

Center for Solar Energy  
Technologies



# CSP with storage

## The energy supply for the future

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10.08.2021

Dr. Frank Dinter

Executive Director

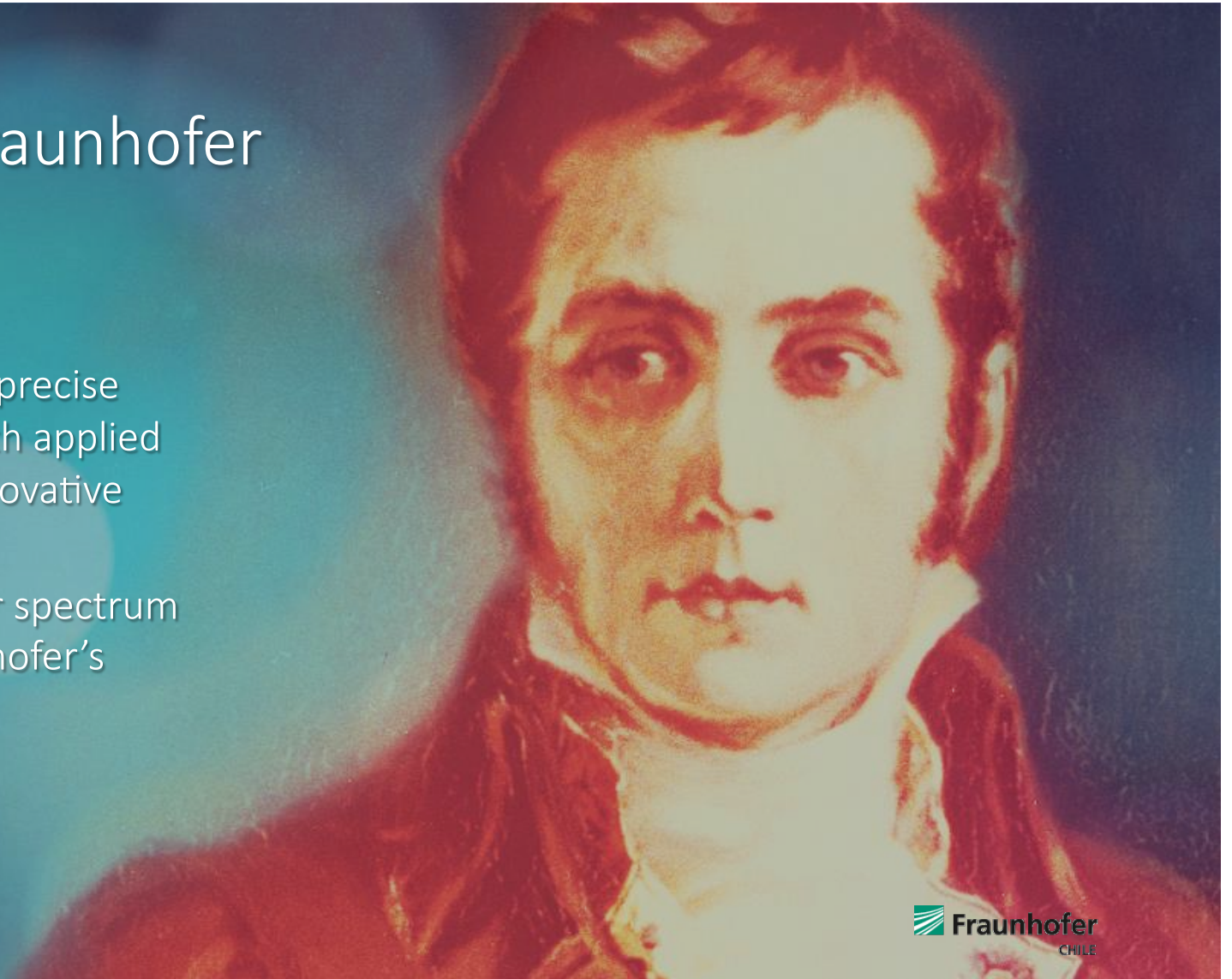
Center for Solar Energy Technologies of Fraunhofer Chile Research

# Content

- 1 Fraunhofer
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# Joseph von Fraunhofer (1787 – 1826)

- Physics and optics
- High scientific and precise work combined with applied application and innovative products
- Described the solar spectrum lines called “Fraunhofer’s lines”



# Bridge between science and industry

## Fraunhofer Gesellschaft



Since its foundation in 1949 in Germany, FRAUNHOFER GESELLSCHAFT focused on applied research that leads to economic development and provide wide benefits for the society.



# Top ranking applied research center in Europe

Fraunhofer Gesellschaft



**74** Institutes in Germany



**26.600** Researchers and Engineers



**2.600** Millions euros yearly budget

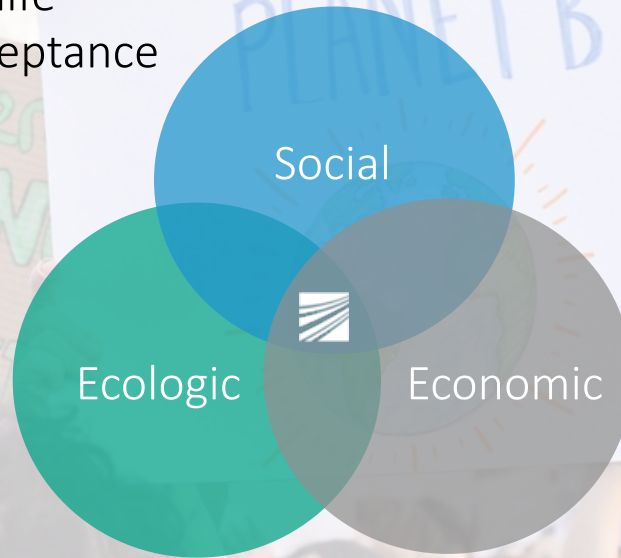


More than **2** patents per day

# Sustainability as a Basis

## Fraunhofer Gesellschaft

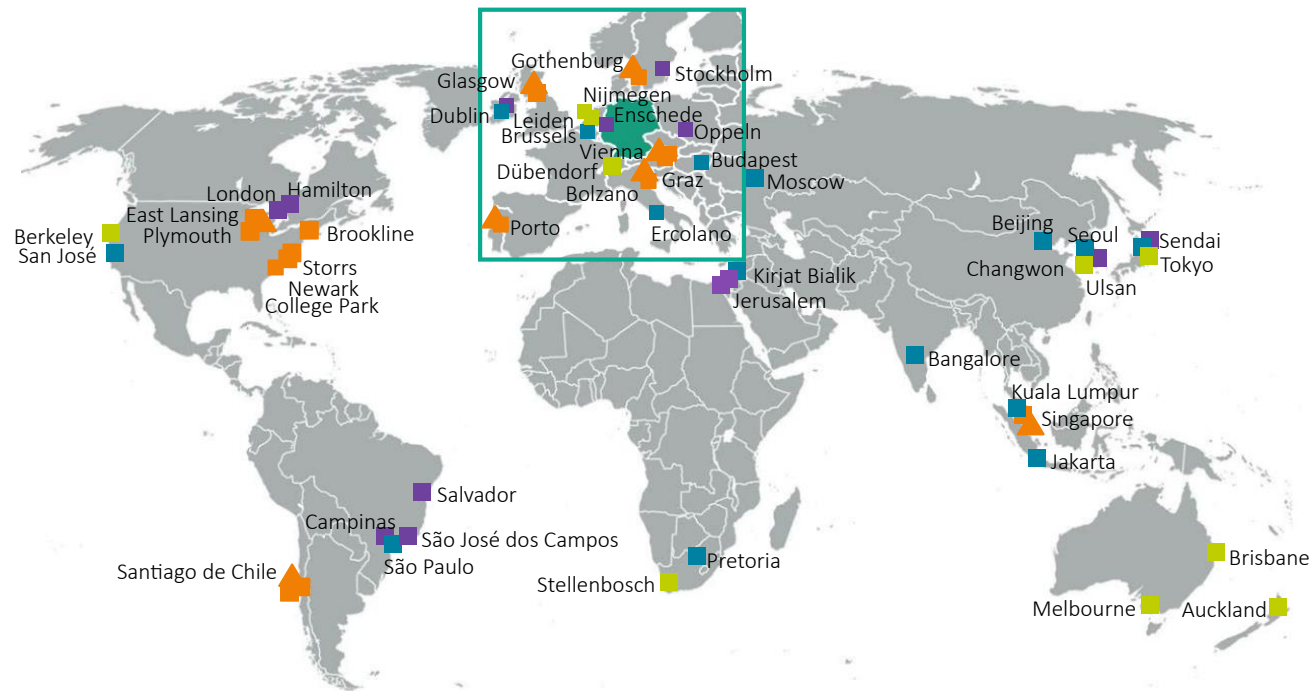
- Improving quality of life
- Increase political acceptance



- Lowering carbon footprint
- Decrease local environmental pollution

- Creation of new jobs
- Investing in the economic technologies of the future

# World representation Fraunhofer Gesellschaft



- ▲ 8 Affiliates
- 15 Center
- 12 Project Center
- 10 ICON
- 6 Repr. Offices
- 7 Senior Advisor

# Technology transfer to Latin-America

Fraunhofer Chile Research



**Our Vision** is to be a referred organization in Chile and Latin-America for technology insertion in priority productive processes in the region.

