Solar Energy Technologies: R&I priorities in an international perspective

Online Workshop, 14 June 2024

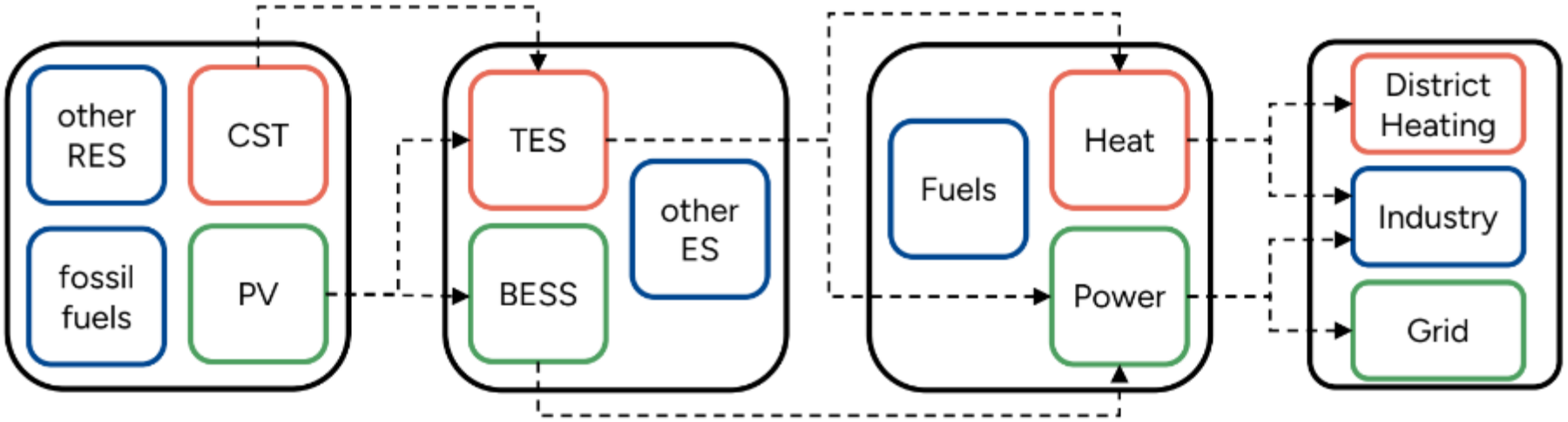
Concentrated Solar Power and Solar Thermal: what role in the energy system?

Julian Blanco
CIEMAT-PSA Director
julian.blanco@psa.es

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

GENERAL CONCEPT

Hybridization:
Optimizing tech integration towards more competitive systems



Source: SolarPACES 2023 - KTH Energy Department - Dr. Rafael Guedez

CONTENTS

1. Electricity production by CST → CSP
2. Industrial process heat production by CST

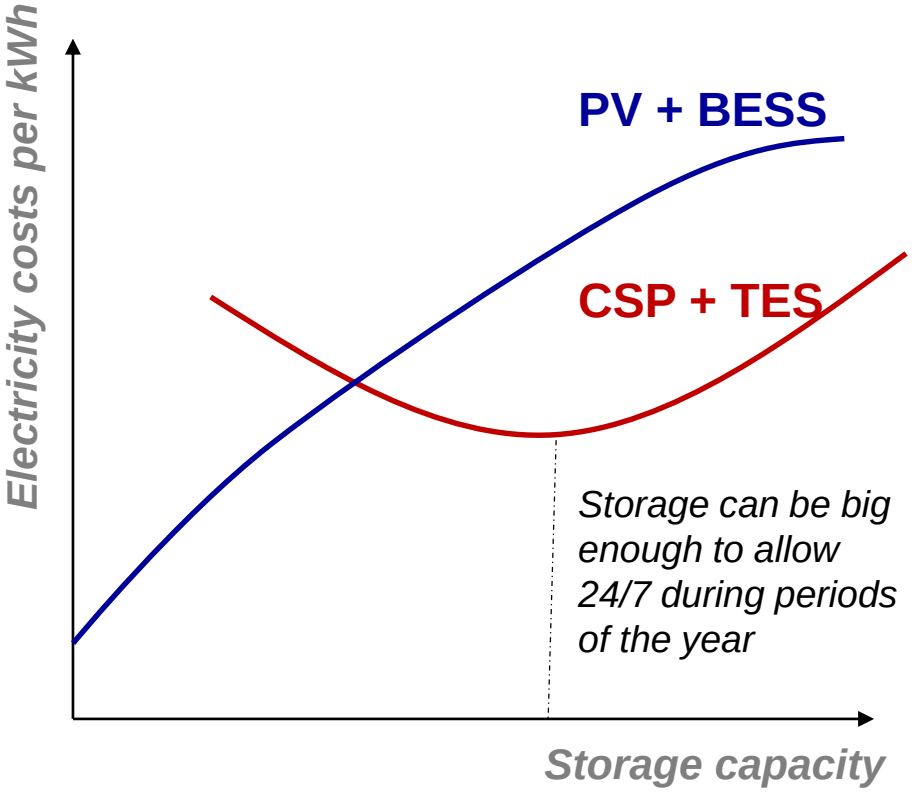
Worldwide Technology Status (June 24)

NOMINAL POWER		Operation	Construction	TOTAL
Parabolic Trough	(79+2)	4.737 MW	643 MW	5.380 MW
Tower Systems	(24+18)	1.448 MW	1.970 MW	3.418 MW
Linear Fresnel	(10+2)	260 MW	200 MW	460 MW
TOTAL		6.445 MW	2.813 MW	9.258 MW

