

RENEWABLE ENERGY TRAINING PROGRAM. MODULE 7 CONCENTRATED SOLAR POWER (CSP). CASE STUDIES: OUARZAZATE PROJECT

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ARIES INGENIERÍA Y SISTEMAS

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2. Ouarzazate Solar Complex

3. Ouarzazate site

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Main aspects

- Launched in November 2009
- Optimize the mix of generation capacity
- Generalized access to energy
- Sustainable development through the promotion of the renewable energies
- Opening up to the Euromediterranean energy markets
- Political will with concrete figures: 20 % Renewable Energies and 12% Wind Energy by 2020
- Creation of National Agency for Solar Energy- Masen
- Launch of Solar Program of 2000 MW by 2020
- New legislation concerning renewable energies and energy efficiency
- Encourage the launch of a local solar energy industry
- Betting on the future of renewable energies

Masen

- The Moroccan Agency for Solar Energy (“MASEN”) created through Moroccan Law 57/09
- State-owned company for the implementation of the Solar Plan
- Key roles of MASEN include:
 - Development of solar projects of minimum 2,000 MW total capacity
 - Industrial integration
 - R&D and training promotion
 - MASEN deal with International Financial Institutions

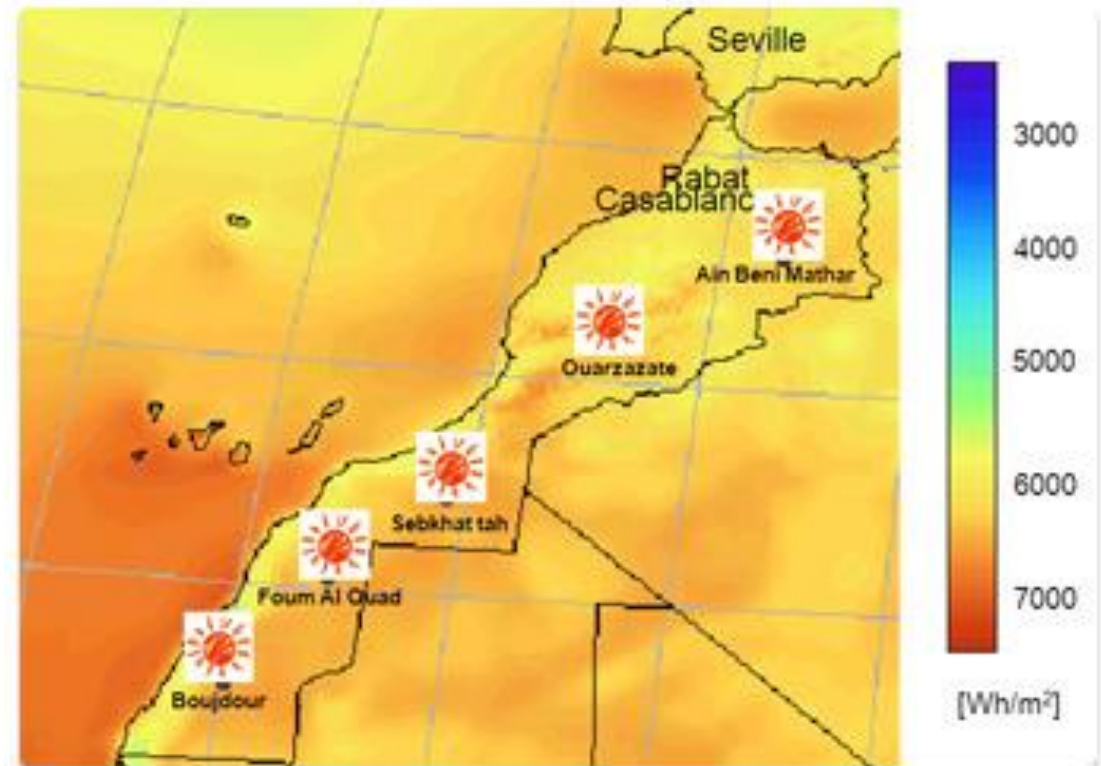
Masen Ownership



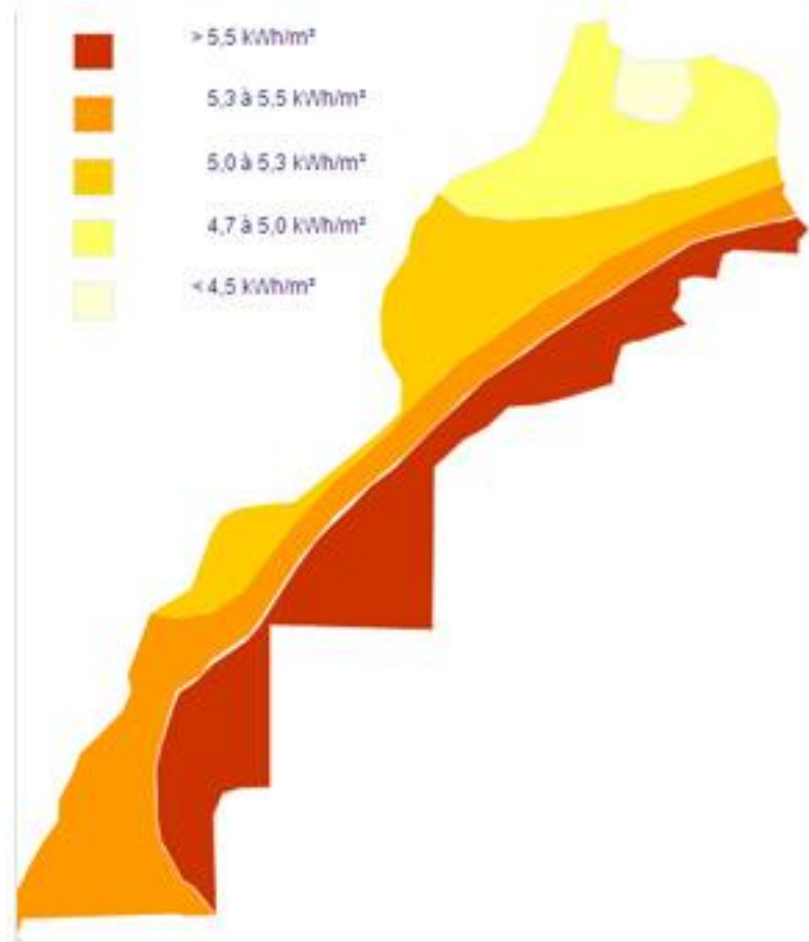
Sites

Sites identified for Solar Plan:

- Ouarzazate
- Ain Beni Mathar
- Foum Al Oud
- Boujdour
- Sebkhatah



Sunshine map (kWh/m²)



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Ouarzazate Solar Power Complex

- Located 0 km East Northeast (ENE) of Ouarzazate
- Fully commissioned by 2015
- Phase 1 Ouarzazate Program in operation in 2014

Phases

Phase 1: between
125 MW and 160 MW

Phase 2 and nexts up
to 500 MW

Technologies

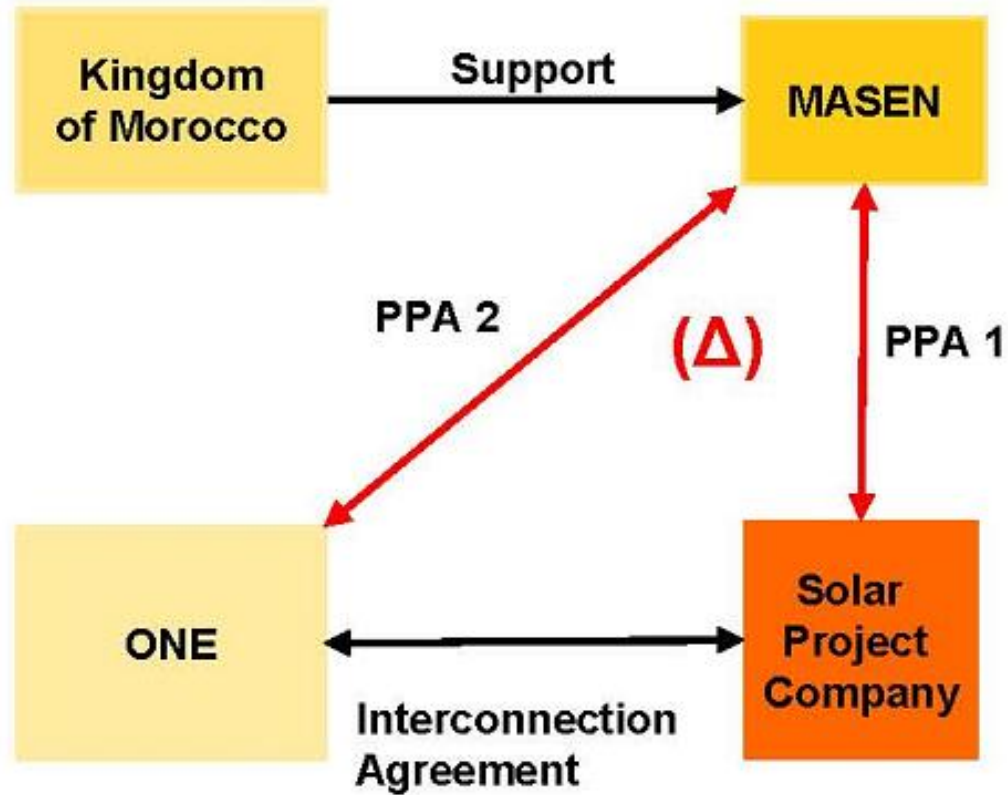
CSP / Parabolic
Troughs

Different
Technologies: PV,
CSP Tower...

