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# “Desafíos de la concentración solar de potencia para suministro continuo y competitivo”

## Fraunhofer Center for Solar Energy Technologies „CSET“

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Prof. Dr. Frank Dinter

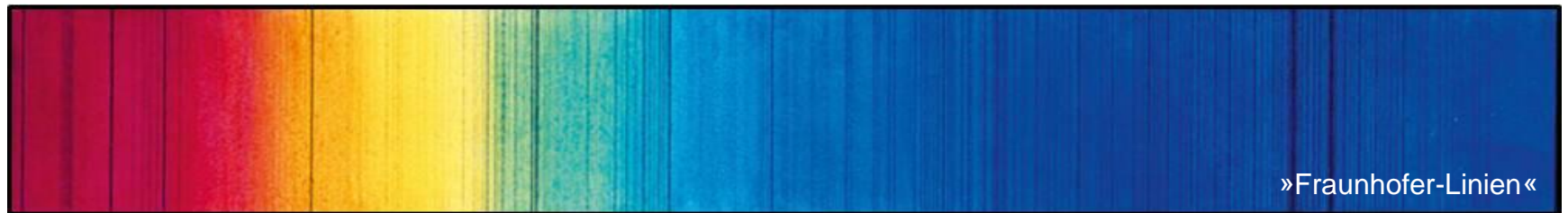
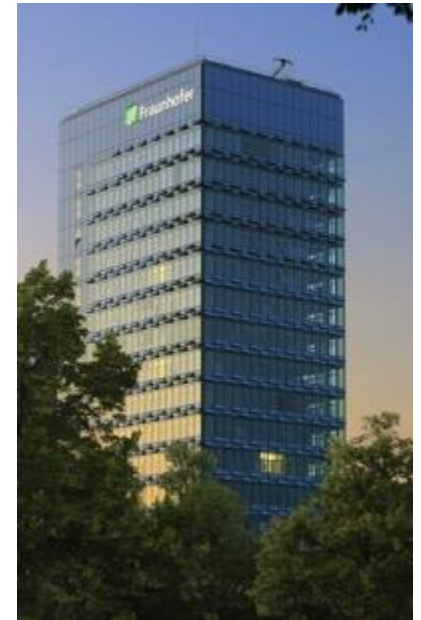
SUMMIT TECNOLÓGICO EN MINERÍA  
Salón Moneda Bicentenario,  
Teatinos #92

21 de Agosto 2018

# The Fraunhofer-Gesellschaft

## Largest Organization for Applied Research in Europe

- 67 institutes and research units
- Staff of more than 23 000
- € 2 billion annual research budget totaling
  - Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects
  - Roughly one third is contributed by the German federal and state governments in the form of base funding
- International co-operations
- In Chile since 2010



# Fraunhofer Chile Research (FCR) Foundation

## Center for Solar Energy Technologies (CSET)

- **Center of Excellence**, co-funded by CORFO
- 2015: Operational Start of CSET
- Location: Innovation Center / Campus San Joaquín UC
- **Executing Partners:**  
Fraunhofer ISE, Germany  
Pontificia Universidad Católica de Chile
- **Application oriented R&D and Support**
  1. PV Systems
  2. Solar Thermal Systems (SHIP, CSP)
  3. Transversal Projects (Energy Efficiency, Buildings, Grid, Market, Analysis...)
- Adaption of Technologies for Chile
- Quality Assurance, Standards and Certification



