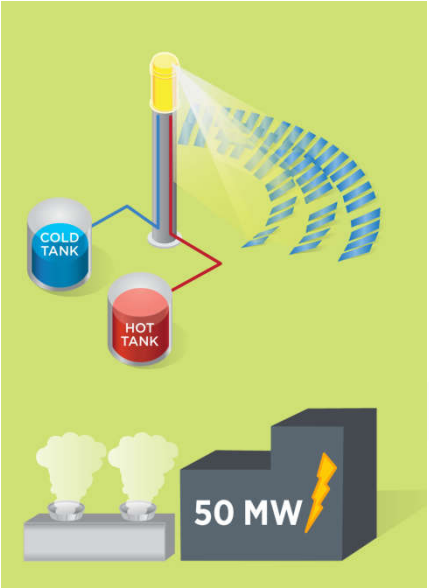
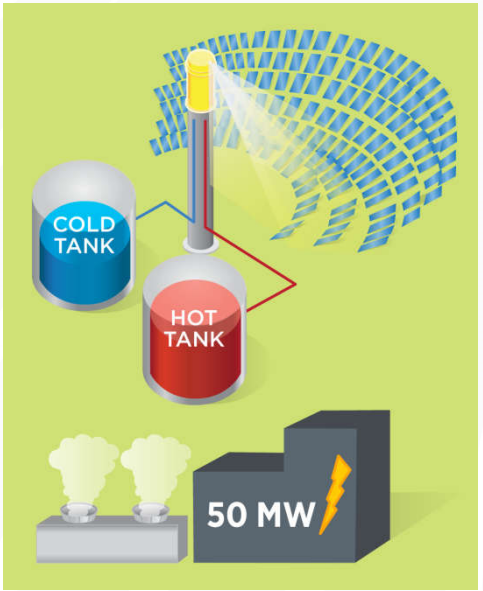
CSP: Flexible Solar Energy On-Demand for an Evolving Grid

'Peaker'
(≤6 hours of storage)



'Baseload'
(≥12 hours of storage)



By choosing the size of the solar field and thermal energy storage, the same CSP technology can be configured to meet evolving demands of the grid

Hybrid renewable systems provide low cost *and* flexible operation

Concentrating solar power (CSP)

PV plus battery

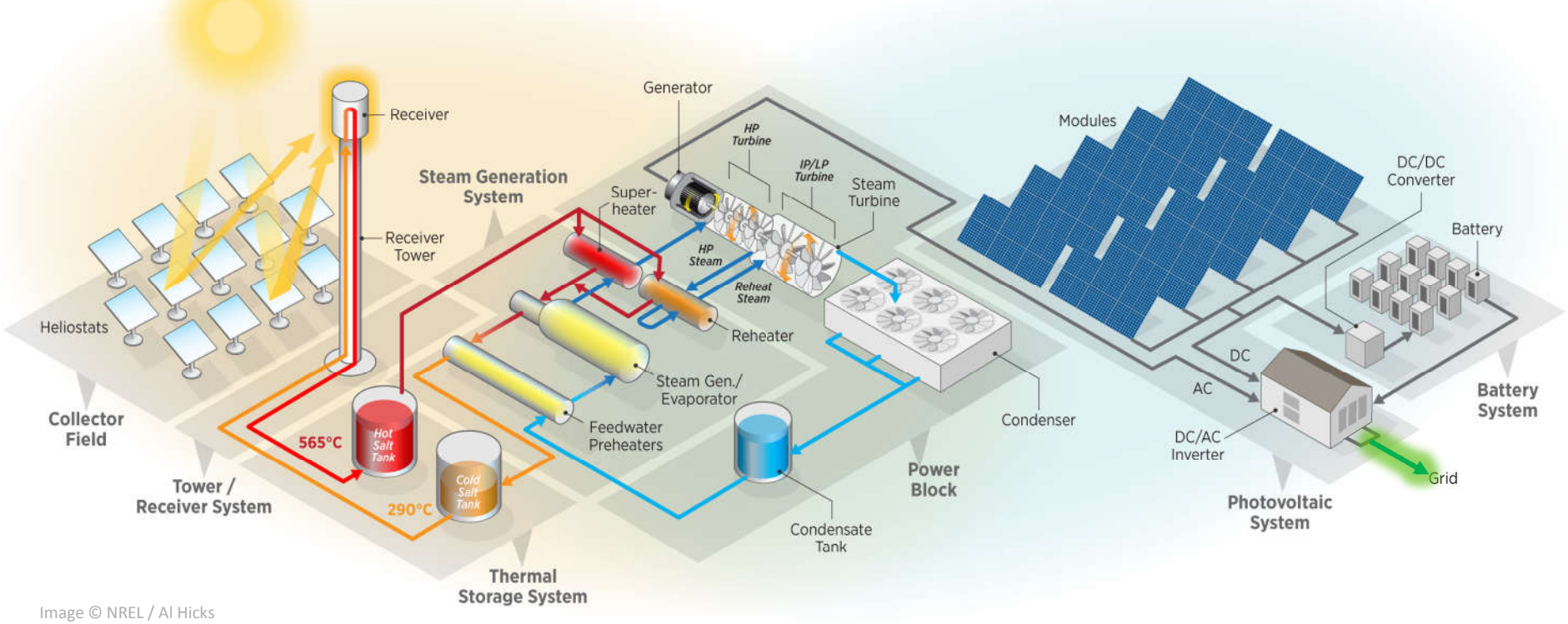
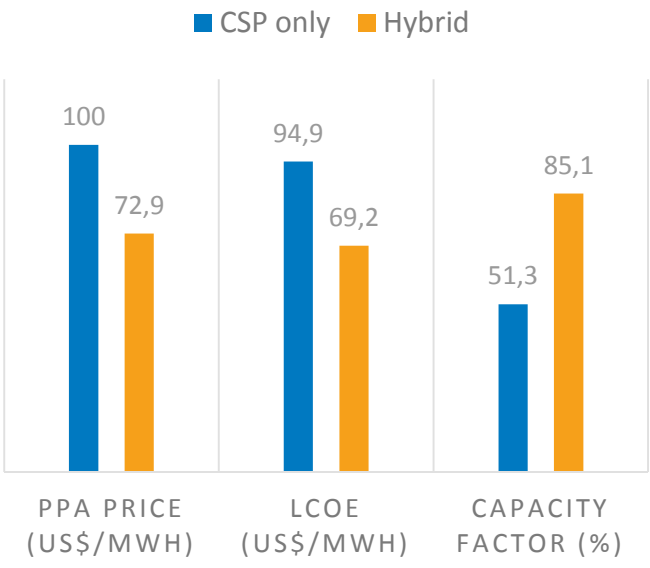


