SFERA-III

Solar Facilities for the European Research Area

1st Summer School "Thermal energy storage systems, solar fields and new cycles for future CSP plants"
WP1 Capacity building and training activities
Odeillo, France, September 9th-11th 2019

"The CSP technologies: market status and opportunities for R&D"

Alain FERRIERE, CNRS-PROMES

NETWORKING

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“The CSP technologies: market status and opportunities for R&D”

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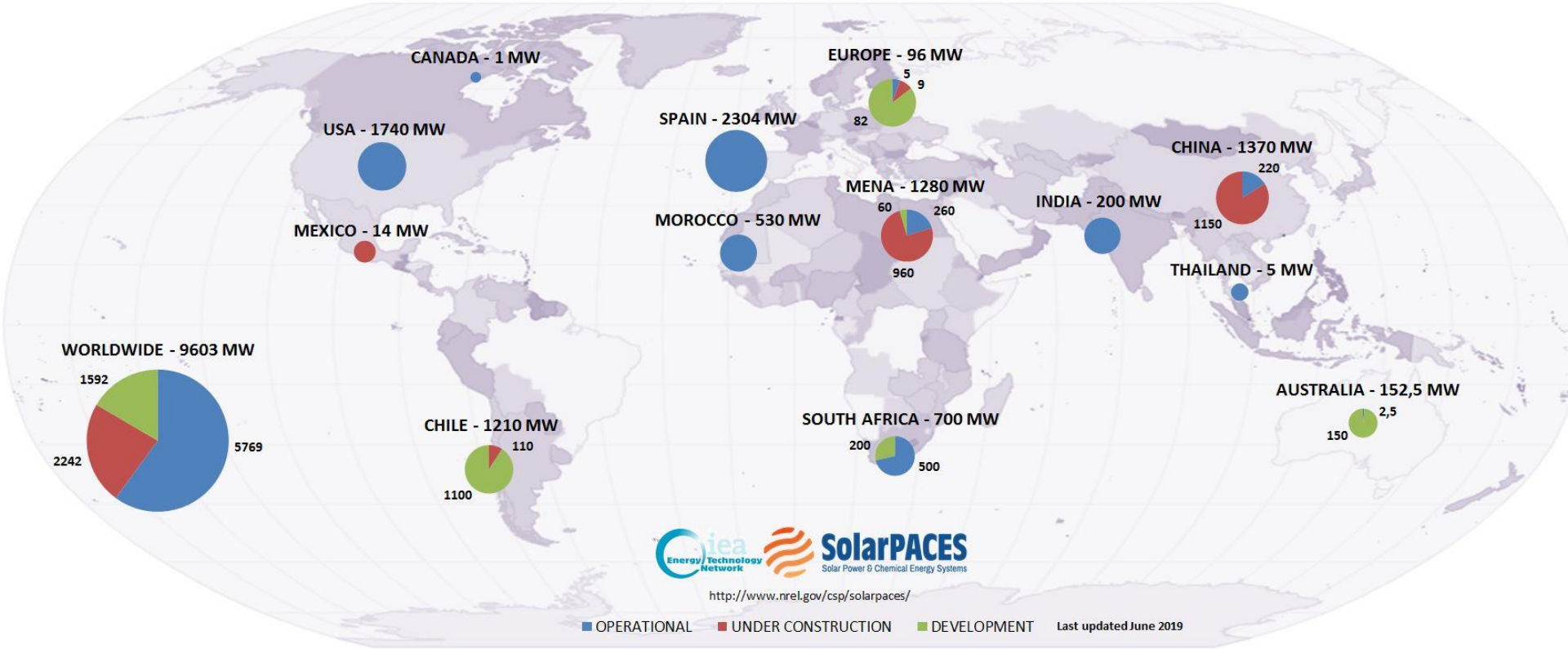
Resources for Electricity Generation

Worldwide electricity generation

66,3%
Share of fossil energy into worldwide electricity mix

Source: www.connaissancedesenergies.org

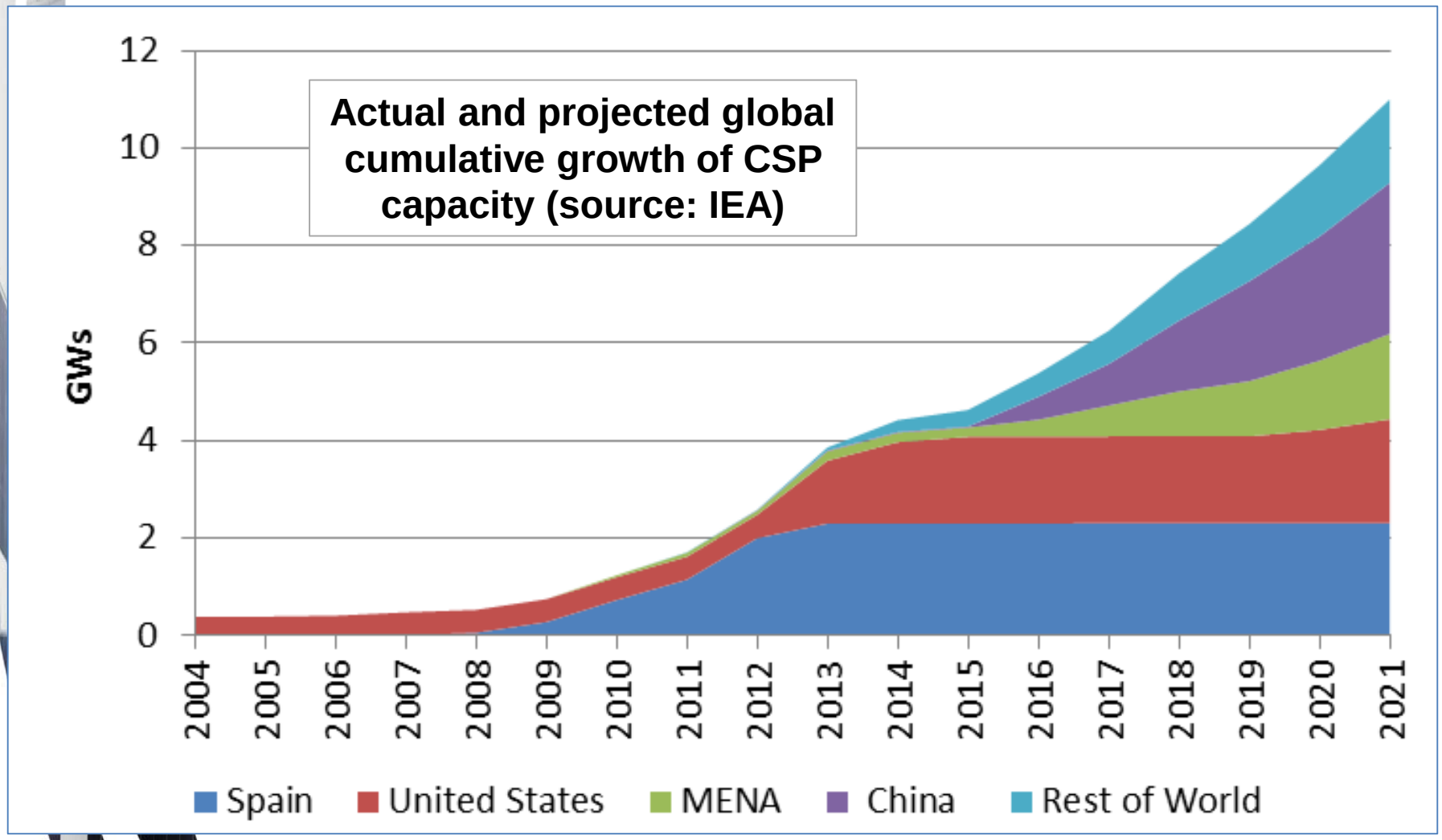
Worldwide CSP Market



Total capacity in operation (2019): 5769 MW

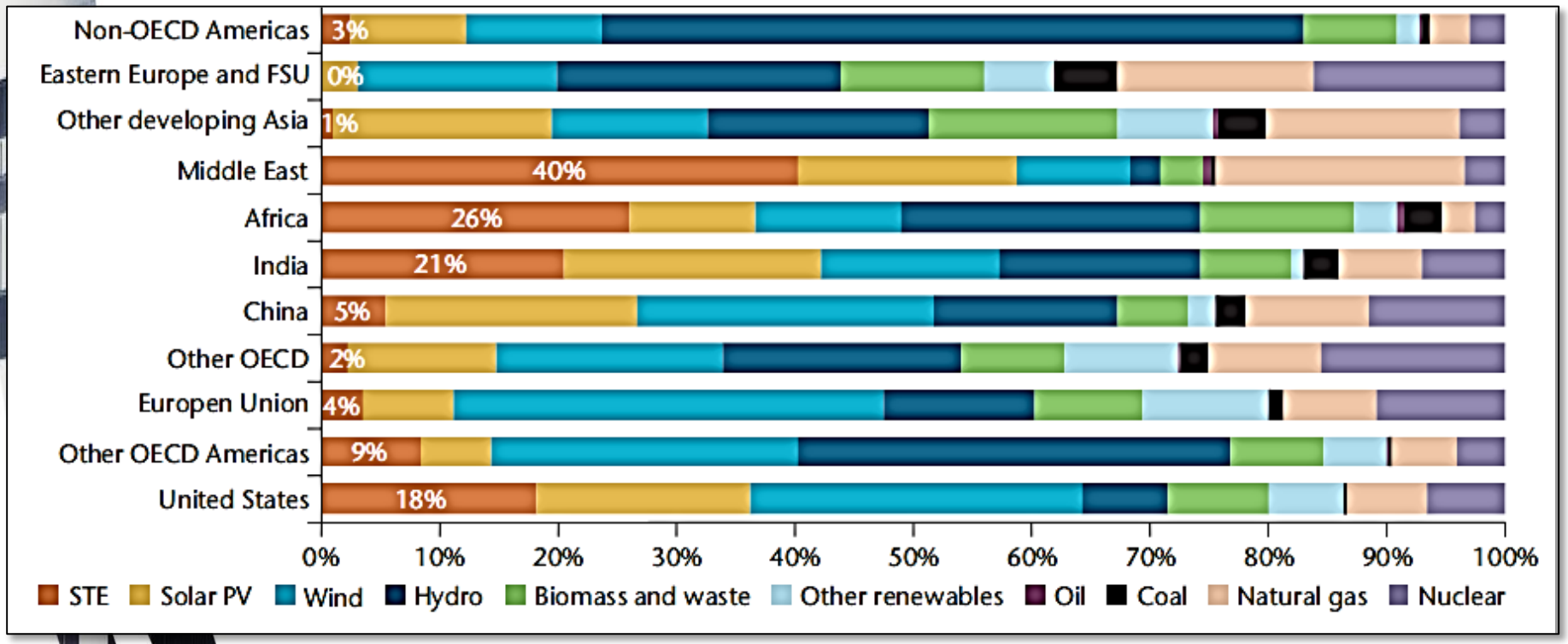
In construction: 2242 MW

Near-term deployment of CSP



IEA 2050 Roadmap

According to the forecasts of the International Energy Agency (IEA), CSP could account for up to **11% of the electricity generated worldwide** and up to **4% of the electricity generated in Europe** by 2050.

