Case Study of a 20 MW PV Power Plant in El Salvador

Large-Scale Photovoltaic Power Plants for Developing Countries

Fred Wendt, April 2012

Case Study of a 20 MW PV Power Plant in El Salvador

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Agenda

- 3D Visualization
- Project Description
- Methodology
- Technical Assessment
- Financial Implications
- Economic Assessment
- Project Implementation
- Conclusions

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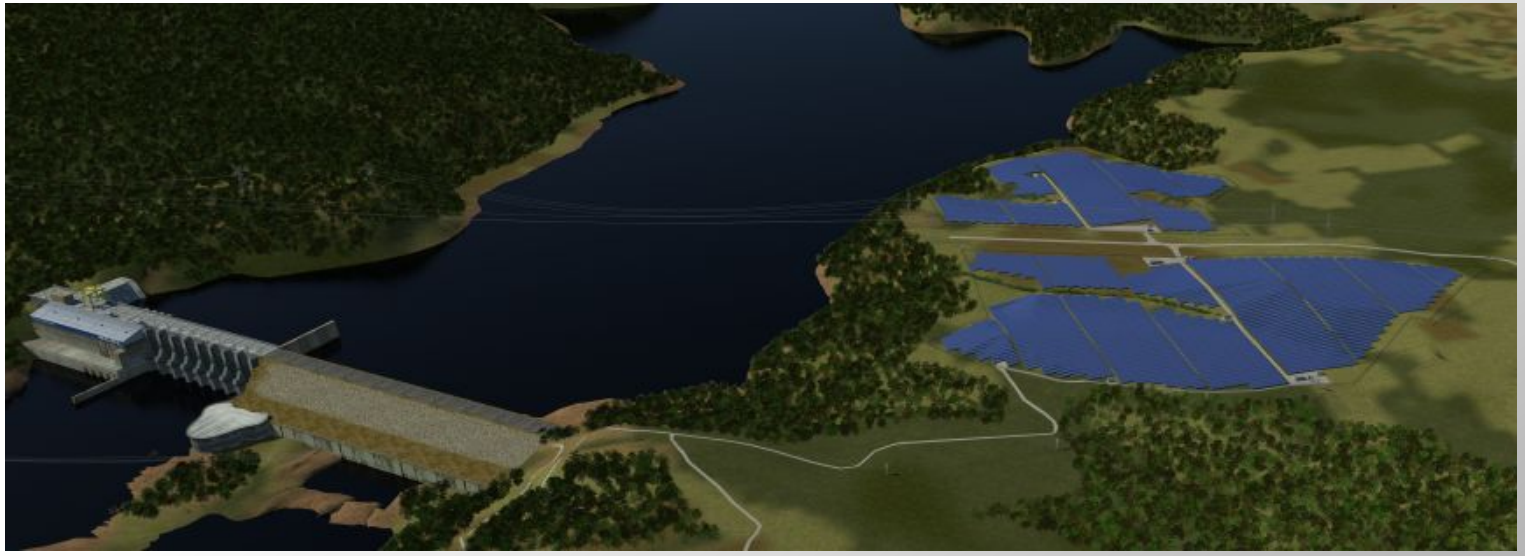
Project Description

