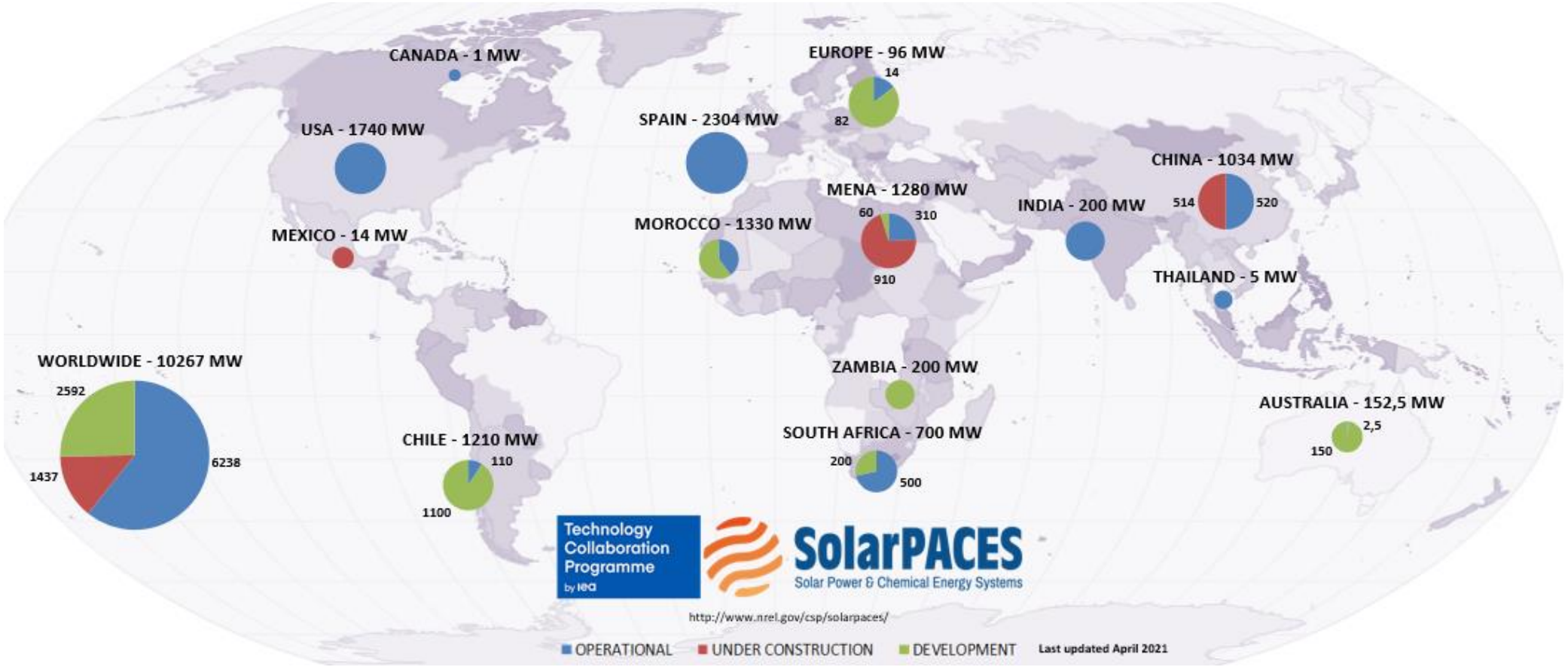
CSP-PV Hybrid Solutions:
Base-load – low-cost solar for grids, industry and hydrogen