# Cooperation National and International



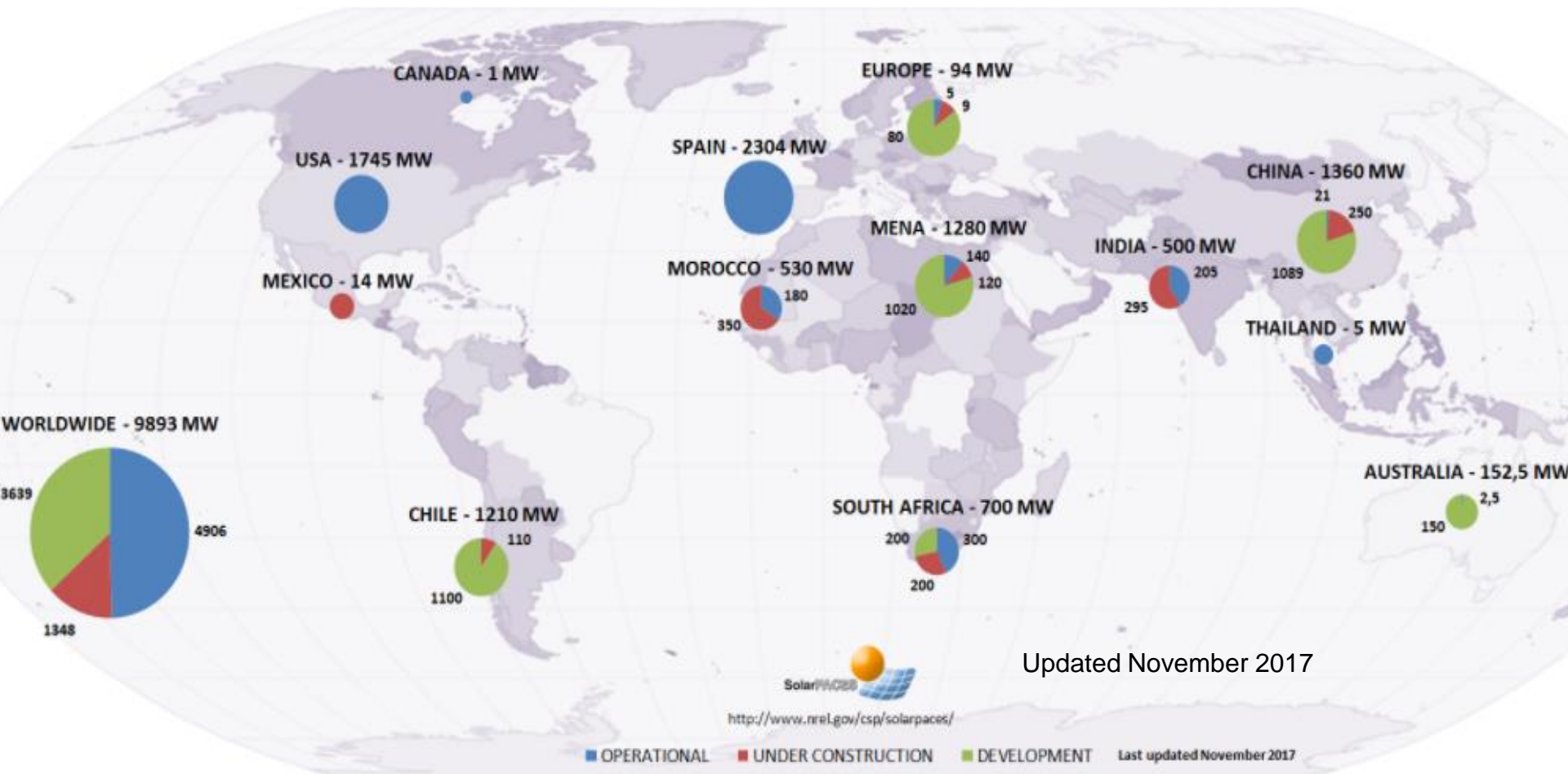


# Customers and Industry Associations



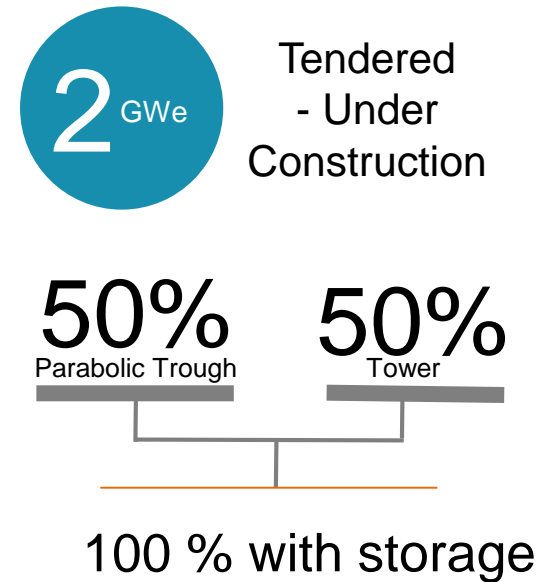
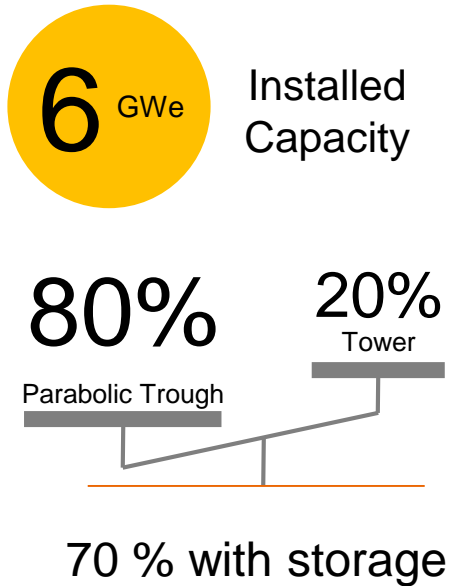
# CSP Market world-wide

## CSP Projects around the world



# CSP Market today:

## Overview and Development



China 1 GW - Morocco 0.7 GW

# CSP Market world-wide

## Race of CSP price reached new records

- DEWA call: **73 USD/MWh** for a **700 MW** CSP Plant in Dubai with a parabolic trough+solar tower by ACWA
- Australia: SolarReserve PPA at **61 USD/MWh** for planned **150 MW** Solar Tower Aurora CSP plant at Port Augusta
- Chile: **48 USD/MWh** were offered by SolarReserve for a Solar Tower CSP Project in Likana



# CSP Market World-wide

## United Arab Emirates

**DEWA (Dubai Electricity and Water Authority) CSP plants (700 MW project):**

- 1 Project of 100 MW Tower CSP plant + 15 h of storage
- 3 Parabolic Trough Projects of 200 MW (600 MW) + 10 h of storage
- **Status:** under development
- Bid: **USD 73 /MWh** in September 2017 by ACWA
- **DNI: 2200 kWh/m<sup>2</sup>a**

Simple Comparison:

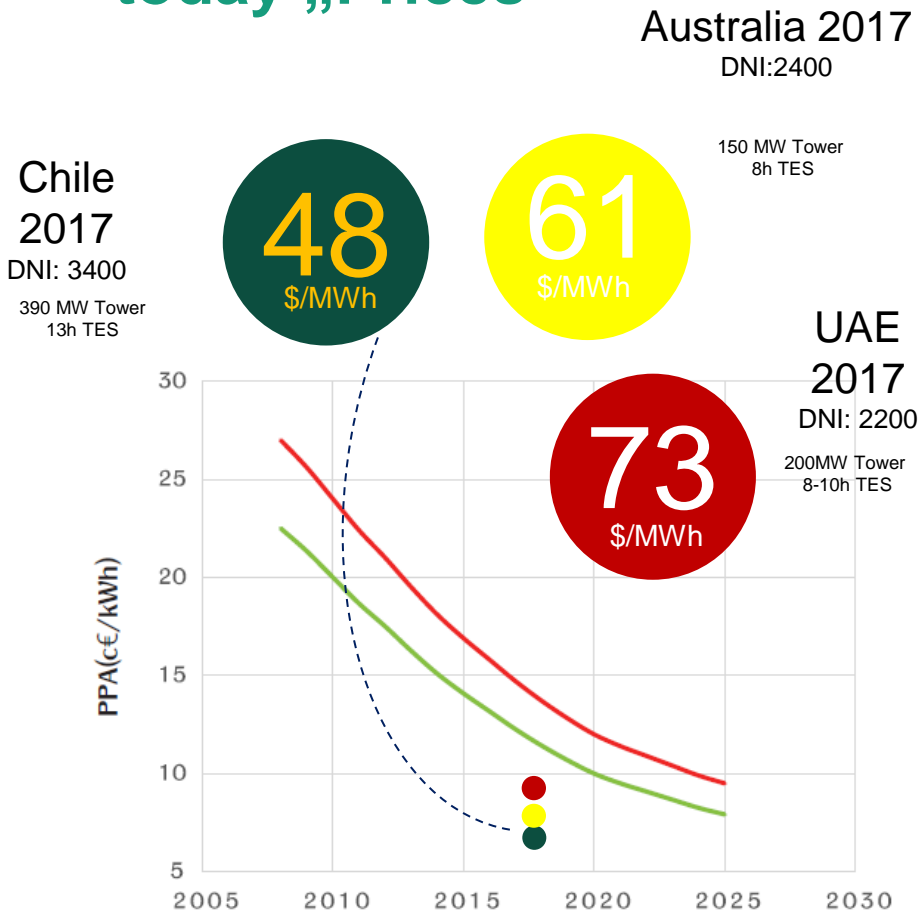
UAE: DNI 2200 kWh/m<sup>2</sup>a: USD 73 /MWh

Chile: DNI 3300 kWh/m<sup>2</sup>a: USD 49 /MWh

Source: [www.helioscsp.com](http://www.helioscsp.com); [www.newenergyupdate.com](http://www.newenergyupdate.com)

# CSP Market world-wide

## today „Prices“



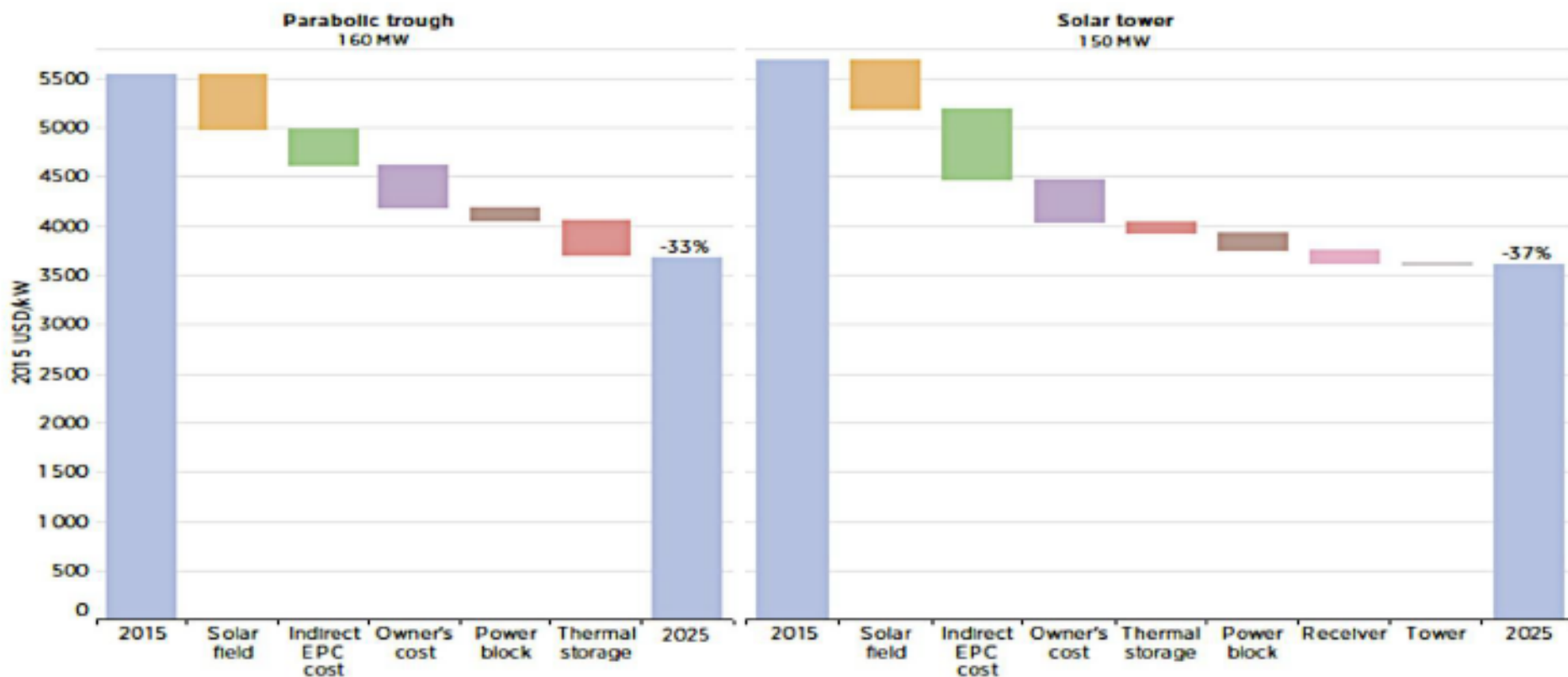
- CSP was generally seen as less competitive on the basis of \$/MWh
- Aggressive PPA bids, yet higher than other renewables e.g. PV
- \$/MWh proportional to solar resource
- It is now being understood that its value relies on its **dispatchable** attribute
- This has led to tech-specific tenders with time-of-use tariffs (hourly)
- This means that the **optimum design** and operation of each plant is **unique to each tender and location**