Ouarzazate Phase 1 Key Aspects

- Independent Power Producer (“IPP) model: design, financing, construction, commissioning, operation and maintenance
- Tender process designed to promote private developers competition to minimize tariff
- Encourage local manufacturing industry and services
- Winner bidding will incorporate Moroccan companies: “Project Company”
- MASEN will purchase electricity for 25 year based in a Power Purchase Agreement (“PPA”) to the Project Company
- MASEN will enter in a separate PPA with ONE
- MASEN will participate in 25% of the Project Company trough Masen Capital
- Technology: Concentrated Solar Plant with thermal storage as optional

Ouarzazate Phase 1 PPA



(Δ) Difference between ONE Tariff and SPC Tariff to be funded by MASEN

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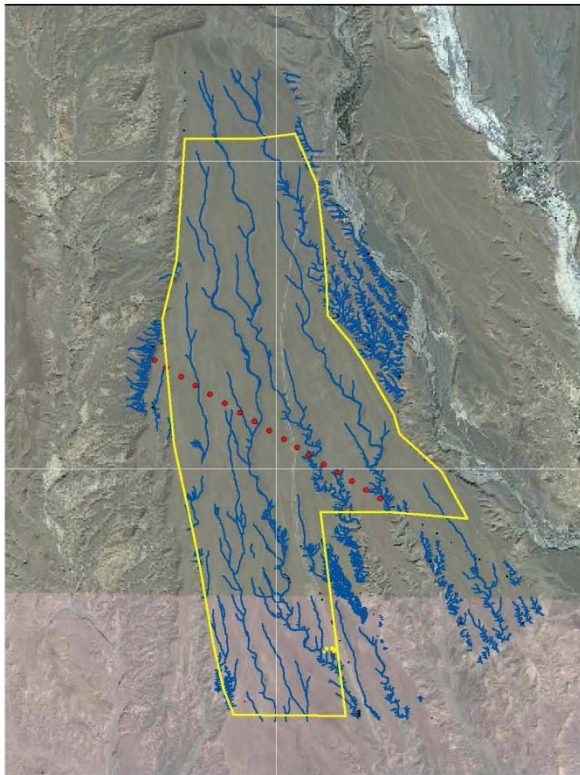
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Ouarzazate Site Characteristics

Situation	10 km NE from Ouarzazate
Accessibility	Road from Agadir port (350 km), airport
Terrain	<ul style="list-style-type: none">•2,500 hectares of greenfield•Slope <1.5%•Very moderate seismic zone
Water	<ul style="list-style-type: none">•Al Mansour Ad-Dhabi reservoir 4 km south•Capacity Max 479 Mm³/Min 80 Mm³
Grid	<ul style="list-style-type: none">•Existing 225kV transmission line 3 km east•New substation planned by ONE
Infraestructure	Availability of utilities and respective connections secured by MASEN/ONE
Radiation	2,394 kWh/m ² /year

Ouarzazate Site Radiation

Site Boundaries



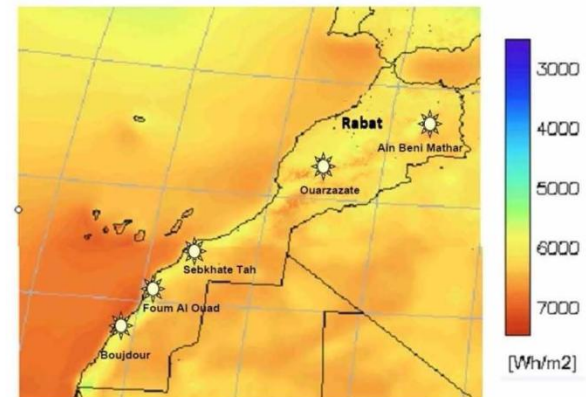
..... Electrical pole

Solar Resources

- According to the “NASA Surface meteorology and Solar Energy” with 22 years historical data, direct normal insolation (“DNI”) available for the site equals 2,635 kWh/m²/year or 7.22 kWh/m²/day on average.
- A meteorological station measuring solar insolation has been in operation at the site since February 2010 and has provided the following measures to date:

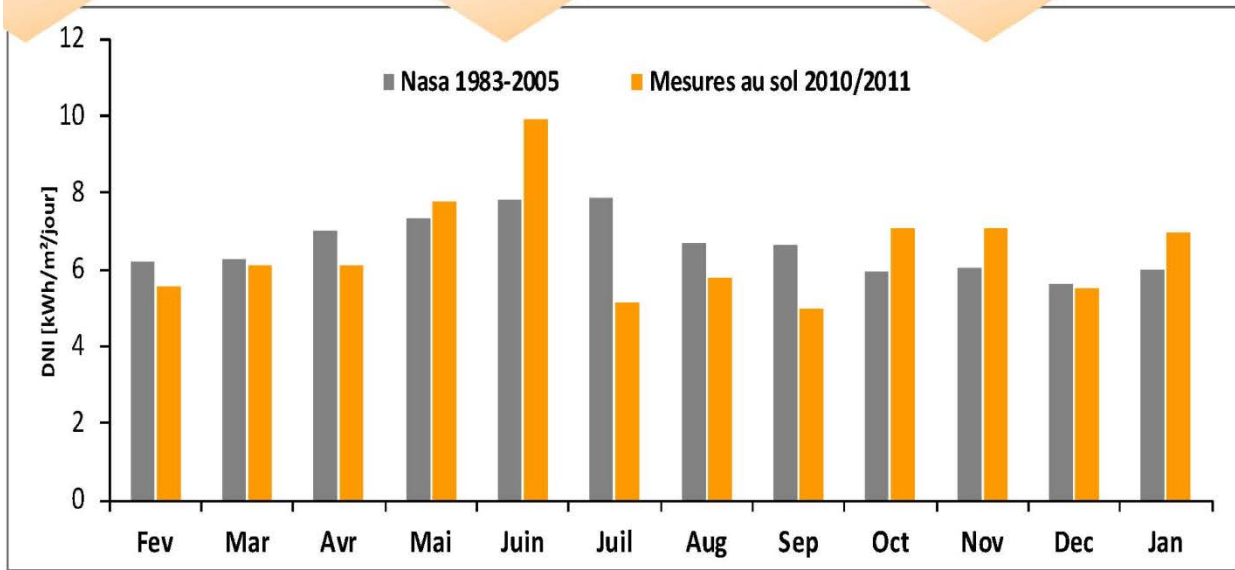
kWh/m ² /day	February 2010*	March 2010	April 2010	May 2010	June 2010
DNI	5.62	6.14	6.15	7.80	9.94
GHI	4.47	6.03	6.70	7.59	8.49
DHI	1.48	2.15	2.48	2.06	1.37

* Exceptionally rainy month



Ouarzazate on site measurements

Comparison between satellital and on site measurements



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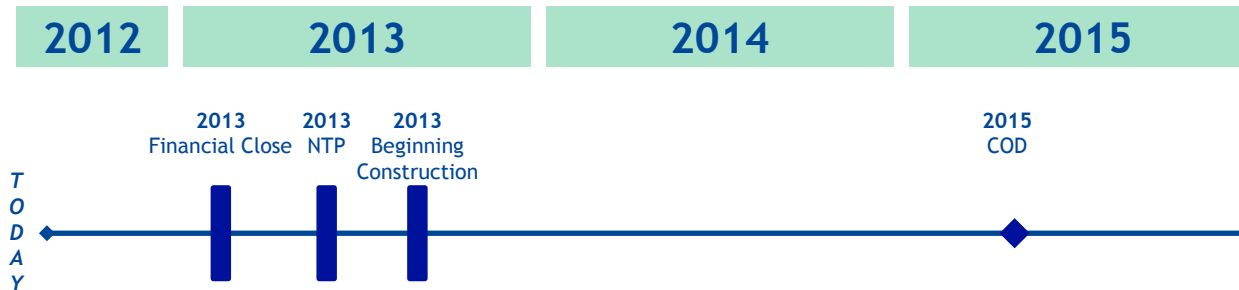
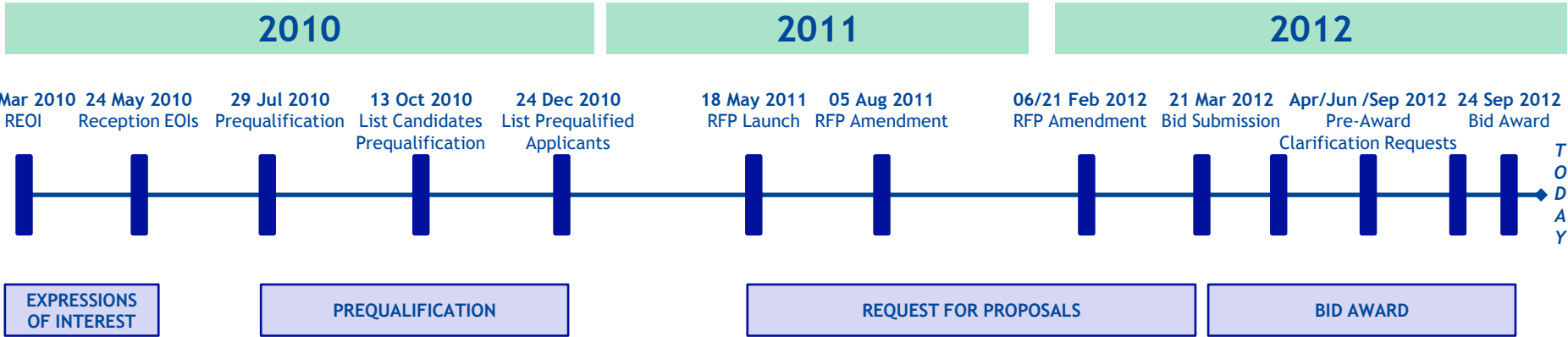
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Project Timeline