Number of active Projects	113	22	135

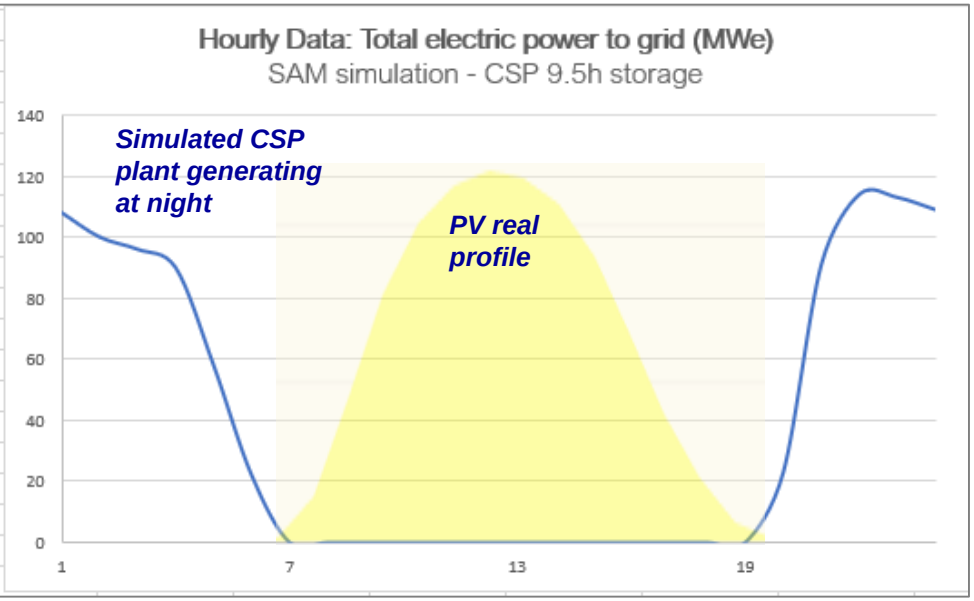
Thermal Energy Storage (TES)

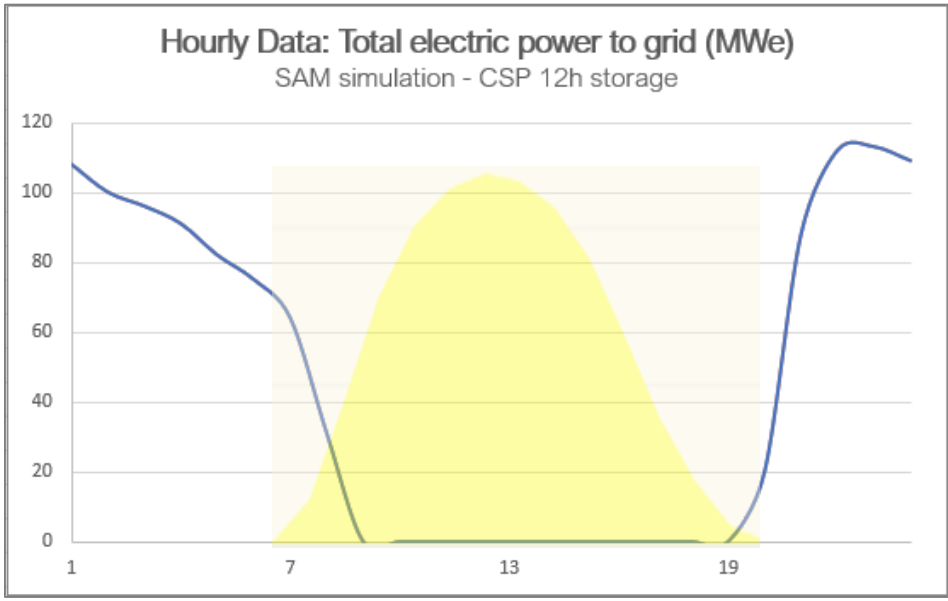
- TES (largely proven since 2008) is the key element of CSP to provide dispatchable electricity
- CSP + TES can fully replace the role of NGCC and/or nuclear power plants



Optimum CSP – PV combination

- Being PV clearly cheaper than CSP, there is no sense to produce electricity by CSP during the day
- Cost of power production by PV + BESS is higher than CSP + TES
- Therefore, CSP + TES, with storage of 9-12h, is the natural complement to PV generation to provide round the clock electricity to the grid