**Our Mission** is to connect science and technology realized in Chile and Germany with the specific needs of the local industry, supporting the technology transfer and rising local competitiveness and innovation.



# Focus according to Chile characteristics

## Fraunhofer Chile Research



### Centro de Biotecnología de Sistemas (CSB) – Systems Biotechnology Center

- Innovation to face challenges in the circular economy, food, aquaculture and sustainable agriculture
- Funded in 2010
- Dr. Pilar Parada: Executive director and General Manager of Fraunhofer Chile



### Center for Solar Energy Technologies (CSET)

- Innovation for the development of a world-class solar industry
- Funded in 2014
- Prof. Dr. Frank Dinter Executive Director

# Center for Solar Energy Technologies

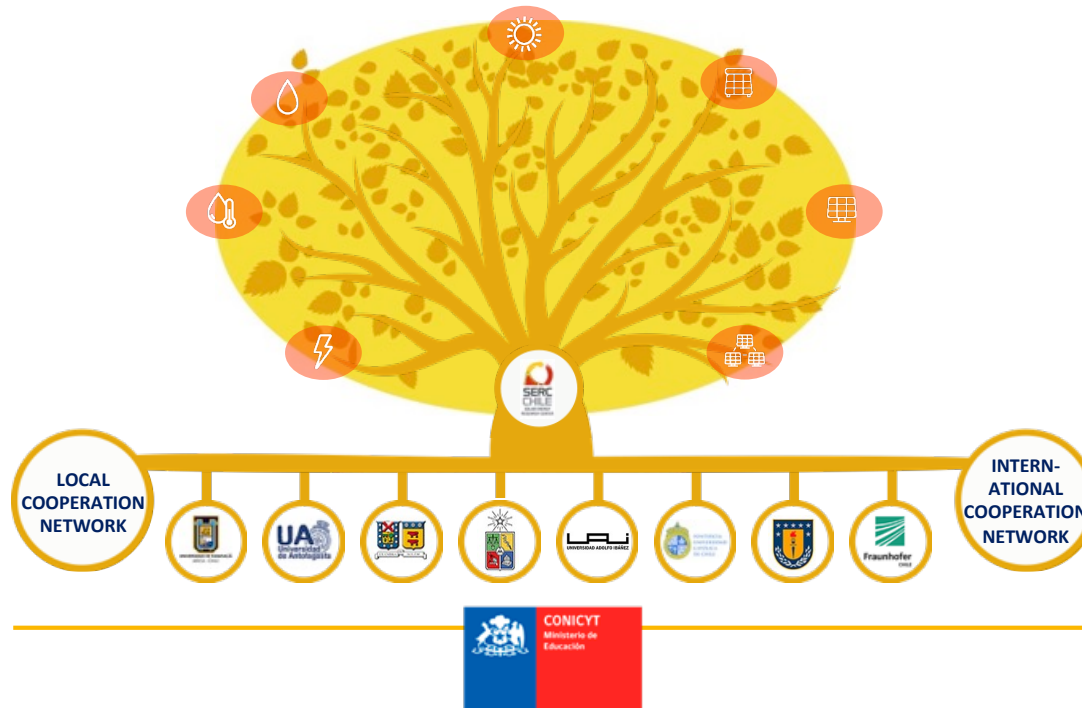
## Fraunhofer Chile Research



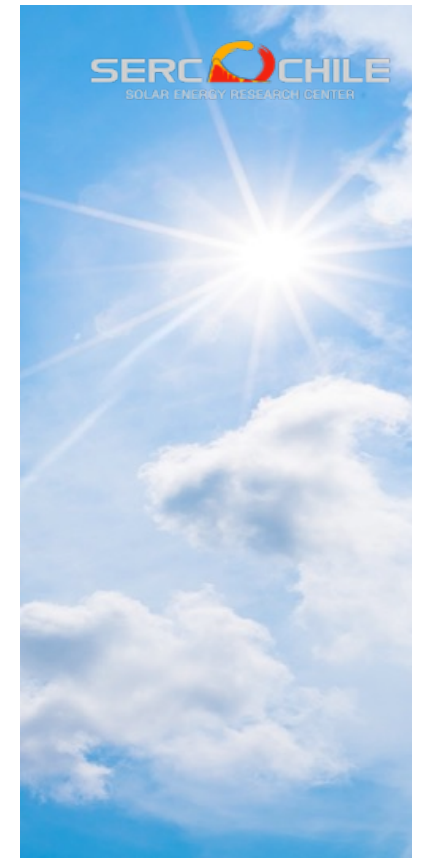
The CSET was constituted in response to the call made by the Ministry of Energy and the Ministry of Economy of Chile

|  |   |   |
|--|---|---|
| <p>Proyecto apoyado por</p>   <p>Subsidized by the Ministry of Energy through the Corporación de Fomento de la Producción CORFO.</p> |  <p>PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE</p> <p>Co-founder and co-executive partner. Solid background in basic and applied research.</p> |  <p>Co-founder partner. Main European Solar Energy Research Center</p> |
|--|---|---|

## SERC Chile 2013 - 2022

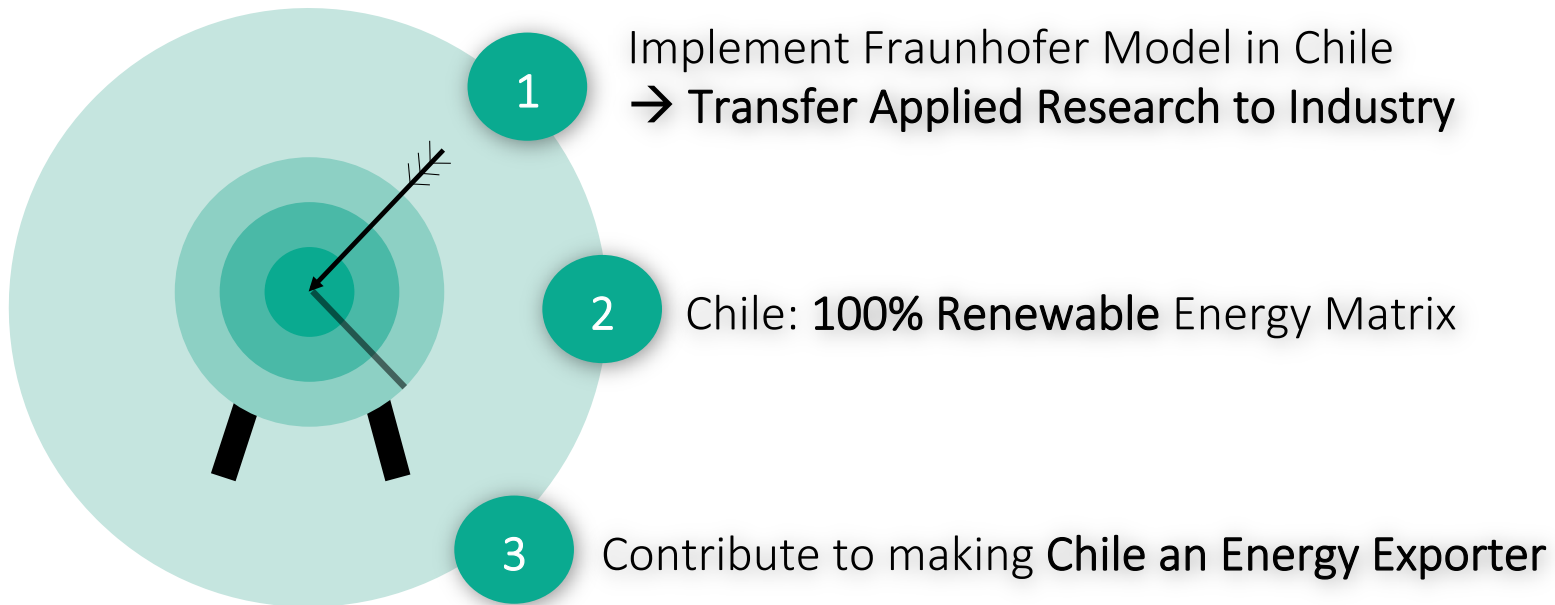


The Solar Energy Research Center of Chile (SERC) was founded in 2008 and is currently in its second phase focused on the integration of solar energy into interconnected electrical systems and also has a line of research for storage.