Robert Pitz-Paal
Director
DLR Institute of Solar Research

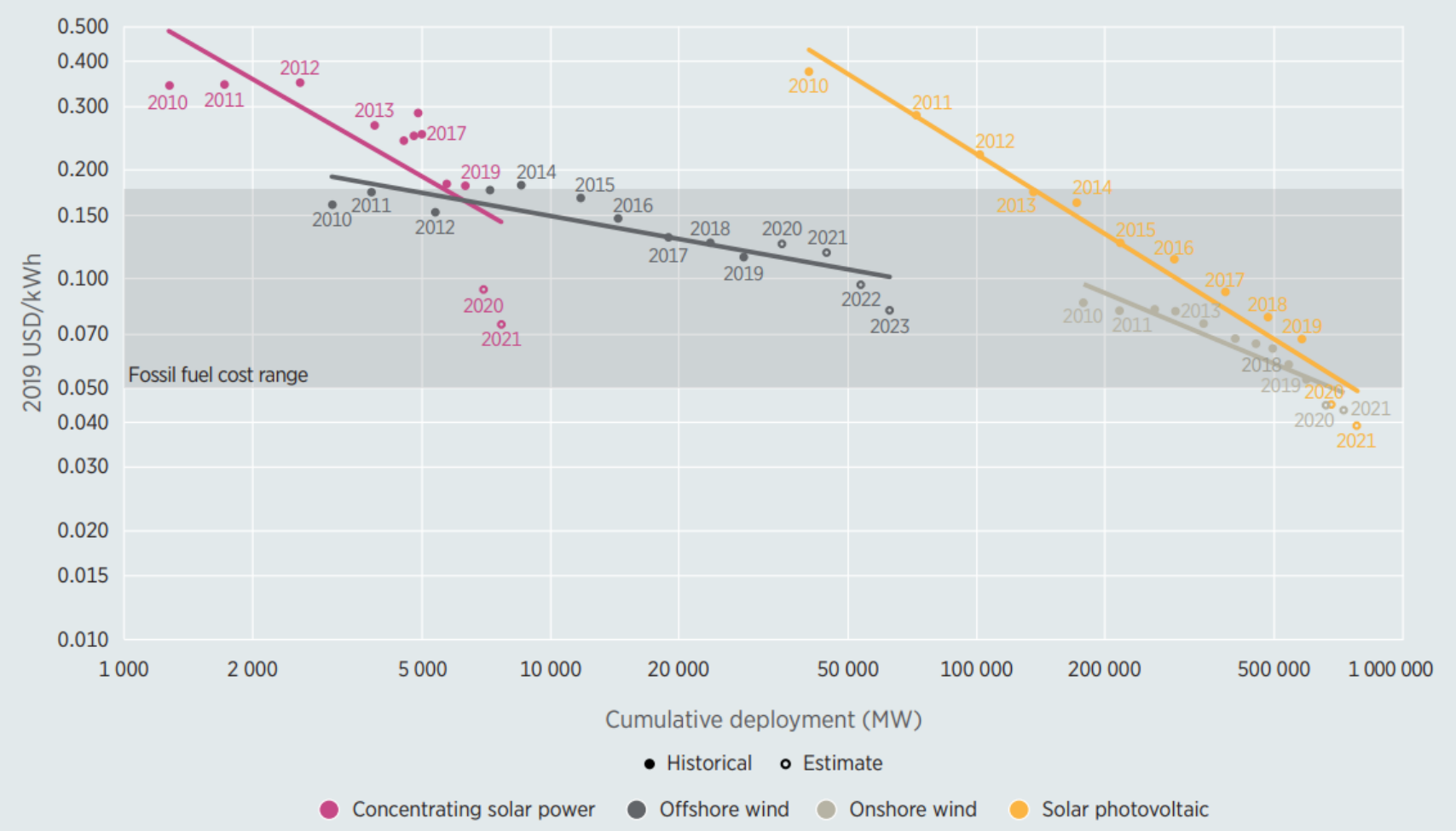
2nd Edition MENA Energy Meet
2021 August 30th