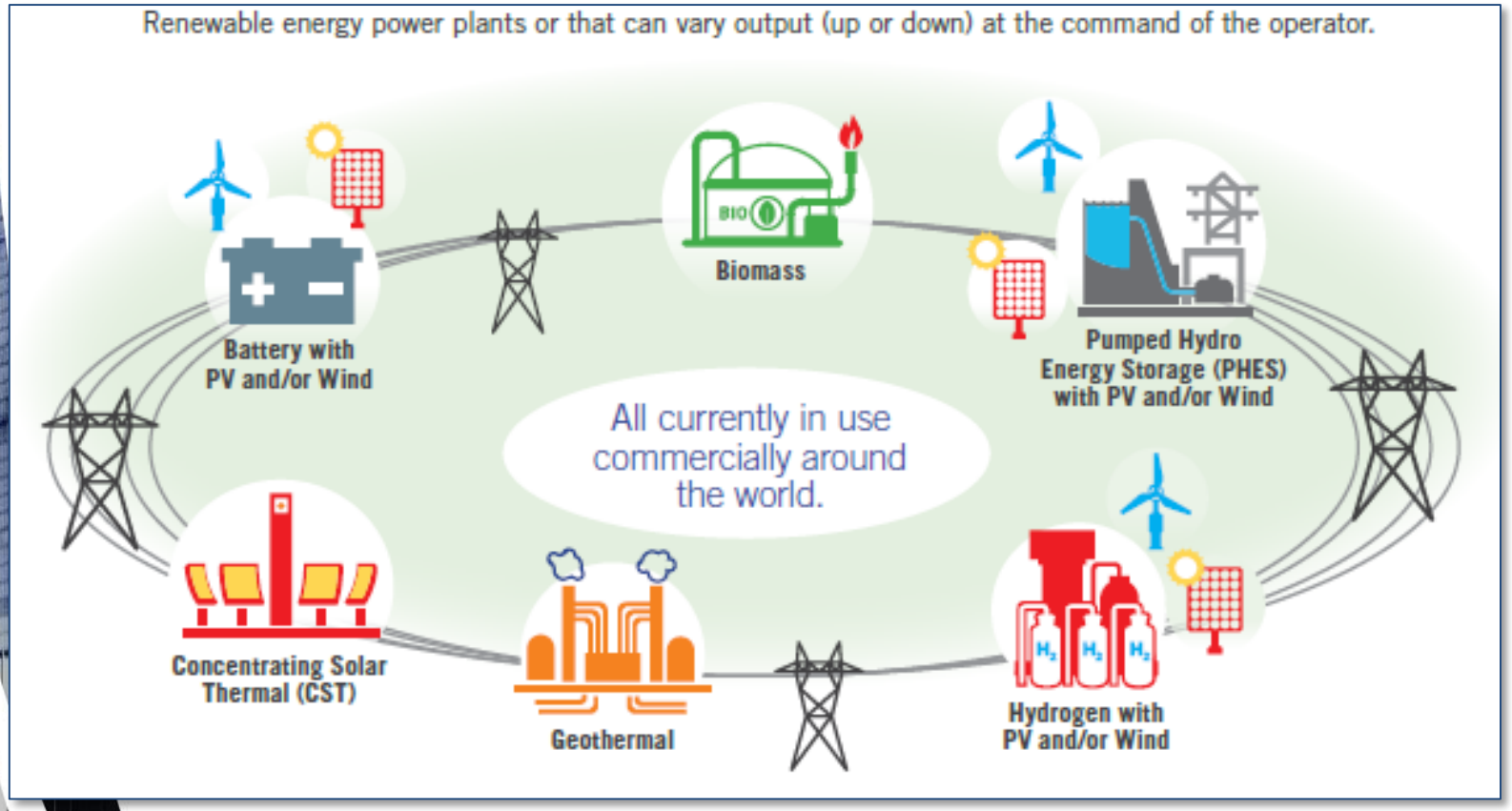


LCOE for CSP

Figure 4.10 Levelised cost of electricity and auction price trends for CSP, 2010-2022

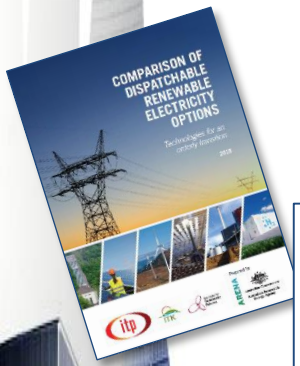
Note: Each bubble represents a renewable energy project. The center of the bubble is the winning bid price in that year.
Source: IRENA Renewable Cost Database and Auctions Database.

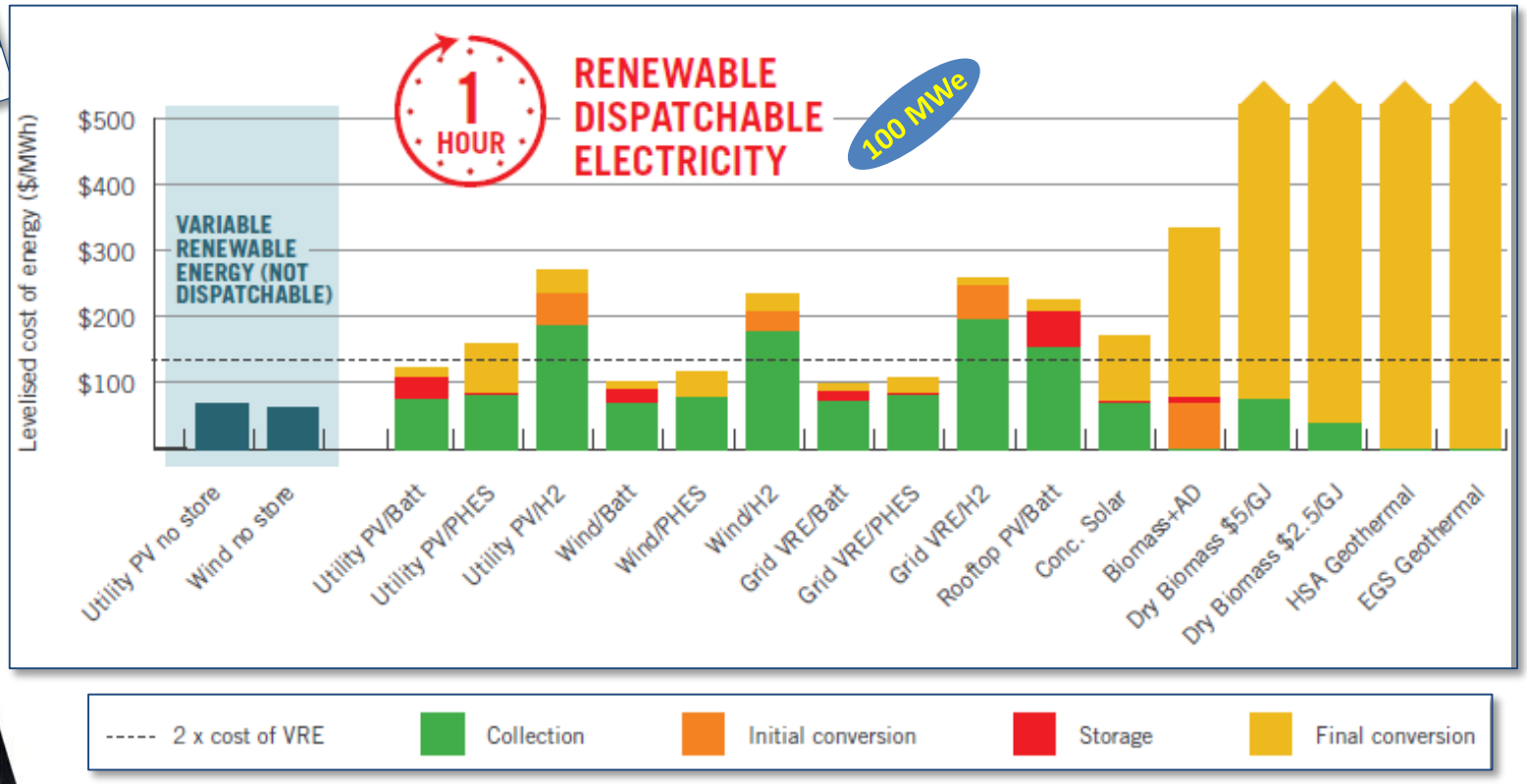
Dispatchable Renewable Electricity



Source: Comparison of Dispatchable Renewable Electricity Options, ARENA-ITP, 2018