# Our goals

FCR CSET



# Research lines

FCR CSET



## Photovoltaic



Photovoltaic technologies,  
Concentrated photovoltaic

## Solar thermal



Concentrated solar  
thermal, Solar Heat for  
Industrial Processes

## New opportunities



Economics models, Market  
analysis, Green Hydrogen  
and Electromobility

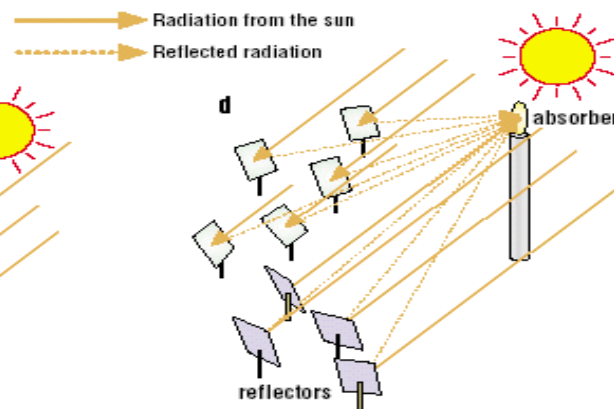
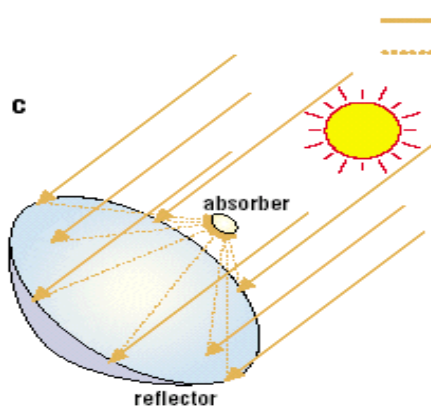
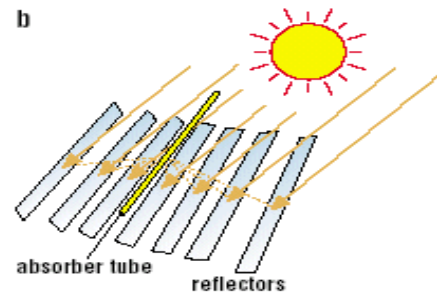
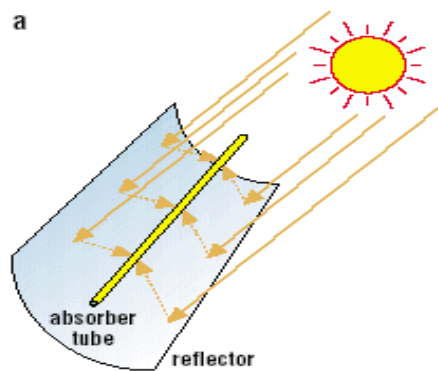
# Content

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The poster is for an online meeting. At the top, it features logos for SERC CHILE (Solar Energy Research Center), TALCA UNIVERSIDAD CHILE, and UNIVERSIDAD DE CHILE. The main title is 'Online Meetings' in a large, bold font, with the subtitle 'OF THE WORLDWIDE ENERGY NETWORK - DISTINGUISHED LECTURES PROGRAM OF SERC'. The central focus is the topic 'CSP with storage: the energy supply for the future' in a large, bold font. To the right, there is a circular portrait of Frank Dinter, identified as 'FRANK DINTER, FRAUNHOFER CHILE SPEAKER'. The date and time are 'AUGUST 10TH 09:25 HRS.'. Below this, it says 'REGISTRATION' in a black box. At the bottom, there are logos for 'vía' with YouTube and Facebook icons, and 'LIVE'. The bottom of the poster features several logos: 'CENTRO TECNOLÓGICO DE CONVERSION DE ENERGIA', 'FACULTAD DE INGENIERIA UNIVERSIDAD DE TALCA', 'MacroFacultad', 'IEEE POWER ELECTRONICS SOCIETY Chile Section Chapter', 'Fraunhofer CHILE', 'ACESOL', and 'AIE 25 años'.

# Concentrating principles for CSP

Line focused and point focused systems



2D Optics  
(Line Focus)

3D Optics  
(Point Focus)

## **CSP with storage**

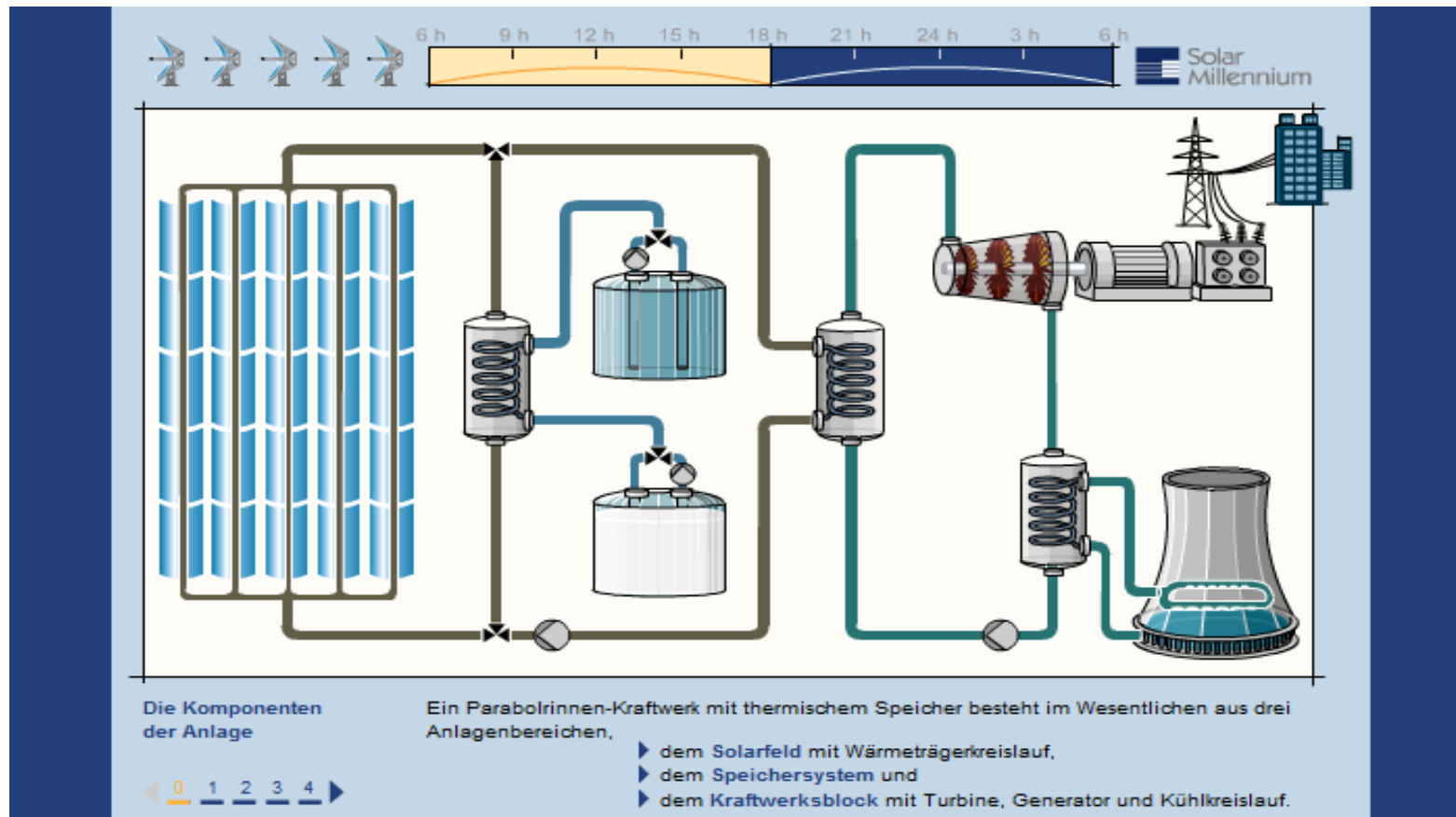
**Parabolic trough is the most mature CSP technology today !!!**





# Commercial Parabolic Trough plants

How does a trough plant with storage work? (SWF-File)



