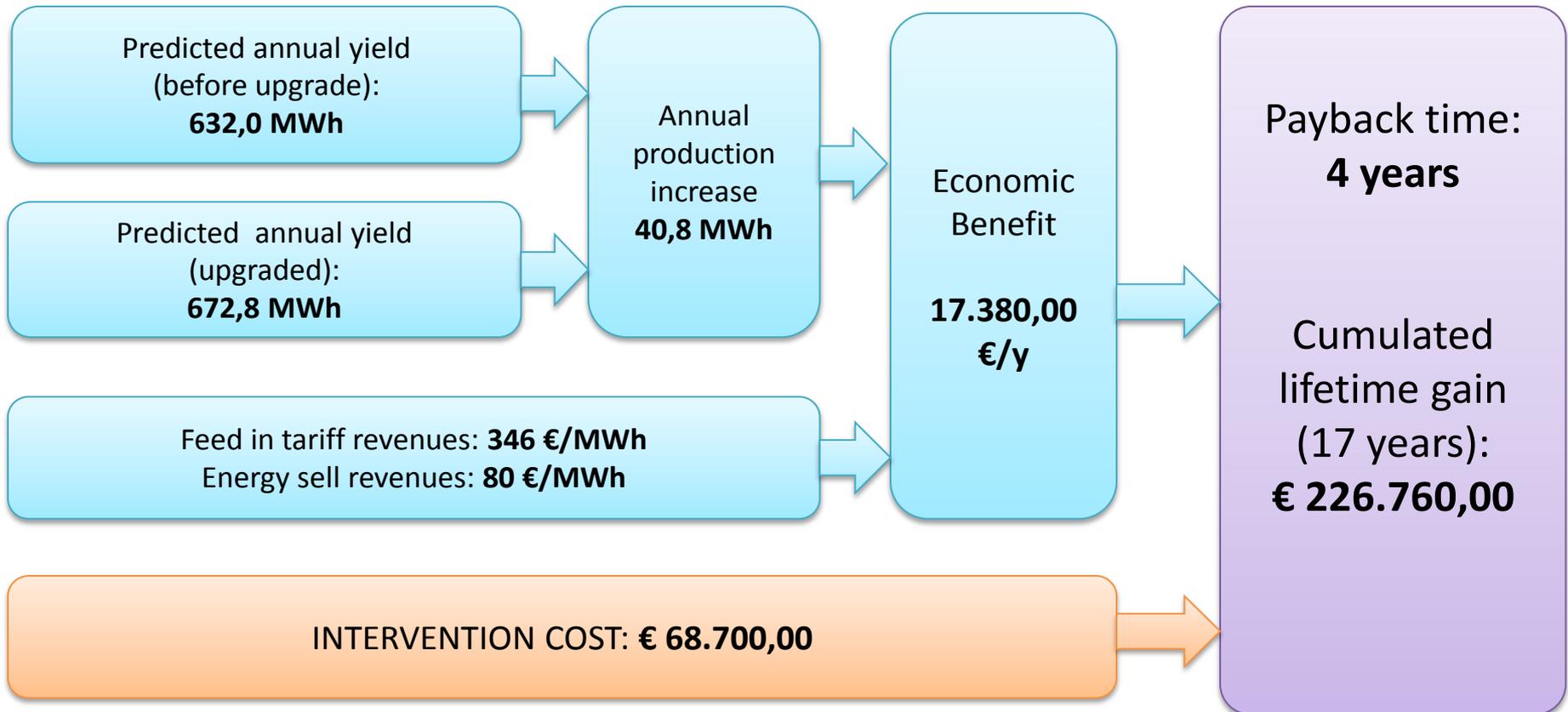
## PLANT MODELING AND SIMULATION – UPGRADED



# Optimization Service BUSINESS CASE ANALYSIS (1)



## ECONOMIC ANALYSIS



# MORONI & PARTNERS

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Via del commercio, 14 A | 60021 Camerano (AN)

**Tel.** (+39) 071 89 50 23 | **Fax.** (+39) 071 73 21 57

info@moronipartners.it

[www.moronipartners.it](http://www.moronipartners.it)

**Coordinate gps, latitude e longitude** 43.5199445, 13.5446554