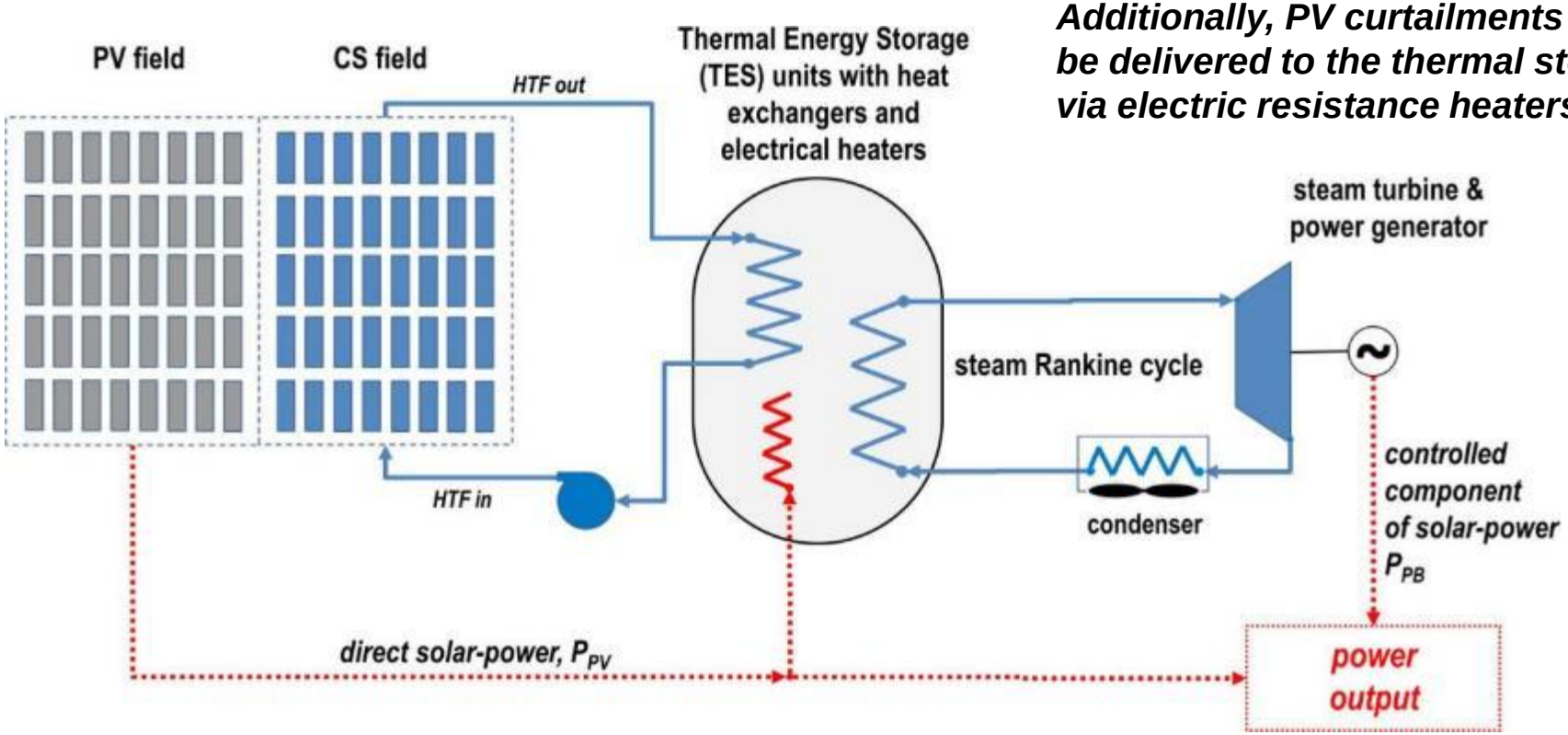


Simulations made using Solar Advisor Model (SAM), NREL

Hybrid CSP-PV Power Plants

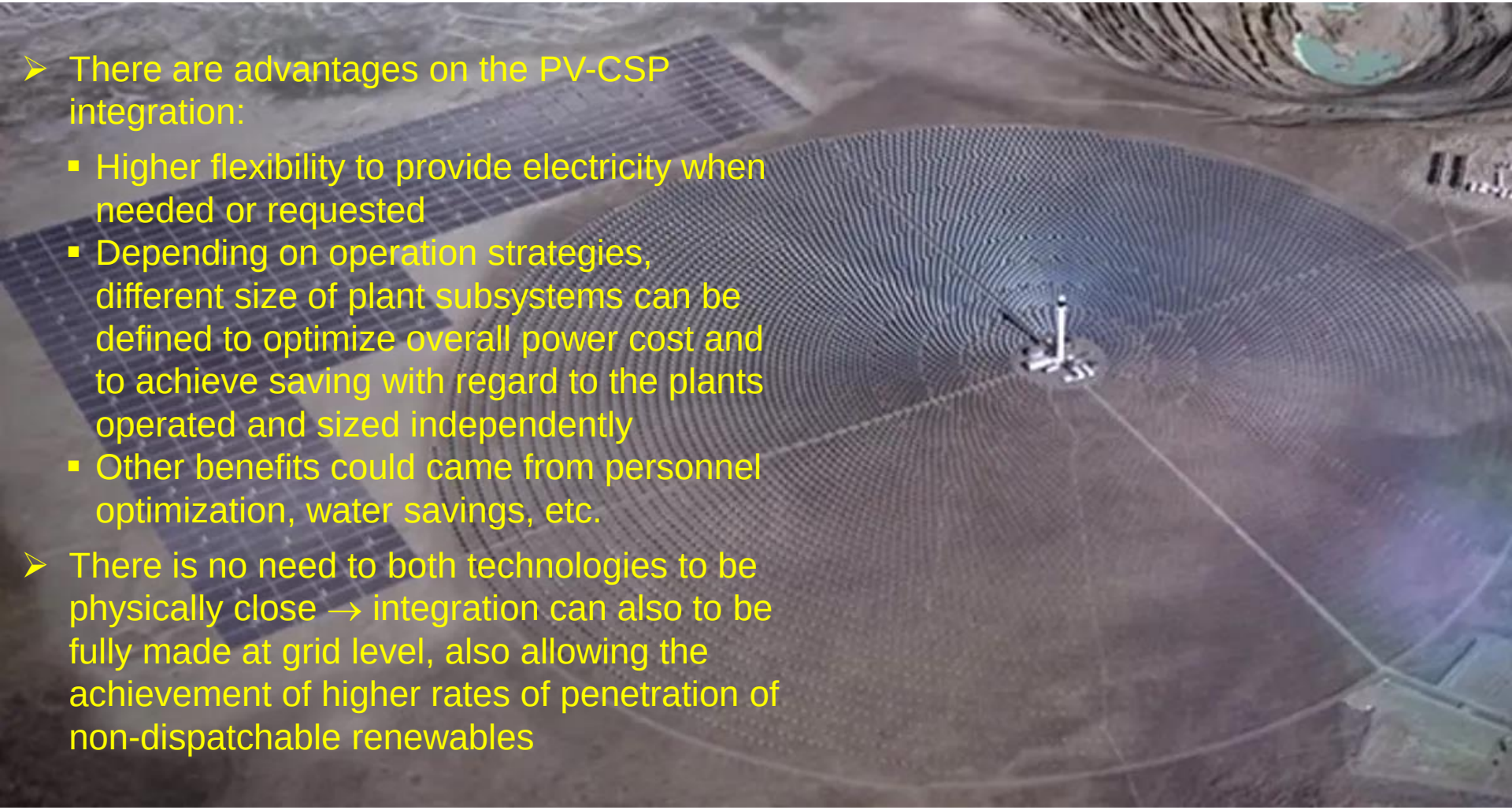
General scheme of hybrid CSP-PV system for dispatchable solar power generation

Additionally, PV curtailments can be delivered to the thermal storage via electric resistance heaters



A. Giaconia, R. Grena, A model of integration between PV and thermal CSP technologies, Solar Energy, Vol 224, 149-159, 2021. https://doi.org/10.1016/j.solener.2021.05.043