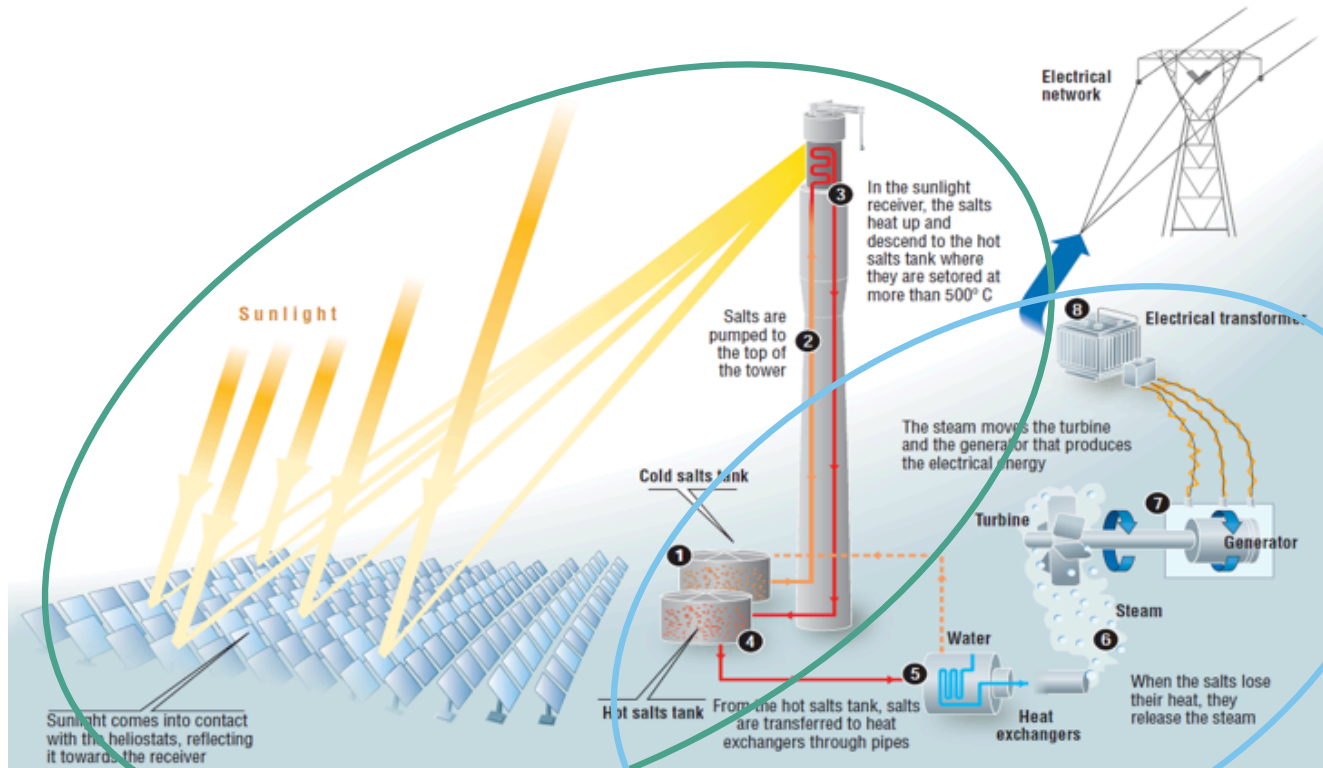
## CSP with storage

Central Receiver Systems are the new  
CSP technology



# CSP with storage

## how works a solar tower?



### First loop (solar)

→ Charging the storage system with 565°C

### Second loop (power generation)

→ Discharging the storage for electricity production

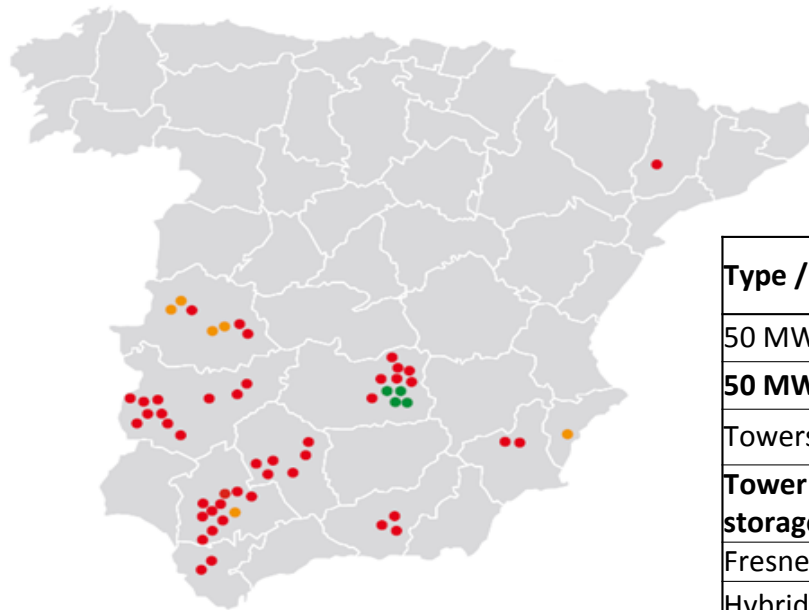
Instead of using fossil fuels in a burner the heat collected from the sun is the heat source

CSP – dispatchable energy on demand

## CSP with storage

In Spain 49 CSP plants in operation (2300 MW)

17 CSP plants with 7.5 h storage and 1 with 15h storage



In operation    under construction    Planned

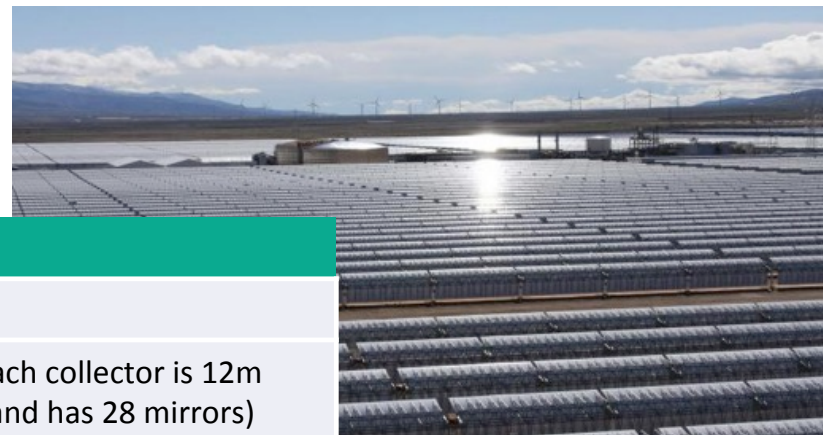


| Type / Technology   | Number of Plants | Capacity (MW) | Storage (MWh) |
|---|------------------|---------------|---------------|
| 50 MW Trough without storage                                | 27               | 1350          | 0             |
| <b>50 MW Trough with storage &gt; 7h</b>                    | 17               | 850           | 6500          |
| Towers with sat. steam receiver                             | 2                | 31            | 31            |
| <b>Tower with molten salt receiver and storage &gt; 15h</b> | 1                | 20            | 300           |
| Fresnel linear reflectors                                   | 1                | 30            | 0             |
| Hybrid Parabolic trough with Biomass                        | 1                | 22            | 0             |
| <b>TOTAL</b>  | <b>49</b>        | <b>2303</b>   | <b>6831</b>   |

