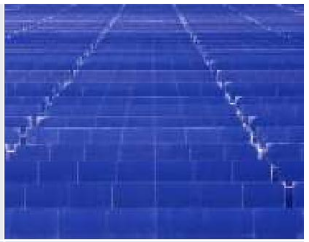









Selecting Suitable Storage
CSP & PV + BESS

Driss Berraho, Senior Business Development Manager

ACWA POWER

ACWA Power At Glance

PROVEN TRACK RECORD

In **10+ years** we have become the **second largest power & water developer** in the **GCC region**, and a name to **contend** with **internationally**

- **22+** GW Power
- **2.7** Mm^3 per day desalinated water
- **40** Assets
- **10** Countries
- **30bn** USD of Assets Under Management
- **15%** Portfolio in Renewable Energy
- **2,750+** Employees
- **30+** Nationalities
- **~60%** Local Employment in projects

Saudi Arabia
2004

Oman, Jordan
2008-2010

Morocco, South Africa, Turkey
2012 - 2014

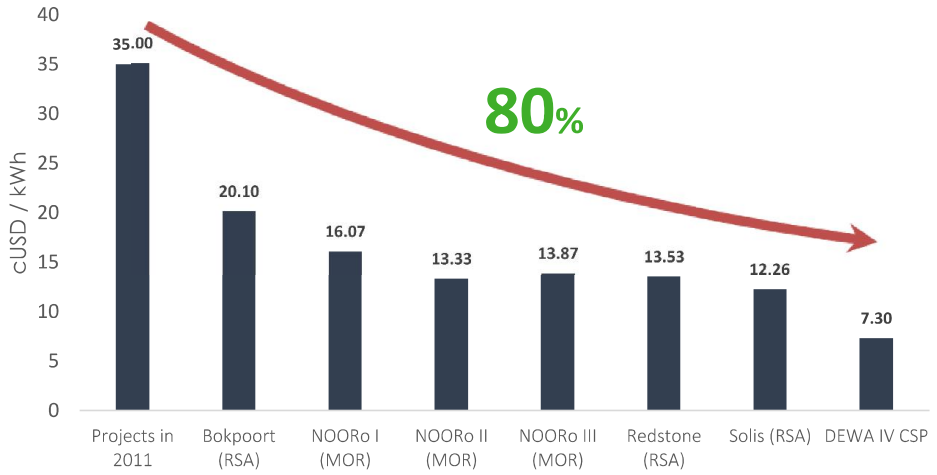
UAE, Egypt, Vietnam
2015 - ...

ACWA Power Track Record In Concentrated Solar Power

CSP Projects	Geography	Status	PCOD (Actual / Expected)	ACWA Power Effective Share	Contracted Power (MW)
Bokpoort CSP IPP 9.3h storage	South Africa	Operational	Q1 2016	40.00%	50
NOORo I CSP IPP 3h storage	Morocco	Operational	Q1 2016	73.13%	160
NOORo II CSP IPP 7h storage	Morocco	Under-construction	Q1 2018	75.00%	200
NOORo III CSP tower IPP 8h storage	Morocco	Under-construction	Q4 2018	75.00%	150
Red Stone CSP tower IPP 12h storage	South Africa	Under Advanced Development	-	Q2 2019	100
Solis I CSP Tower IPP 9h storage	South Africa	Lowest bidder			150
DEWA IV CSP 15h storage	UAE	EPC Contract signed			700

ACWA Power is Leading Global CSP Tariff Reduction:

- Learning curve;
- Technology improvement and shift to central tower technology;
- Economies of scale;
- Financing terms.