Image © NREL / Al Hicks

Hybrid technology can reduce energy production cost

- A recent analysis by NREL and Colorado School of Mines showed promising cost and performance improvement for a Northern Chile location
- Recommendations – when do hybrid plants make sense?
  - When capacity and reliability are important and incentivized
  - When both daytime and nighttime production are valuable
- When do hybrids **not** make sense?
  - When timing or consistency of production is not important
- Hybrid plants require methods for optimizing the timing of energy production from each subsystem

Techno-economic benefits of a conceptual hybrid CSP-PV- facility in Northern Chile



CSP + BIOMASS HYBRID

HIGH CAPACITY FACTOR PLANT

PROVEN TECHNOLOGY

- NOOR III (MOROCCO) CSP PROJECT
- PUERTOLLANO (SPAIN) BIOMASS PROJECT

BENEFITS of CSP+BIOMASS

- LCOE DECREASE:
  - *Only one turbine required, only one common area*
  - ***Biomass conversion efficiency increase: molten salt tower cycle is highly efficient (>45%)***
  - *O&M cost decrease: resources optimization*
- MORE FLEXIBLE/DISPATCHABLE PLANT
- NO DAILY STARTUPS of TURBINE
- HIGH CAPACITY FACTOR

CSP to HEAT HYBRID

CSP CAN PROVIDE HEAT FOR INDUSTRIAL PROCESSES

APPLICATIONS

- DISTRICT HEATING
- WATER DESALINATION
- MINING CHEMICAL PROCESSES
- ORGANIC RANKINE CYCLES

BENEFITS of CSP to HEAT

- DISTRICT HEATING:
  - *Surplus heat from cycle is used at a low cost*
- WATER DESALINATION:
  - *Decrease in desalinated water cost, fuel saving (SENER patent)*
- MINING CHEMICAL PROCESSES:
  - *Electrolyte heating (lithium…)*
- ORGANIC RANKINE CYCLES:
  - *Low temperature applications*

IEA SolarPACES facilitates LAEF session

- **IEA SolarPACES VISION**

  Our vision is that concentrating solar technologies contribute significantly to the delivery of clean, sustainable energy worldwide.

- **IEA SolarPACES MISSION**

  Our mission is to facilitate technology development, market deployment and energy partnerships for sustainable, reliable, efficient and cost-competitive concentrating solar technologies by providing leadership as the international network of independent experts.

Solar Power and Chemical Energy Systems

SolarPACES membership 2019

- **Currently SolarPACES has 19 members:** Austria, Australia, Brazil, Chile, China, European Commission (DG RESEARCH and DG TREN), France, Germany, Greece, Israel, Italy, Mexico, Morocco, Republic of Korea, South Africa, Spain, Switzerland, United Arab Emirates and United States of America.
- **Potential new members are:** Namibia, Portugal,