Source: Protermosolar

# CSP with storage

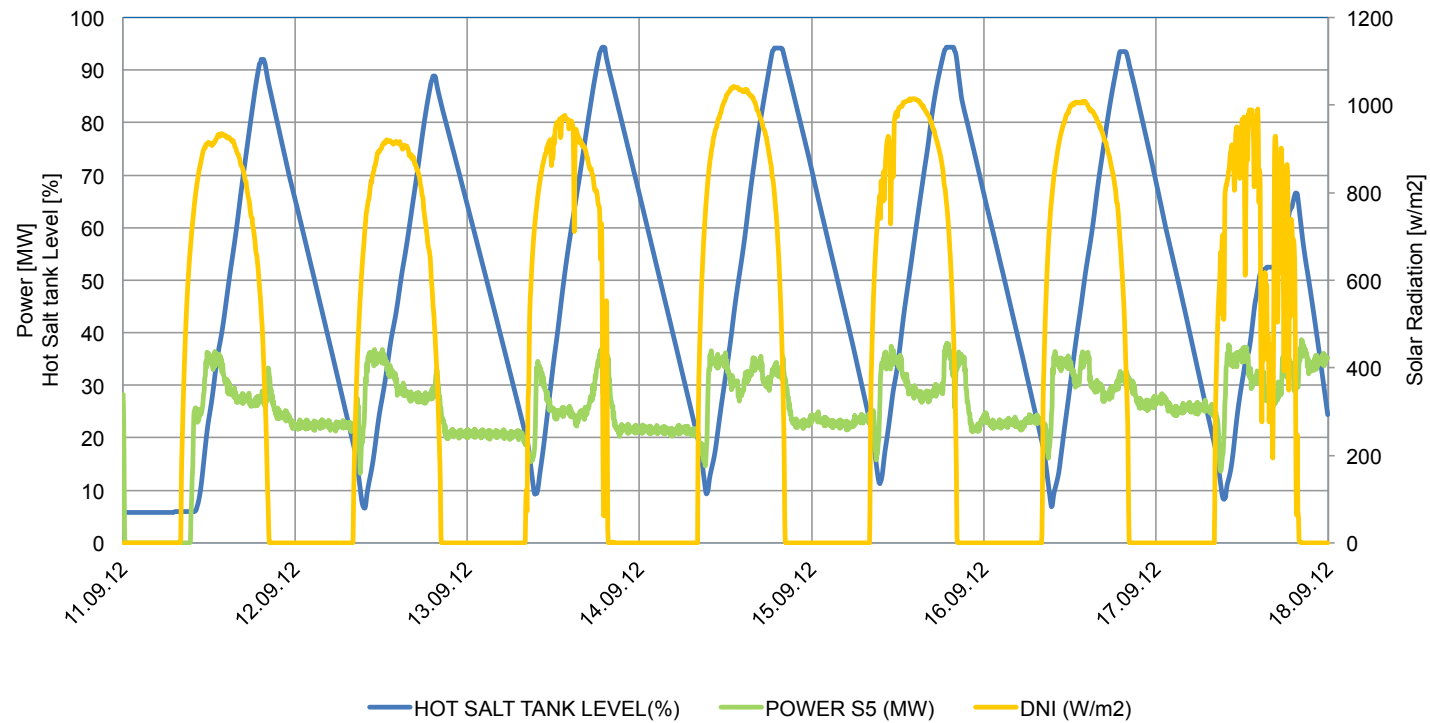
## Andasol 3: Technical data



| 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 with storage

## Andasol 3: 24 h/d Operation



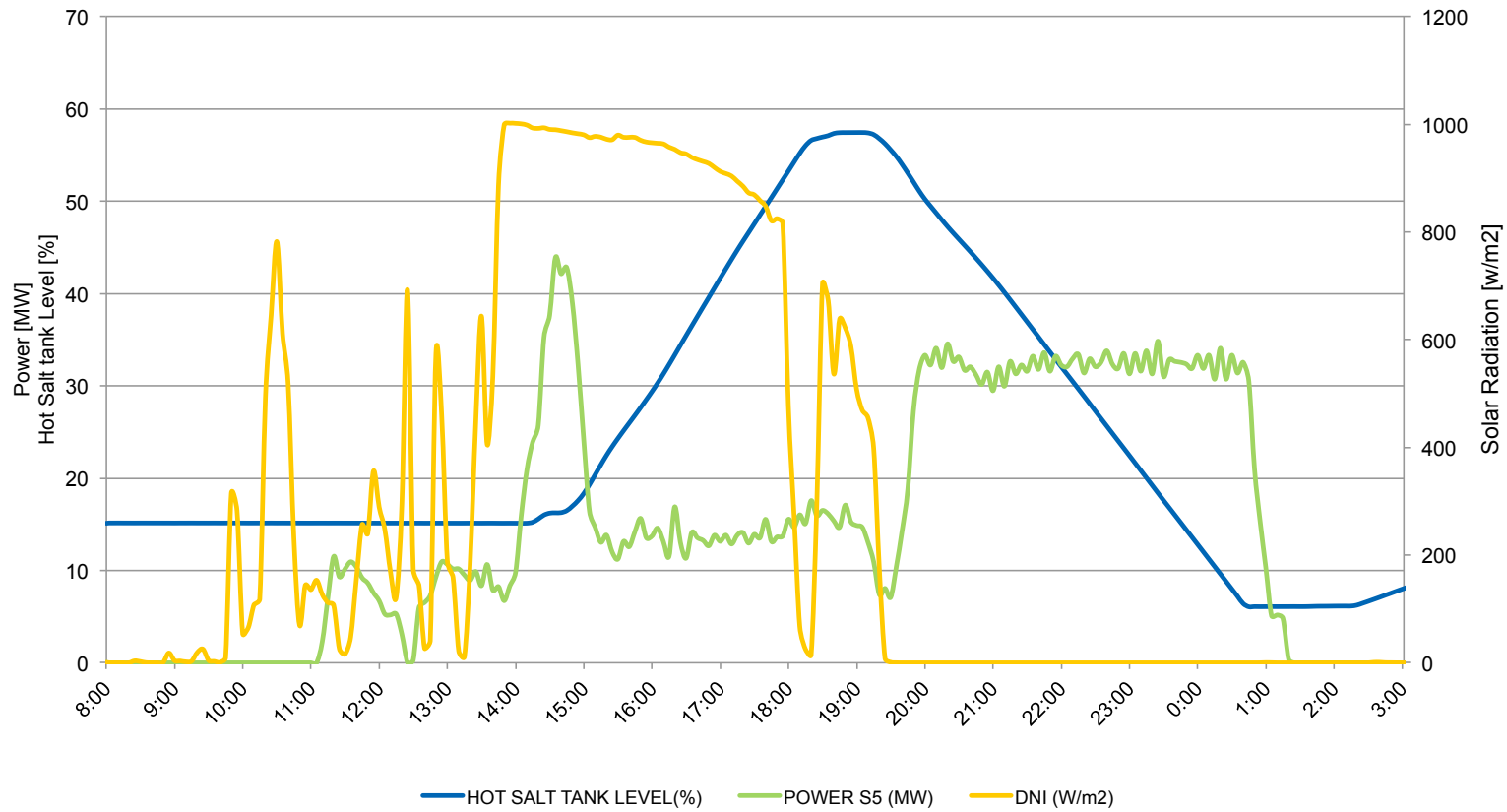
# CSP with storage

## Andasol 3: last day with valatile irradiation



# CSP with storage

## Andasol 3: dispatchability with high PV electricity production





## CSP with storage

Andasol 3: Photo of the plant from storage



# CSP with storage

## Electricity production 24/7

### CSP = Concentrating Solar Power

- Using direct radiation for concentrating to generate high temperatures onto the receivers
- CSP plants produce electricity between 20 and 300 MW
- 24/7 production is possible because of the integrated thermal storage system

### CSP plants need:

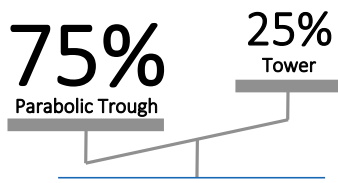
- High direct radiation
- Nearly flat landscape
- Nearby access to electricity high or medium voltage grid
- Water for cleaning the mirrors similar as PV cleaning and also water for the water/steam cycle
- About 1000 persons work on such a plant at the same time during construction phase
- The construction phase lasts about 2 years
- Many suppliers and service providers are needed afterwards