- **Introduction**



-**“15 de Septiembre” 14.2 MW**

- **“Guajoyo” 3.6 MW**

- **Funded by KfW**

-**Client CEL (Comision Ejecutiva Hidroelectrica del Rio Lempa)**

Case Study of a 20 MW PV Power Plant in El Salvador
Project Description

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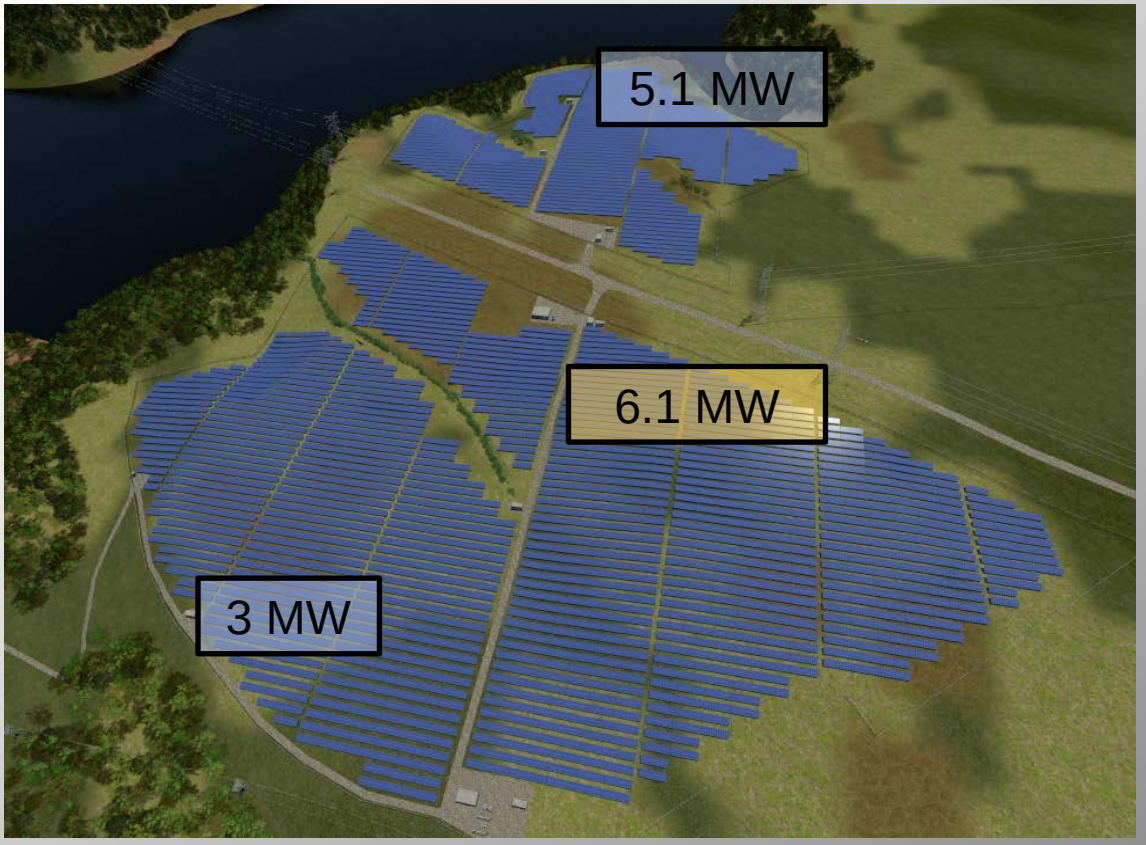
■ Results Conceptual Plant Design 15 de Septiembre

- Installed power 14.2 MW
- Module tilt of 12°
- 60,480 x Module 235 W
- 840 x Inverter 15 kW
- ~10,500 piles
- Grid connection 46 kV
- Performance Ratio 78.5%
- Specific Yield 1,615 kWh/kW
- Area 240,000 m²:

32 soccer / 45 football fields

area of Champ de Mars, Paris



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Project Description

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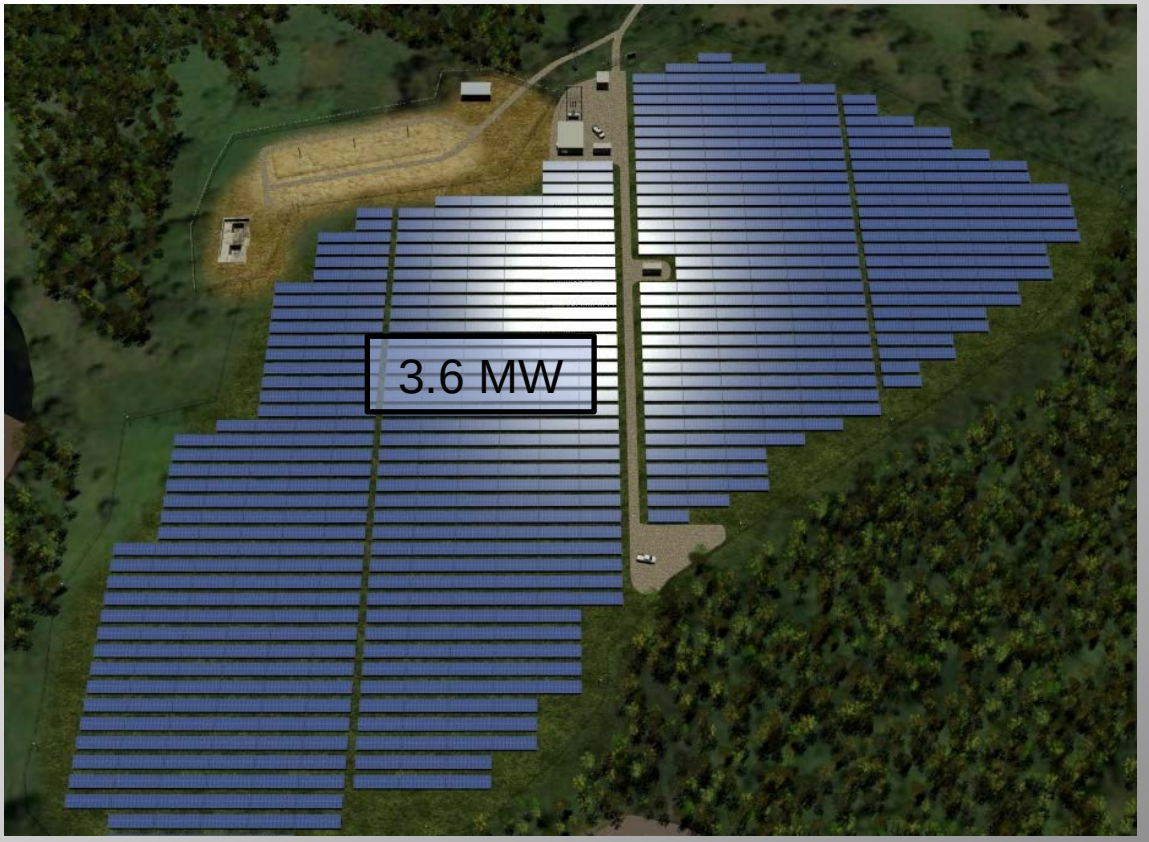
■ Results Conceptual Plant Design Guajoyo

- Installed power 3.6 MW
- Module tilt of 12°
- 15,552 x Module 235 W
- 216 x Inverter 15 kW
- ~3,000 piles
- Grid connection 46 kV
- Performance Ratio 80.8%
- Specific Yield 1,605 kWh/kW
- Area 61,000 m²:

8 soccer / 11 football fields

footprint of Cheops pyramid



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Methodology

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Key Questions

Potentials

- Rapidly evolving technologies
- Favorable political and societal conditions
- Secure revenue structures
- Sustainable investments
- Low-emission
- High operational safety

Risks

- Project reliability
- Changing political and economic market conditions
- Availability of renewable energy sources

How can the potential electricity generation of the sites in El Salvador be maximized, and technical and legal framework risks be minimized?