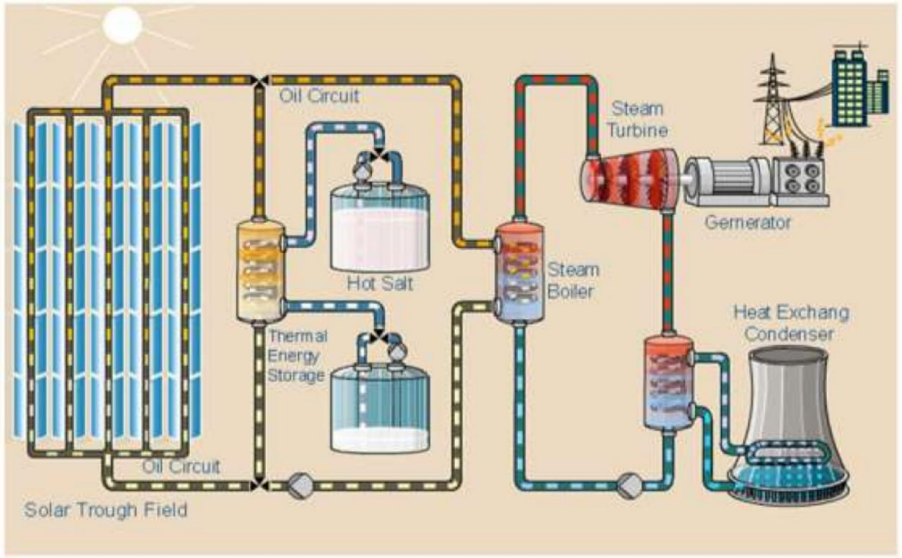
Concentrated Solar Power – Technology Overview

CSP Technologies – Key Features

- NOORo I – 160 MW, Parabolic Trough, 3h storage
- NOORo II – 200 MW, Parabilic Trough, 7h storage
- NOORo III – 150 MW, Central Tower, 8h storage

NOOR Ouarzazate Solar Complex – Aerial View

CSP Technologies – Key Features



Parabolic Trough Technology

Central Tower Technology

Solar Resource Limitations

WHAT IS SOLAR RESOURCE?

Global Horizontal Irradiance (GHI)

=

Diffuse Horizontal Irradiance (DHI)

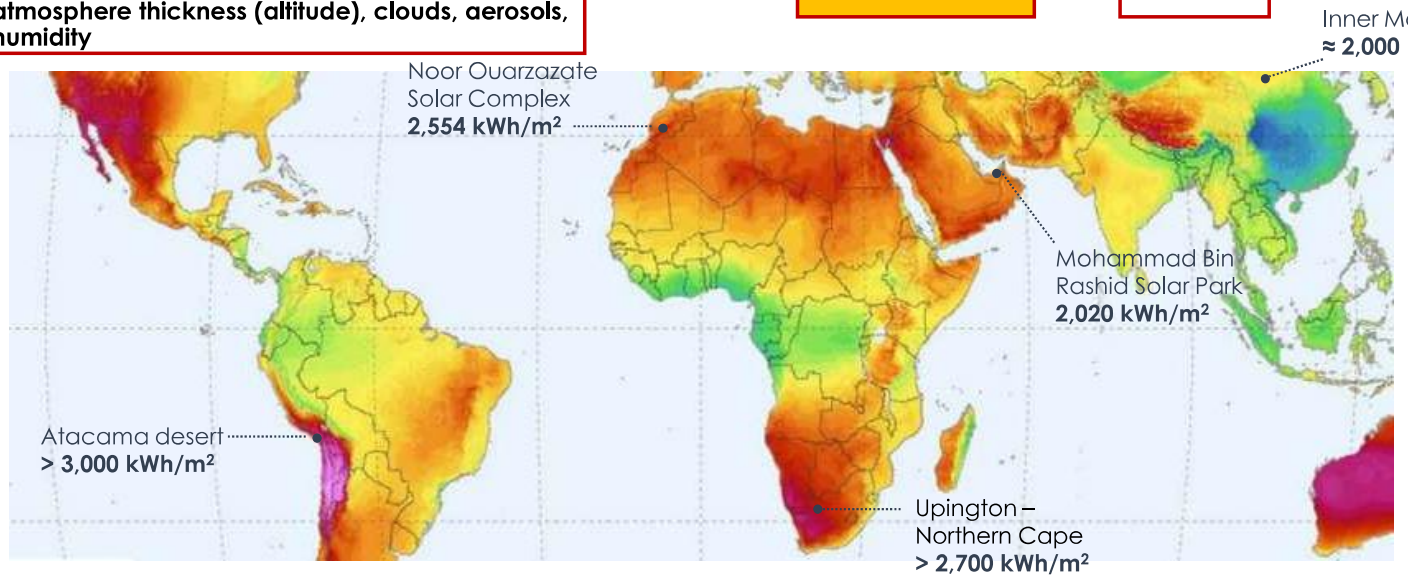
+

Direct Normal Irradiance (DNI)