# CSP with storage

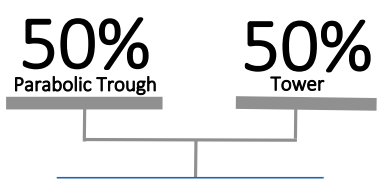
## Market worldwide

**6.5 GWe** Installed capacity



**70%** With storage

**1.5 GWe** Contracted / under construction



**100%** With storage

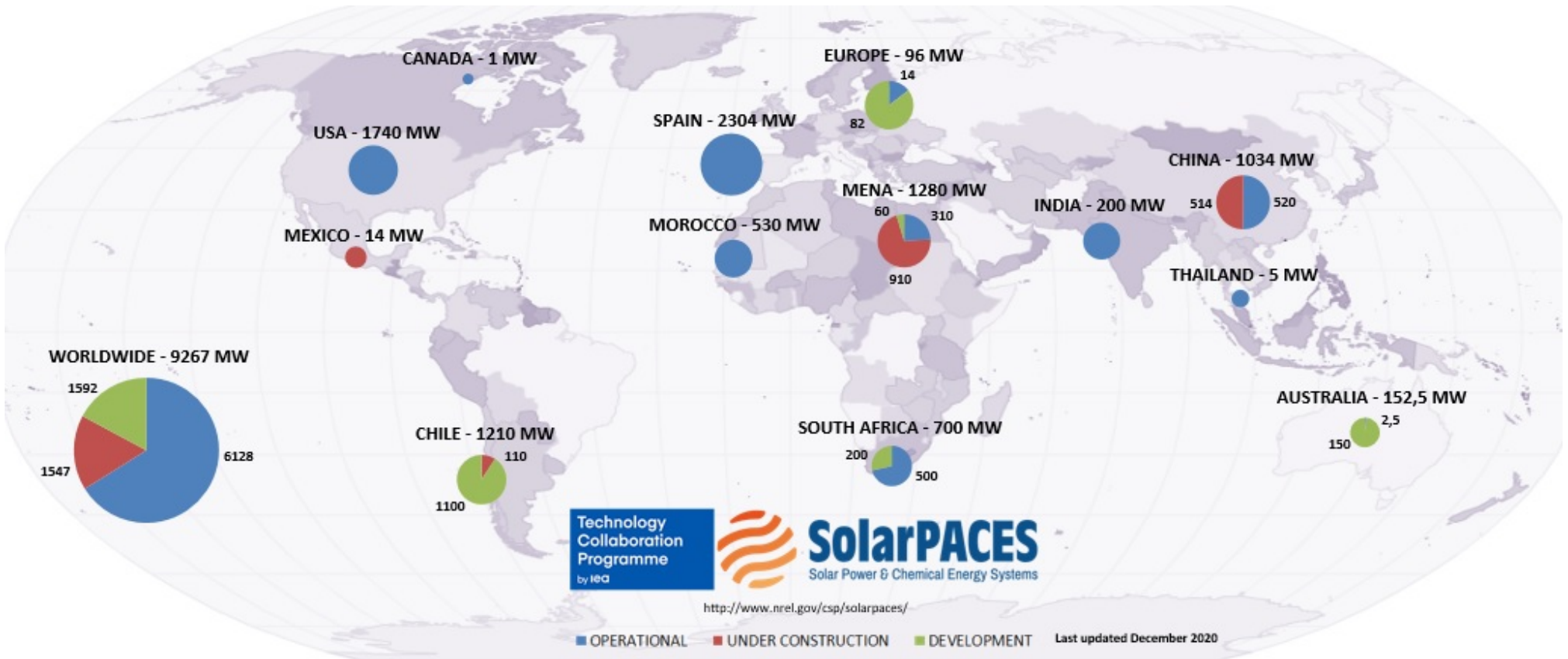
China 1 GW - Morocco 0.7 GW

Direct Normal Irradiation (DNI)  
Chile Mainlands



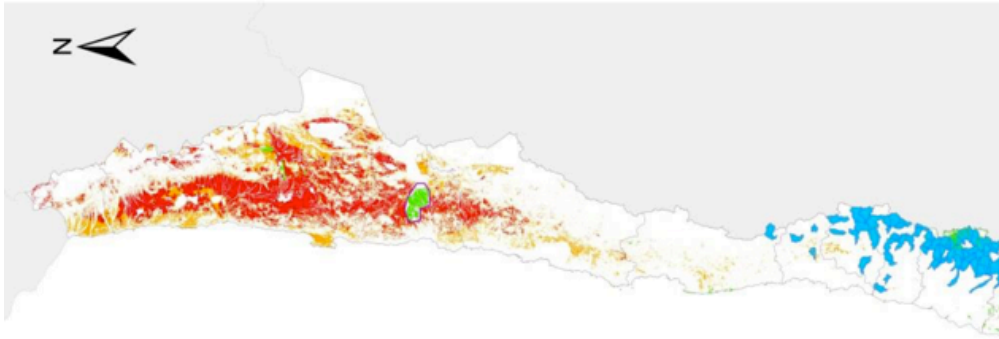
# CSP with storage

## Market worldwide



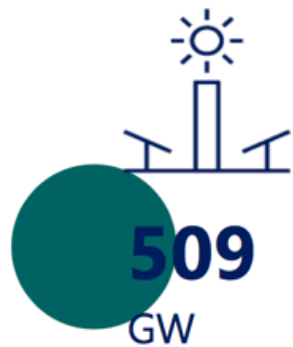
# CSP with storage – The technology for the future

Chile has the best solar radiation all over the world



**The potential of solar energy in the north of Chile is great**

- Photovoltaic (PV) and
- Concentrated Solar Power (CSP)



**Concentrated solar power**

+



**Solar photovoltaic**

**This combination is the opportunity for large scale, cheap and reliable electricity production in the future !**

## CSP with storage – The technology for the future

Today 5 GW coal plants  
27 Plants  
24 Mio t. CO<sub>2</sub> emissions in 2017

- 2019 to 2024 to be shut down 1 GW
- 2040 to be shut down remaining 4 GW

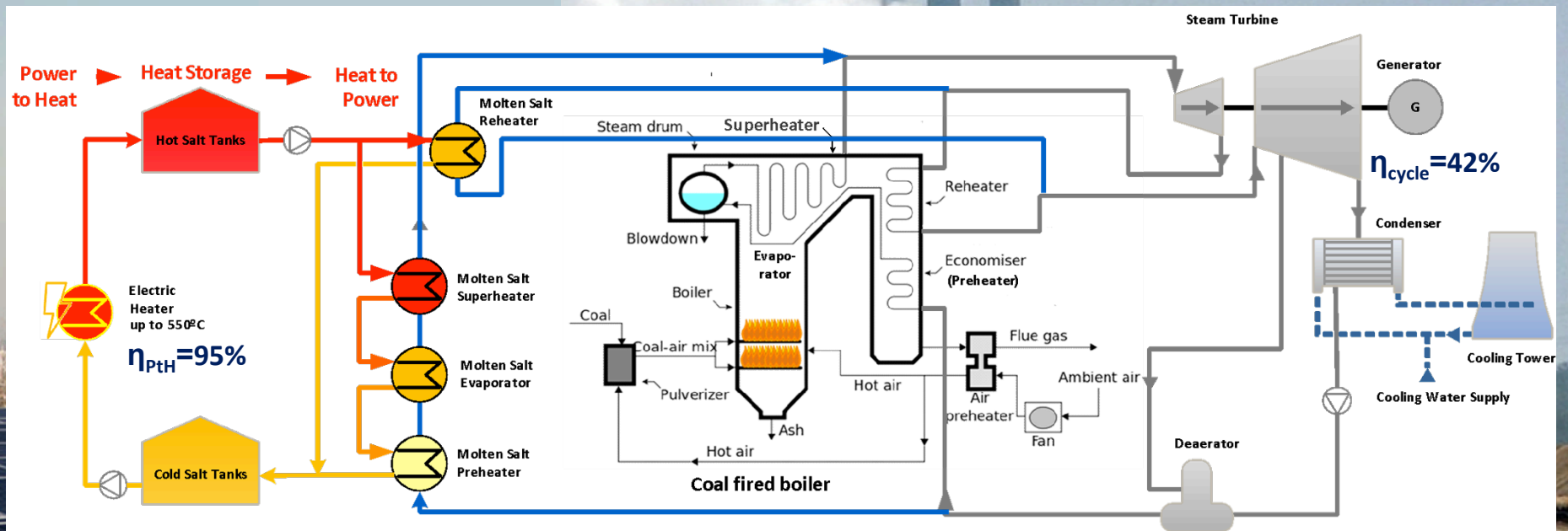


**CSP technology is the best substitute for coal fired power stations**

# CSP with storage – The technology for the future

## CSP technology is the best substitute for coal fired power stations

Phase 1: Pilot integration of molten salt storage in existing coal plant – proof of concept  $\eta_{\text{roundtrip}} = 40\%$