Hybrid CSP-PV Power Plants

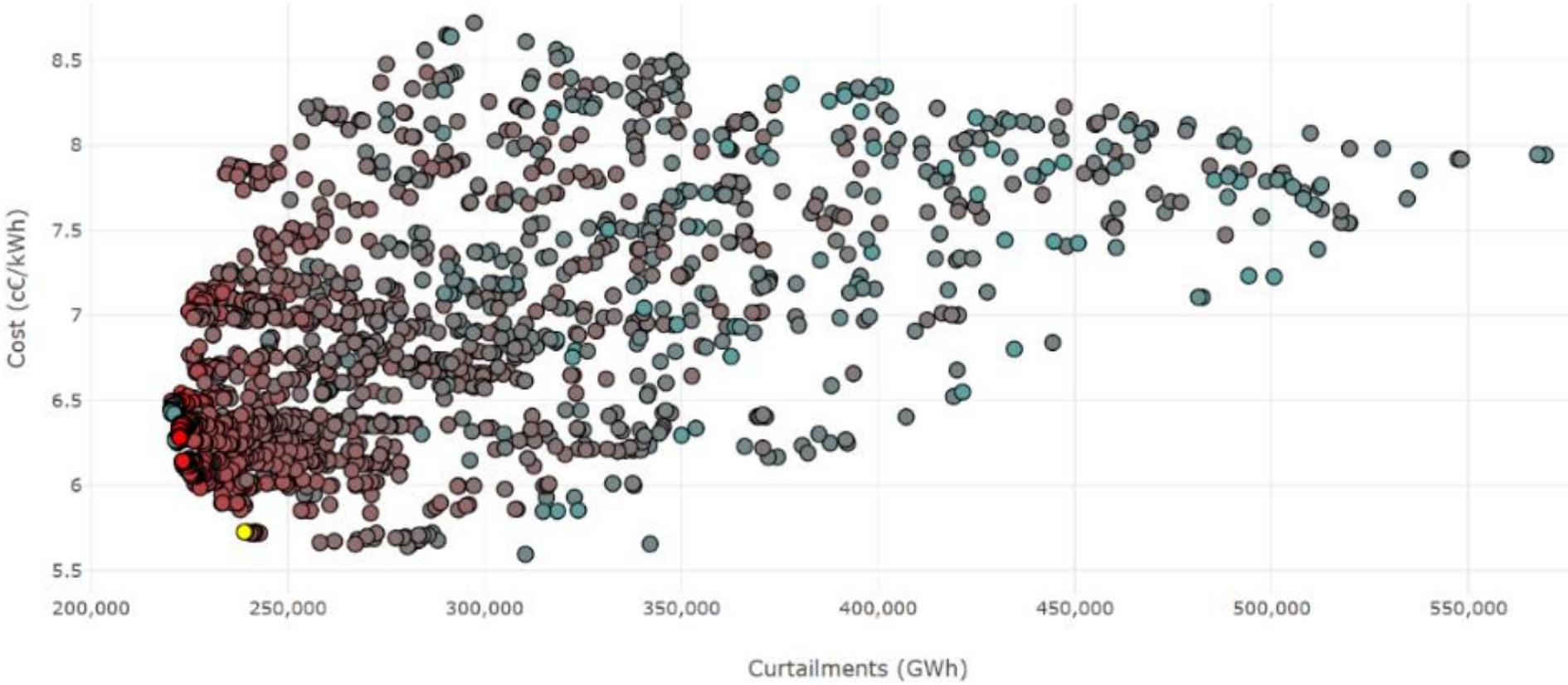


- There are advantages on the PV-CSP integration:
  - Higher flexibility to provide electricity when needed or requested
  - Depending on operation strategies, different size of plant subsystems can be defined to optimize overall power cost and to achieve saving with regard to the plants operated and sized independently
  - Other benefits could came from personnel optimization, water savings, etc.
- There is no need to both technologies to be physically close → integration can also to be fully made at grid level, also allowing the achievement of higher rates of penetration of non-dispatchable renewables

The Problem of Curtailments

Spain / Year: 2050

Emissions reduction of power sector: 100%



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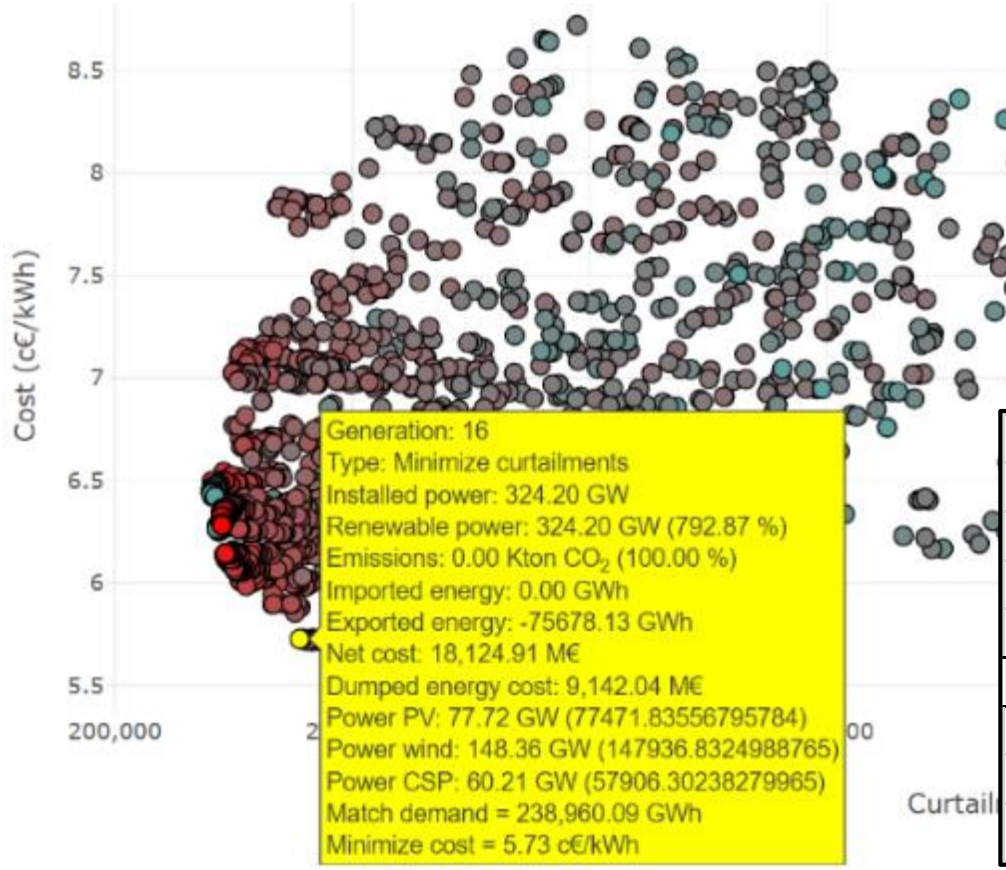