Current Market Overview CSP: 6.2 GW operational around the world

https://www.solarpaces.org/csp-technologies/csp-projects-around-the-world



Strong cost degression in CSP at relatively low total deployment

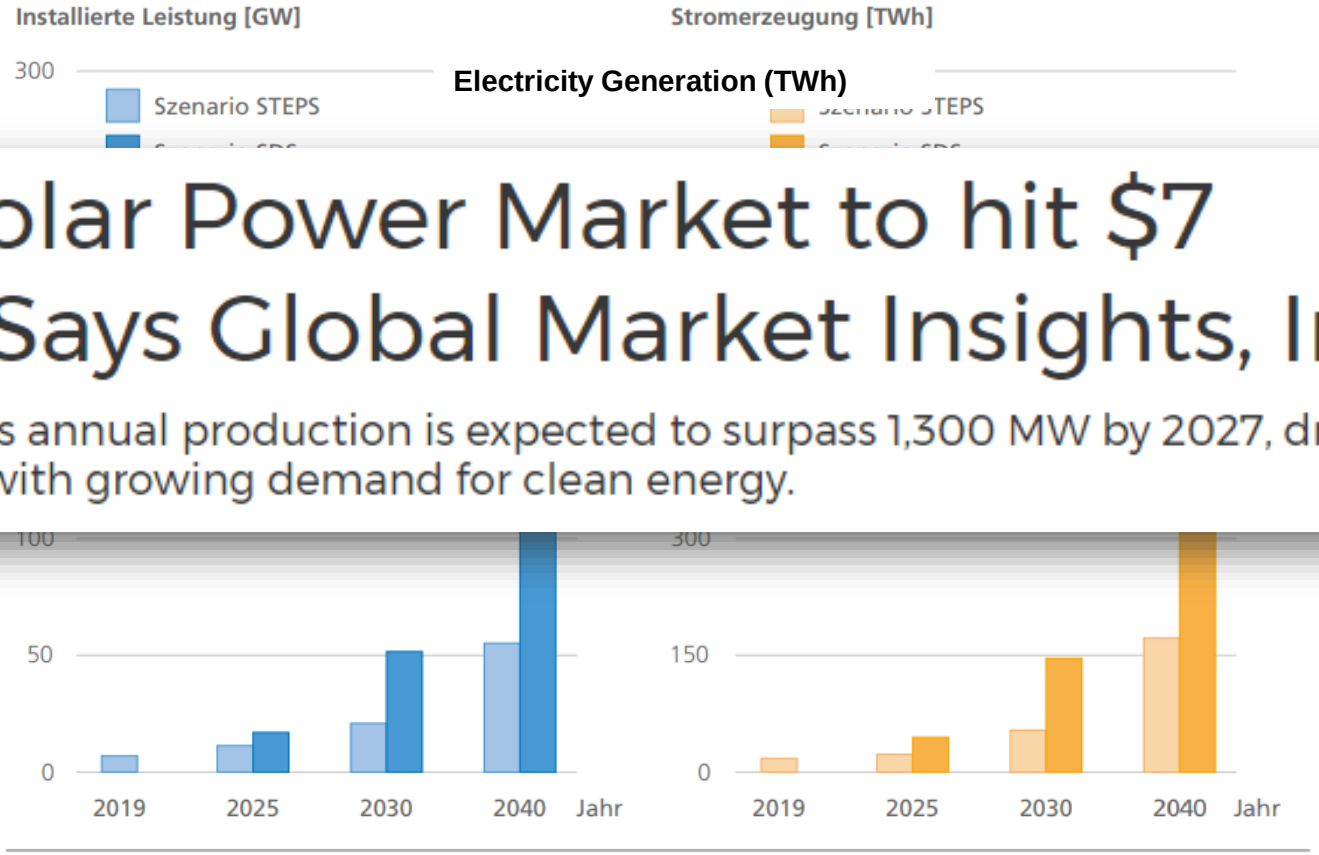


Source: IRENA, RENEWABLE POWER GENERATION COSTS IN 2019, Figure 1.11 The global weighted-average LCOE and Auction/PPA price learning curve trends for solar PV, CSP, onshore and offshore wind, 2010 – 2021/23

- Annual growth rate 15% - 25% needed

Possible CSP growth scenarios 2020-2040

(in conjunction with growing capacities of PV and Wind)



Electricity Generation (TWh)

Concentrated Solar Power Market to hit $7 billion by 2027, Says Global Market Insights, Inc.

Concentrated Solar Power Industry's annual production is expected to surpass 1,300 MW by 2027, driven by rising electricity demand along with growing demand for clean energy.

STEPS: Stated Policies; SDS: Sustainable Development (<1,5 °C)

Source: DLR, Solarthermische Kraftwerke; Data from IEA-WEO 2020, Table A.3

https://www.dlr.de/content/de/downloads/publikationen/broschueren/2020/studie-solarthermische-kraftwerke.pdf?__blob=publicationFile&v=8

English version available soon!

DLR

CSP-PV Hybrid Solutions

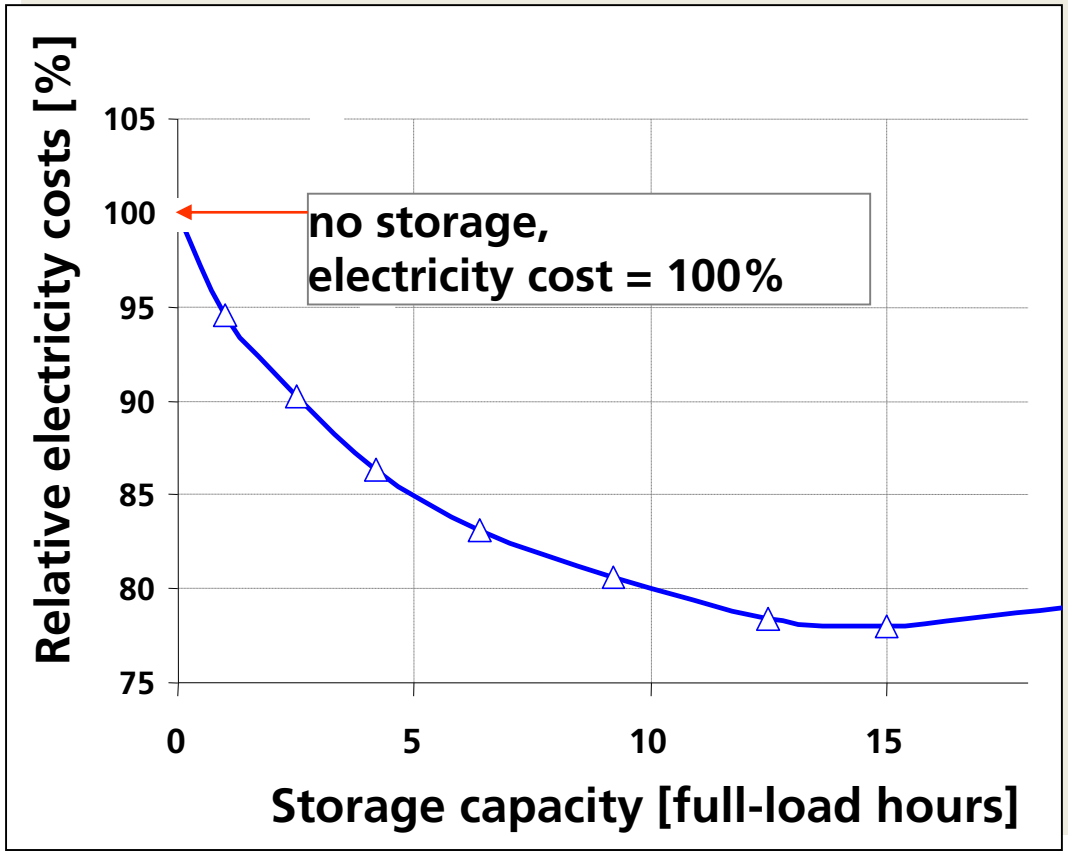
- **photovoltaic power** plants can provide **cheap** electricity from solar when the sun is shining
- **Storage solutions** are required to satisfy demand **after sunset**
- Battery storage systems are expensive, particularly for large power units with several hours of storage capacity
- **Concentrating solar power** plants offer **dispatchable** solar power generation with cheap and proven **thermal storage** units
- **CSP** spinning turbine provides **ancillary services to the grid**
- Combining both solar power generation technologies offers **low cost <u>and</u> dispatchability**