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Methodology

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Methodology Techno-Economic Feasibility Study

Technical Assessment

Site Assessment
- Geotechnical-
- Environmental-
- Social-
- Climatic aspects

Technology Assessment
- PV Module Selection
- Inverter Concepts
- O&M Requirements

Permitting process
- Validation of grid connection
- Legal Framework Report

Technical Design

Financial Implications

Evaluation of CDM Revenues

Yield Verification

Evaluation revenue and operating expenditures
- Feed-in tariff analysis
- Demand analysis

Assessment capital expenditures
- Investment costs incl. decommissioning

Financing Plan and Structure
- Co-operation with international financing Institutions

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Technical Assessment

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Site Assessment

Objective Site Assessment

- **Evaluation of the site suitability based on:**

1. **Meteorological data**
2. **Terrain usability**
3. **Area accessibility**

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Technical Assessment

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Irradiation El Salvador

S/W yield verification:

PV Sol, PV Syst, Insel, ILF inhouse

Solar Data resources:

-local rooftop plant:
-local measurement station

- data supplier such as:

SoDA , Meteonorm, SolarGIS, NASA , DLR, RETscreen, …

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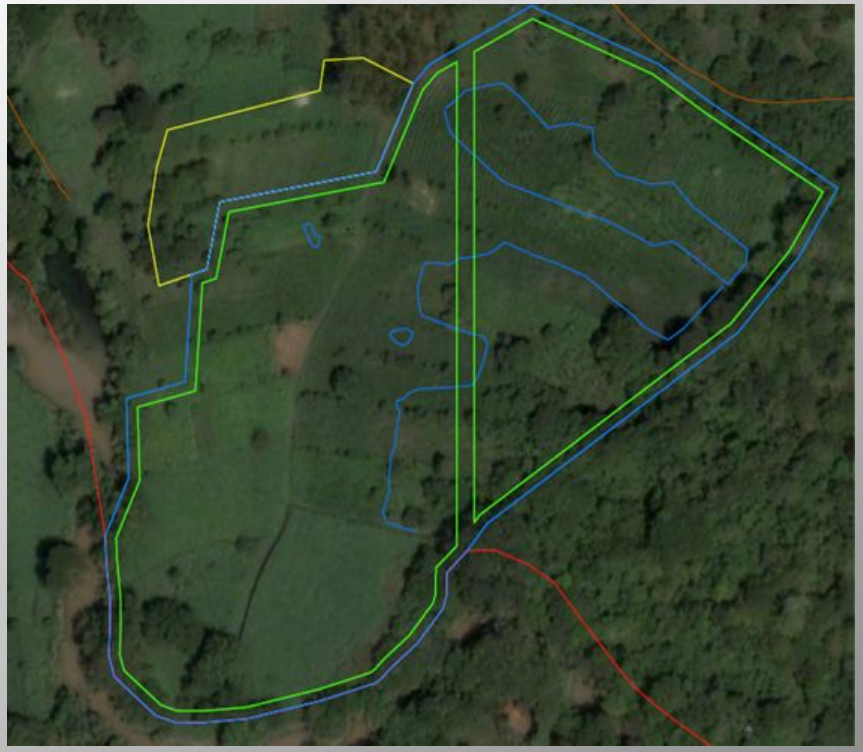
- **Site Evaluation**

Resulting area 15 de Septiembre

Resulting area Guajoyo



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Technical Assessment

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■ Environmental and Social Evaluation

Objective

- **Identification** of sensitive environmental and social features
- **Consideration of impacts**
  - Site preparation
  - Construction
  - Operation
  - De-commissioning
- **Development of mitigation measures**

Result

- **Both sites are feasible for development of a PV plant**

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Technical Assessment

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■ Technology Selection

Objective of Technology Assessment

- **Identification** of potential technological solutions

- **Evaluation** of the following technical components :

1. **PV Modules**
2. **Mounting Structure and Foundations**
3. **Inverter Concept**