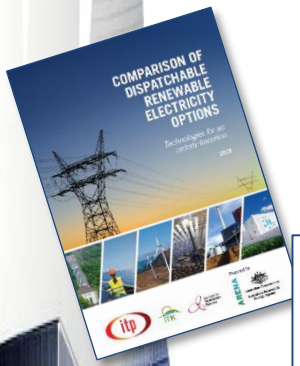
Dispatchable Renewable Electricity

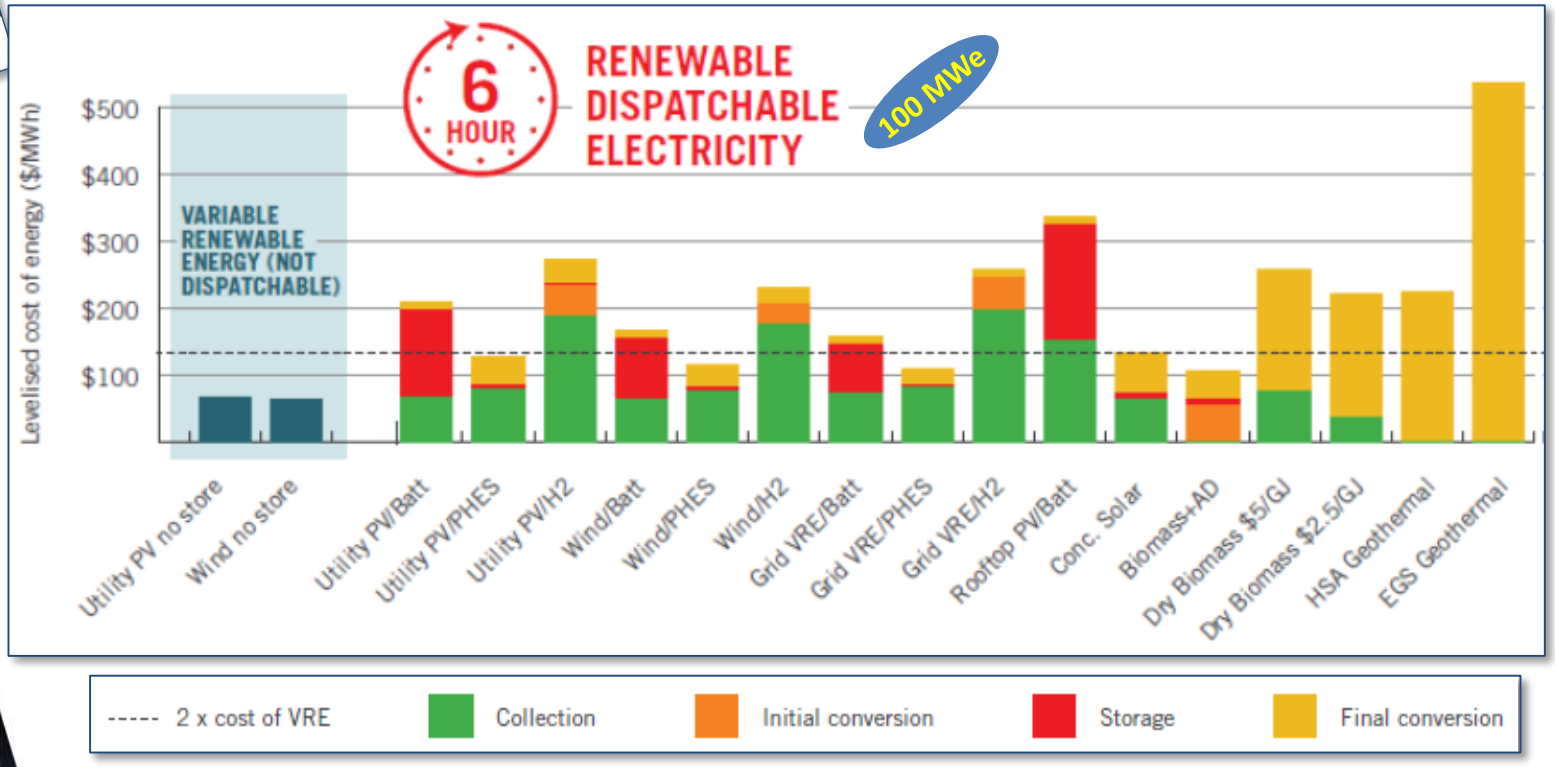




Source: ARENA-ITP, 2018

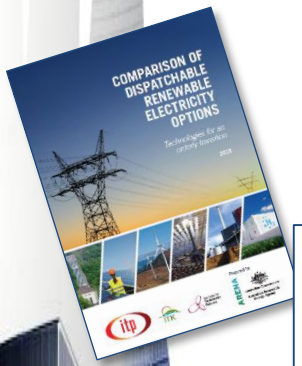
Dispatchable Renewable Electricity

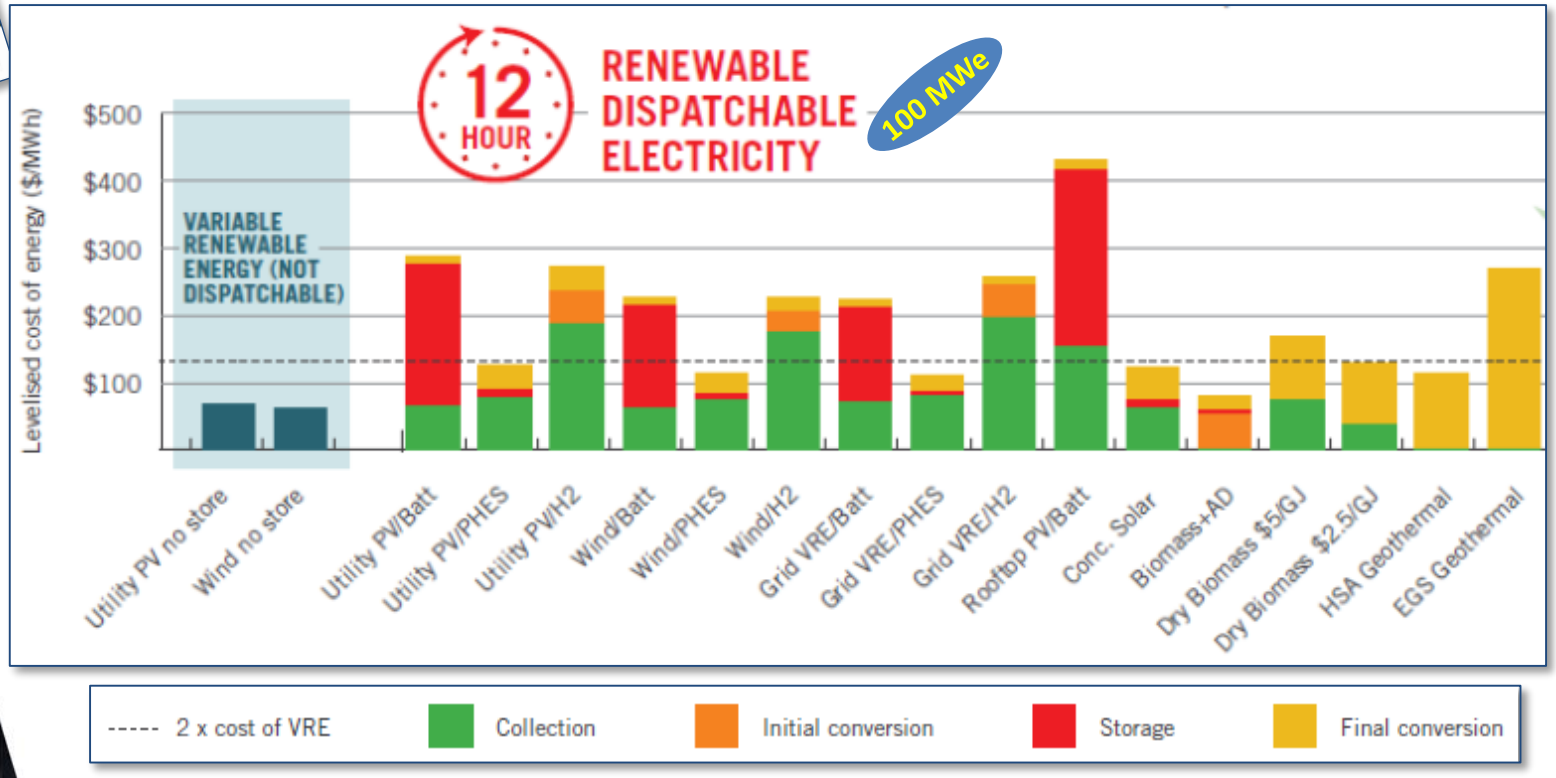




Source: ARENA-ITP, 2018

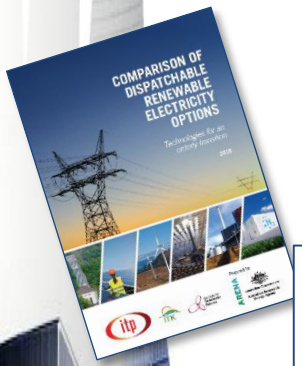
Dispatchable Renewable Electricity

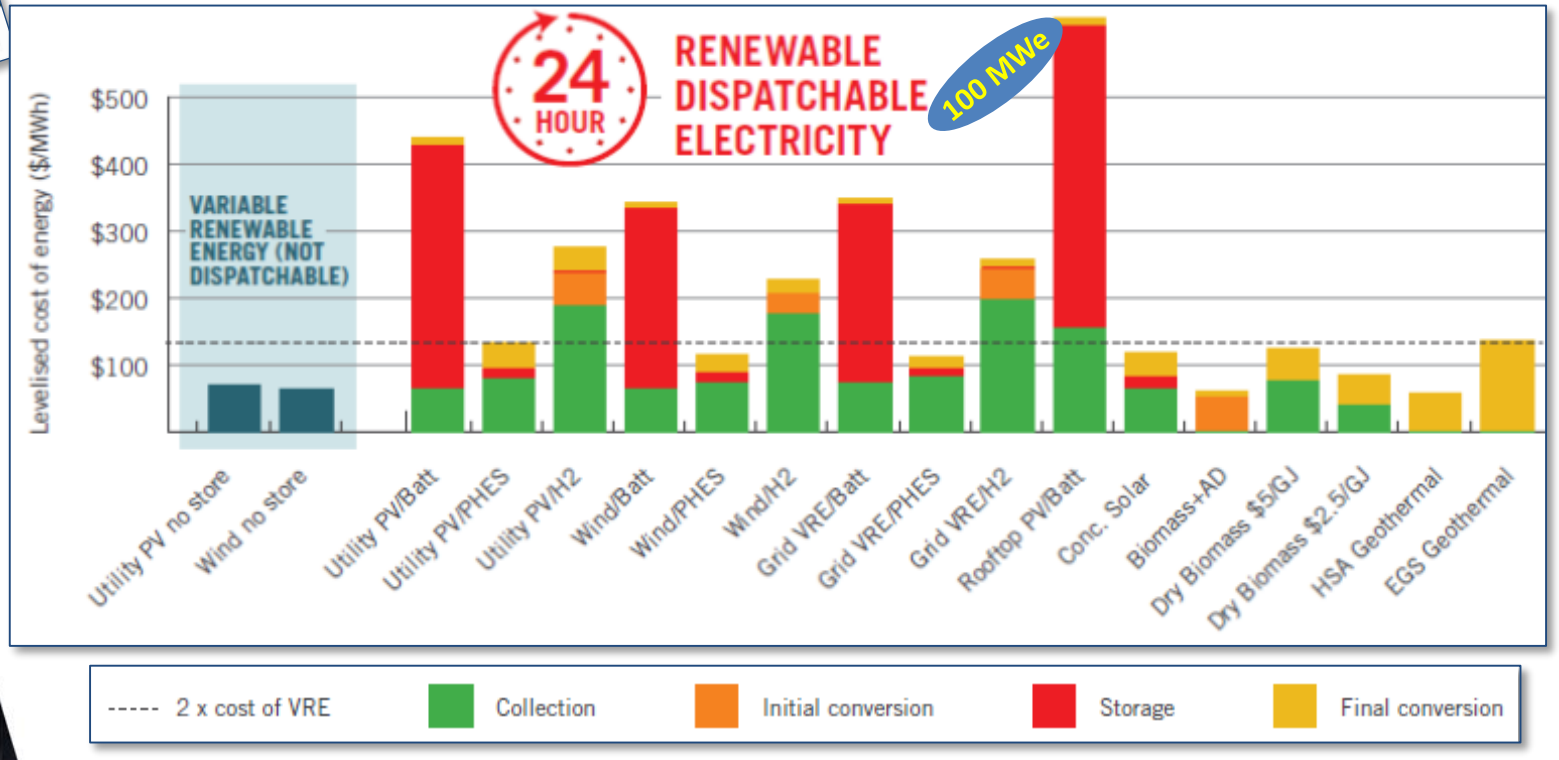




Source: ARENA-ITP, 2018

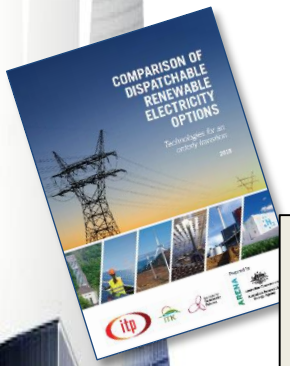
Dispatchable Renewable Electricity





Source: ARENA-ITP, 2018

Dispatchable Renewable Electricity

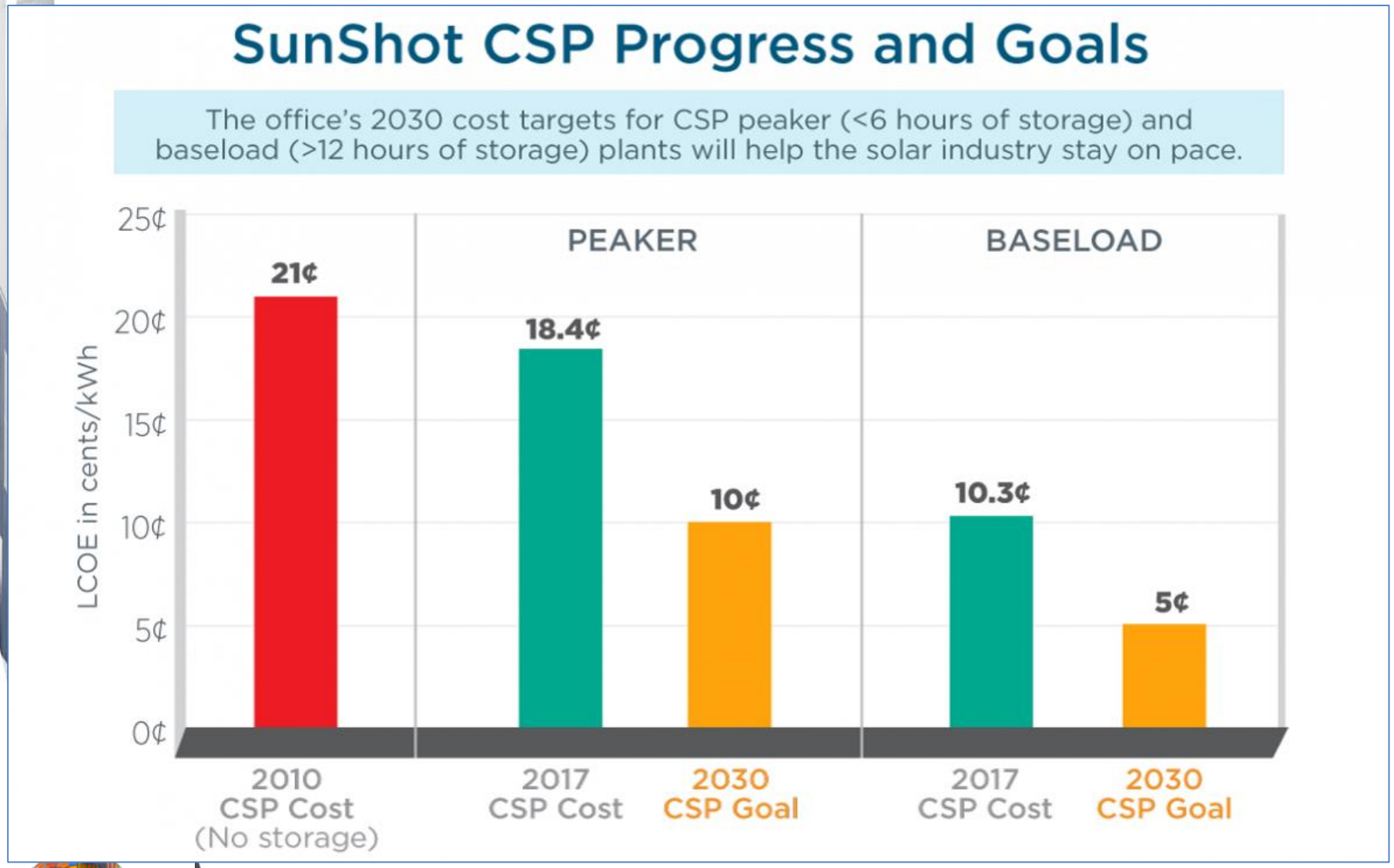


Concentrating Solar Power

- **CSP competitive >6hrs storage**
- **high LCOE** for **short** durations of storage (<3 hrs) reflects the relatively **high installed cost** of **power** related components
- **lower LCOEs** for **longer** durations (>6hrs) reflect the **low cost per stored energy** of the **molten salt** system
- **Minimum LCOE** in the range **15 - 20 hrs** of storage
- CSP with **less storage** may be preferred to target generation in **peak** periods
- CSP with **molten salt** storage has been applied commercially since 2006
  - ✓ **growth rate** of deployment **~40%/year**
  - ✓ high potential for **cost reduction**