Source: Powerway Renewable Energy Co., Ltd

Source: Solar Millennium AG

CSP w/ storage cheaper than CSP w/o storage

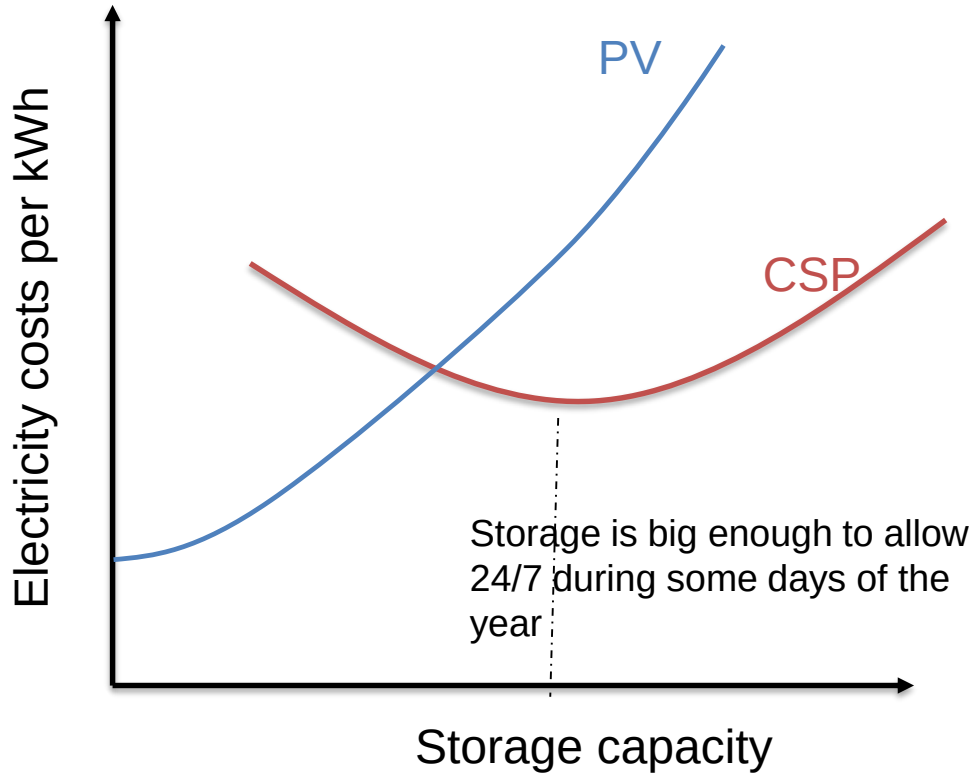
Thermal Storage = more operating hours = higher capacity factor = cost reduction