➤ **CSP costs are coming down seriously**

# CSP Market world-wide

## Future CSP Capital Cost Reductions

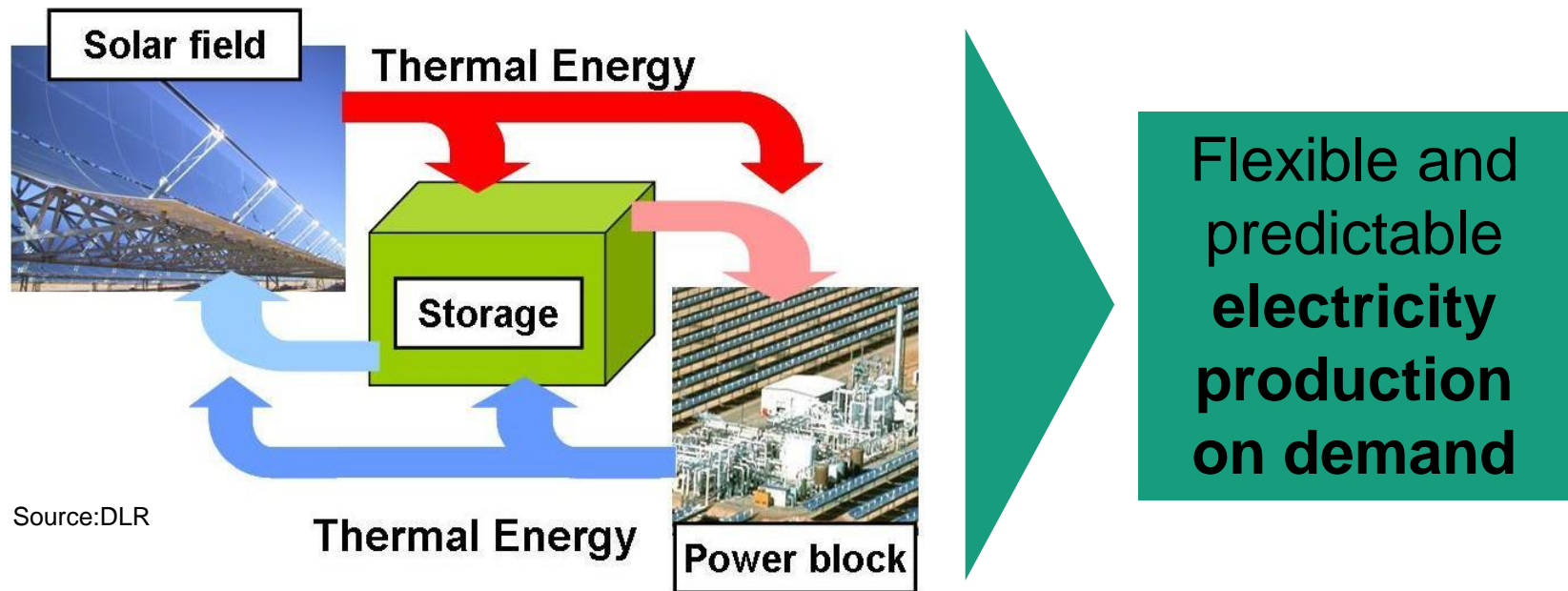
PTC and ST total installed cost reduction potential by source, 2015-2025



# CSP - Proven technology

## Benefits of CSP with storage

The main advantage of CSP technology against other RES as PV or wind power is the capability to **provide dispatch-able power** by storing solar energy through thermal energy storage.