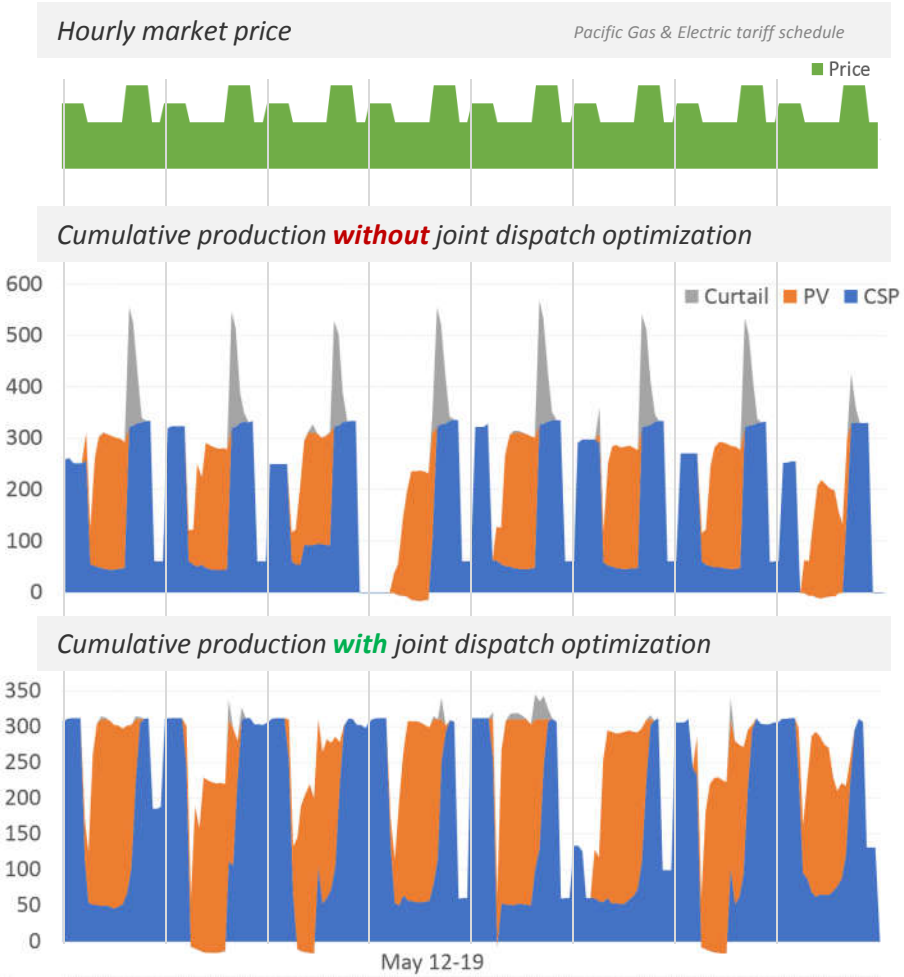
Panel: Developing Thermal and Hybrid Power in Latin America

Robert Pitz-Paal (Moderator)	Director Institute of Solar Research, Chairman SolarPACES	German Aerospace Centre (DLR)
Avi Shultz	Program Manager, Solar Energy Technologies Office	U.S. Department of Energy
Fernando Gonzalez	Chief Executive Officer	Cerro Dominador
Miguel Domingo	Director of Renewable Energy	SENER
Michael Wagner	Senior Research Engineer	NREL
Alfons Juan	Business Development Director	ACCIONA Industrial