Candidates to the Pre-Qualification

- 1) Abeinsa Ingeniería y Construcción Industrial, Abengoa Solar, Mitsui et Abu Dhabi National Energy Company (Taqa)
- 2) Cromasolar International Energy Group SL
- 3) Delta Holding, Energy Consulting Group et SOCOIN
- 4) ENEL S.p.A et ACS Servicios Comunicaciones y Energía, S.L.
- 5) Entrepose Contracting, IWB, Solar Euromed - Novatec Biosol, Cegelec Maroc et GE O&G
- 6) Forclum - Groupe Eiffage, STEG International Services, BrightSource Energy, CNIM, Caisse des Dépôts et Consignations, Alstom Power, Alstom Maroc, Nur Energie, SGTM et Brookstone Partners
- 7) Infra Invest
- 8) International Company for Water and Power (ACWA Power International), Aries Ingeniería y Sistemas SA et TSK Electrónica y Electricidad SA
- 9) International Power, Nareva Holding, Marubeni Corporation et Siemens Project Ventures GmbH
- 10) JGC Corporation
- 11) Korea Midland Power Company, Ltd., Daewoo Engineering Company et Asea Brown Boveri SA
- 12) Litwin SA, Groupe S.E.E.M., M+W Group, Ynna Holding et Sytelco
- 13) Lockheed Martin, CBI, Colenergie, Zavala Moscoso et Electria
- 14) Mitsubishi Corporation et Auto Hall
- 15) Orascom Construction Industries, Solar Millenium AG et Evonik Steag GmbH
- 16) Shenzhen Xintian Solar Technology Co, Ltd.
- 17) SNC-Lavalin Inc.
- 18) SolarReserve et Veolia Environnement Maroc
- 19) Torresol Energy Investments et Sener Ingeniería y Sistemas

Pre-Qualified applicants

Lead member	Abeinsa Ingeniería y Construcción Industrial
Operational members	Abengoa Solar, Mitsui, Taqa
Lead member	ACWA Power International
Operational members	Aries Ingeniería y Sistemas, TSK Electronica y Electricidad
Lead member	ENEL
Operational members	ACS Servicios Comunicaciones y Energia
Lead member	Orascom Construction Industries
Operational members	Solar Millenium, Evonik Steag

Financial bids open results

	MAD/kWh	\$/kWh	€/kWh	% increase
ACWA Power International Aries Ingeniería y Sistemas, TSK Electronica y Electricidad	1.597944	0.1863	0.1439	
ENEL ACS Servicios Comunicaciones y Energia	2.057201	0.2398	0.1853	28.74%
Abeinsa Ingeniería y Construcción Industrial Abengoa Solar, Mitsui, Taqa	2.057503	0.2398	0.1853	0.01%

Awarded Bidder

Awarded Consortium members



EPC Contractor



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Minimun Functional Specifications

- Between 125 and 160 MWe with parabolic trough technology
- Solar stand-alone configuration, Fuel only for auxiliary support
- Molten salt thermal storage system with a capacity oh 3 hours generation at steam full load
- Thermal storage at full load in the start of the peak hours slot time
- Wet cooling
- 450 hectares maximun area available
- Comply with air, soil and water pollution; solid wastes disposal and water flows segregation
- Extreme ambient conditions
- Designed for 20,000 thermal cycles
- Reputable manufacturers for the critical components
- HTF eutectic mixture of dyphenil oxide and dyphenil, with maximun temperature of 400°C
- 225 kV connection

Peak Hours Time Slots

Month of the Year	Peak Hours Time-Slot (5 hours)		Off-Peak Hours Time-Slot
	From	To	
January	5 pm	10 pm	The rest of the day
February	5.30 pm	10.30 pm	The rest of the day
March	6 pm	11 pm	The rest of the day
April	6.30 pm	11.30 pm	The rest of the day
May	7 pm	12 pm	The rest of the day
June	7 pm	12 pm	The rest of the day
July	7.30 pm	00.30 am	The rest of the day
August	7 pm	12 pm	The rest of the day
September	6.30 pm	11.30 pm	The rest of the day
October	5.30 pm	10.30 pm	The rest of the day
November	5 pm	10 pm	The rest of the day
December	5 pm	10 pm	The rest of the hours

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Critical Components: Solar Collector Senertrough



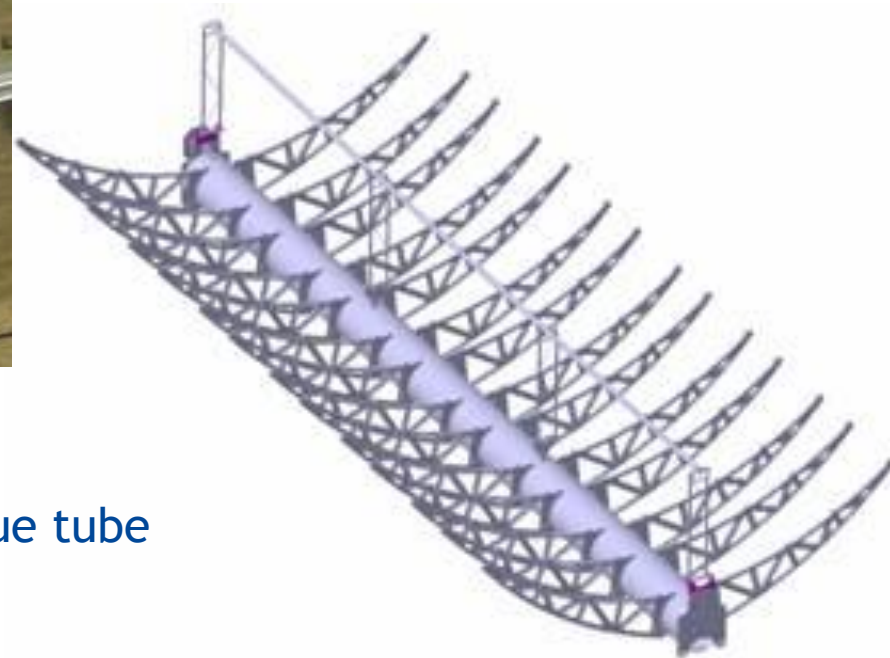
Critical Components: Solar Collector Senertrough



More than 950MW supplied



Critical Components: Solar Collector Senertrough



Stamped cantilever arms and torque tube

Critical Components: Mirrors

Proposed suppliers:

Rioglass

Flabeg

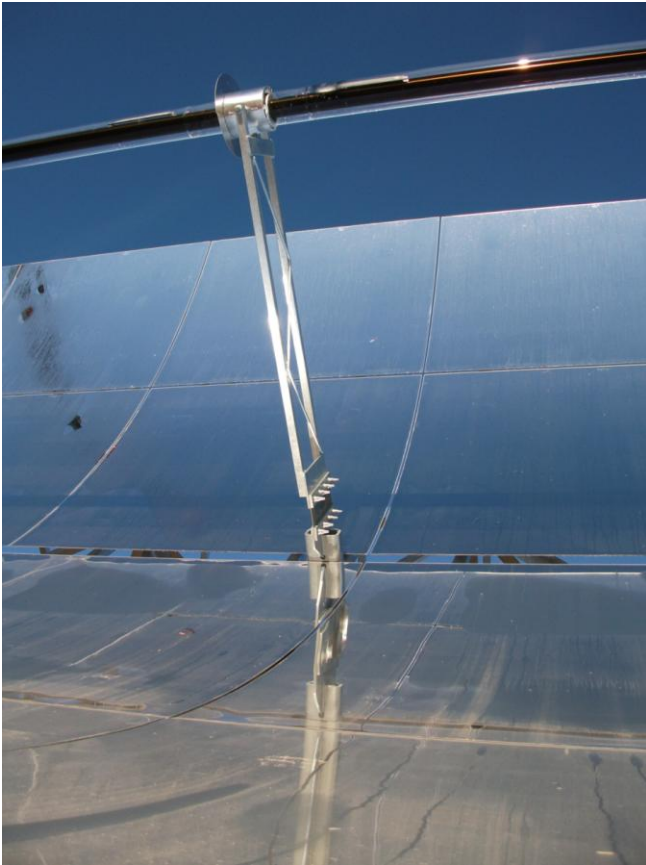
Saint Gobain

Guardian



Critical Components: Receiver Tubes

Proposed suppliers: Siemens Solel and Schott



Critical Components: Steam Turbine

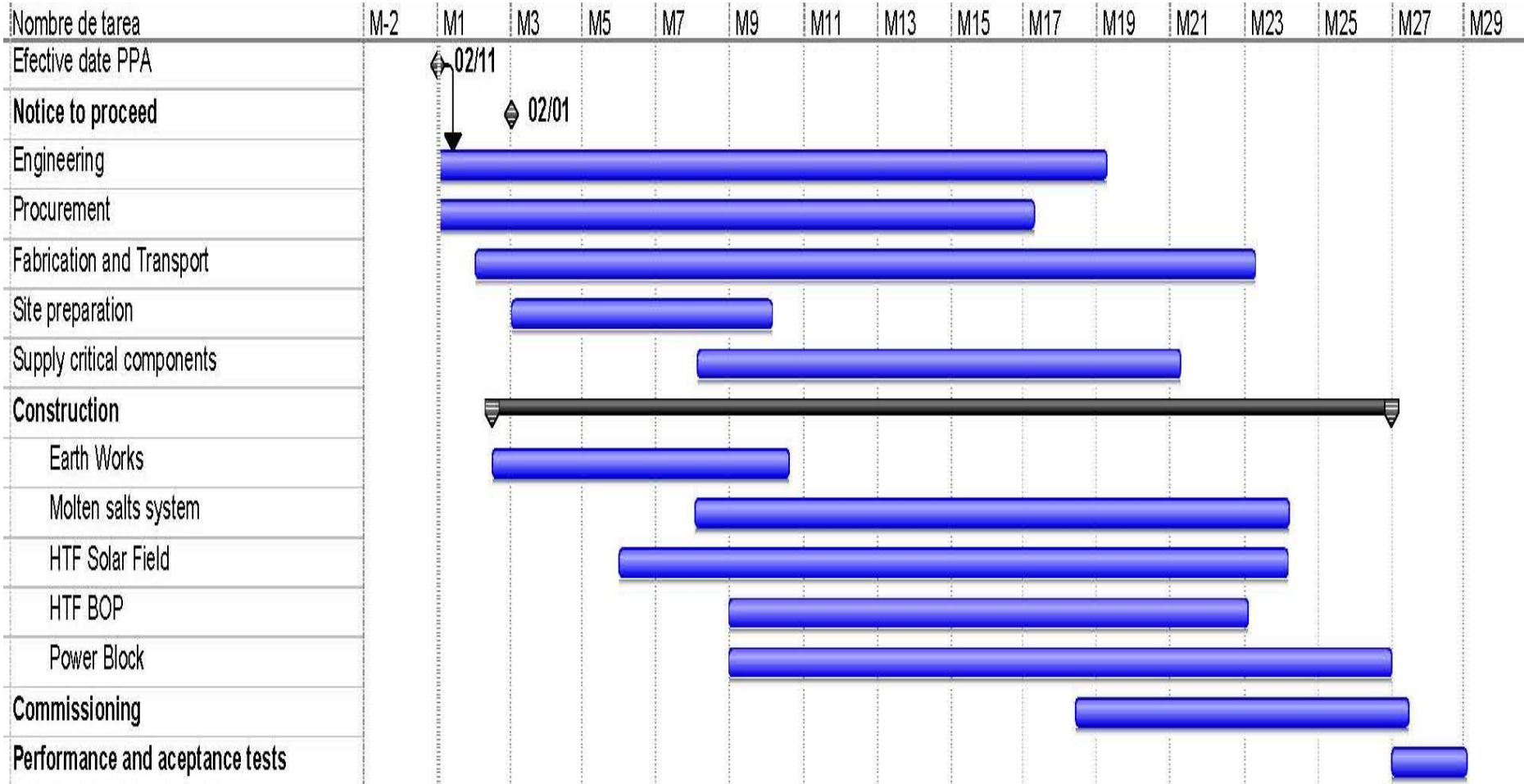
Proposed suppliers: Siemens, Mitsubishi, Alstom and General Electric



Other Critical Components

Equipment	Proposed Supplier
Solar Field Control System	ABB, Schneider, Emerson
Ball Joints	Hyspan and ATS
Steam Generator	Lointek, SPX
HTF/Salts Heat exchanger	Lointek, Foster Wheeler
Salts	Haifa, Basf, SQM
HTF	Dow, Lanxess, Solutia
Pumps (HTF, salts, others)	Flowserve, Sulzer
HTF Heater	Sugimat
Main transformers and switchgears	ABB, Siemens, Schneider
DCS	ABB, Emerson, Honeywell

Project Milestones Schedule



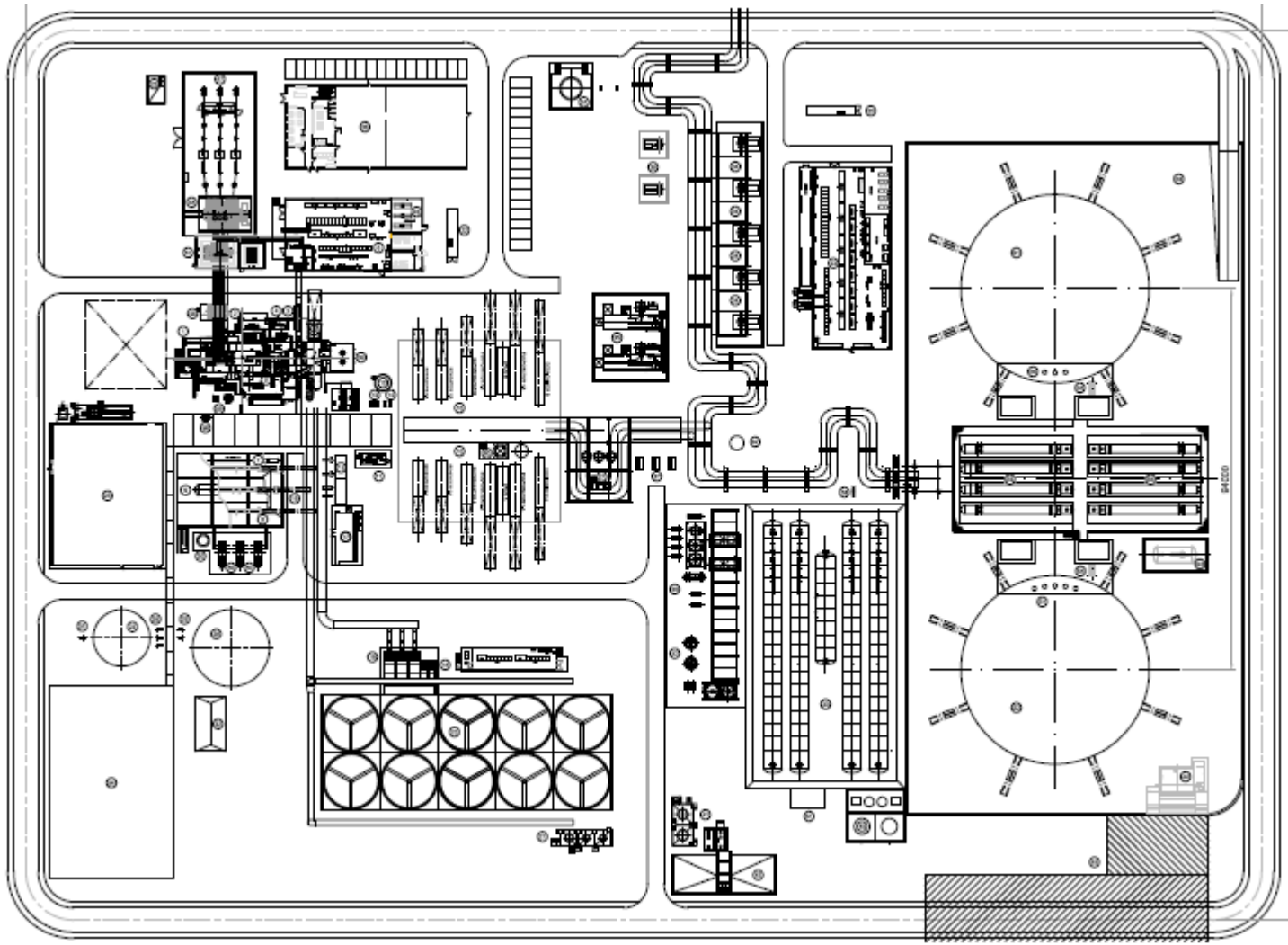
Ouarzazate Phase 1 160 MW CSP Plant proposed layout



Technical parameters

POWER BLOCK		
Turbine Gross Output	160	MW
Turbine Net Output	146.5	MW
Gross efficiency	40.27%	
Live steam temperature	384	°C
Live steam pressure	108	bar
Cooling system	Wet	