# CSP - Proven technology

## SPAIN - Gemasolar CSP Plant

**GemaSolar the first commercial solar tower 20 MW and storage for up to 15 h**



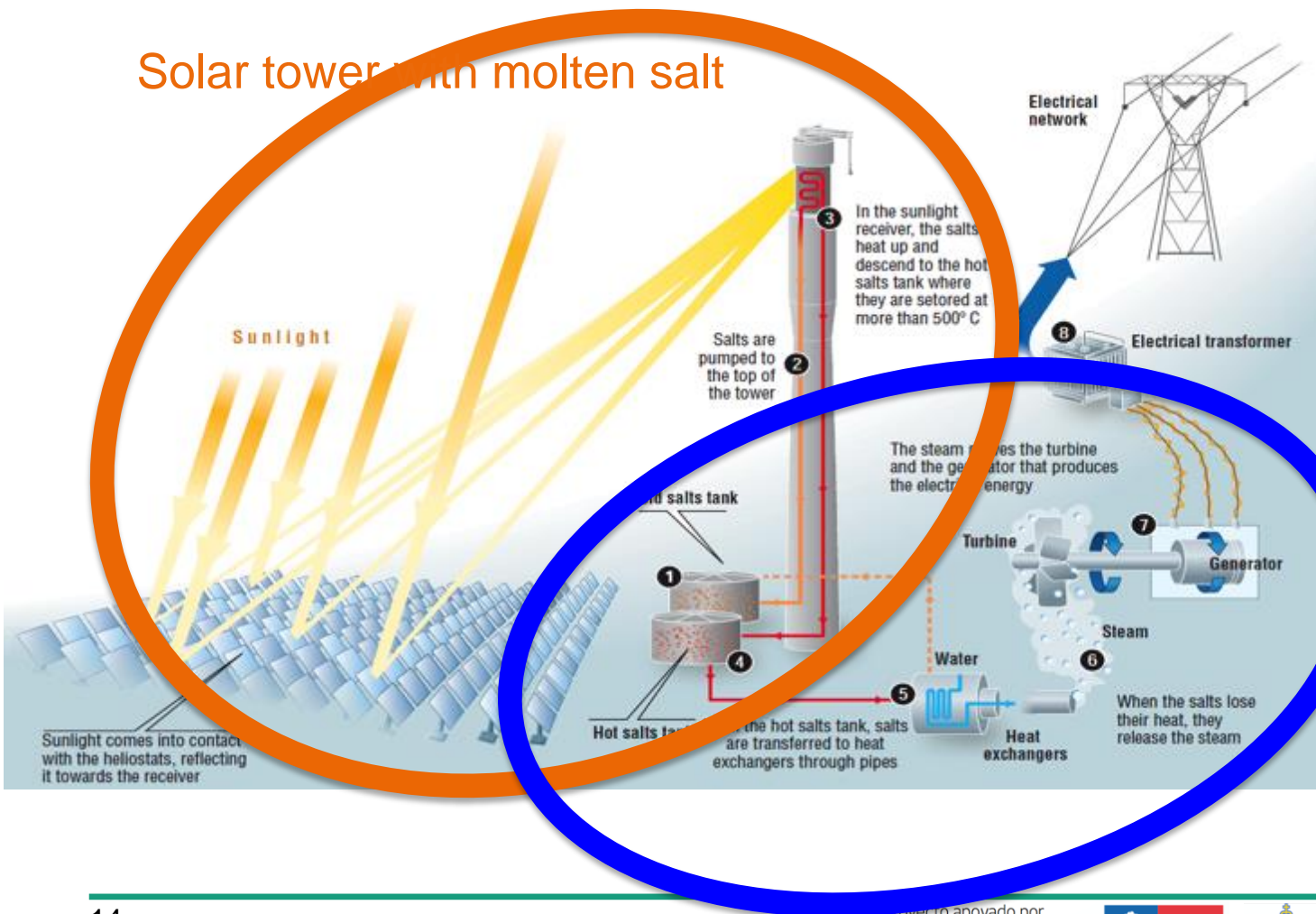
- Location: Spain with an annual **DNI of 2100 kWh/m<sup>2</sup>a**
- Heat transfer fluid (HTF): Molten salt
- Storage: 2-tank system (hot and cold) for molten salt
- World Record in 2013:  
**36 consecutive days of continuous 24 h production**



# CSP - Proven technology

## SPAIN - Gemasolar CSP Plant

Solar tower with molten salt



- **1. loop (solar):** charging the storage system with 565°C HTF
- **2. loop (heat to steam generator):** discharging the storage for steam generation -instead of fossil fired boiler in a conventional power plant

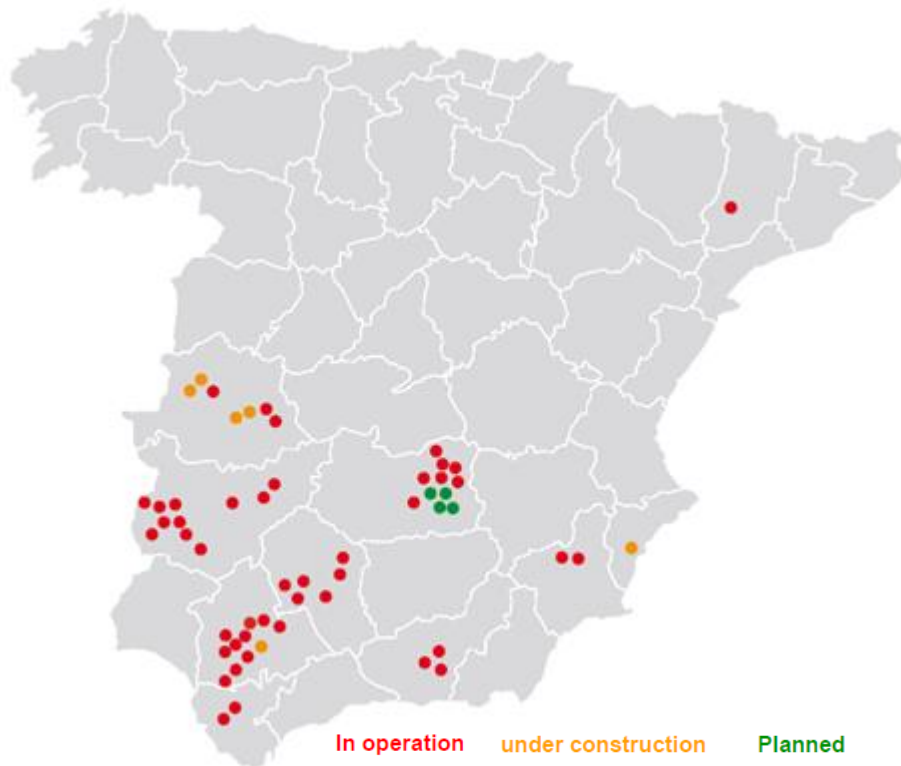
# CSP - Proven technology

## SPAIN - Gemasolar CSP Plant – additional data



# CSP - Proven technology

## More than 2.3 GW of STE plants in operation in Spain



Source: Protermosolar

- About 40 trough plants with 50 MW<sub>el</sub> each are in operation
- About half of them have thermal storage
- Most players in CSP are now coming from Spain, because of experience