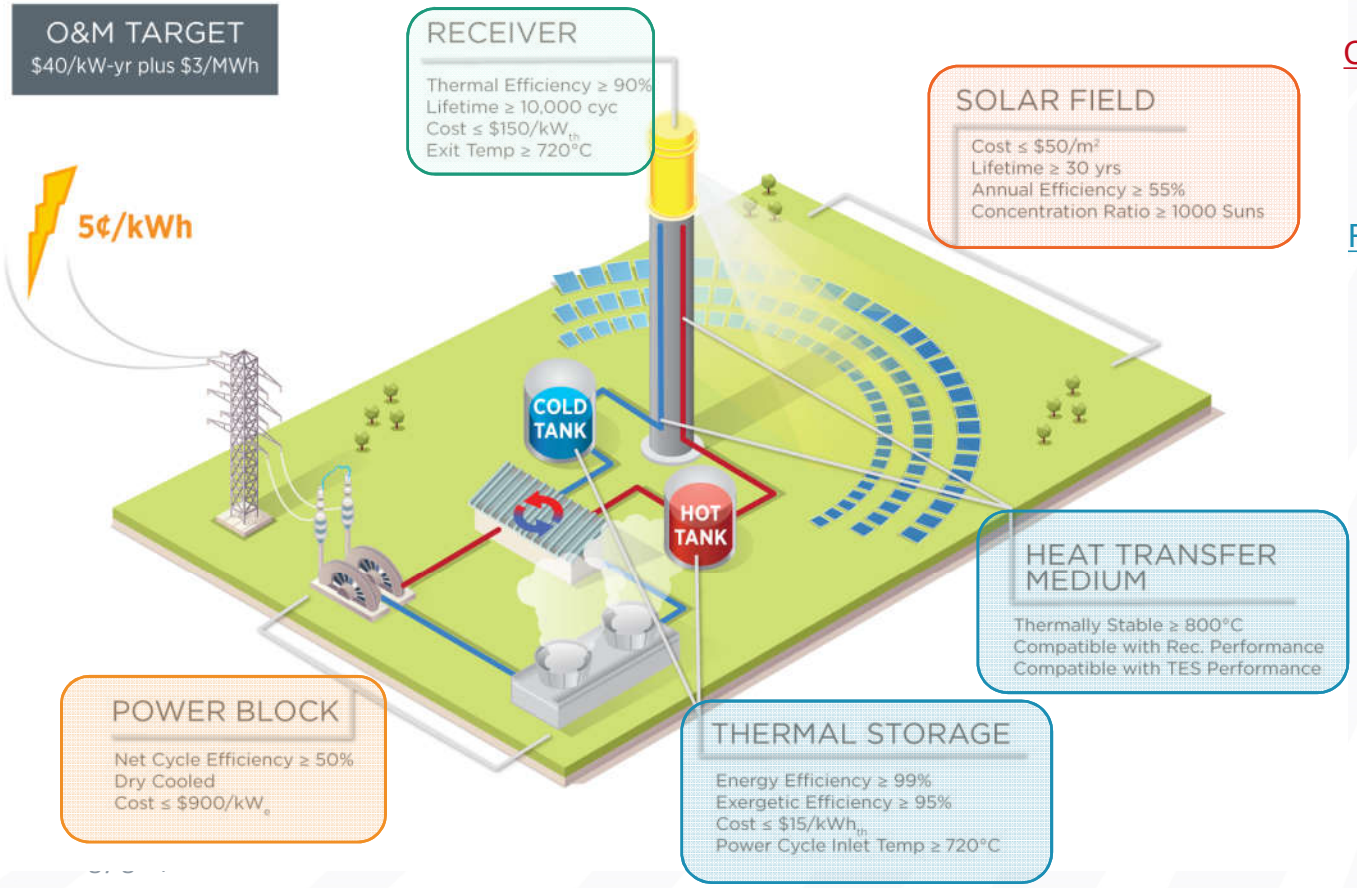
Back-up Slides

CSP and PV can produce complementary power

- Two forms of solar energy generation with differing characteristics can be used to meet market demands
- Optimized production from CSP can overlap PV
- *Cumulative* production of a paired plant exacerbates grid challenges or induces PV curtailment
- Goal: Shift CSP production using thermal storage to generate "around" PV



DOE CSP Program R&D→ LCOE of 5¢/kWh by 2030



Collector Field

- Lower capital cost designs
- Increased automation and reduced operational complexity

Receiver & Thermal Transfer/Storage

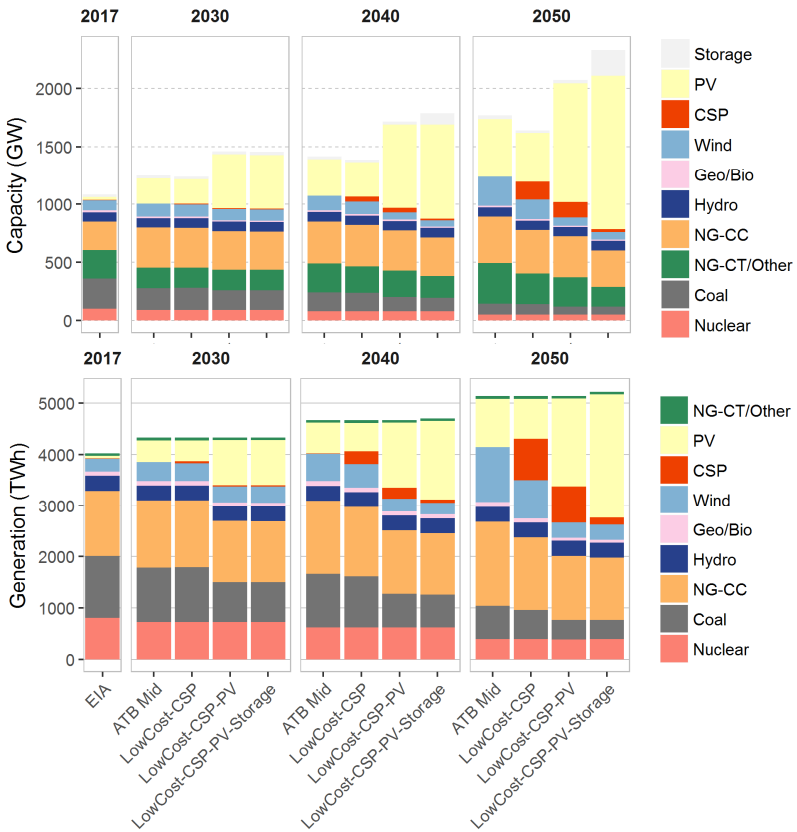
- High-temperature 'Gen3 CSP' systems to increase system efficiency
- Optimization of thermal energy storage dispatch to maximize value to the grid