160 MW Ouarzazate proposed Power Block



50 MW CSP Plant Power Block

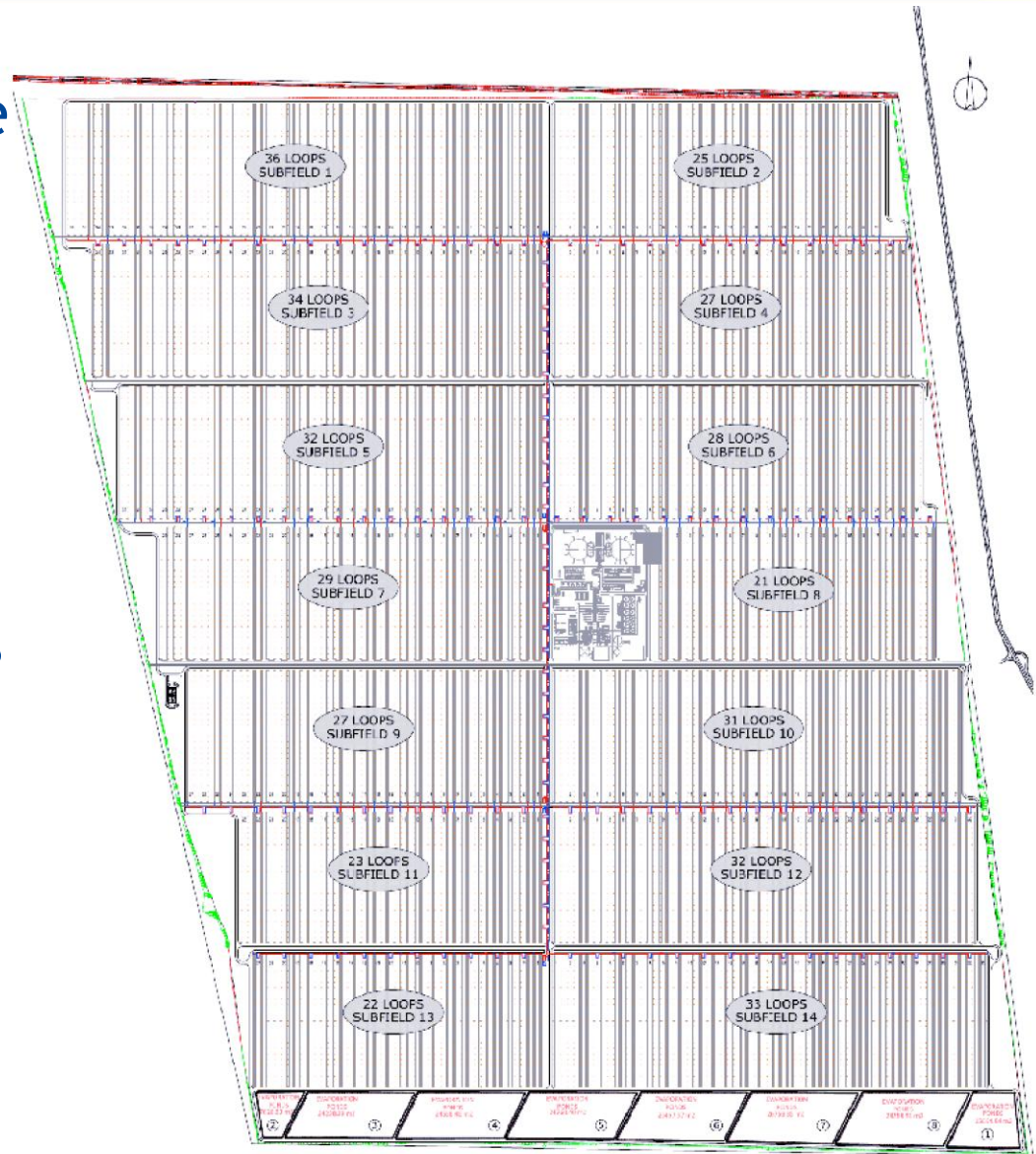


Technical parameters

SOLAR FIELD		
Aperture area	1,308,000	m2
Number of loops	400	
Solar multiple	2.4	
Collector optical efficiency	80%	
Row space	15	m
Cold HTF temperature	297	°C
Hot HTF temperature	393	°C
Total HTF mass	8,300	ton

160 MW Ouarzazate proposed lay out

- 400 loops
- 14 subfields
- Centered power block
- Evaporation ponds in the south
- Grid connection NE



100 MW CSP Plant with 240 loops



Solar field



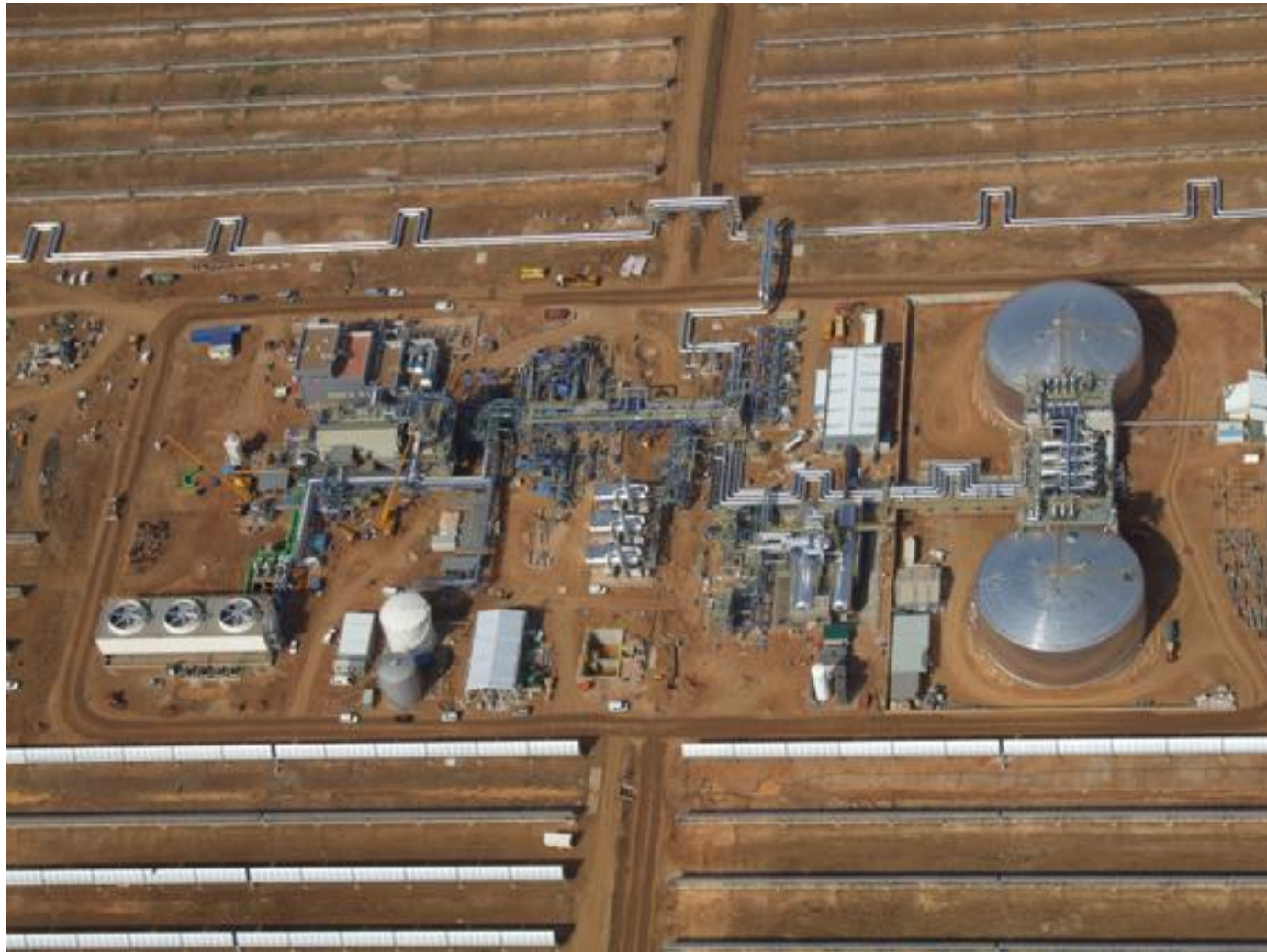
Technical parameters

THERMAL STORAGE		
Equivalent time	3	hours
Thermal capacity	1200	MWh
Tank height	14	m
Tank diameter	46.5	m
Vertical pumps	3 (cold) 5 (hot)	

Thermal storage tank



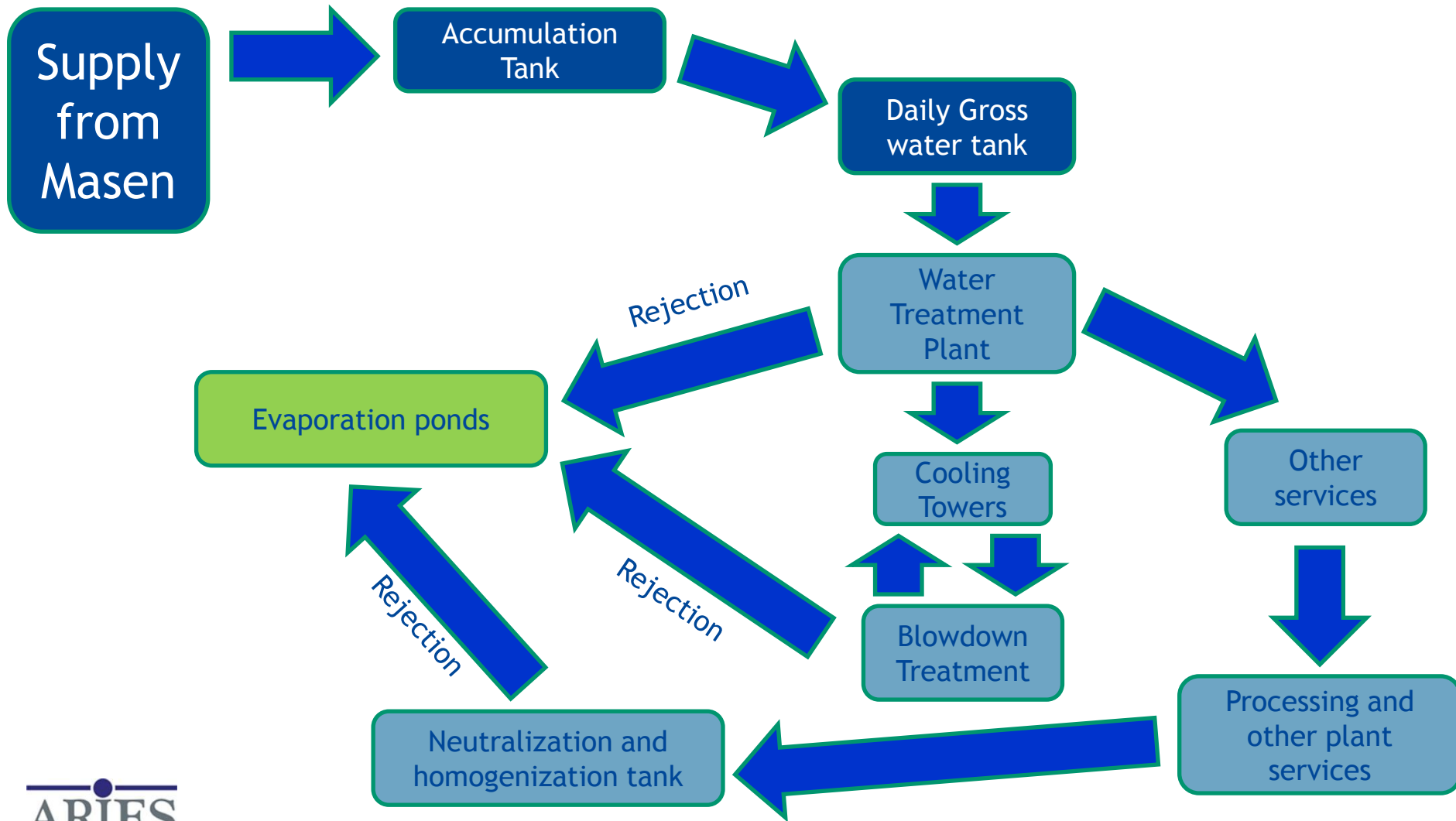
50 MW CSP Plant Power Block with thermal storage