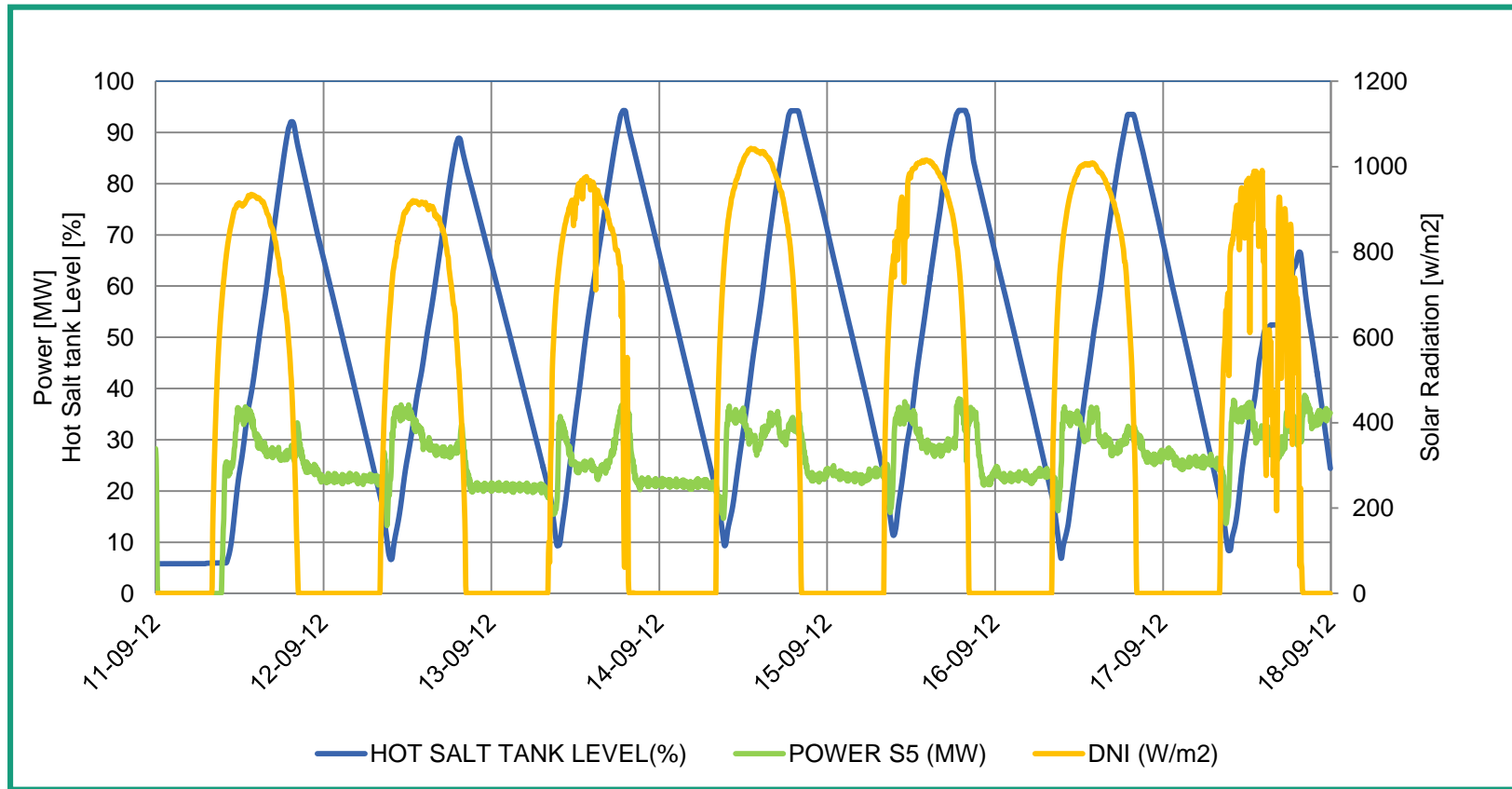
# CSP - Proven technology

## SPAIN – Andasol 3

Solar field	
Size of solar field	497 040 m <sup>2</sup>
No. of parabolic mirrors	204 288 mirrors (each collector is 12m long and 6m wide and has 28 mirrors)
No. of receivers (Dewar tubes)	21,888 tubes, each 4m long
No. of sensors	608 units
Annual direct normal irradiation (DNI)	<b>2 136 kWh/m<sup>2</sup>a</b>
Altitude above sea level	1 100 m
Thermal storage	
Storage capacity of heat store	28 500 t salt, <b>7.5 full load hours</b>
Power plant output	
Turbine output	49.9 MW
Annual operating hours	<b>approx. 4 000 full load hours</b>
Forecast gross electricity generated	approx. 200 GWh/a
Estimated service life	At least 40 years