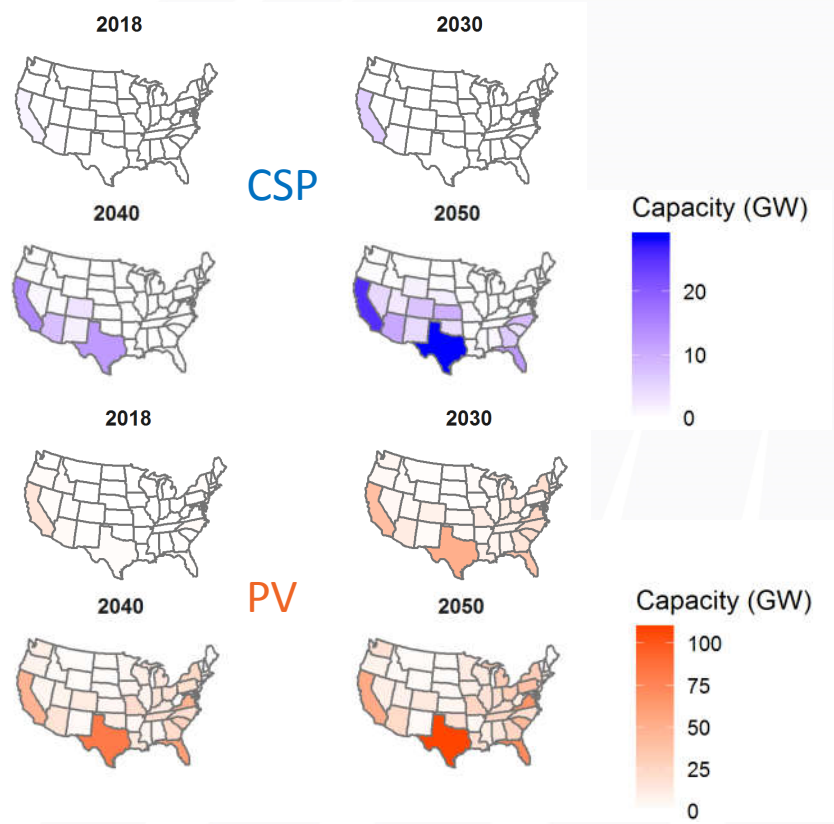
Power Block

Novel power cycles using supercritical-CO_2 working fluid:

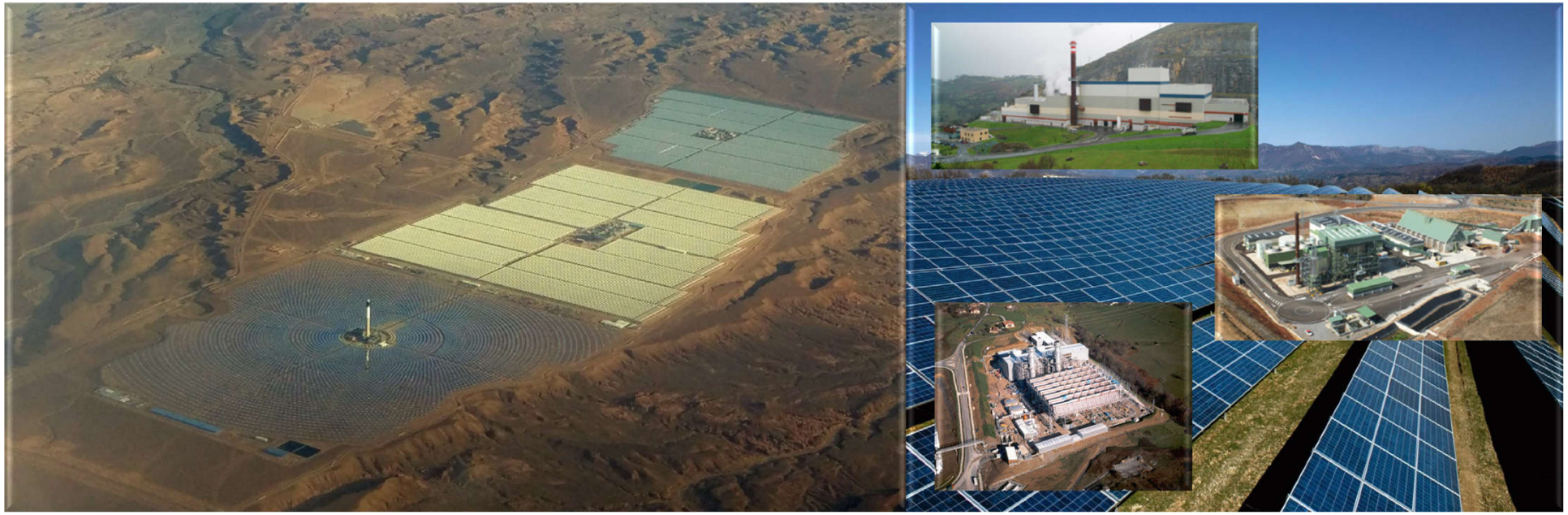
- Reduced capital cost
- Higher efficiency at smaller scale
- Amenability to dry cooling

Potential CSP Deployment in the US if DOE CSP and PV 2030 Cost Targets are Achieved





Murphy, et al. **2019**, NREL/TP-6A20-71912



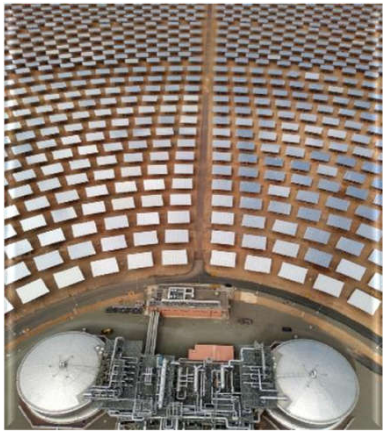
Developing Thermal and Hybrid Power in Latin America

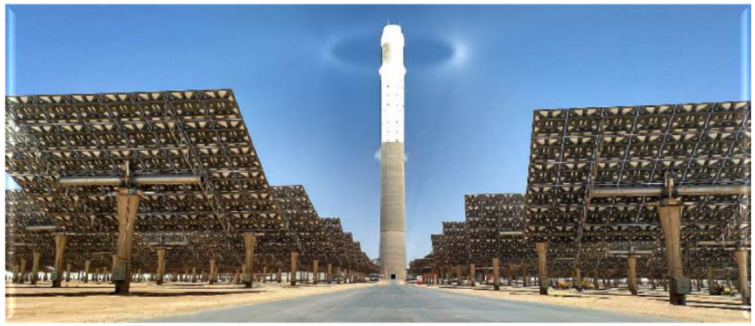
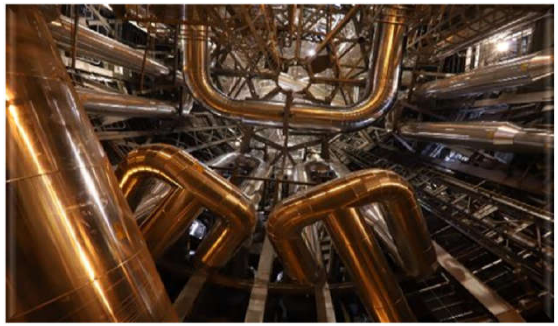
Miguel Domingo, Director of Renewables, SENER