	2030	2040	2050
	70%	85%	100%
CSP (GW)	8,58	17,37	60,21
WIND (GW)	59,33	89,73	148,36
PV (GW)	31,95	48,55	77,72
Total (CSP+PV+Wind)	**99,86**	**155,65**	**287,29**
Cost (c€/kWh)	**4,80**	**4,61**	**5,73**
Curtailments (TWh)	**5,84**	**36,41**	**238,96**
Emissions (kton CO_2)	**19.347**	**9.680**	**0**

CSP projects under construction

Some examples of projects currently under development & construction in China

Project name	CSP power	PV power	Wind power
Three Gorges CTGR Henderson Energy Guazhou	2 x 50 MW	200 MW	400 MW
Power China Ruoqiang	100 MW	900 MW	
CTGR Qinghai Golmud	100 MW	1000 MW	
CTGR Qinghai Quingyu DC	100 MW	900 MW	
Huidong New Energy Akesai	110 MW	640 MW	
Jinta	100 MW	600 MW	
Golmud	100 MW	900 MW	
Turpan	100 MW	900 MW	
Da An	100 MW	200 MW	400 MW
TongYu	100 MW	200 MW	400 MW
SPIC Turpan	100 MW	900 MW	
Delingha	200 MW	800 MW	
Hami	150 MW	1350 MW	

CSP projects under construction

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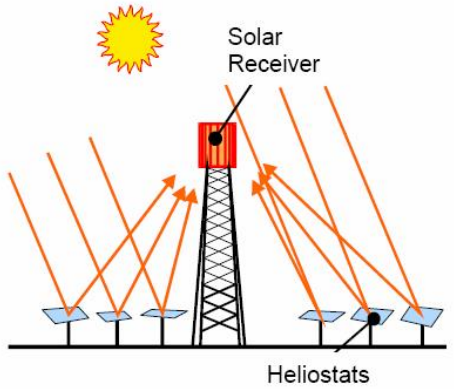
Three Gorges CTGR Henderson Energy Guazhou	2 x 50 MW		
Power China Ruoqiang			
CTGR Qinghai Golmud			
CTGR Qinghai Quingyu DC			
Huidong New Energy		0 MW	
Jinta		0 MW	
Golmud		900 MW	
Turpan	100 MW	900 MW	
	100 MW	200 MW	400 MW
	100 MW	200 MW	400 MW
	100 MW	900 MW	
	200 MW	800 MW	
	150 MW	1350 MW	

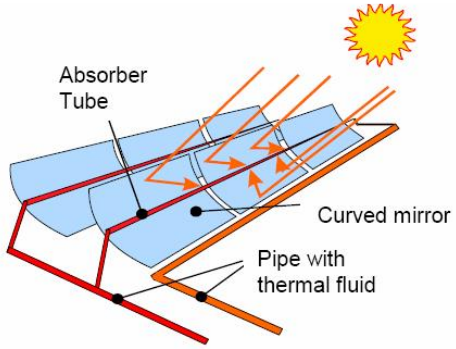
Why Towers for power production?

Advantages of Central Receiver Systems (CRS), against Parabolic Troughs Collectors (PTC) for Power Production

- CRS has lower CAPEX and OPEX due to the use of only one Heat Transfer Fluid (molten salts) against two in the case of PTC (thermal oil + molten salts) → less personnel needed
- Higher thermodynamic efficiency in the Rankine cycle due to the higher operating temperature (565ºC in CRS against 395ºC in PTC)
- More efficient and compact TES, as the ΔT is more than double in the case of CRS (more than 200 ºC against 100 ºC in PTCs), using the same concept and material (salts)
- Better solar field efficiency, thanks to the two-axis tracking → more efficient use of TES in winter time in European latitudes