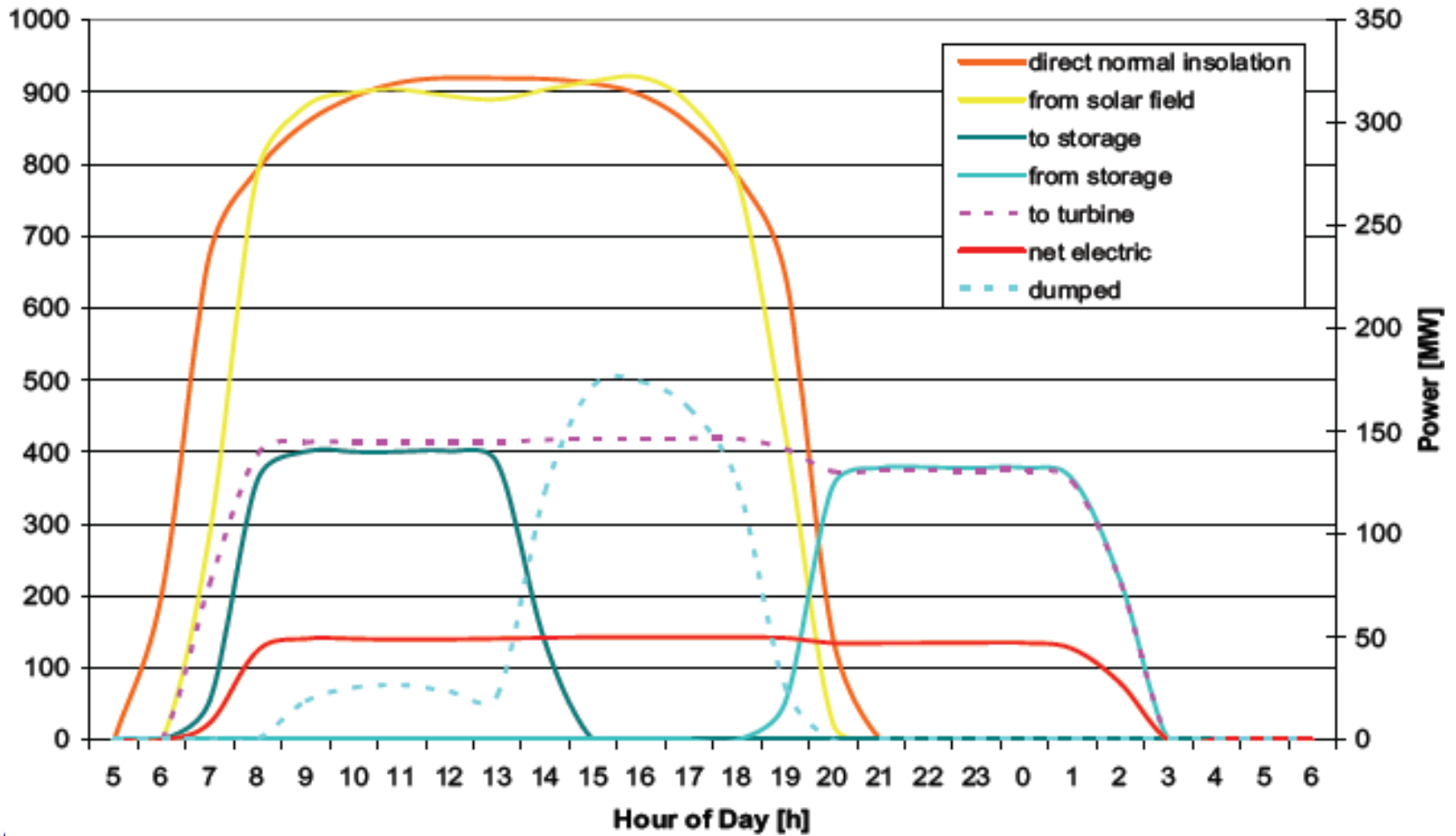
Technical parameters

ANNUAL PERFORMANCE		
Gross electric generation	555	GWh
Net electric generation	499	GWh
Annual Plant availability	> 96%	
Cumulated annual degradation	< 4.2%	
Total water consumption	1,750,000	m3
Mirror water consumption	55,000	m3
Wastewater disposal	425,000	m3
Antifreeze fuel consumption	40,000	MWh