NOOR III is ONLINE

150 MW + 7.5 hours: the LARGEST Molten Salt Power Tower in OPERATION





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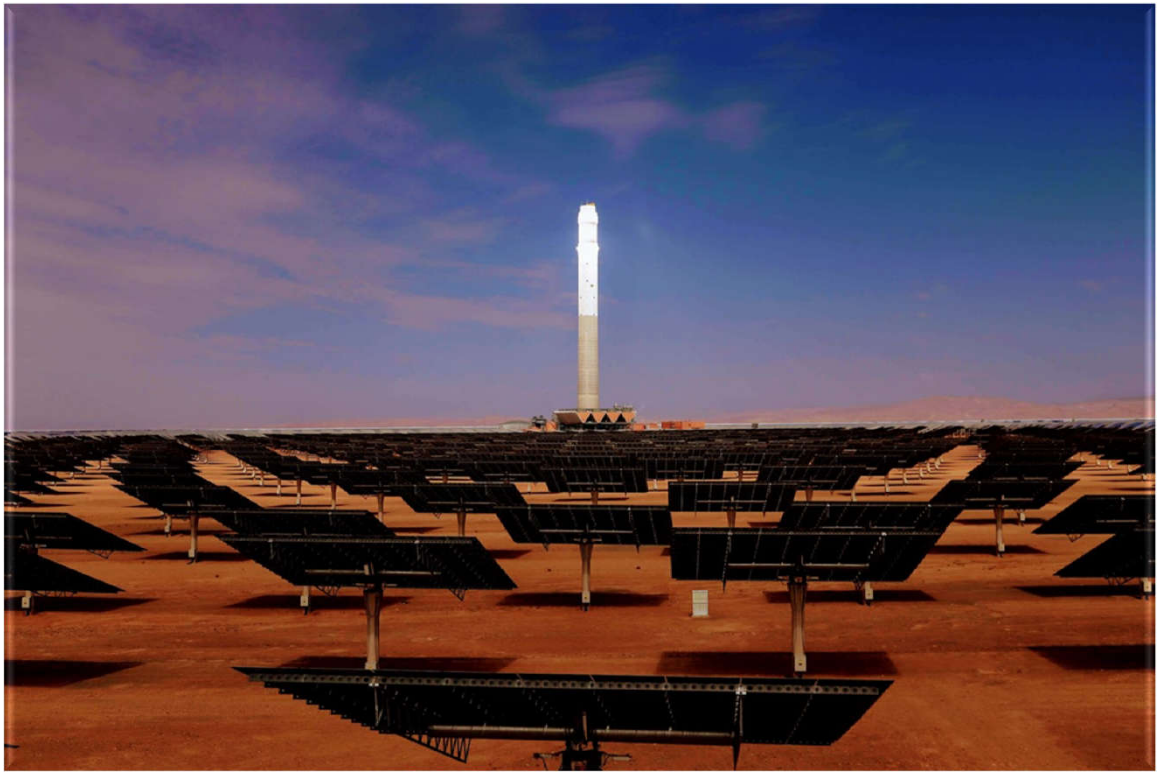