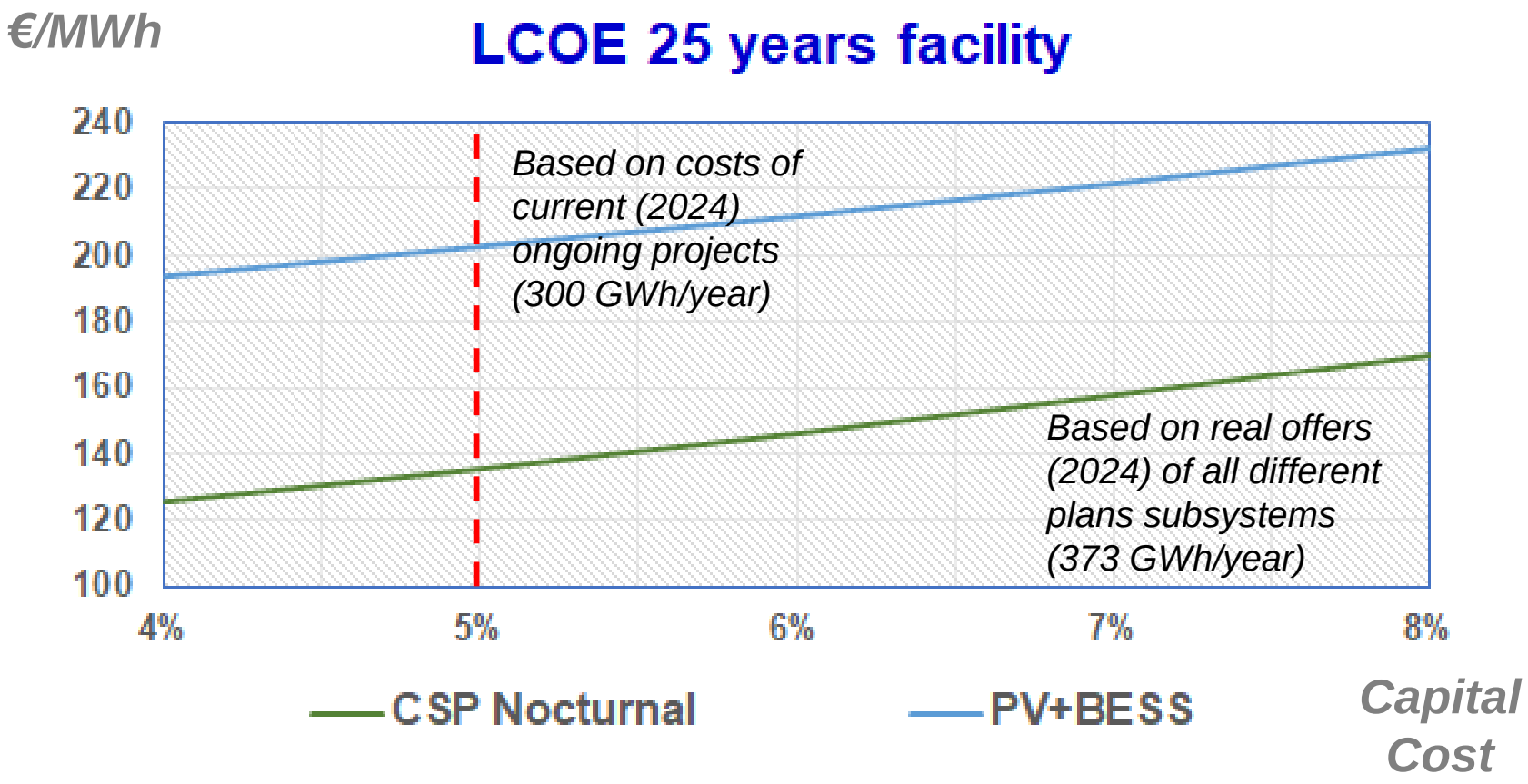
Central Receiver



Parabolic Trough

Technology Cost in Europe (2024)

Costs projection of eventual solar projects in Spain



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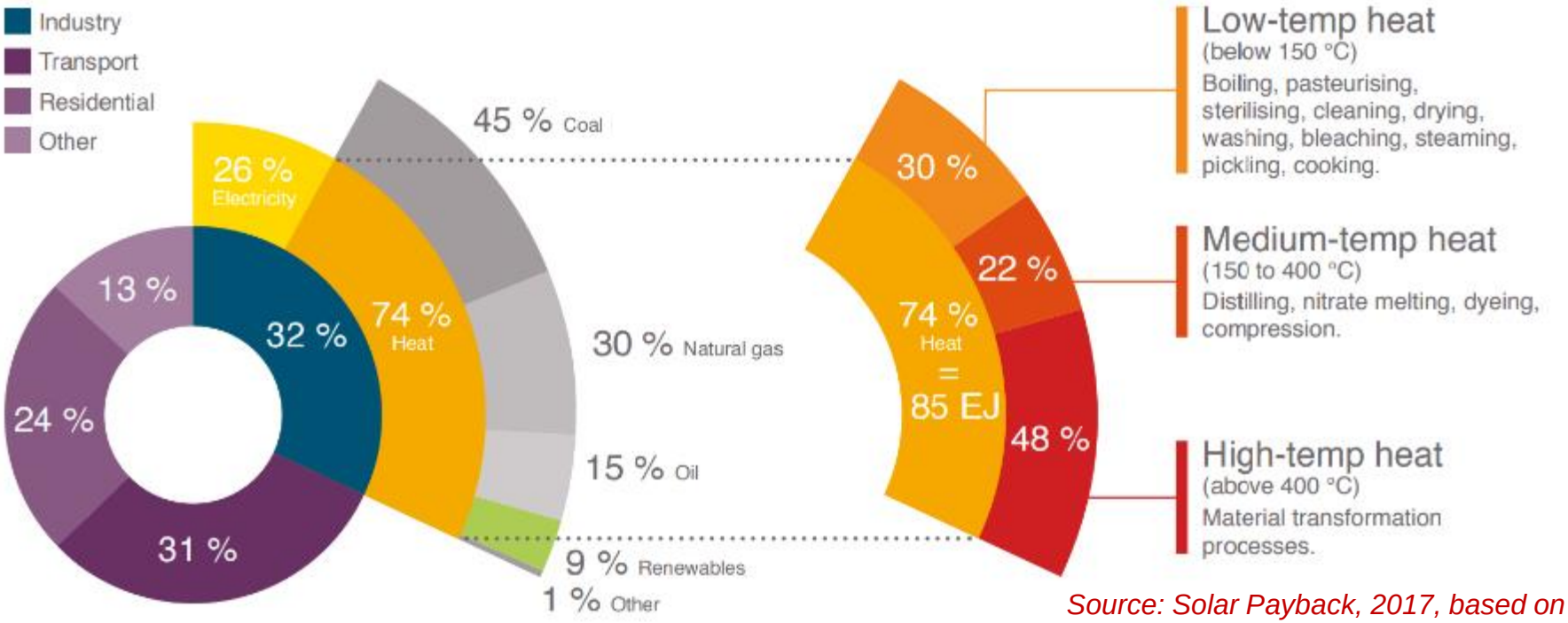
2. Industrial process heat production by CST