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Technical Assessment

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■ Module Selection

Description	Thin Film Technology		Crystalline Technology	
Module Technology	Amorphous Silicon a-Si	Cadmium Telluride CdTe	Monocrystalline	Polycrystalline
Total Number of Modules / MW	10,020	12,528	4,008	4,008
Module Area / MW	14,329 m^2	9,020 m^2	6,447 m^2	6,447 m^2
Total Area	1.9 ha - 3.1 ha	1.3 ha - 2.2 ha	0.8 ha - 1.5 ha	0.8 ha - 1.5 ha
Max Power El Salvador / ha	0.5 MW	0.75 MW	1.25 MW	1.25 MW
Yield / Year	****	1,528 kWh/kW	1,419 kWh/kW	1,420 kWh/kW
PR	****	79.8 %	74.1 %	74.2 %
Turnkey Price in Euro per kW	2,300 € - 2,600 €	2,300 € - 2,600 €	2,500 € - 2,800 €	2,300 € - 2,600 €

Result: Poly-crystalline

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Technical Assessment

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■ Technology Selection

2. Objective Mounting Structure

- **Elaboration** of cost and time efficient adequate mounting structure
- **Identification** of geological requirements

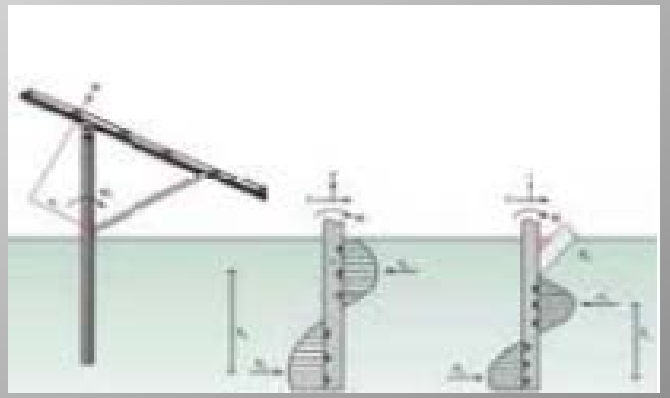
Results

- **15 de Septiembre:**

→Pile driven foundations sometimes pre-drilling required

- **Guajoyo:**

→Pile driven foundations often pre-drilling required



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■ Technology Selection

3. Objective Inverter Concept

- **Elaboration** of adequate inverter technology based on availability of maintenance and cost- efficiency
- **Identification** of costs and service availability

Results

String inverter concept

→ No on-site maintenance services required

→Maintenance for central inverter concept are not available in El Salvador

→ Less operation costs

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Technical Assessment

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■ Operation & Maintenance

Status Operation & Maintenance

Extremely low O&M

No rotating equipment

Results

→ O&M Concept

- **24 h security service**
- **Cleaning of modules**
- **Maintenance main components**
- **Maintenance low and medium voltage system**
- **Visual inspection**

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Technical Assessment

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■ Permitting Process

Results of Legal Framework

- **Permits and Authorizations**
  - Environmental Permit Process
  - City Hall Permit
  - Working Establishment regulation

  } Dialogue with Authorities
- **Connection to Grid**
- **Contract and Pricing**
- **Tax Benefits**