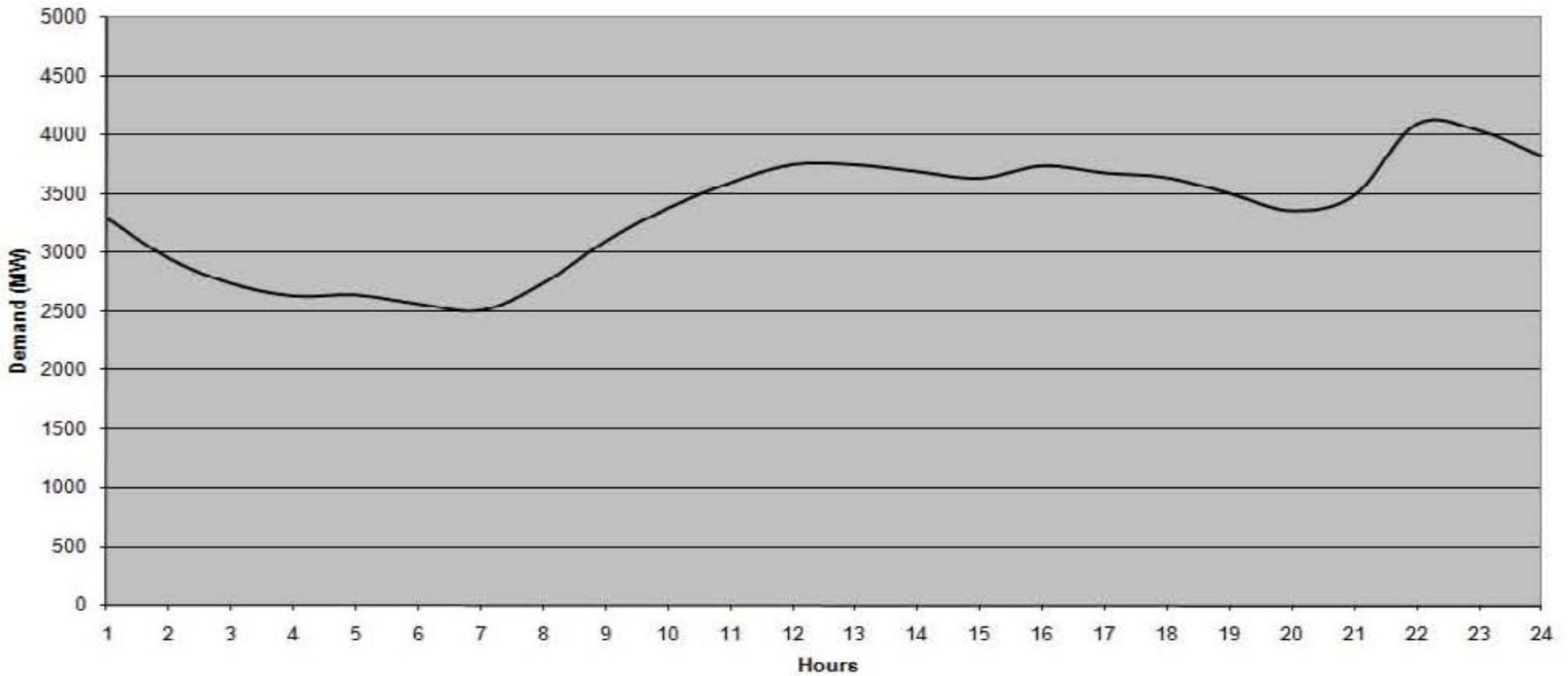
Water management strategy



Standard CSP Plant Operation strategy

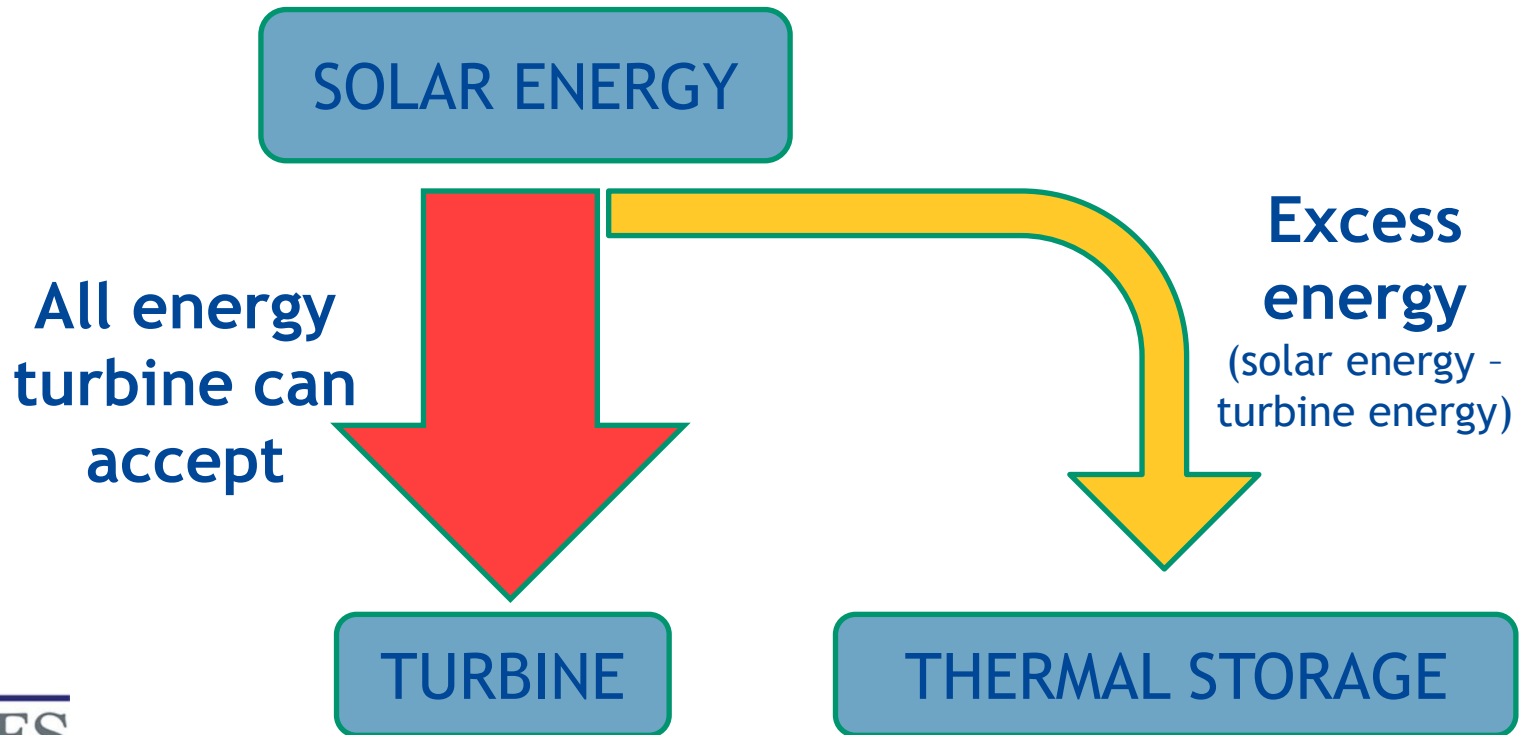


Morocco Electricity Demand Curve July 2009

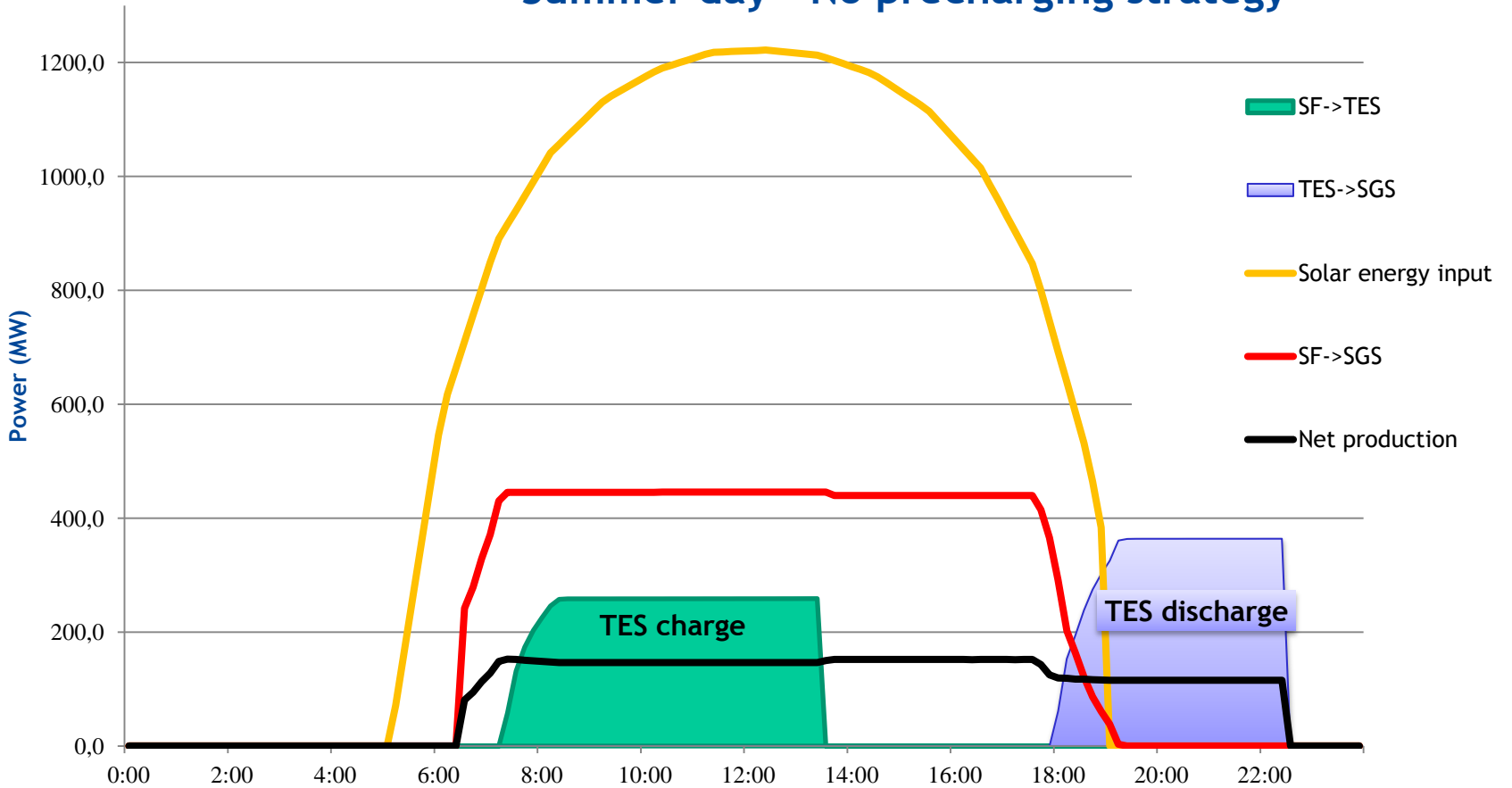


SUMMER STRATEGY - NO PRECHARGE

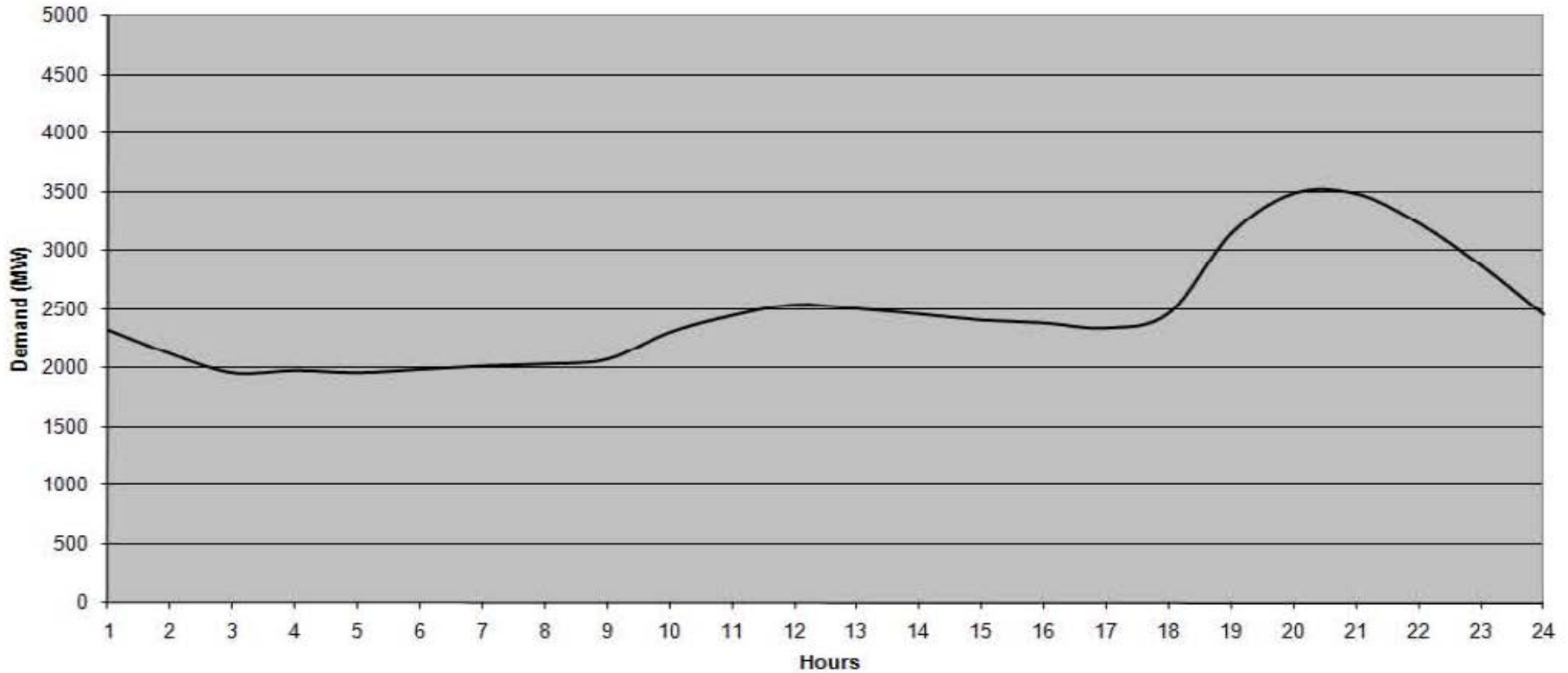
Turbine is prioritized over TES charge so incident energy is sent to the turbine and only the surplus above its maximum thermal energy input is sent to TES.