# CSP - Proven technology

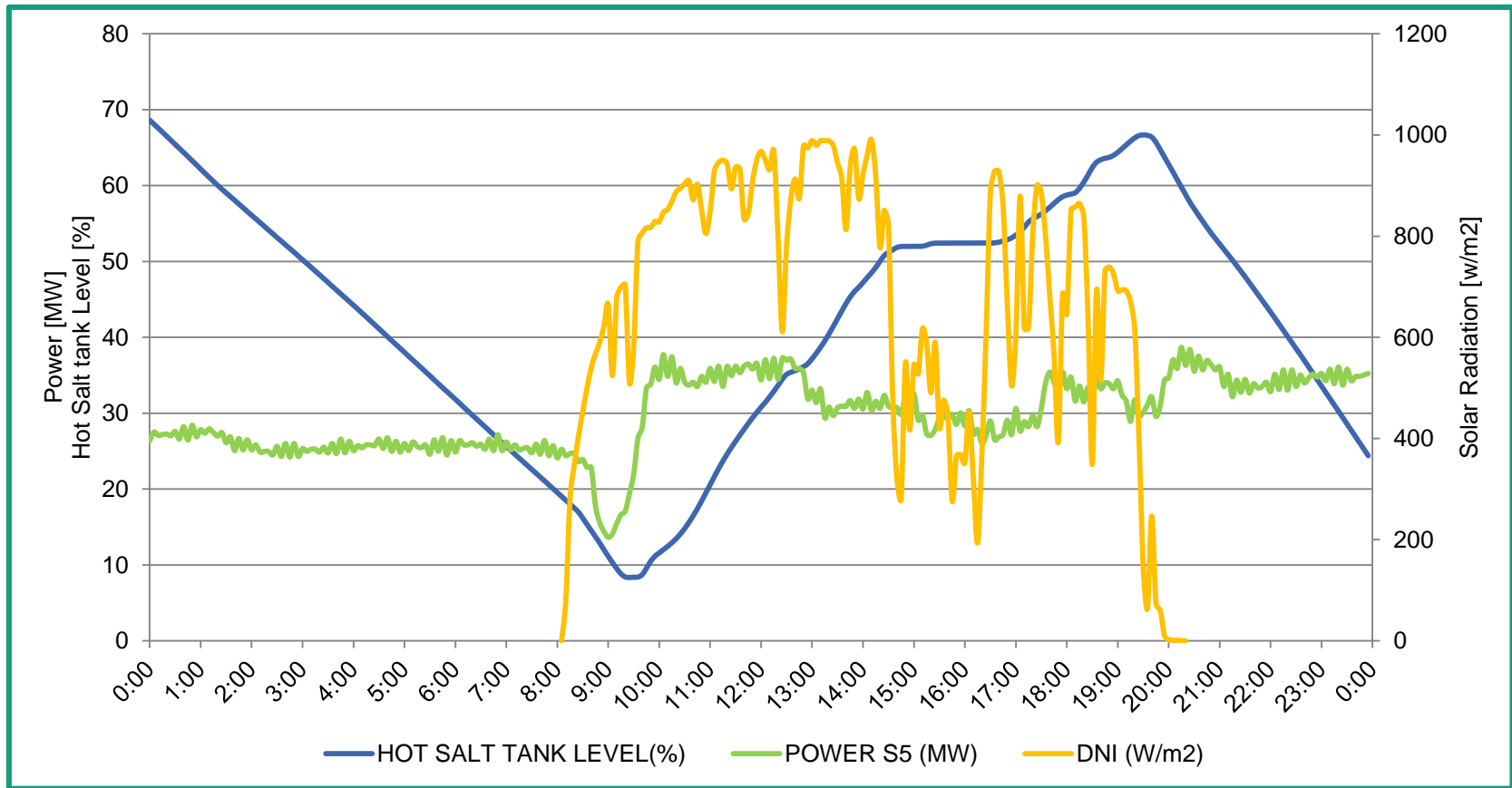
## SPAIN – Andasol 3 – 24 h production





# CSP - Proven technology

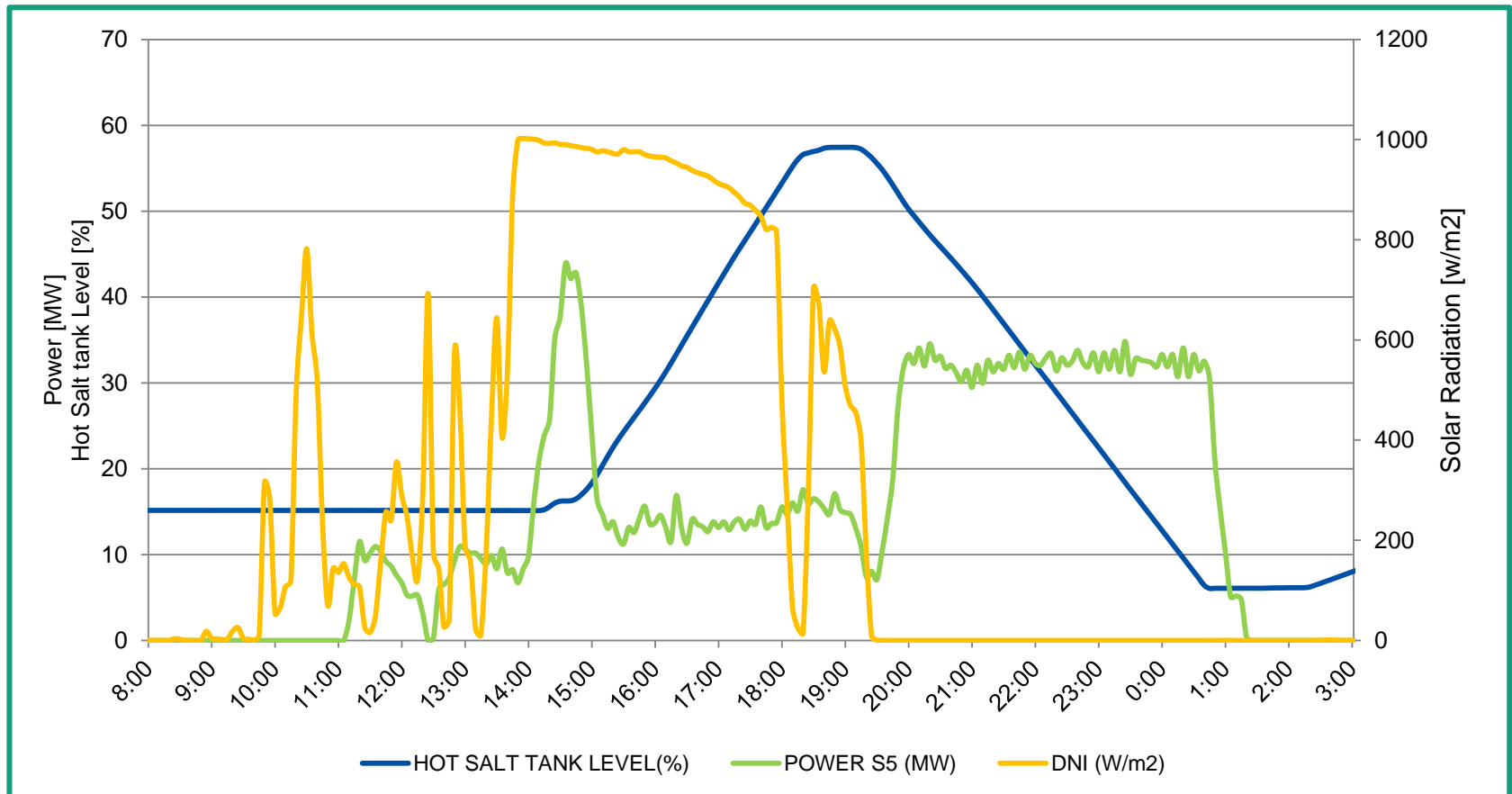
## SPAIN – Andasol 3 – last day of previous slide