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Financial Implications

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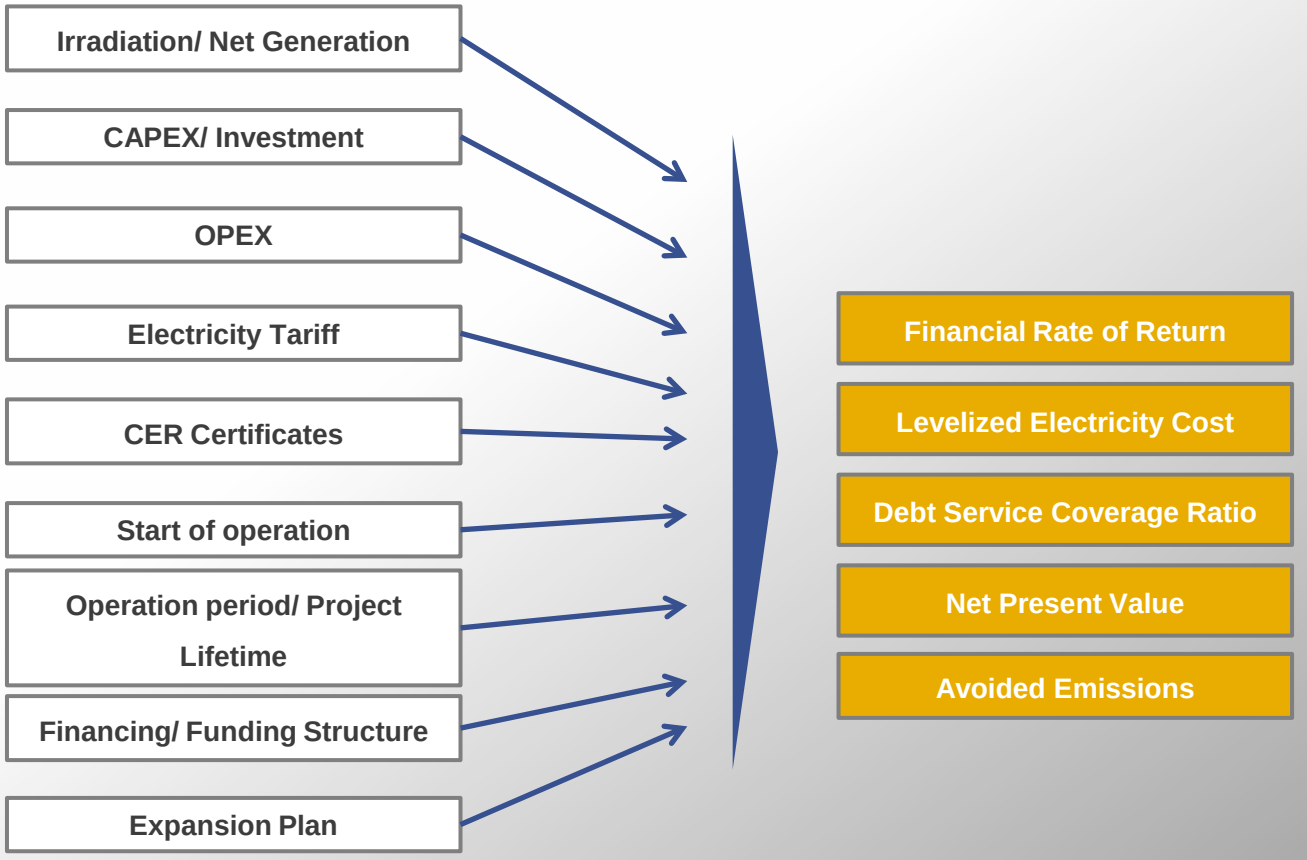
- **Financial Analysis:**



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Financial Implications

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■ Financial Analysis:

Irradiation/ Net Generation;	9,878 MWh/a
CAPEX/ Investment;	17,950 TEUR
OPEX;	205,87 TEUR/a
Cost-based vs. Market regulated Tariff	
CER Certificates;	12 EUR/ t
Start of operation;	2012
Operation period;	25 years
KfW Funding/ CEL Equity	
Potential Ext. Steps	

FIRR:	7,36%
LEC :	0,13 EUR/KWh
DSCR:	1,60
NPV :	13,836.01 TEUR
Avoided Emissions:	158,494 t

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Financial Implications

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Cost Estimation

	15 de Septiembre Initial	15 de Septiembre Extension	Guajoyo
	6.1 MW	8.1 MW	3.6 MW
Modules	8,612.68	11,485.24	5,169.11
Inverter	1,375.00	1,825.00	822.50
Civil material and construction	760.00	207.00	459.75
Electrical Material	3,894.80	4,832.90	2,394.13
Grid connection	717.50	-	567.50
Engineering, tendering, site supervision	840.00	655.00	460.00
Insurances	81.00	95.03	49.36
Contingencies	1,628.10	1,910.02	992.24
	TEUR	TEUR	TEUR
Specific Investment Costs (EUR/kW)	**2,522 (3,556 USD)**	**2,340 (3,299 USD)**	**2,701 (3,808 USD)**