Summer day - No precharging strategy

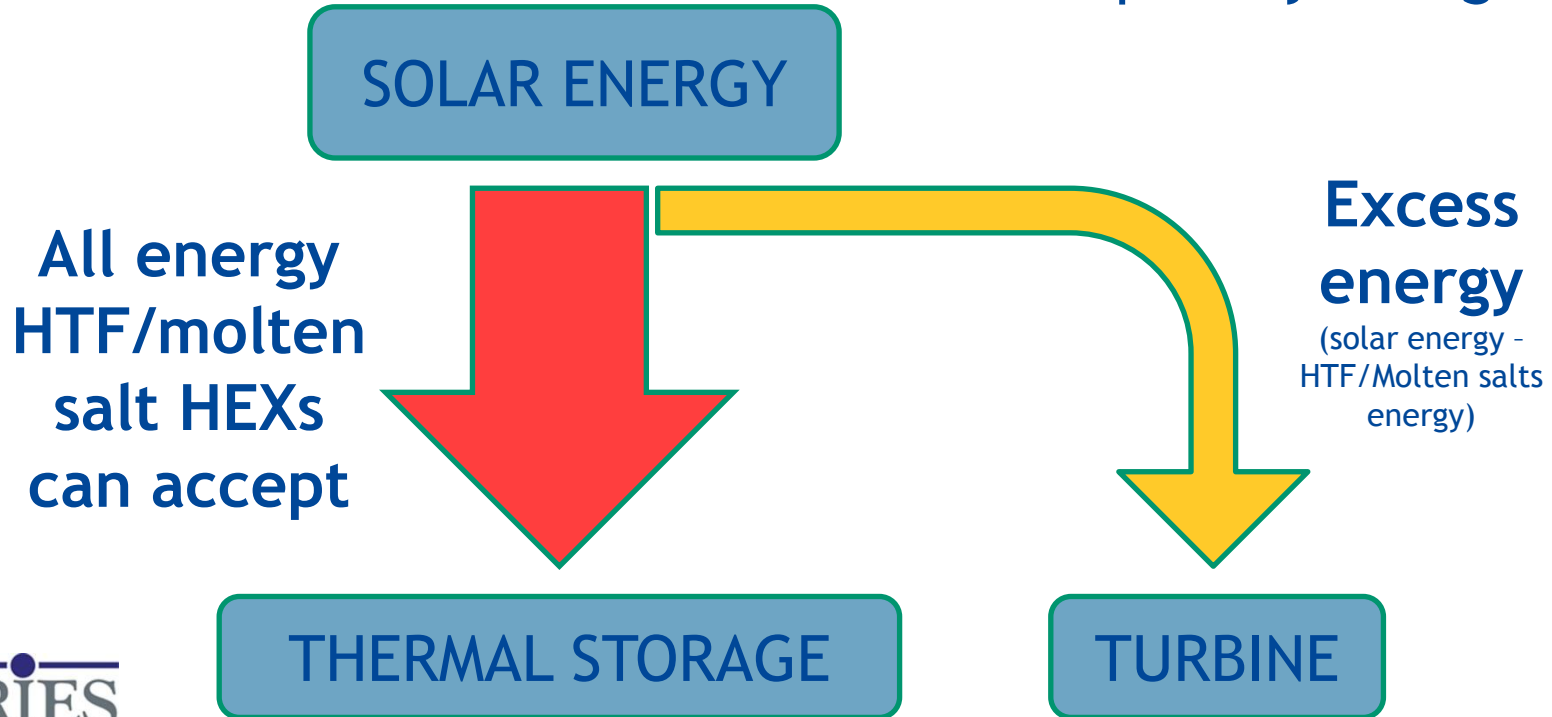


Morocco Electricity Demand Curve February 2009

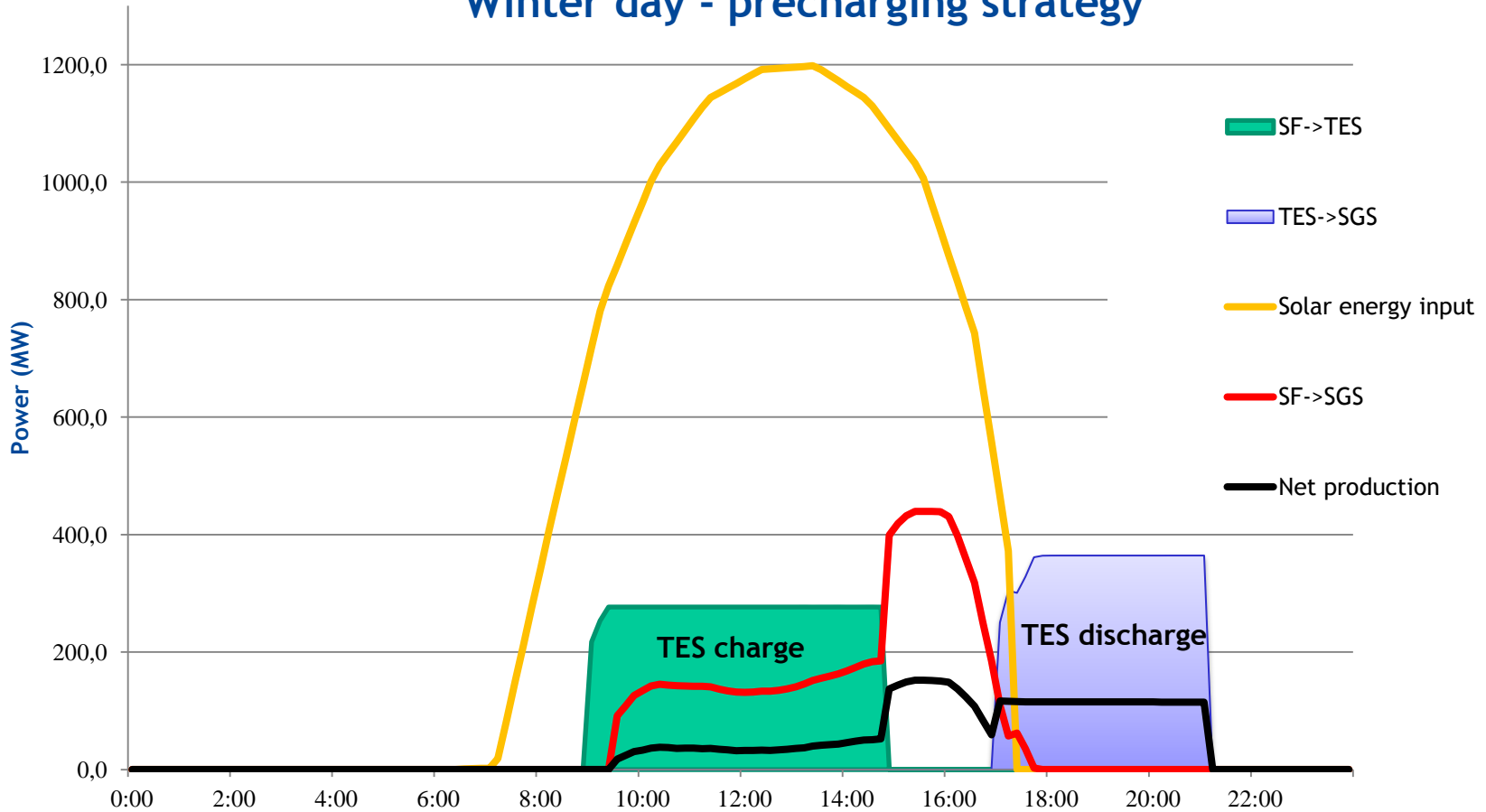


WINTER STRATEGY - PRECHARGE

TES charge is prioritized over turbine so incident energy is sent to the TES and only the surplus above its maximum HTF/molten HEXs salt thermal energy capacity is sent to the turbine. This is done until the TES is completely charged.



Winter day - precharging strategy



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Main financial aspects

- The Project Company's shareholding pattern is as follows:
 - ACWA Power International 70.0%
 - MASEN 25.0%
 - Aries 2.5%
 - TSK 2.5%
- 28 months of construction period
- 25 years of operation period
- Financial close: december 2012
- Equity 20% of total investment costs
- Total investment cost: aprox. 800 MUSD
- EPC cost: less than 4.15 MUSD/MW
- 2% inflation

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Conclusions

- Ouarzazate Phase 1 is a REAL MILESTONE in thermal solar energy plants
- First real IPP
- Project size close to the “optimal design”
- Turbine efficiency increase for big sizes
- Big production up to 37% capacity factor
- Big size decreases dramatically the EPC costs, from the previous standard market 5-5.7 MUSD/MW
- Development of local manufacturing makes sense for big size
- With new market figures plants projects are “reawaken” worldwide
- New players will enter in the components production (China, India, Japan...)

...next time same site with the biggest CSP Plant of the world



THANKS FOR YOU ATTENTION

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