* assuming specific investment costs for the storage of 10 Euro/kWh

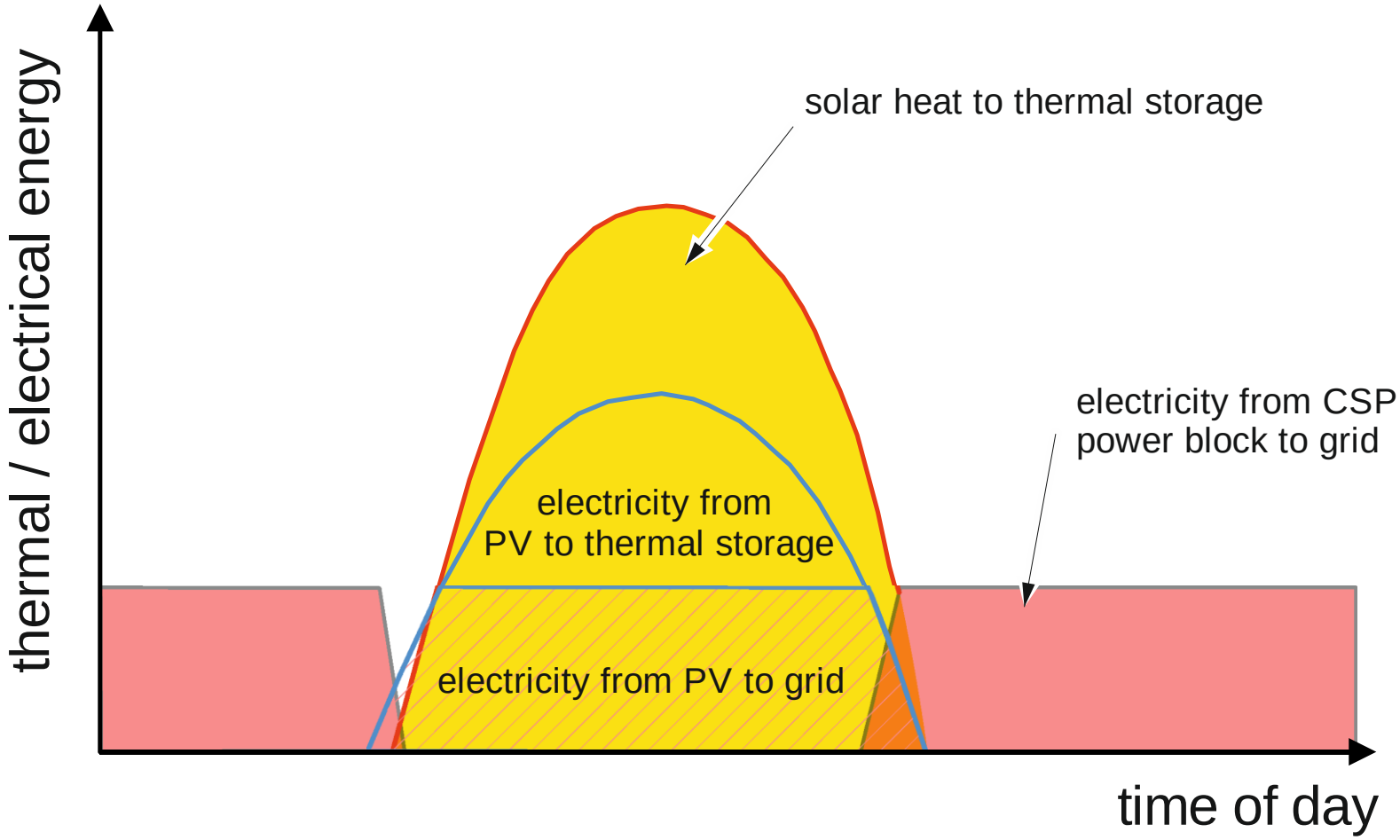
Design of hybrid plants

- Standalone CSP or PV plants are typically optimized for least cost electricity production (the nominal power output must be fixed in advance)
- For CSP plants the least cost design version often includes thermal storage because this part is cheap, raises the number of production hours and helps to improve the economy of the whole plant
- For PV plants a system without storage has always the lowest electricity cost
- Hybrid plants are beneficial if one of the following conditions apply
  - A certain fraction of power demand during night time
  - A limit for the power fed to the grid at any time
  - Time-of-delivery tariffs to favor night time production over direct feed-in