source: DLR-GIZ-Fraunhofer

## CSP with storage

200 MW Noor 2 parabolic trough plant with 6 hour storage in Morocco



Source: Acwa



## CSP with storage

Noor 3: World largest CSP Tower 150 MW with 7.5 h of storage in Morocco



## CSP with storage

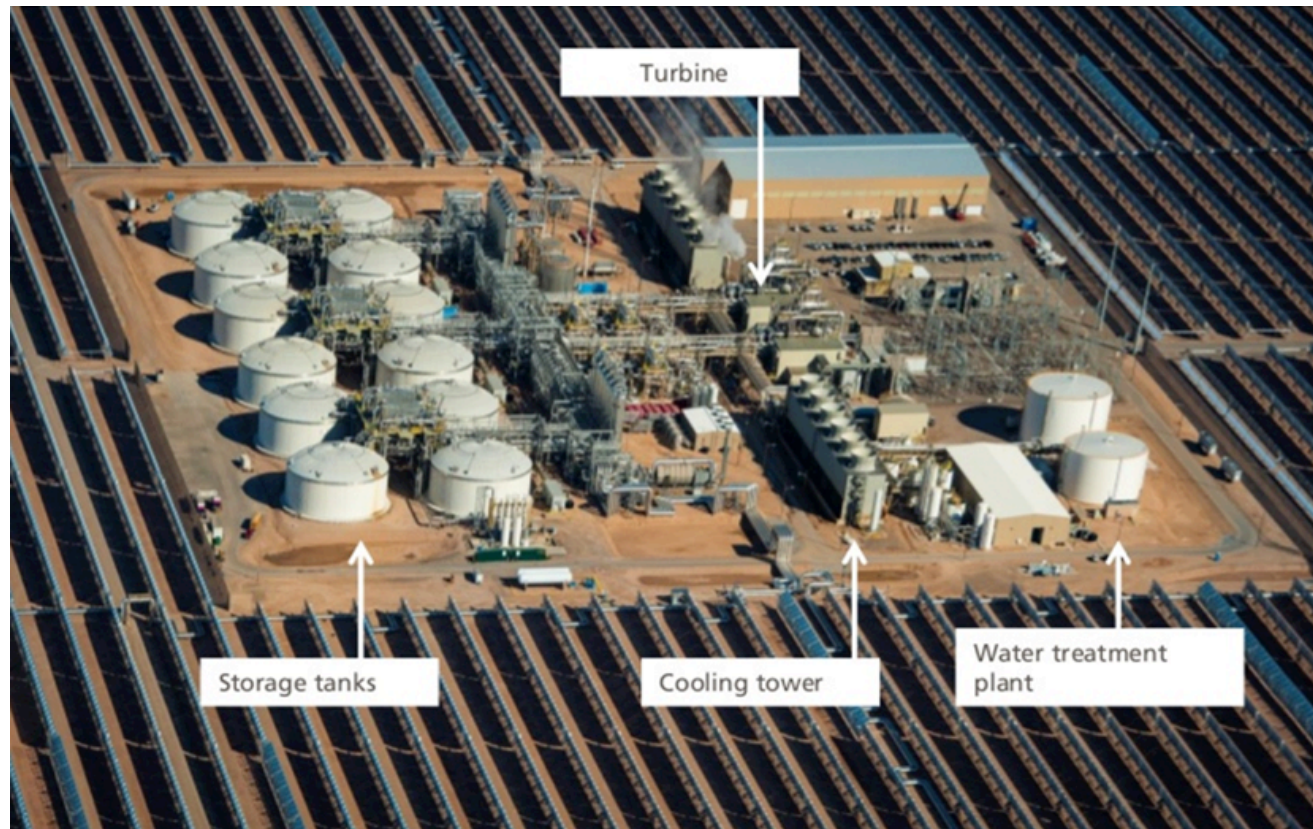
Solana: world largest parabolic trough plant (Arizona) 280 MW 6 hours storage



Source: Abengoa

## CSP with storage

Solana: world largest parabolic trough plant (Arizona) 280 MW 6 hours storage

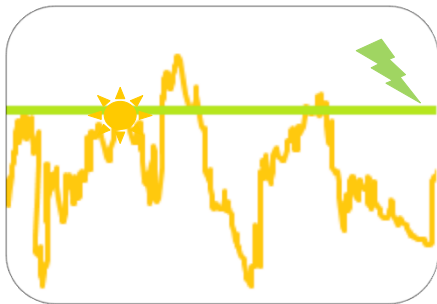


Source: Abengoa

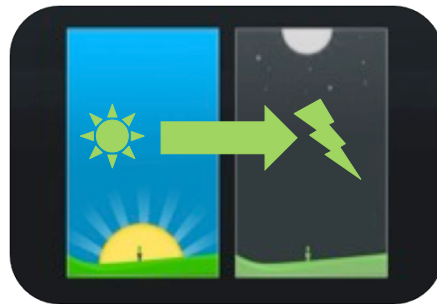
# Value of CSP with storage

Additional benefits:

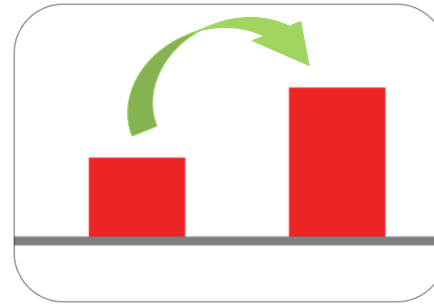
Flexible and predictable electricity generation



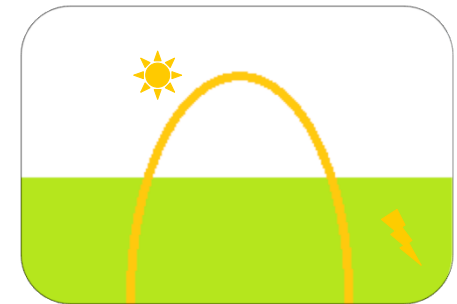
Avoidance of production interruptions resulting from the intermittency of solar radiation



Generation of solar power decoupled from weather conditions and time



Shifting of power generation to periods of highest demand



24 h/d continuous production capability

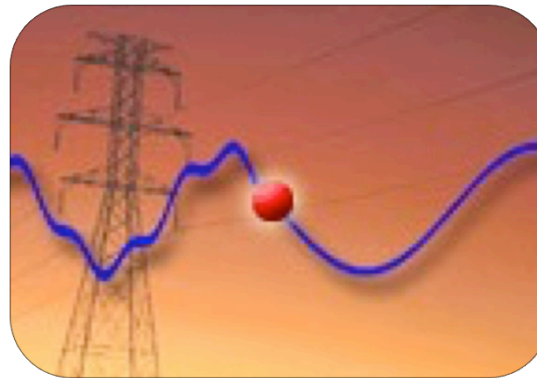
# Value of CSP with storage

Additional benefits:

Flexible and predictable electricity generation



Regulation and frequency response



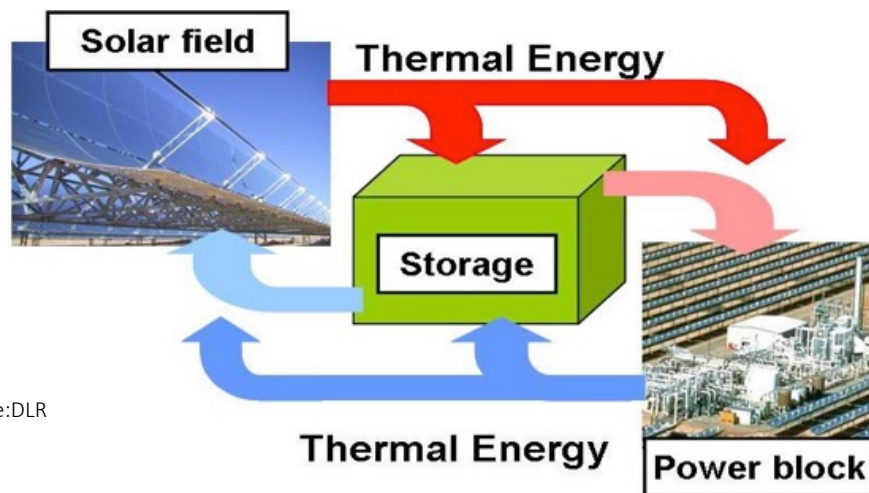
Support for power quality



Contribution to system flexibility  
supporting the integration of other RE  
sources

## CSP with storage proven technology

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.



Source:DLR

Flexible and  
predictable  
electricity  
production  
on demand

## CSP with storage

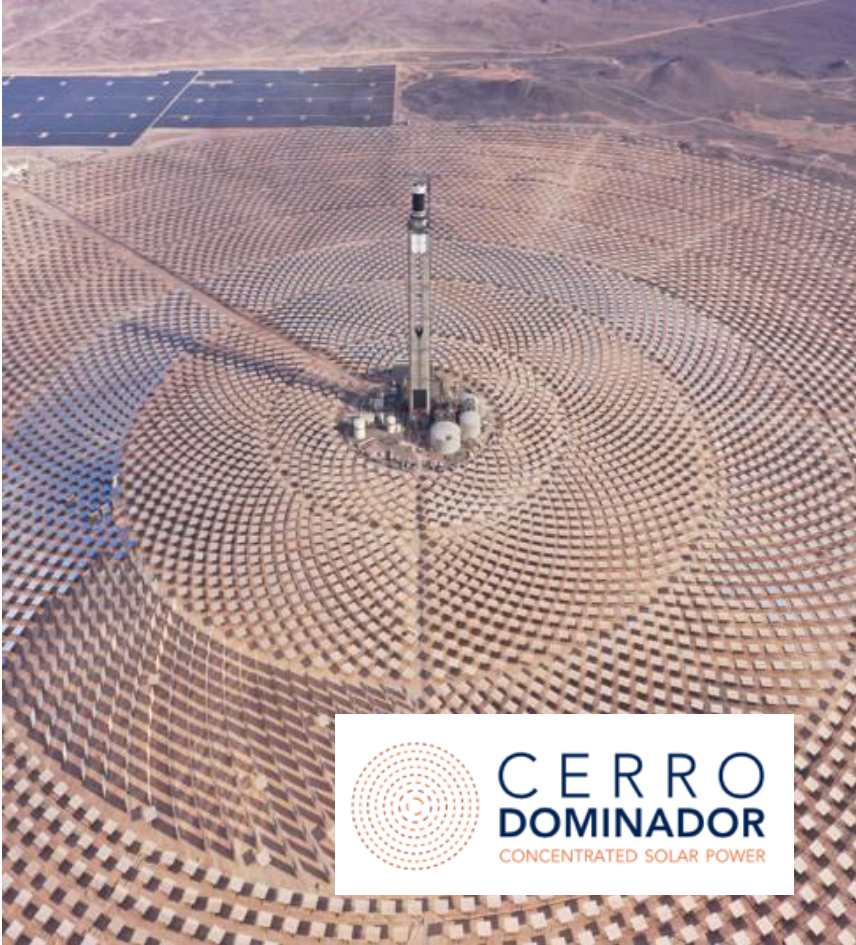
### Cerro Dominador in Chile



- > Location: Maria Elena, Antofagasta, **Chile**
- > Power: 110 MW with 17.5 h storage **for 24h production**
- > 50 000 tm salts
- > 1 484 000 m<sup>2</sup> heliostat field
- > Commission date: 2021
- > Combined with 100 MW PV plant
- > EPC: Abengoa + Acciona