- **Diffuse Irradiance is the product of atmospheric scattering of Direct Irradiance because of atmosphere thickness (altitude), clouds, aerosols, humidity**

SOLAR PV ⇒ **GHI**

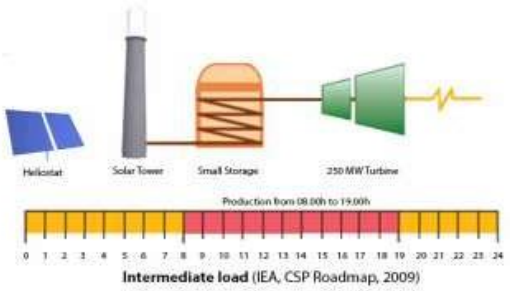
CONCENTRATED SOLAR POWER ⇒ **DNI** only



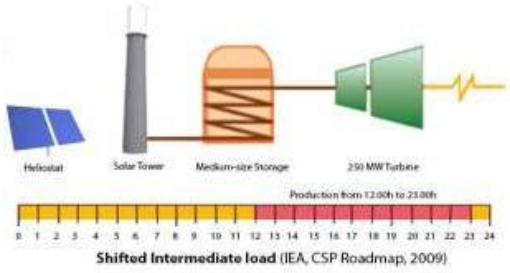
CSP + Storage

CSP plant can be configured to match the electricity demand profile, setting parameters such as:

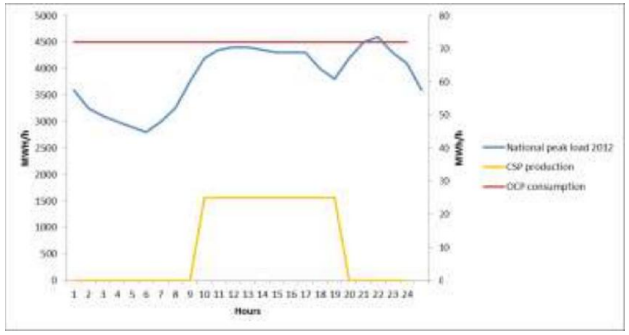
- **Size of the solar field**
- **Size of the storage**
- **Size of the turbine**

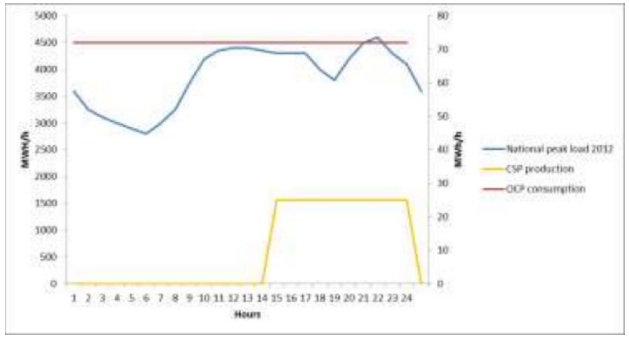


Intermediate load (IEA, CSP Roadmap, 2009)



Shifted Intermediate load (IEA, CSP Roadmap, 2009)