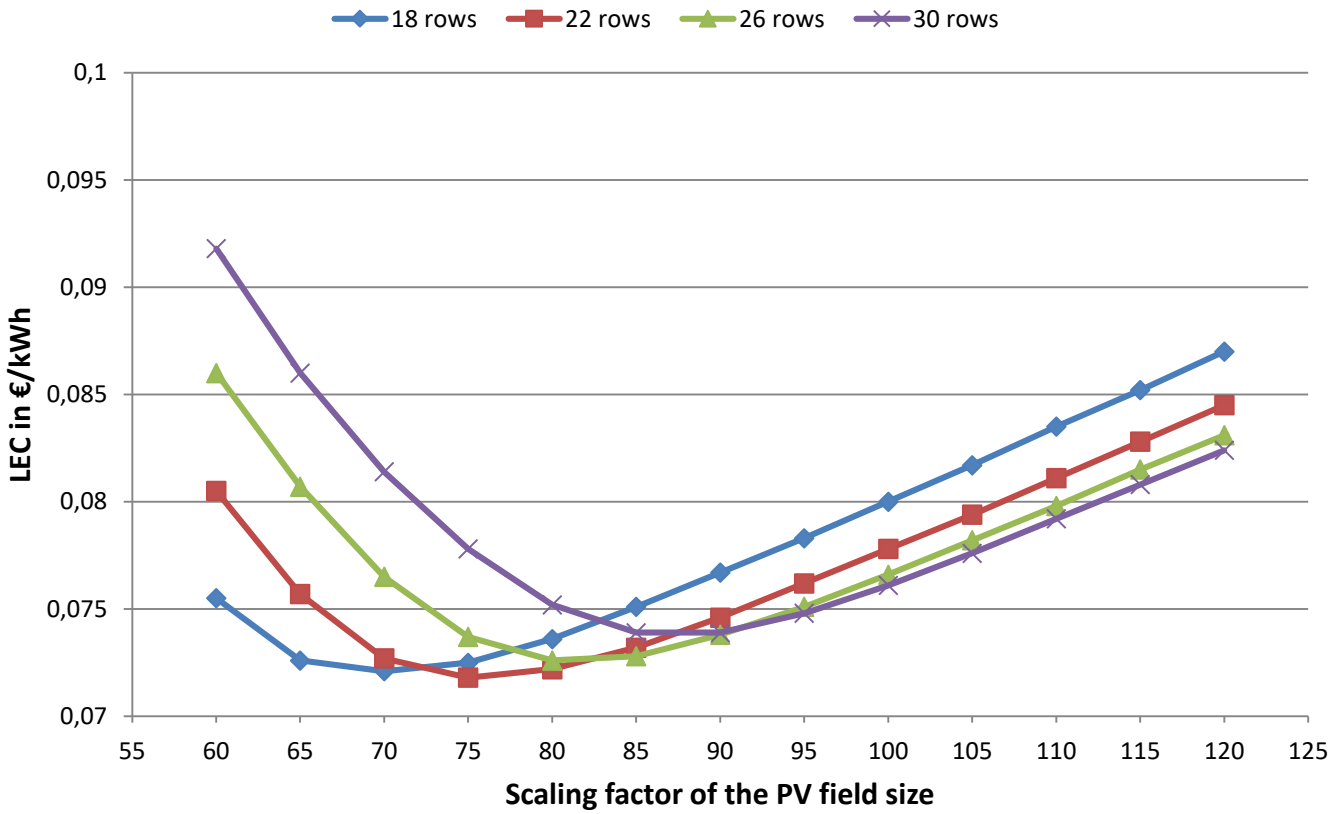


Typical daily production

- During sunshine hours the PV plants delivers electricity to the grid
- Additionally, it delivers electricity to the thermal storage (via electric resistance heaters)
- The CSP power block is not operating during daytime, only the storage is charged
- The hybrid plant will be capable to deliver „round the clock“ solar electricity, for lower cost than two standalone plants



Example Cost optimization for CSP–PV Hybrids
Parabolic trough plant with electrical heater as booster

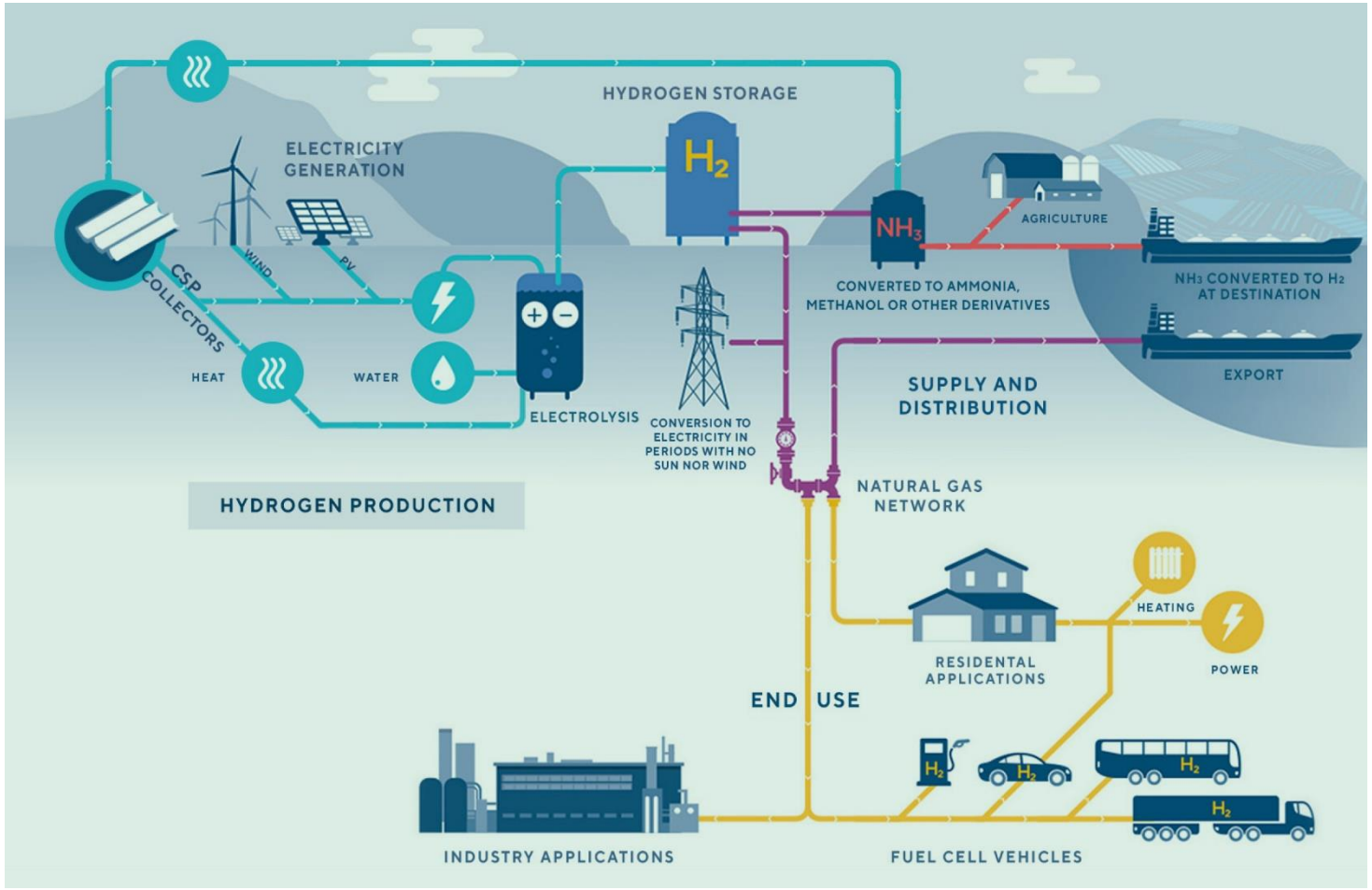


- Power block capacity 110 MW
- Thermal storage capacity : 6 h
- PV capacity 3 MW x scaling factor
- Thermal power per parabolic trough collector row 2.7 MW
- Power to grid limited to 100 MWe
- Lowest LEC:

  225 MW PV + 60 MW CSP

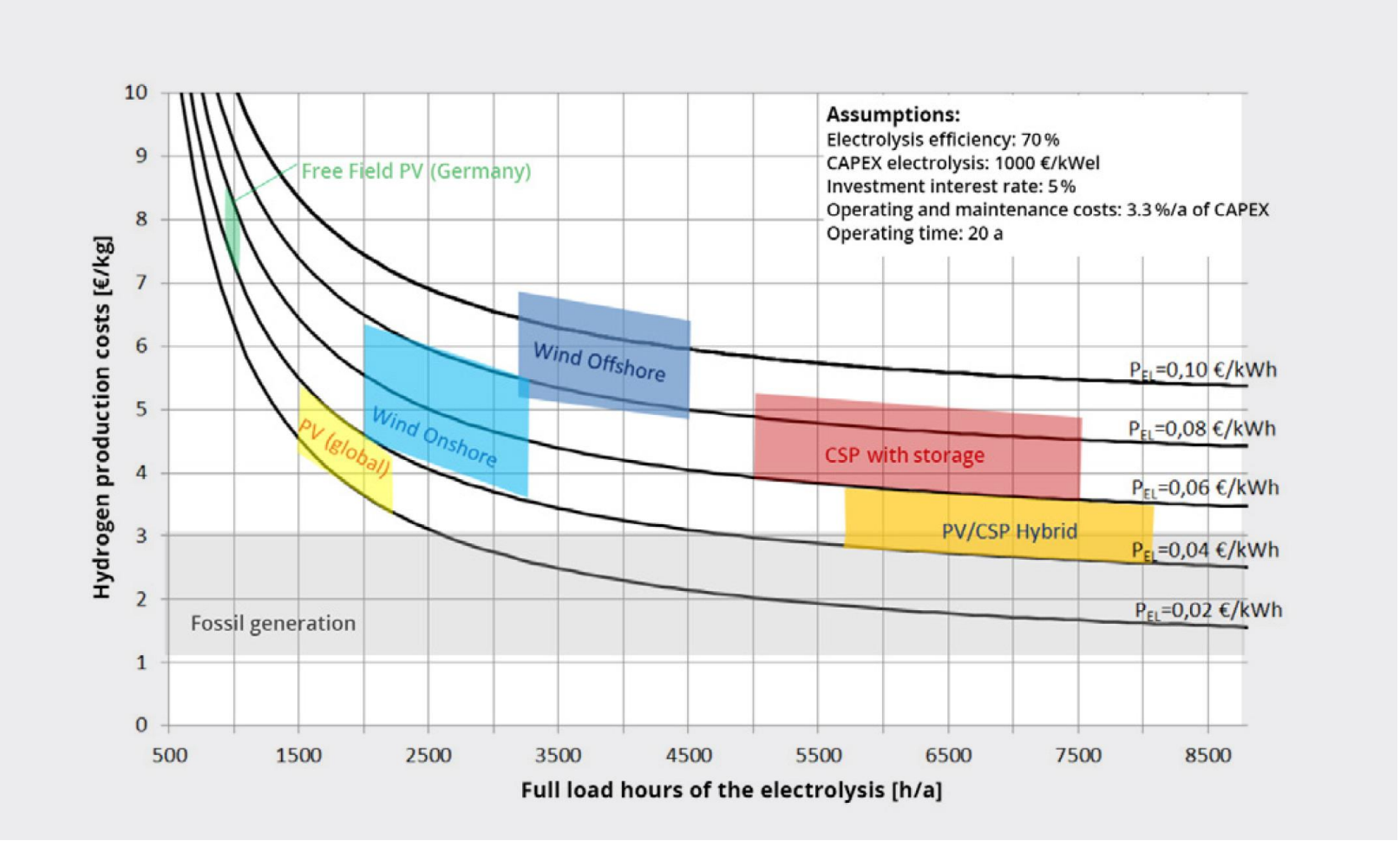
The contribution of CSP to hydrogen production

- CSP/PV-hybrids offer high full load hours at low electricity and lowest heat generation costs
- Constant utilization of the electrolyzer enables high conversion efficiencies
- Cost reduction potential through high-temperature electrolysis
- Use of the heat for further processing of the H_2 into derivatives