# CSP with storage

## Cerro Dominador in Chile



### 100% Construcción finalizada

- ✓ Campo solar terminado
- ✓ Tuberías terminada
- ✓ Pruebas con aguas realizadas
- ✓ Recta final para el comisionamiento
- ✓ 10.600 Heliostatos instalados
- ✓ Sales Fundidas en estanques
- ✓ Receptor instalado con pruebas realizadas





# CSP with storage

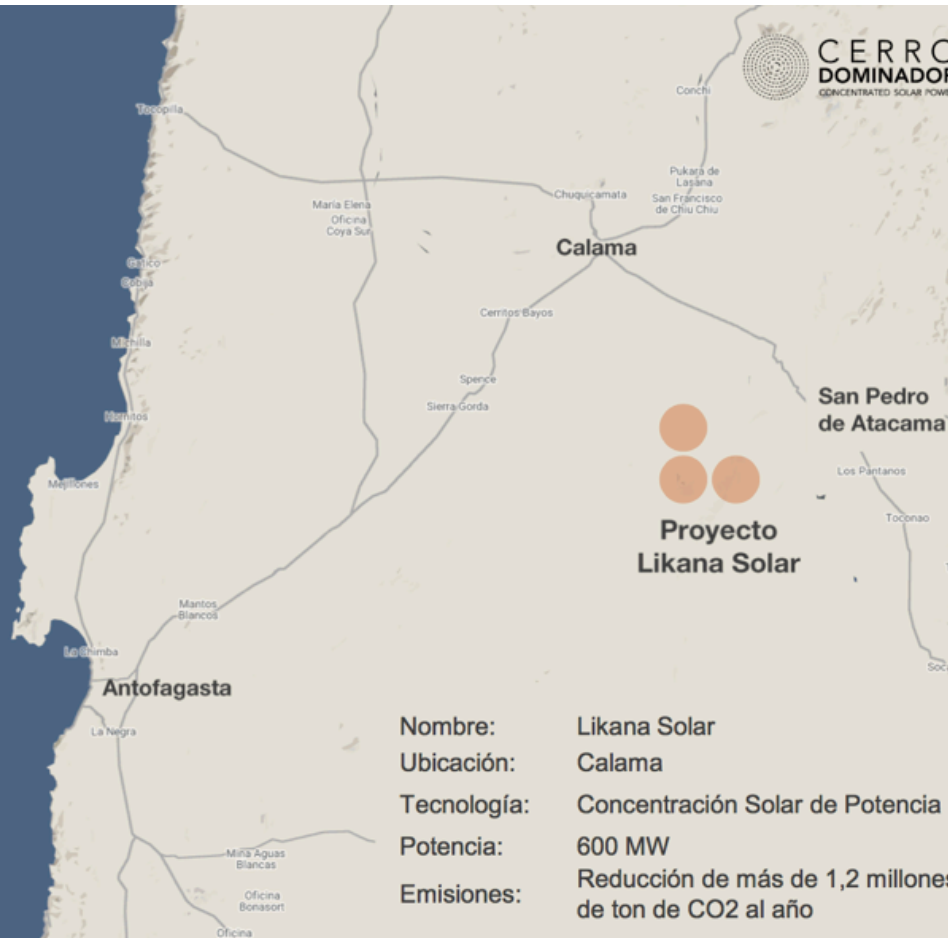
## Cerro Dominador Project Likana Solar

### PROYECTOS

# Likana Solar

El proyecto está ubicado en la localidad de Calama, contempla la construcción de 3 torres con un almacenamiento de energía de 12 horas y tendrá una potencia instalada de 450-600 MW, lo que la posiciona como una de las centrales renovables con mayor capacidad del mundo.

Cada torre será hasta 200 MW, por tanto se proyecta una generación de energía anual neta prevista de unos 2.400 GWh/año

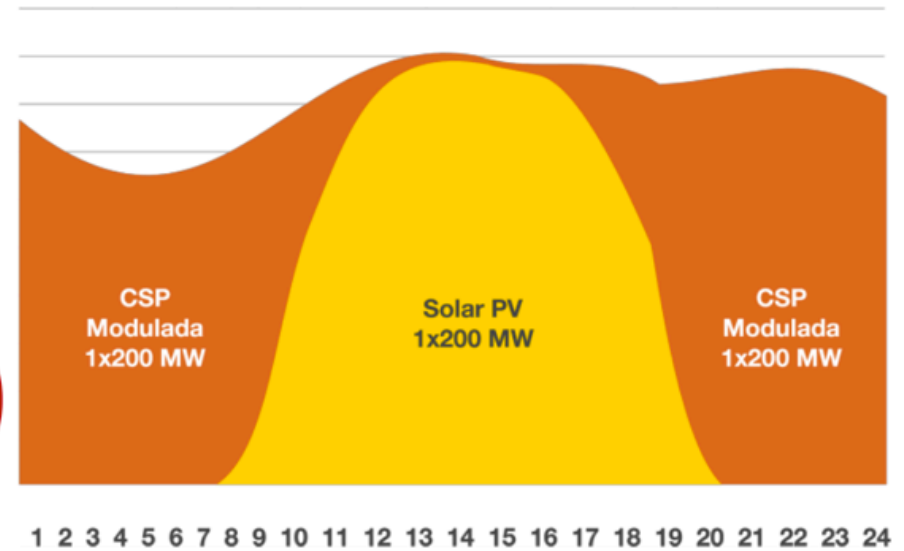
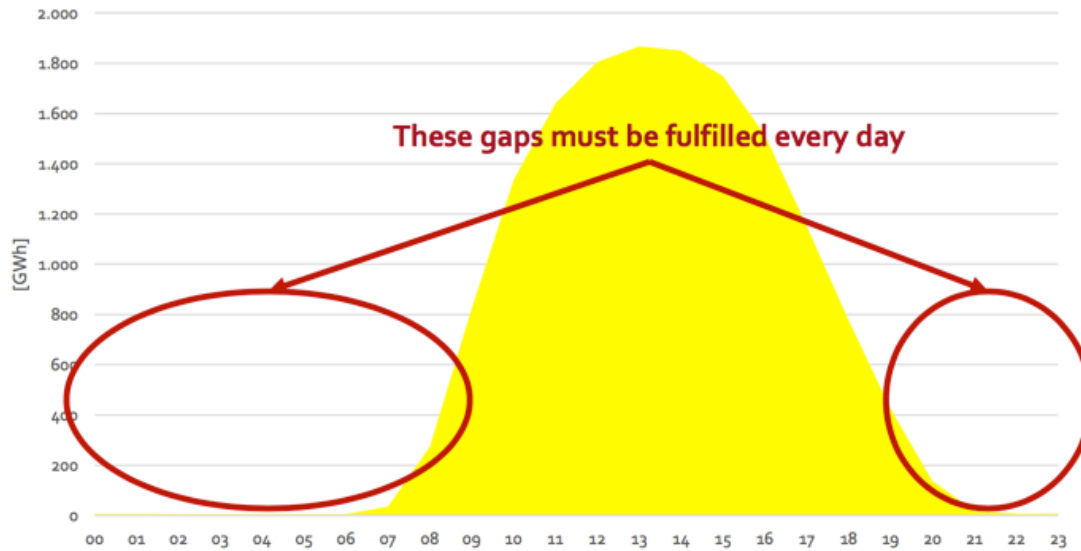


# CSP with storage

## Situation with PV and CSP



PV Generation in Spain  
Cumulative per hour 2020



There is not only one solution for energy transition. Both solar technologies including storage will contribute to a secured electricity production of Chile in future.



# Thank You !



## Fraunhofer

Supporting solar energy  
integration in Chile and  
LATAM

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