Source: ARENA-ITP, 2018

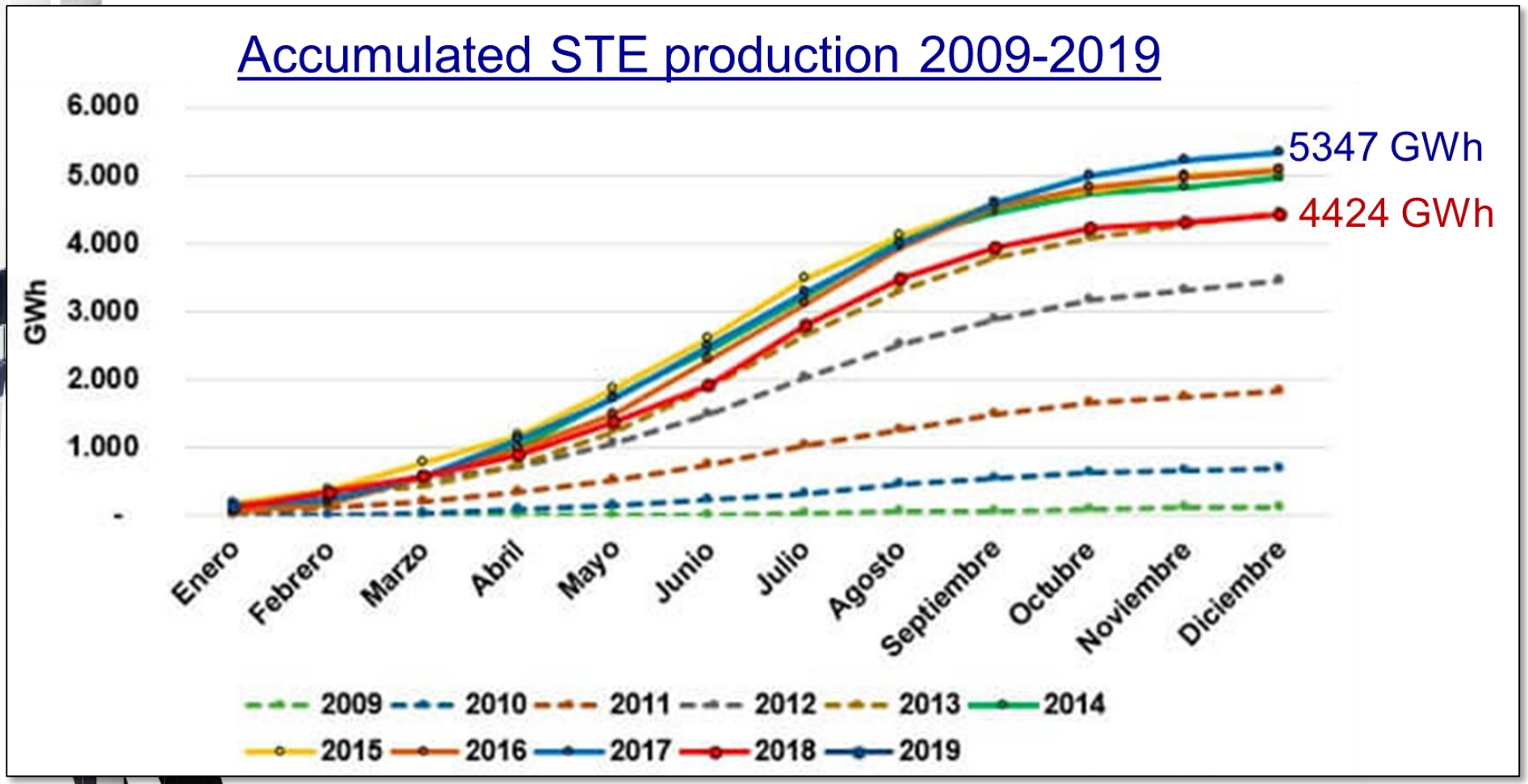
Cost perspective



Trends

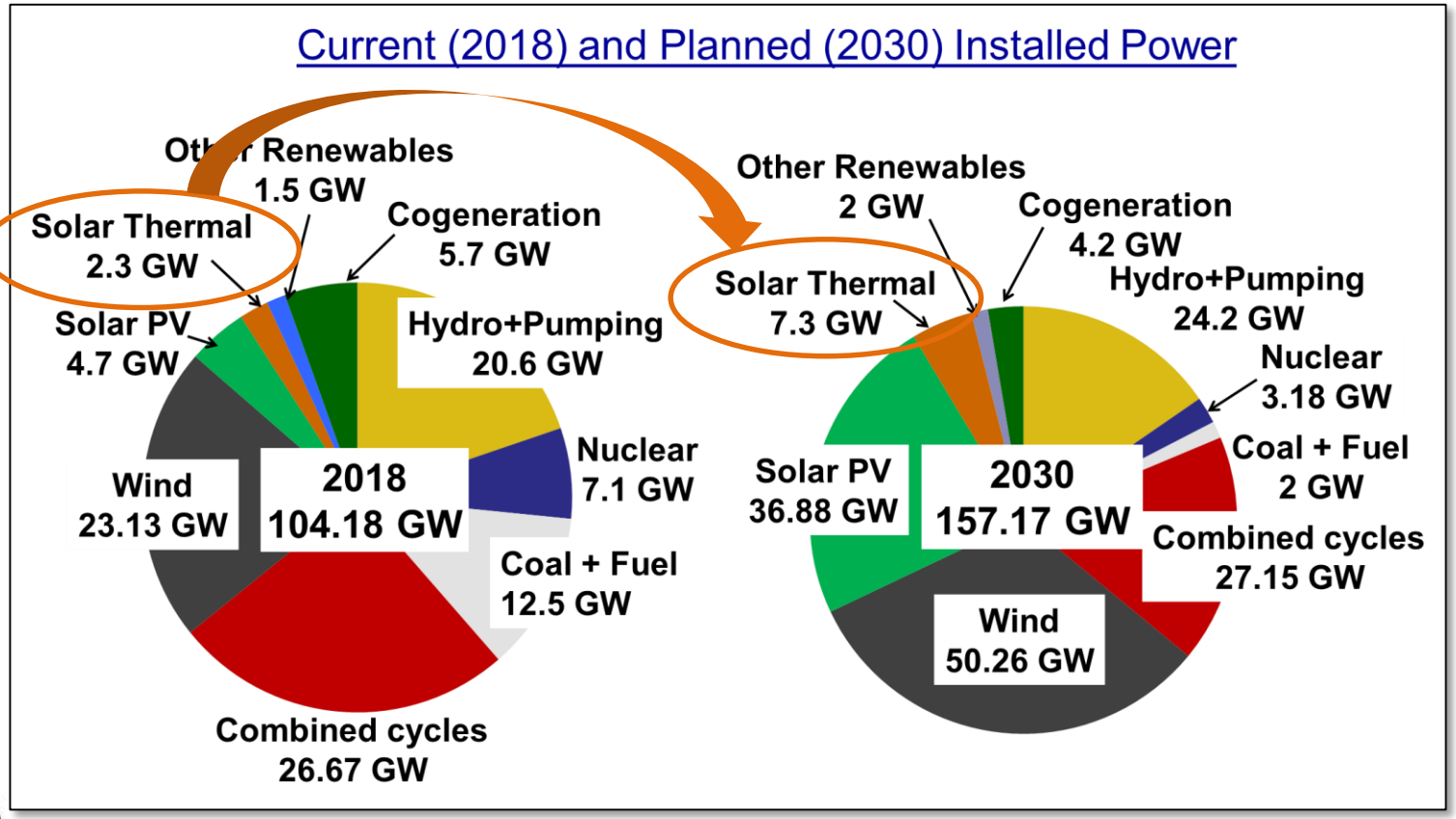
- **CSP roadmaps** released in several countries with high solar resource
- **Projects development** supported by public incentives (Feed-in tariffs)
- **Implementation plans in USA and in EU** to support market penetration by US and EU industries
- Market present in USA, competition with PV
- Limited market in EU, need for firm Ren power

CSP performs very well in Spain



Source: E. Zarza, SolarPACES ExCO #96, 2019

Expected growth in Spain



Integrated National Plan for Energy and Climate (PNIEC) 2021-2030 (02/2019)

- ✓ 74% of electricity will be produced with renewable energies
- ✓ 42% of overall energy consumption will be supplied by renewable energy
- ✓ A total investment of 236.124 M€ will be required between 2021 and 2030 (80% private and 20% public) to achieve the proposed objectives
- ✓ 363.000 new jobs will be created