SENER ROLE

- TECHNOLOGY PROVIDER
- *50% EPC CONTRACTOR*
- O&M CONTRACTOR

MILESTONE in CSP TECHNOLOGY

- LARGEST MS TOWER PLANT in OPERATION
- UTILITY SCALE - 150 MW
- ADAPTED to PEAK DEMAND – 7.5 HOURS

PERFORMANCE FULFILLED

- *TARGET PERFORMANCE ACHIEVED in MONTH #1*
- AUTOMATIC OPERATION, DIGITALIZATION
- LESSONS LEARNED from GEMASOLAR

SENER, founded in 1956

Strategic business units

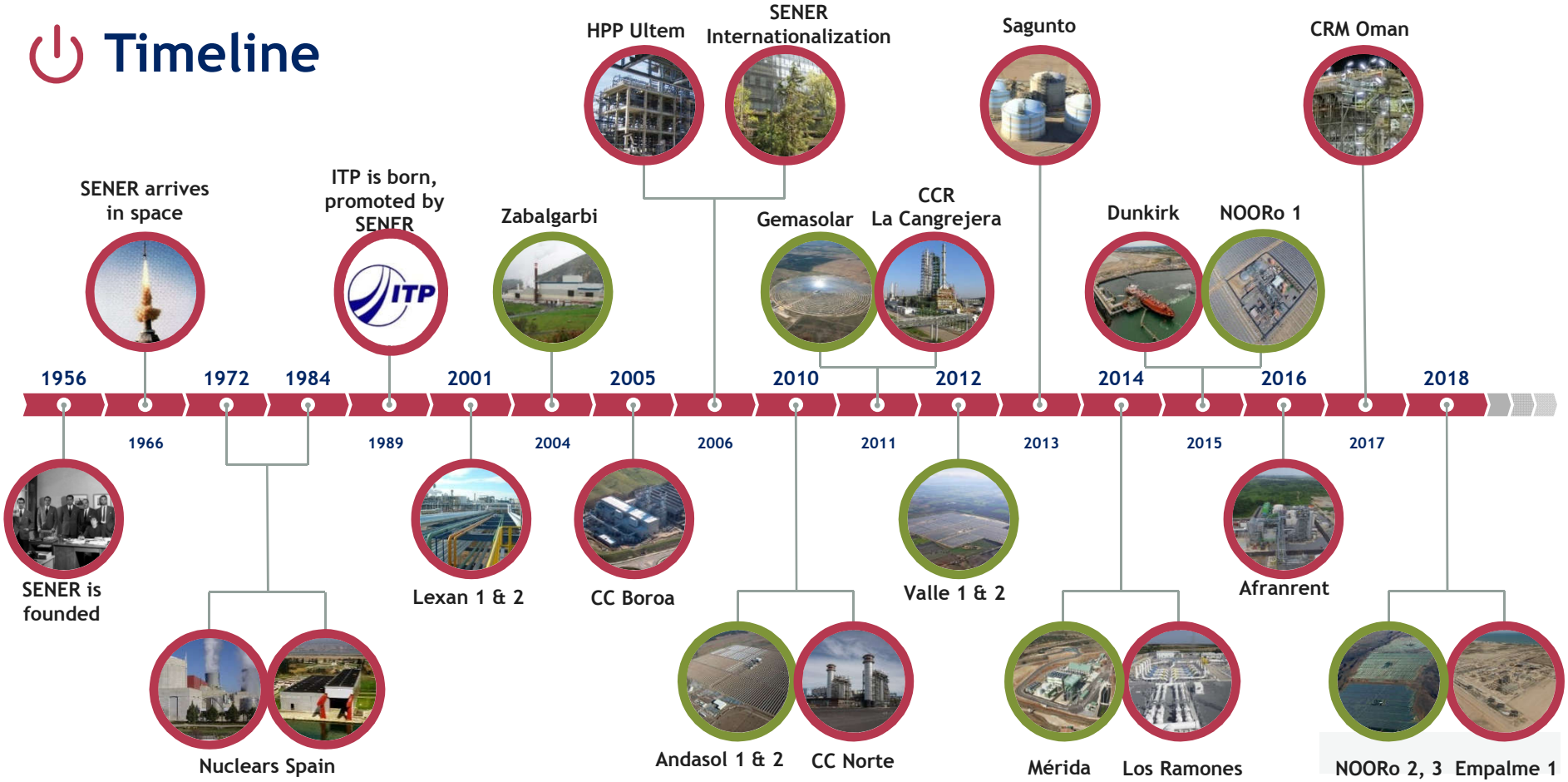
- Space
- Defense
- Aeronautics

- High speed railways
- Freight & mainline railways
- Metro systems
- LRT's & tramways
- Roads & highways
- Airports
- Ports
- Architecture
- Water & environment

- Concentrated Solar Power
- Photovoltaic
- Storage
- Biomass
- Hybrid CSP+PV, CSP+Biomass
- Offshore wind
- Waste to energy
- Power & industrial solutions
- Oil & Gas