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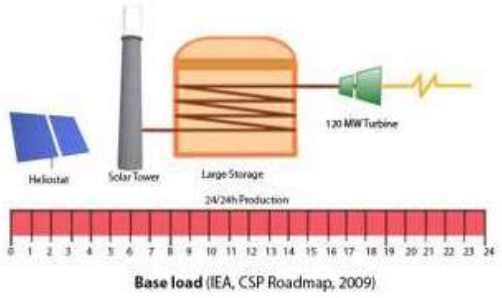
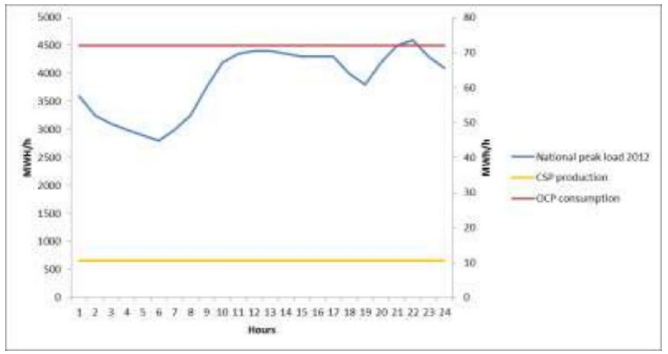
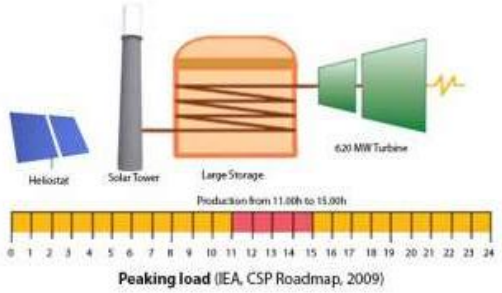
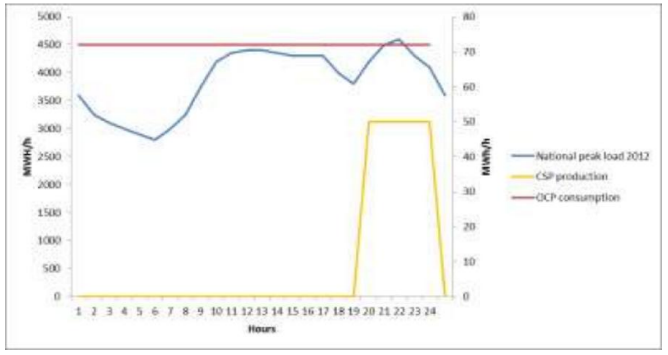


Base load (IEA, CSP Roadmap, 2009)





Peaking load (IEA, CSP Roadmap, 2009)



Dispatchable Solar with CSP + PV + BESS

Battery Storage Status

- Energy storage can allow for efficient integration of renewables into the grid by addressing each of the mentioned challenges
  - **Electric battery storage to become a widespread solution**
    - No limitation for location – at plant or at grid level
    - Electric storage can be integrated with any generation technology (solar PV, wind)
    - Size flexibility – modular solution, with building blocks that can be configured to meet specific needs
  - **Current limitations to electric battery storage include**
    - Cost, even if fast declining
    - Size – expected to address in the medium term short time storage capabilities (2-3 hours)
    - Selecting the storage application vs. type of battery – energy vs capacity (fast and deep discharge)
    - Operational experience over the long term – high number of cyclings under normal operation
    - Lack of track record and high concern over long term durability

CSP & PV + BESS – Complementing Technologies

Item	CSP with thermal energy storage	PV with electric battery storage
Application	• Long term energy storage • Load shifting (evening) for over 4 hours • Base load generation	• Short to medium term energy storage • Short term fluctuation management • Load shifting for 2 -4 hours
Cost	• Low cost of thermal energy storage • 30-50 USD/kWh • Directly competing with conventional gas fired base load generation	• High cost of electric battery storage, but fast decline curve driven by electric vehicles • Can only be competitive for short term storage, but cost still high • 200-250 USD/kWh
Track record	• CSP with thermal energy storage under operation almost10 years (Andasol, Spain) • Technology based on conventional systems proven for many years from other industries	• Limited large scale battery storage under operation
Long term performance	• Little to no degradation of the system • Usual regular maintenance required	• Degradation of the system • Expected replacement of the system over the lifetime of the plant, but uncertainty
Ancillary services	• Frequency/voltage regulation, reactive power • Mechanical based system = conventional plant	• Frequency/voltage regulation, reactive power • Power electronics based system
Long term outlook	• Higher operating temperatures to decrease storage media requirements • New storage media for lower cost option • Hybridization with PV for 100% dispatchable solar • Disconnection from CSP for use as electric storage	• Fast cost decrease curve, similar to solar PV • Large investment required for scale up • Focus on short term storage only, until new technologies developed

Dispatchable Solar

- Storage, by any means, shall be seen an opportunity to reach the ability to reach the ultimate goal of a 100% renewable mix

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