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Economic Assessment

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Definition

Economic Analysis

- Quantification of costs and opportunity cost of compared to conventional thermal power generation
- Focus is on a macro-economic and national level
- Costs and Benefits adjusted to market structure and government intervention

Performance Indicators

- **Economic Rate of Return**
- **Benefit – Cost Ratio**
- **CO_2- Avoiding Costs**

Financial Analysis

- **Focus on interest of shareholders** of the project infrastructure
- Application of market prices, exertion of factors i.e. inflation and taxes
- Application of Funding Scenarios

Performance Indicators

- **Internal Rate of Return (IRR)**
- **Net Present Value (NPV)**
- **Levelized Energy Cost (LEC)**

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Economic Assessment

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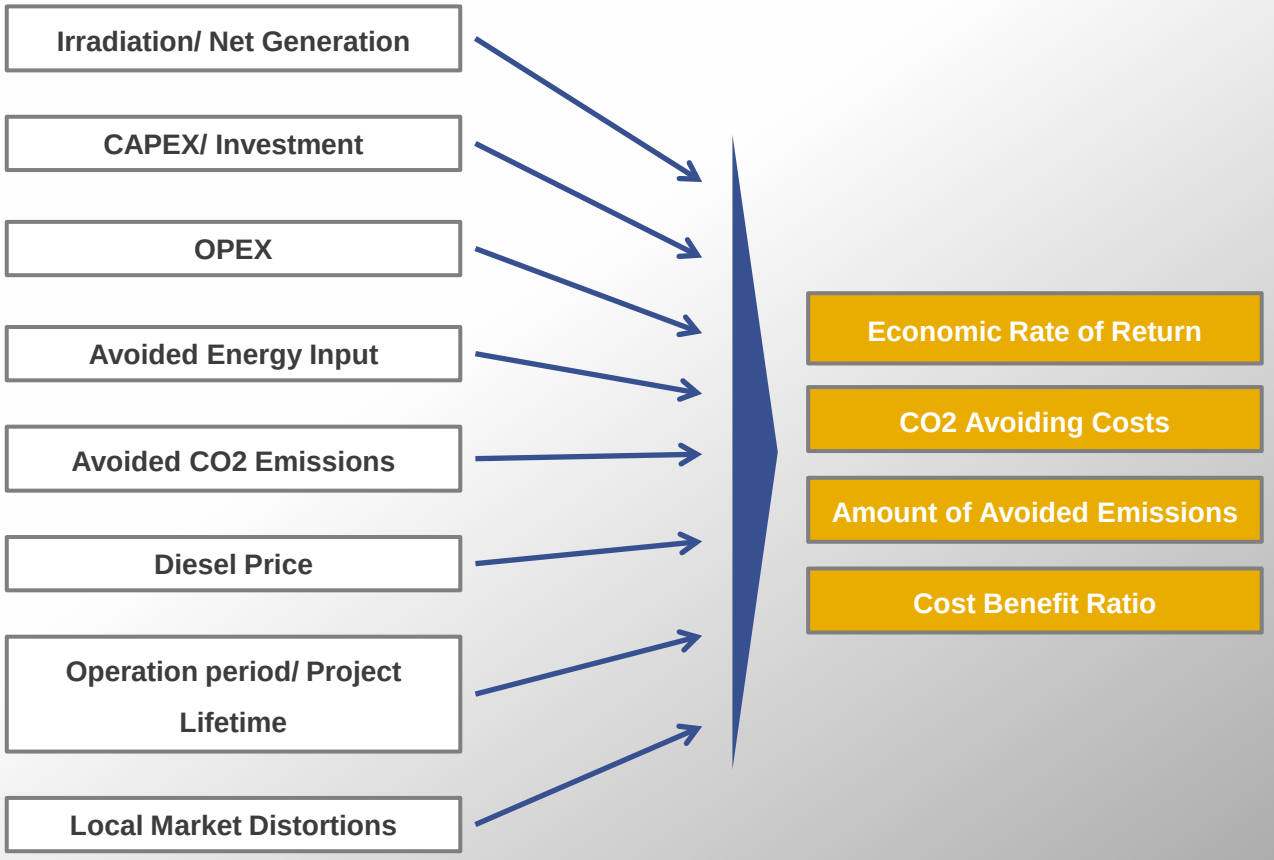
■ Impact Parameters on Economic Ratios