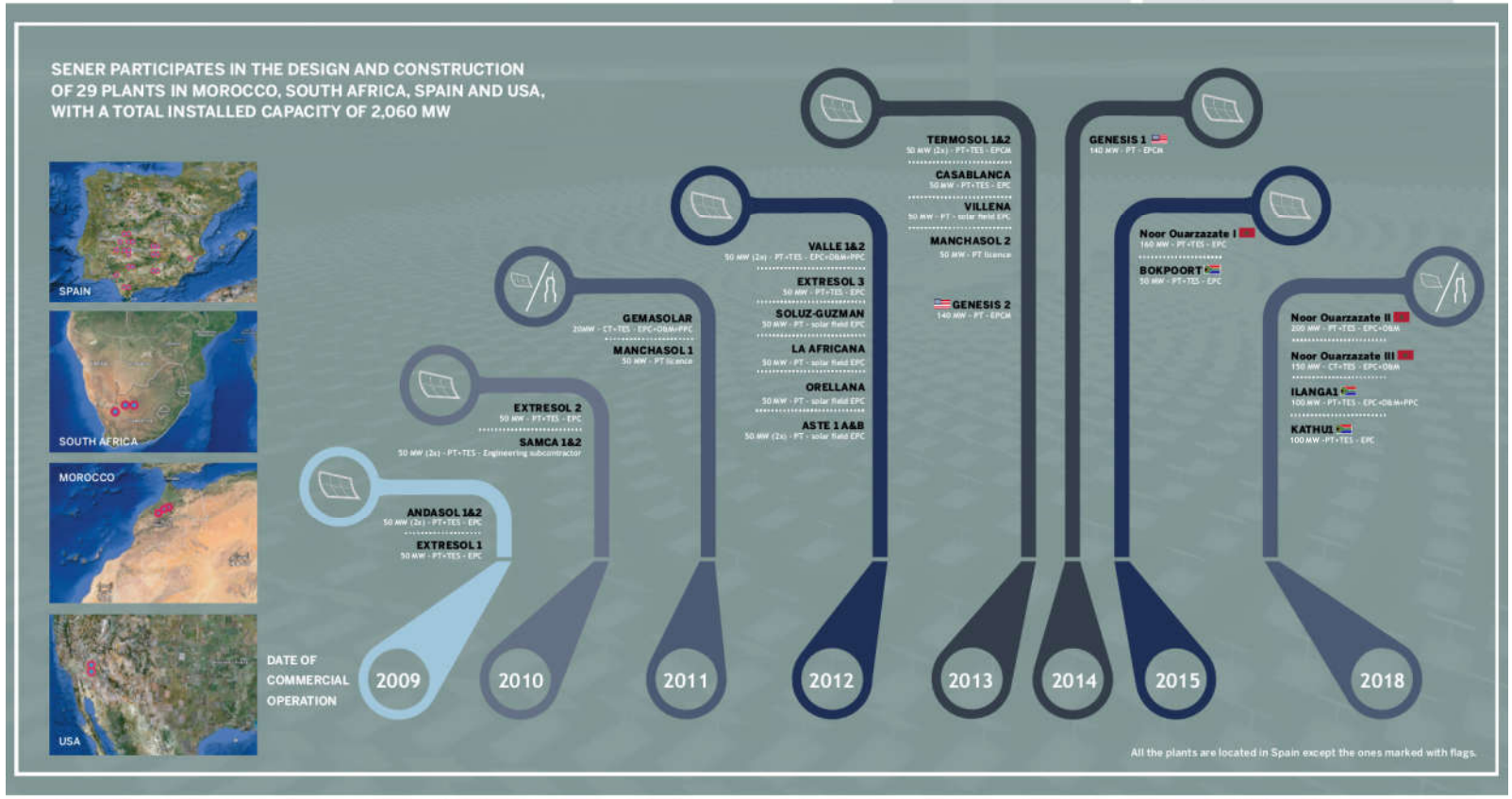
- Marine engineering
- FORAN

Timeline


HPP Ultem
SENER Internationalization
Sagunto
CRM Oman
SENER arrives in space
ITP is born, promoted by SENER
Zabalgarbi
Gemasolar
CCR La Cangrejera
Dunkirk
NOORo 1
1956
1972
1984
2001
2005
2010
2012
2014
2016
2018
1966
1989
2004
2006
2011
2013
2015
2017
SENER is founded
Lexan 1 & 2
CC Boroa
Valle 1 & 2
Afranrent
Nuclears Spain
Andasol 1 & 2
CC Norte
Mérida
Los Ramones
NOORo 2, 3
Empalme 1

SENER experience in solar thermal power (CSP)

29 PLANTS | **2,060** MW TOTAL



PT: parabolic trough technology | CT: molten salts central tower technology | TES: molten salts thermal storage system | EPC: engineering, procurement and construction | EPCM: EPC management | O&M: operation & maintenance | PPC: SENER participation in the project company

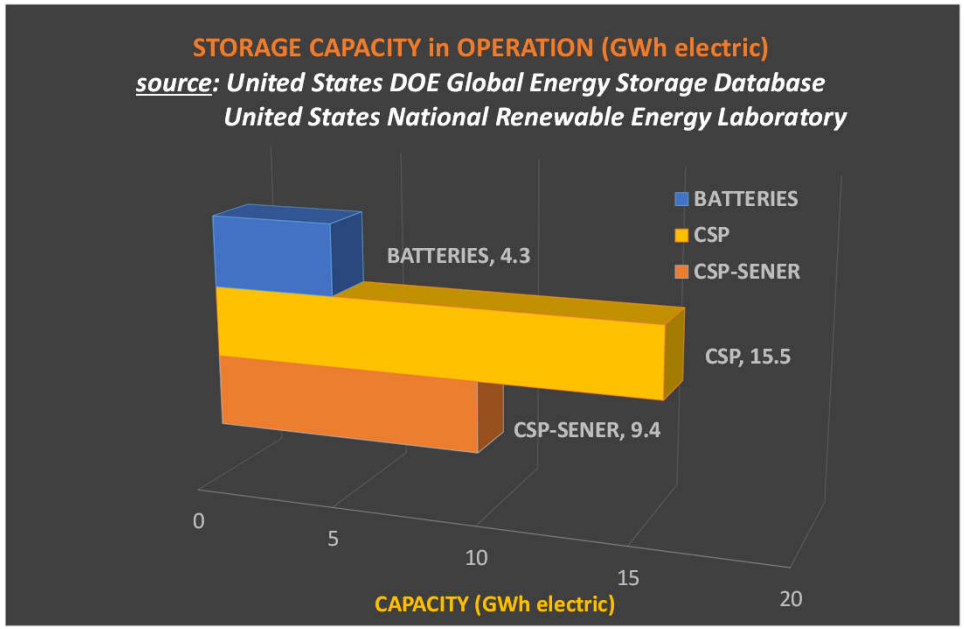
SENER experience in solar thermal power (CSP)

29 PLANTS **2,060** MW TOTAL

- ✓ **VALUE of CSP CONTRACTS** for SENER (2006-2018): >**2500 MUSD**
- ✓ **SHARE** of WORLD CSP CAPACITY (MW): **33%**

- ✓ **STORAGE development:**

SENER is the company most involved in MOLTEN SALT STORAGE TECHNOLOGY



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