Source: DCSP 2021, modified presentation according Herbert Smith Freehills

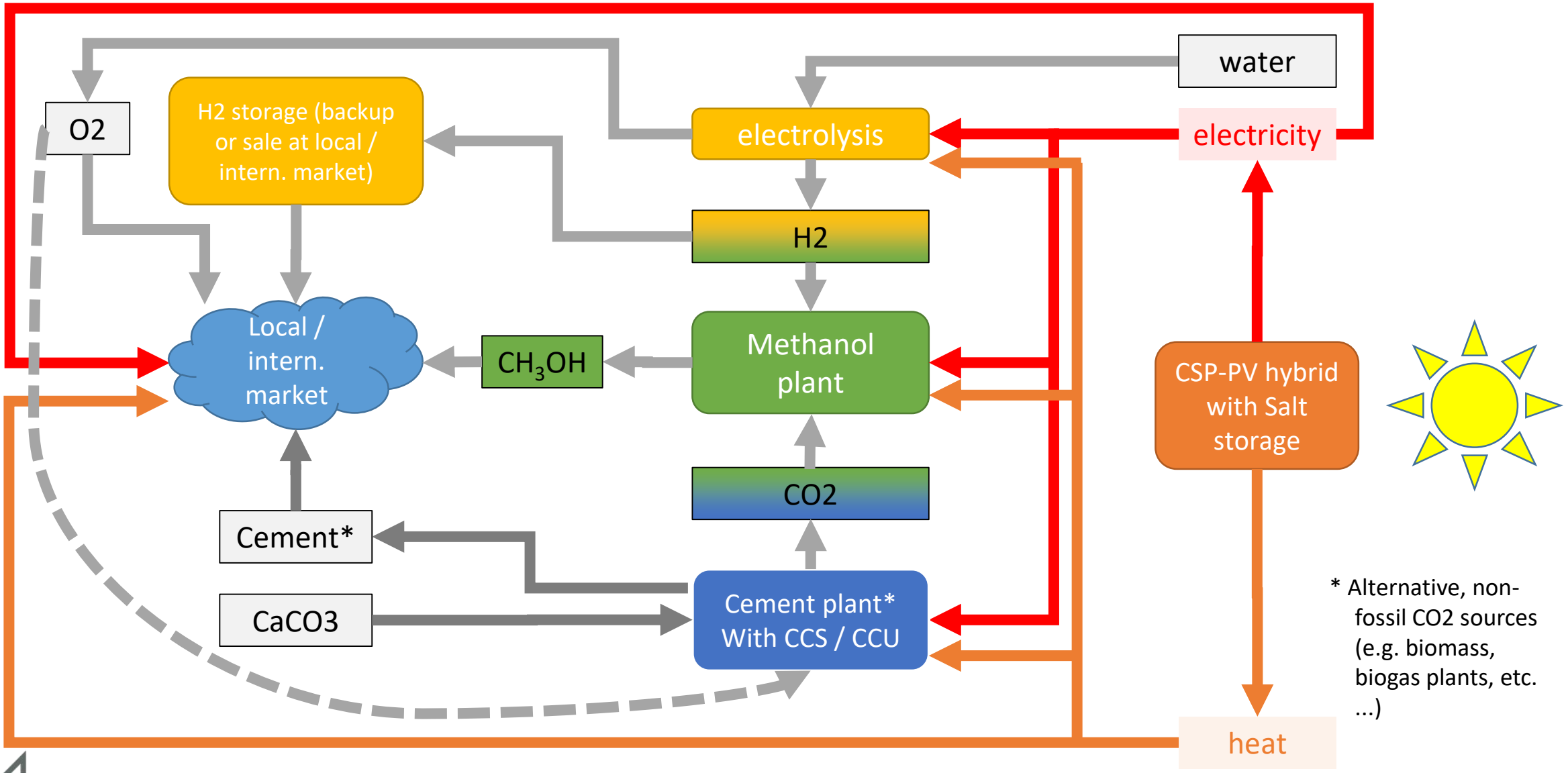
Production costs for green hydrogen



Assumptions Electrolysis:
Smolinka, T., et al., *Study IndWEDe Industrialisierung der Wasserelektrolyse in - Deutschland: Chancen und Herausforderungen für nachhaltigen Wasserstoff für Verkehr, Strom und - Wärme.* 2018. https://www.now-gmbh.de/wp-content/uploads/2020/09/indwede-studie_v04.1.pdf

Electricity generation costs:
Kost, C., et al.,
Study *Fraunhofer ISE: Stromgestehungskosten Erneuerbare Energien, 2018.*
https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/DE2018_ISE_Studie_Stromgestehungskosten_Erneuerbare_Energien.pdf

Example: Integrated industry complex for the production of green hydrogen and methanol



DLR

Conclusions

- CSP-PV hybrid power plants offer the chance to deliver cheap and dispatchable solar electricity/heat
- Several design options are feasible including extreme variants using just one of the technologies
- Boundary or operating conditions are determining the least cost solution. The optimized systems will look different for 2 hours and for 12 hours of storage capacity
- Costs are developing dynamically for all subsystems and will influence optimal solution
- Software tools are under development and can help to find the best system for given boundary conditions