PERFORMANCE VALIDATION AND OPTIMIZATION OF UTILITY SCALE PV PLANT
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

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
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 - Photovoltaïca International Exhibition, Casablanca, Morocco
- 4-7 May 2015 - Private Sector Liaison Officers (PSLO) Energy Mission, Washington D.C., USA
Solar Breeder Morocco
M&P WORLDWIDE

M&P India pvt ltd
Gurgaon - Delhi
M&P at a glance
COMPANIES THAT HAVE CHOSEN US
PERFORMANCE VALIDATION
Performance Validation
THE TECHNICAL ADVISORY ROLE

PROJECT PHASE

DEVELOPMENT

CONSTRUCTION

OPERATION

ADVISOR ACTIVITY

TECHNICAL DUE DILIGENCE

CONSTRUCTION MONITORING

PROVISIONAL ACCEPTANCE (PAC)

ONGOING MONITORING

FINAL ACCEPTANCE (FAC)

MAIN TOPICS

- ENERGY PRODUCTION
- FINANCIAL MODELING
- CONTRACTS
- TECHNOLOGY
- ENGINEERING

- COMPLIANCE TO EPC CONTRACT
- COMPLIANCE TO TECHNICAL REQUIREMENTS
- DEADLINES

- DOCUMENTATION REVIEW
- INSPECTIONS TESTS

- OPERATING COSTS
- O&M ACTIVITIES
- PLANT AVAILABILITY
- PERFORMANCES

- ON SITE TESTS
- HISTORICAL DATA EVALUATION
- PERFORMANCE WARRANTIES
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

- ELECTRICAL DESIGN REVIEW
- STRUCTURAL DESIGN REVIEW
- CIVIL WORKS DESIGN REVIEW
- SPECIAL EQUIPMENTS REVIEW

- DC SIDE
  - AC SIDE
  - GROUNDING

- FOUNDATIONS
  - MATERIALS

- ACCESS
  - INTERNAL ROADS
  - CABINS
  - METEORIC WATER

- MONITORING
  - ANTI-THEFT

EVALUATION OF THE:
- RELIABILITY
- SUITABILITY
- FLEXIBILITY
- QUALITY STANDARDS

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

- **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

- REVENUES
- ENERGY SELL
- INCENTIVES
- CAPEX
- COSTS
- OPEX
- CREDIT LINE
- FINANCIAL

BUSINESS PLAN EVALUATION

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

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

\[ P.R. = \frac{Y_F}{Y_R} = \frac{Eca}{Pn} \cdot \frac{G_{STC}}{Hi} \]

where:
- \( Y_F \): Final yield (final energy index of the plant)
- \( Y_R \): 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

**Technical Analysis** (Due Diligence)

- Identification of potentially critical design solutions
- Dynamic simulation of AS-BUILT plant performances

**Identification and engineering of the upgrades**

- Dynamic simulation of upgraded plant performances
- Upgrades costs estimation

**BENEFITS**

**COSTS**

Business plan
Optimization Service

BUSINESS CASE ANALYSIS (2)

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

- Main services executed:
  - Technical Due Diligence
  - Optimization study
  - Upgrades design
  - Economic analysis
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

Plant main features modelling

Plant specific features modelling (issues reported)

Dynamic software simulation

Predicted annual yield

925,6 MWh
Proposed upgrades after re-engineering study

- Defective PV modules
  - Modules replacement
  - COST € 72,000
  - Plant Downtime 8 days

- Stringboxes and wires without protection
  - Protection installation
  - COST € 3,500
  - Plant Downtime 1 day

- Shadows caused by internal objects
  - Design of new cables path
  - COST € 12,500
  - Plant Downtime none

- Unproper installation of monitoring system
  - Sensor and system fixing
  - COST € 1,600
  - Plant Downtime none

TOTAL UPGRADE COSTS (INCLUDING CONSULTANCY): € 89,600
PLANT MODELING AND SIMULATION – UPGRADED

- Plant main features modelling
- Plant specific features modelling (issues reported)
- Dynamic software simulation

Predicted annual yield: 1.058 MWh
Upgraded Performance Ratio 77.2%
**ECONOMIC ANALYSIS**

- Predicted annual yield (before upgrade): 925.6 MWh
- Predicted annual yield (upgraded): 1,058.0 MWh
- Annual production increase: 132.4 MWh
- Feed in tariff revenues: 422 €/MWh
- Energy sell revenues: 80 €/MWh
- Economic Benefit: 66,465 €/y
- Intervention Cost: € 89,600

Payback time: 2 years
Cumulated lifetime gain (17 years): € 1,040,305
Optimization Service
BUSINESS CASE ANALYSIS (1)

• Plant type: Ground mounted photovoltaic

• Main services executed:

  Technical Due Diligence  ➔  Optimization study  ➔  Upgrades design  ➔  Economic analysis
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%)
PLANT MODELING AND SIMULATION – AS BUILT

Plant main features modelling

Plant specific features modelling (issues reported)

Dynamic software simulation

Predicted annual yield

6320 MWh
Proposed upgrades after re-engineering study

- **Defective PV modules**
  - Modules replacement
  - COST: Free (warranty)
  - Plant Downtime: 1 day

- **Defective fuse and wires connections**
  - Fuse replacement
  - Clamps fastening
  - COST: € 1.500
  - Plant Downtime: 1 day

- **Shadows caused by internal objects**
  - Proper Grass cutting
  - COST: € 1.200
  - Plant Downtime: none

- **Shadows caused by external objects**
  - Installation of power optimisation
  - COST: € 66.000
  - Plant Downtime: 7 days

**TOTAL UPGRADE COSTS (INCLUDING CONSULTANCY): € 68.700**
PLANT MODELING AND SIMULATION – UPGRADED

- Plant main features modelling
- Plant specific features modelling (issues reported)
- Dynamic software simulation

Predicted annual yield: 672,8 MWh
Upgraded Performance Ratio 70,1 %
ECONOMIC ANALYSIS

Predicted annual yield (before upgrade): 632,0 MWh
Predicted annual yield (upgraded): 672,8 MWh
Annual production increase: 40,8 MWh

Feed in tariff revenues: 346 €/MWh
Energy sell revenues: 80 €/MWh

Economic Benefit: 17,380,00 €/y

Payback time: 4 years
Cumulated lifetime gain (17 years): 226,760,00 €

INTERVENTION COST: 68,700,00 €