Solar Heat for Industrial Processes

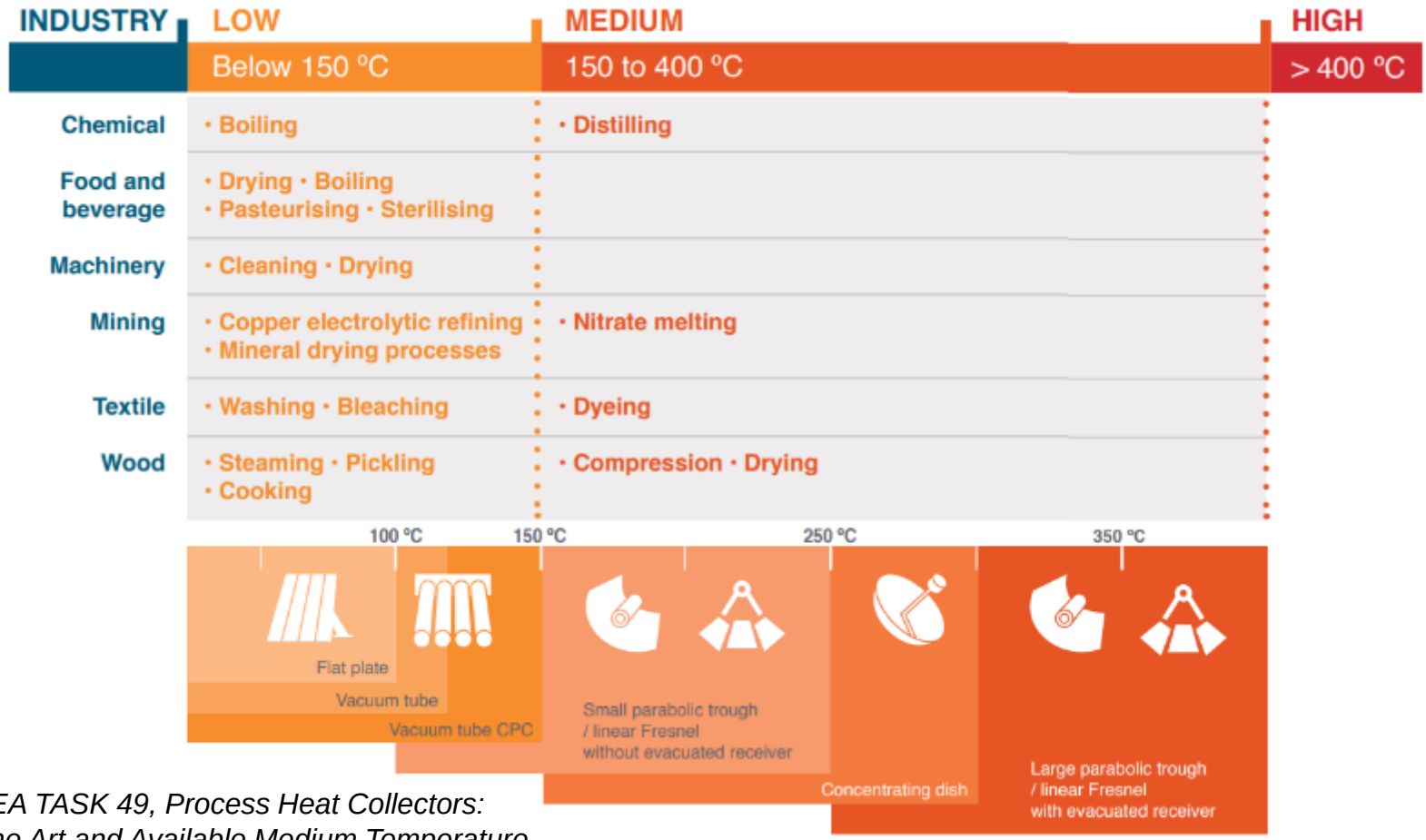
- **Industry** is the first sector in greenhouse gas emissions
- Regarding its demand, 26% is in the form of electricity and **74% in the form of heat**
- In Europe the **heat demand is equivalent to the electricity demand** ~ 11 EJ (3000 TWh)*
- **70% of the demand** is concentrated in medium and high temperature processes

* ***Long Duration Energy Storage Council, 2022.*** ***https://ldescouncil.com/***