# CSP - Proven technology

## SPAIN – Andasol 3

Dispatchable: high PV and reduced CSP output



# CSP Market

## CHILE

- **Cerro Dominador plant (Atacama 1):** A 110 MW CSP tower plant with **17.5 hours of molten salt storage**, together with 100 MW PV Project
  - **Location:** Atacama Dessert
  - PPA of **\$114/MWh**
  - **Status of the plant:** under-construction.
  - Predicted date to be finished: **2019**
  - First Solar Tower in Chile



Image source: cerrodominador.com

# CSP Market

## CHILE

3 Projects of SolarReserve ready to build (under development), waiting for PPA

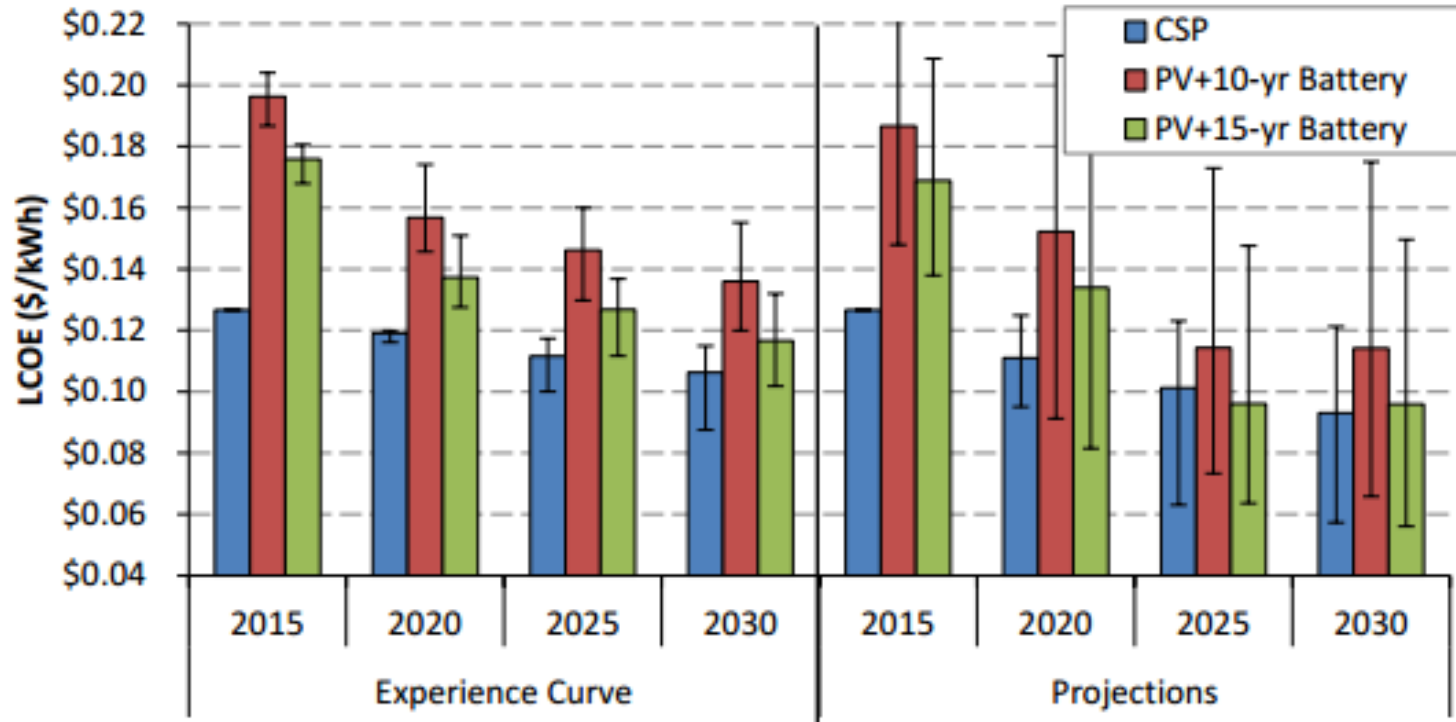
- Copiapó: **260 MW** CSP tower technology with Molten Salt Thermal Energy Storage of 13 h  
Possible start year: 2019
- Likana: **World Bid record of USD 48/MWh** for **390 MW** tower CSP project with 13 h of molten salts offered by SolarReserve in 2017 for dispatchable 24-hour  
Possible start year: 2021
- Tamarugal: **450 MW** tower plant + 13 h of molten salt storage  
Possible start year: 2021

# CSP vs. PV+Batteries with a 6 h storage

Even for most aggressive battery-cost projections\* CSP still retains its competitive advantage over equivalent PV-battery systems

## “6h STORAGE”

- For a 200 \$/kWh combined battery and battery BOS costs and increased lifetime
- \* For PV systems (module + BOS) of 1\$/W



➤ Probably a combination of CSP and PV make sense



# CSP Market Word-wide

## Conclusions

- CSP with storage is the only large scale renewable technology for dispatchable energy
- Solar Tower technology is becoming more present
- CSP prices offered in auctions have decreased considerably below USD 50/MWh in Chile
- PV with battery hardly becomes compatable for large scale storage systems
- Hybrid systems could be a solution



## For a Solar Future in Chile

### Contact:

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