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Economic Assessment

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■ Impact Parameters on Economic Ratios

- Irradiation/ Net Generation; 9,878 MWh/a
- CAPEX/ Investment; 26,083 TUSD
- OPEX; 297 TUSD
- Avoided Energy Input; 2,069.4 TUSD
- Avoided CO2 Emissions; 7,083t CO2/a
- Diesel Price; 718.13 USD/t
- Operation period/ Project Lifetime; 25 years
- Grid Emission Factor El Salvador; 0.717 t CO2/ MWh

→

- ERR: 6.01%
- CO_2 Avoid. Costs: 59.99 USD/ t
- Avoided Emissions: 7,083 t/a
- Cost Benefit Ratio: 0.7

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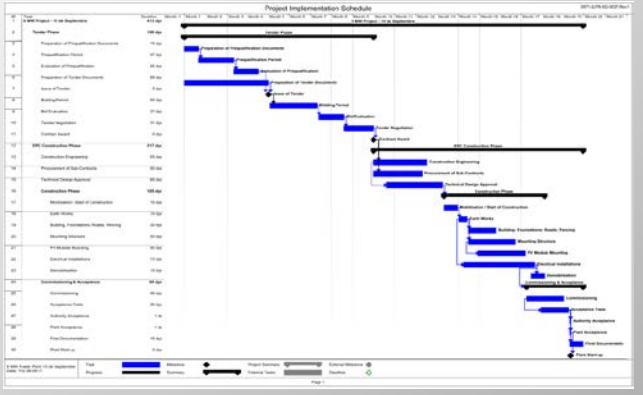
Project Implementation

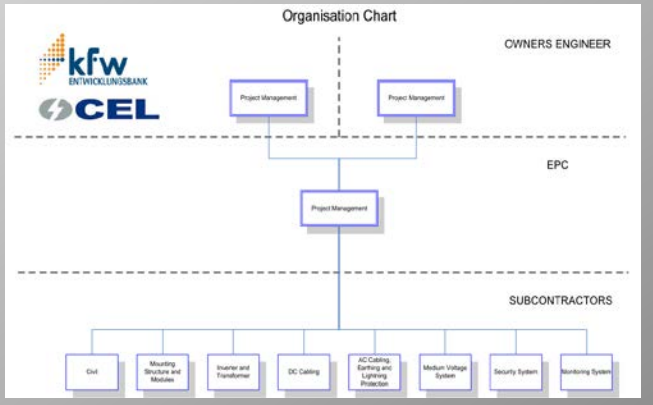
Objective

- **Elaboration** of project time “initial phase”
- **Identification** of milestones



Results

- **Initial project phase** >19 months
- **Tender phase** > 9 months
- **Construction phase** > 10 months



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Conclusions

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■ Recommendations

- **Communication of PV Technology**
  - **-> Presentation Workshop with Local Authorities**
  - **-> Project Visualization**
- **Sourcing Strategy**
  - **Local Content -> Assessment of Local Capacities**
  - **Knowledge Transfer -> Training**
  - **Technology Selection -> Consideration of Local Skills**
  - **Make projects attractive to int. EPCs**
- **Reliable Tariff System for RE must be established for project lifecycle**

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Thank you for your attention!

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