Source: Solar Payback, 2017, based on IEA statistics and calculations by IRENA

Solar Heat for Industrial Processes

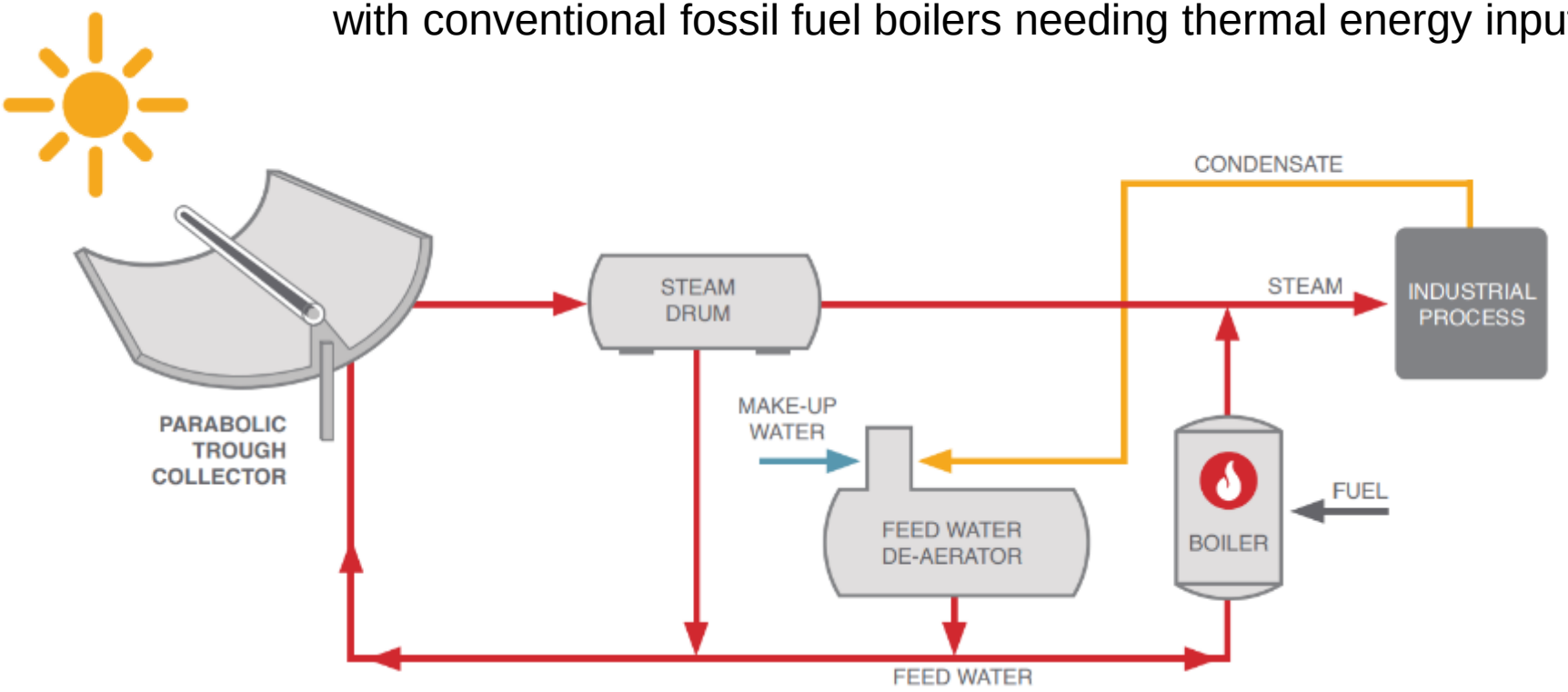


Source: IEA TASK 49, Process Heat Collectors: State of the Art and Available Medium Temperature Collectors, December 2015. www.task49.iea-shc.org

Solar Heat for Industrial Processes

Key technologies: Parabolic Trough and Fresnel collectors

Very easy and simple integration into existing industrial processes with conventional fossil fuel boilers needing thermal energy input



Examples of recent large CST plants

- The current costs of Concentrated Solar Thermal for thermal self-consumption is fully competitive with the current prices of fossil fuels.
- There are barriers that should still need to be addressed:
  - Lack of knowledge of the industrial sector
  - Expertise in O&M
  - Space (on the ground or on deck)
  - Financing

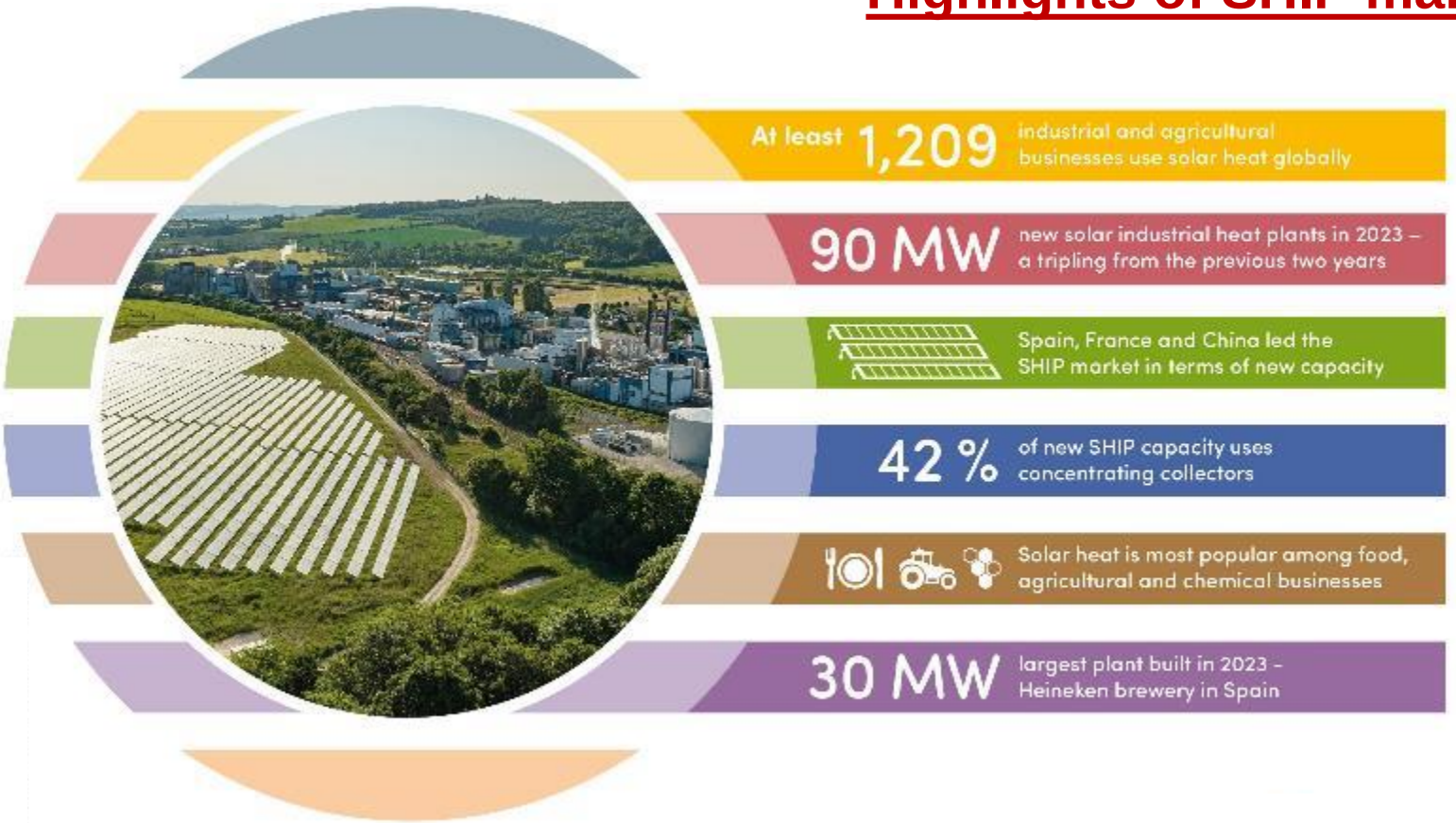
Sep. 2023
CST plant (5 MW) at Avery Dennison production facilities in Turnhout, Belgium

Sep. 2023
Inauguration of CST plant (30 MW) at Heineken's factory in Seville, Spain

Feb. 2024
Inauguration of CST plant (4 MW) at Heineken's factory in Quart de Poblet (Valencia), Spain

Solar Heat Worldwide 2024

Highlights of SHIP market 2023



Source: Solar Heat Worldwide 2024, Solar Heating & Cooling Programme – IEA, 2024
https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2024.pdf

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Thank you for your attention

Questions ?

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