Source: E. Zarza, SolarPACES ExCO #96, 2019

CSP in Morocco

2000 MW solar in 2020 (14% of total capacity), REn = 42% of energy mix

NOOR$_O$ III
CSP TOWER

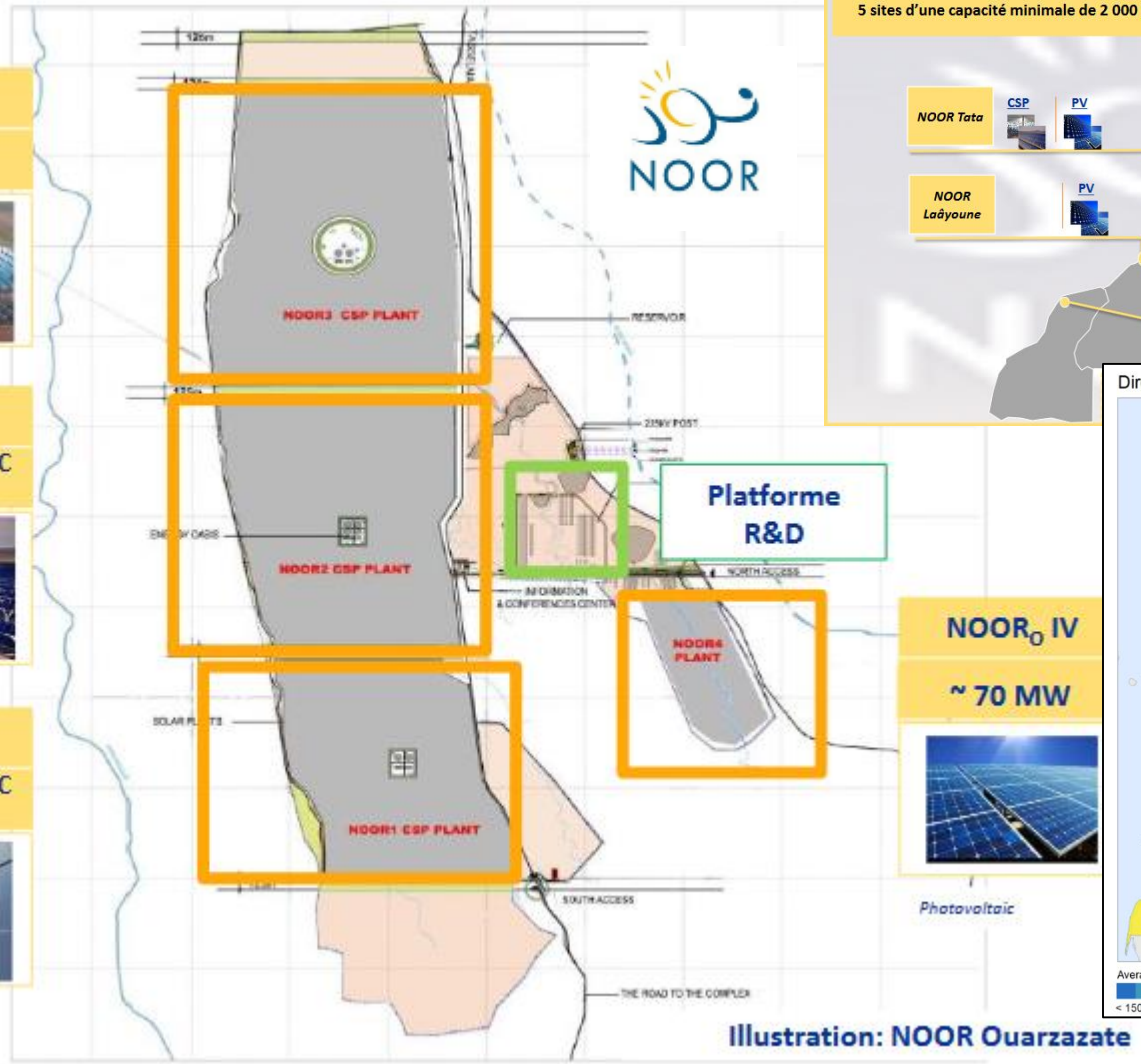
150 MW

NOOR$_O$ II
CSP PARABOLIC TROUGH

200 MW

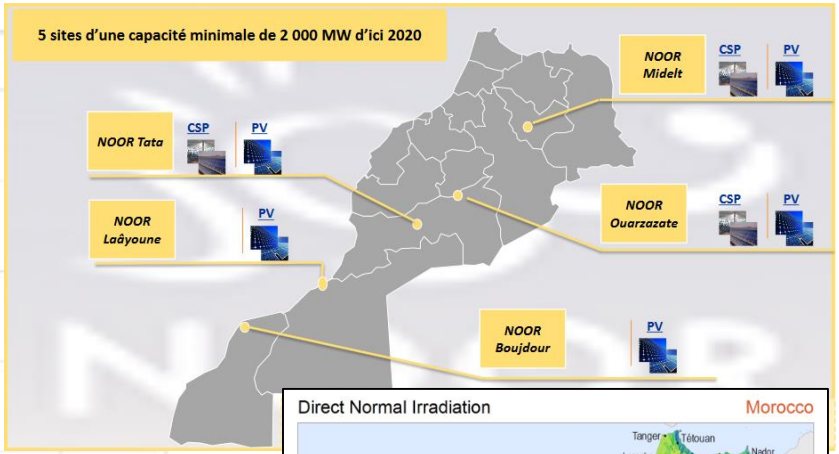
NOOR$_O$ I
CSP PARABOLIC TROUGH

160 MW



NOOR$_O$ IV
~ 70 MW

Photovoltaic



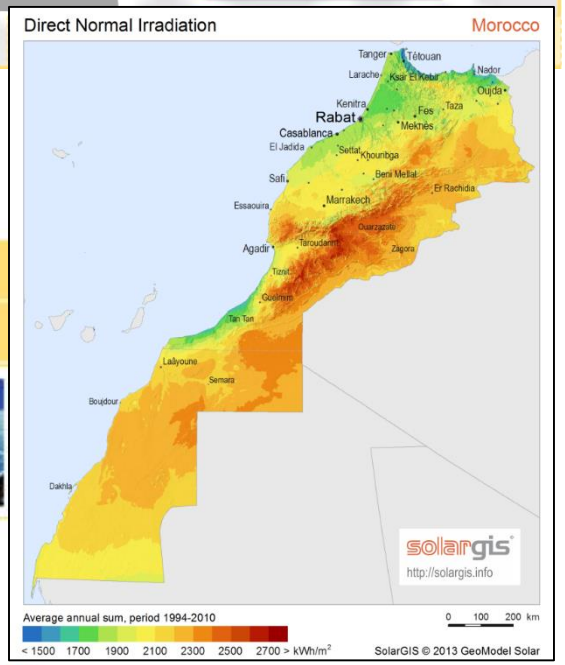
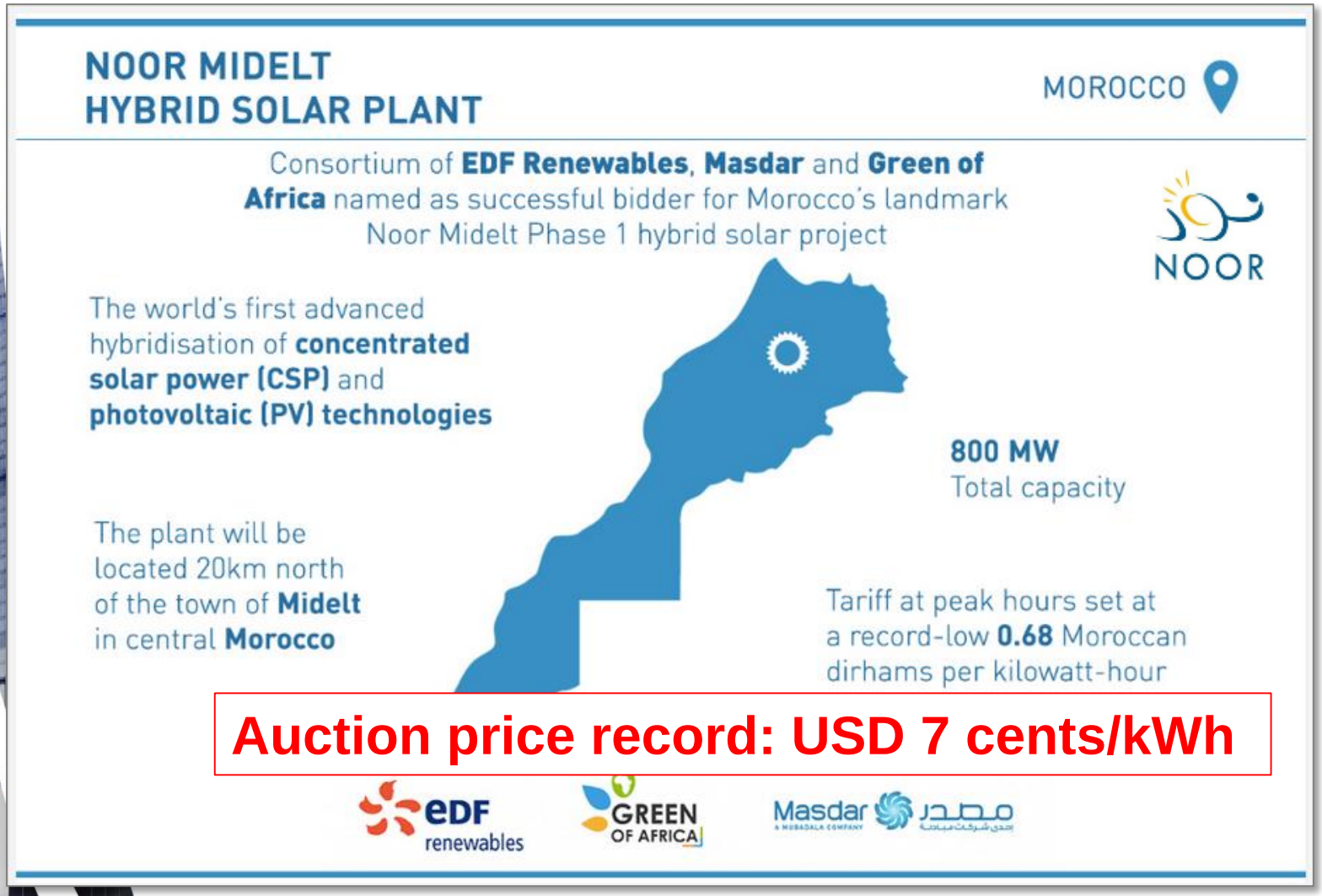


Illustration: NOOR Ouarzazate

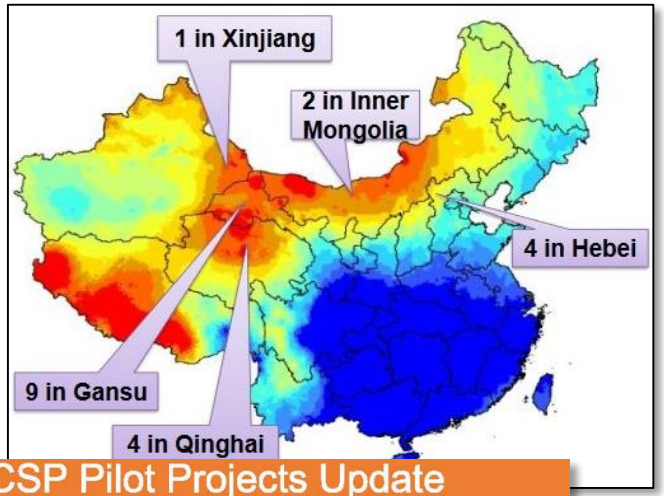
Morocco's 800 MW CSP-PV Noor Midelt

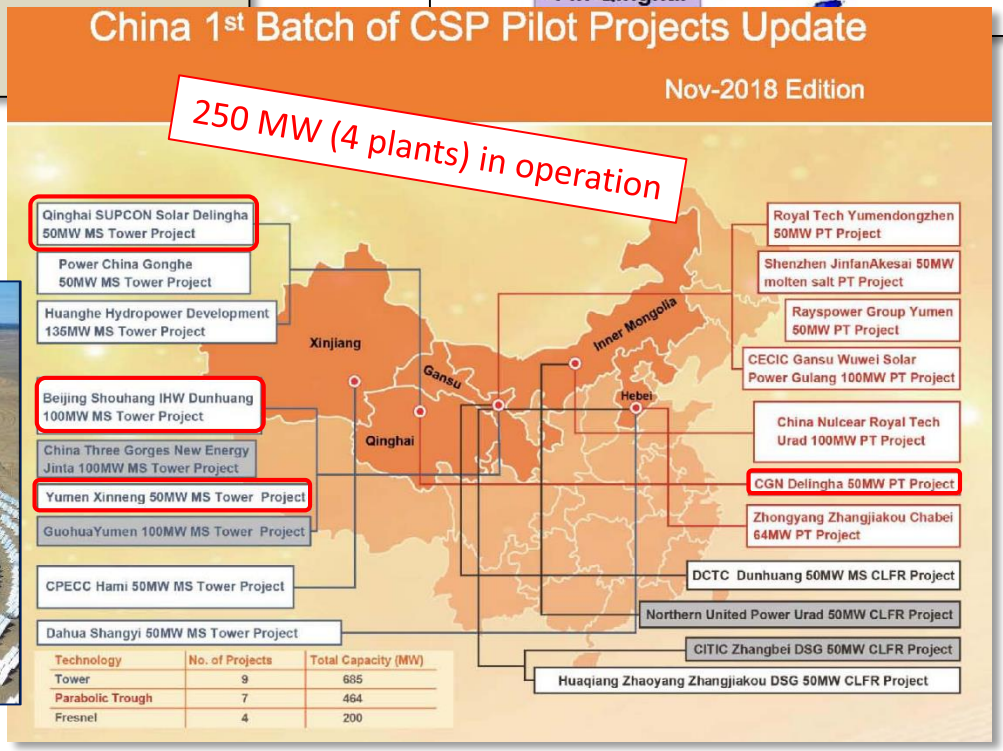


Courtesy of MASEN

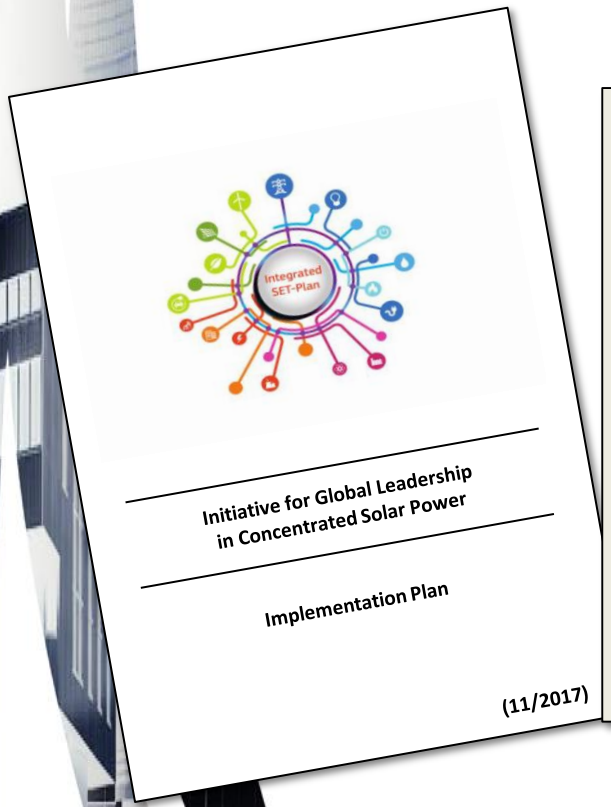
CSP in China

- **5 GW** total CSP in **2020**
- **2016-2019: 1,35 GW, 20 projects**, all with **thermal storage** (min 4h, max 10h)
  - 7 molten salt towers (50-100 MW)
  - 2 DSG towers (50 MW, 135 MW)
  - 5 oil PT (50-100 MW)
  - 2 molten salt PT(50 MW, 64 MW)
  - 4 Linear Fresnel (50 MW)
- **Tariff: 0,15 €/kWh**



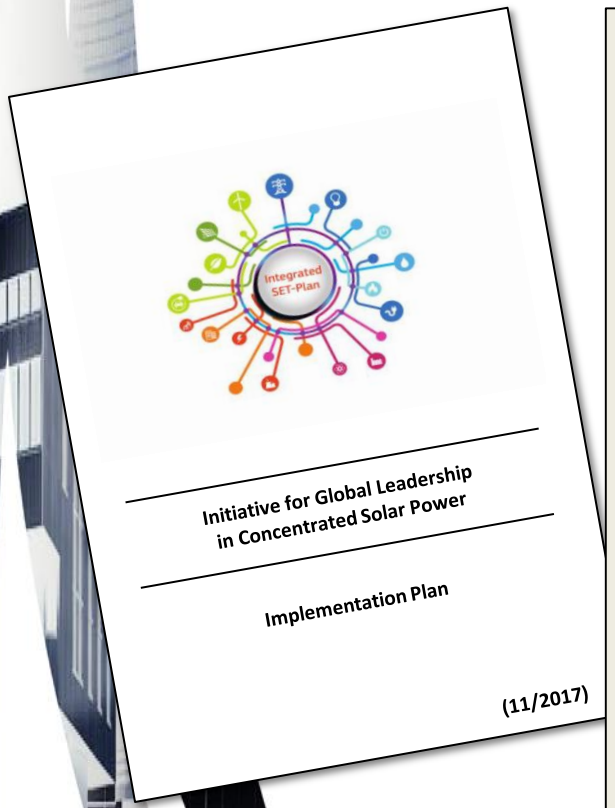


Sustainable Energy Technologies SET Plan



- By means of **thermal energy storage**, CSP can make a significant contribution to the transformation of the European energy system by providing an important share of **dispatchable renewable electricity**.
- By providing **flexibility for grid services**, CSP can facilitate the **integration of variable output renewables** such as photovoltaic (PV) or wind energy, thereby contributing to the **reliability of the transmission grid**.

Sustainable Energy Technologies SET Plan



- There is a clear **market failure in Europe** to bring new CSP technologies to the market
- **CSP innovation** needs to be reactivated
- **Reduce costs**
  - ✓ technology improvements
  - ✓ volumes deployed
  - ✓ risk-financing to support innovation projects
- **First-of-a-kind demonstration** projects
- Subsequent **market deployment**
  - ✓ ability to supply dispatchable electricity generated by CSP plants from Southern Europe to Central/Northern Europe
  - ✓ facilitating CSP access to **new markets**

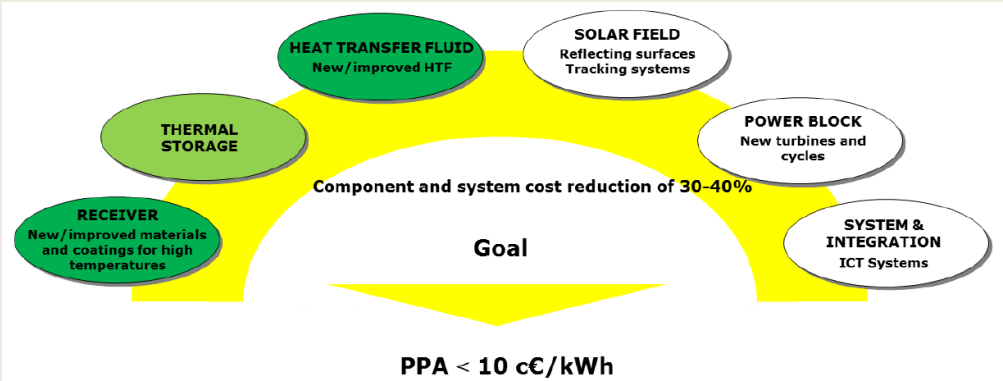
Sustainable Energy Technologies SET Plan

Strategic Targets on CSP

Short term target

Cost reduction: PPA price **< 10 c€/kWh** for a radiation of 2050 kWh/m2/year (conditions in Southern Europe)

→ 40% cost reduction by 2020 (from 2013)



Longer term target

Develop the **next generation of CSP technology: new cycles** (sCO_2 & Supercritical Steam)

→ first demonstrator by 2020

→ achieve additional **cost reductions**

→ open **new business opportunities**

Sustainable Energy Technologies SET Plan

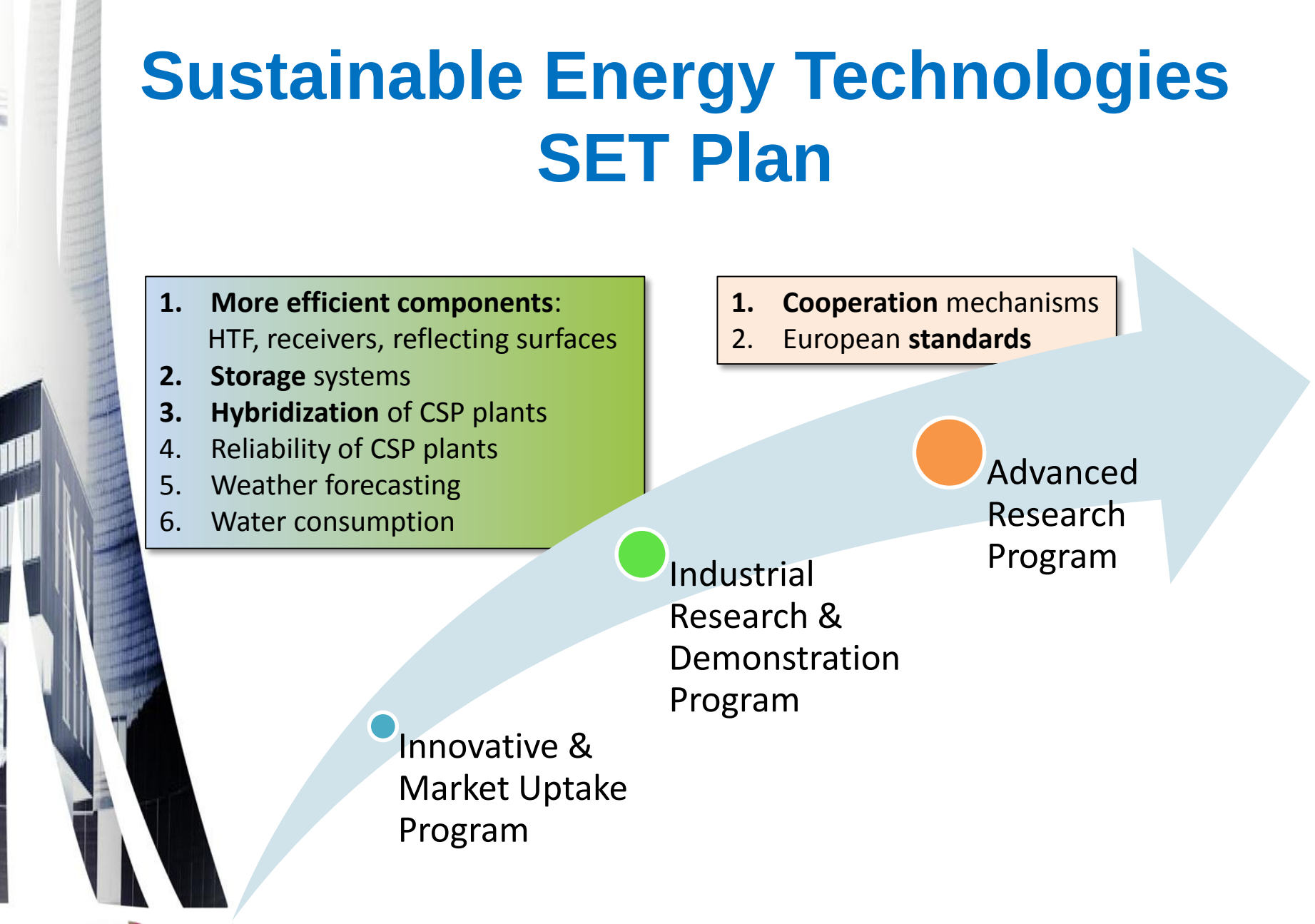
R&I Activities to reach the targets

1. Improved central receiver molten salt technology
2. Parabolic trough with silicon oil
3. Next generation of central receiver power plants
4. Advanced linear concentrator Fresnel technology with direct molten salt circulation as heat transfer fluid and for high temperature thermal energy storage
5. Parabolic trough with molten salt
6. Solar tower power plant to commercially scale-up and optimize the core components of the open volumetric air receiver technology
7. Multi-tower central receiver beam down system
8. Thermal energy storage
9. Development of supercritical steam turbines optimized for CSP applications
10. Development of advanced concepts for improved flexibility in CSP applications
11. Development and field test of CSP hybrid air Brayton turbine combined cycle sCO2 systems
12. Pressurized air cycles for high efficiency solar thermal power plants

Sustainable Energy Technologies SET Plan

1. **More efficient components**: HTF, receivers, reflecting surfaces
2. **Storage** systems
3. **Hybridization** of CSP plants
4. Reliability of CSP plants
5. Weather forecasting
6. Water consumption

1. **Cooperation** mechanisms
2. European **standards**



EU Work Program

Secure Clean and Efficient Energy: active calls

Reduce the cost and increase performance and reliability of CSP plants

Deadline: 11 December 2019

The proposals will demonstrate innovations that **reduce the cost and/or increase the performance and/or the reliability of CSP plants**, in relation to any of the plant subsystems.

Proposals are expected to bring the solutions to **TRL 6-8**

Efficient combination of Concentrated Solar Power and desalination (with particular focus on the Gulf Cooperation Council region)

Deadline: 01 September 2020

Support will be given to demonstrate efficient solutions that **couple the thermal cycle of a CSP plant to a water desalination system**.

The proposals are expected to bring technologies to **TRL 6**.

International cooperation is encouraged, in particular with Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.

Solar Energy in Industrial Processes

Deadline: 27 August 2019

The potential of applying **solar energy for industrial purposes** is still largely untapped. Using solar energy to provide the heat or cooling necessary to industrial processes that need high reliability and high quality **heat and cooling and continuous operation** requires innovative advances in solar energy technology. Also, industrial processes might need to be adapted to the use of the solar resource. Industrial actors expect solutions with limited installation, maintenance and operation requirements and which are **easy to operate**. This challenge is also in line with the roadmap of the SPIRE cPPP.

Support will be given to solutions that cover by means of solar thermal energy the highest possible share of the heating and/or cooling demand of one or more industrial processes. In the case of heating, the **process temperature** shall be **higher than 150°C**.

Proposals are expected to bring the technologies to **TRL 4-5**

EU Work Program

Secure Clean and Efficient Energy: active calls

Integrated solutions for flexible operation of fossil fuel power plants through power-to-X-to-power and/or energy storage

Deadline: 27 August 2019

With a **growing share** of energy produced from **renewable resources**, **fossil fuel power plants** will have to increasingly shift their role from providing base-load power to providing fluctuating back-up power (i.e. **ramping up and down**) in order to **control and stabilize the grid**. Severe ramping up and down can be limited through load-levelling i.e. **storing power during periods of light loading** on the system and **delivering** it during periods of **high demand**.
Validation and pilot demonstration of the integration of **energy storage and/or use of excess energy** (including via power-to-X-to-power) in fossil fuel power plants.
Proposals are expected to bring technologies to **TRL 6-7**

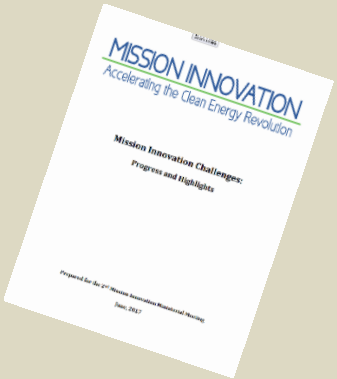
Converting Sunlight to storable chemical energy

Deadline: 27 August 2019

To replace fossil energy with sustainable alternatives that provide the same flexibility and convenience of use, we need **to store sustainable energy on a large scale and for a long time** in new kind of energy storage compounds.
Proposals are expected to address renewable energy technologies that will answer the challenge described in the "Converting Sunlight Innovation Challenge" of Mission Innovation,
bringing them up to **TRL 4 or 5**. At least one of the following technology-specific challenges has to be addressed:

- Improved light-harvesting and efficient charge separation in photocatalytic systems;
- Photoelectrochemical cells – PECs and catalyst development;
- **Thermochemical pathways to energy rich chemicals (using concentrated solar light)**
- Design and engineering of devices, systems or prototypes integrating together the different processes, with day and night control and applicability for the production of chemical energy rich carriers.

The area of **electrolysers** efficiently utilizing a renewable electricity input, such as provided by photovoltaics, wind turbines or other sustainable means, is **not covered** by this challenge.



R&D: Programme Gen3 US DOE

	PHASE 1	PHASE 2	PHASE 3
TOPIC 1			
• Sandia National Laboratories	Integrated Solids System	Component Level Design and Testing	System Design
• National Renewable Energy Laboratory	Integrated Liquids System	Component Level Design and Testing	System Design
• Brayton Energy	Integrated Gas System	Component Level Design and Testing	System Design
	Down-Selection to One Path		Integrated System Construction and Testing
TOPIC 2A			
• Brayton Energy • Hayward Tyler • Massachusetts Institute of Technology (x2) • Mohawk Innovative Technology • Powdermet • Purdue University	Component Level R&D	Component Level Design and Testing	Topic 1 Awardees have the opportunity to incorporate Topic 2A components
TOPIC 2B			
• Electric Power Research Institute • Georgia Institute of Technology (x2) • Rensselaer Polytechnic Institute • University of California, San Diego • University of Tulsa	Applied Gen3 R&D	Support Testing	Support Testing Support Testing

R&D: Programme Gen3 US DOE

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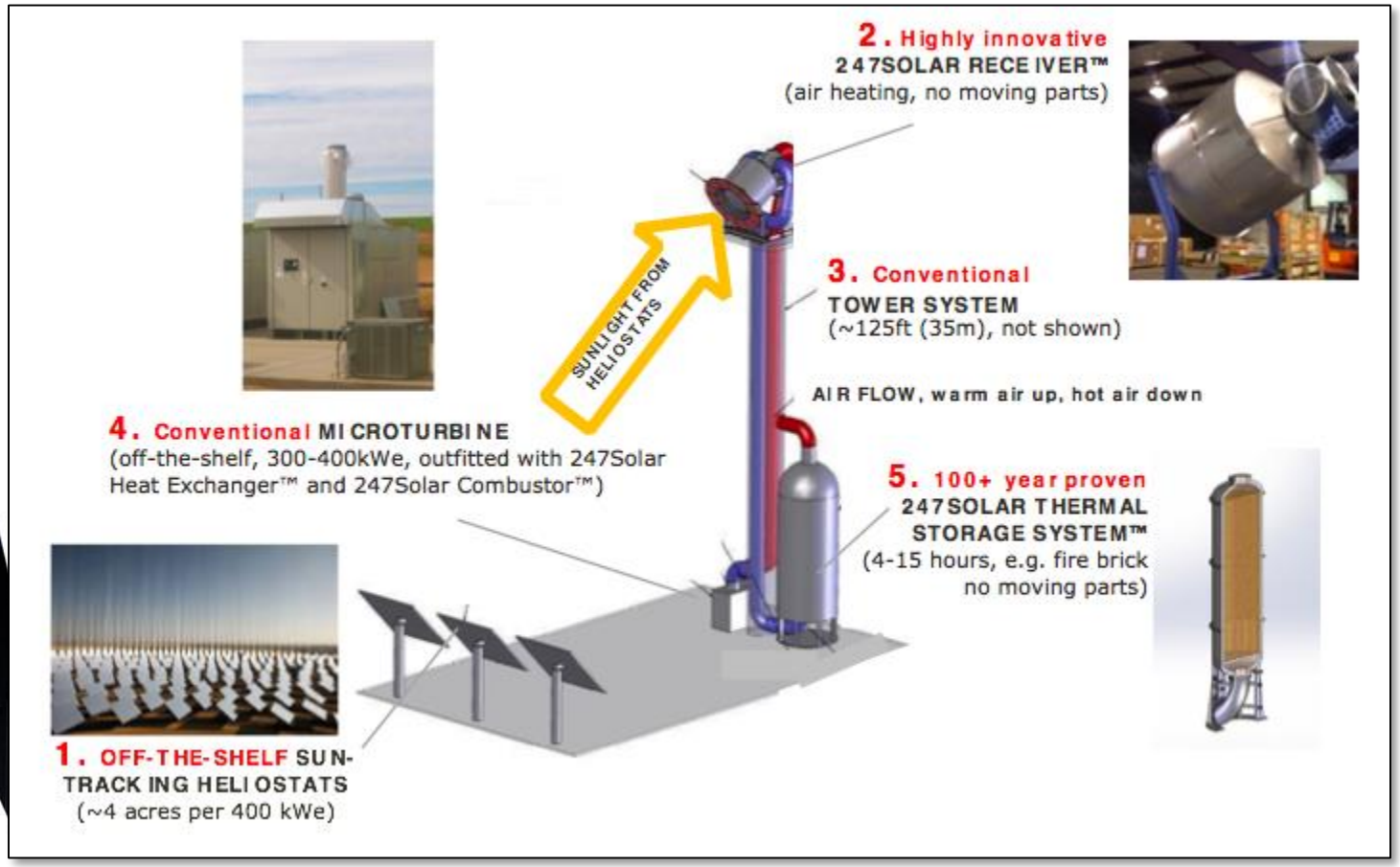

Main research centers in CSP

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