STE competitiveness vs other renewables and conventional

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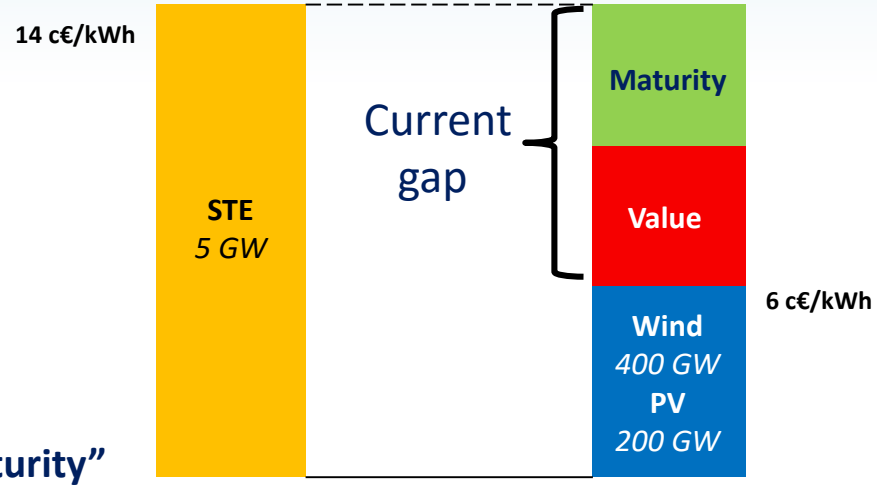
The big question mark:

Onshore Wind and PV have reached already competitive cost levels.

Thus, is it still worth continuing to support the STE technology?



about "Maturity"

- ✓ The PPAs for the two recently awarded STE plants in Morocco Noor 2 & 3 (200 MW PT & 150 MW T) were 15% lower than the previous one for Noor 1 awarded 2 years ago.

- ✓ A 110 MW STE plant with 17,5 hours of storage, partly hybridized with PV, was recently selected in Chile with a PPA of $110/MWh, in competition with all other generation technologies including Gas Combined Cycle.

- ✓ The tariff for the current "Expedited round" in South Africa is close to 20% less than the previous one for Round 3 established 18 months ago.

GLOBAL GROSS POWER GENERATION CAPACITY ADDITIONS, 2010–30 (GW)

Bloomberg NEW ENERGY FINANCE

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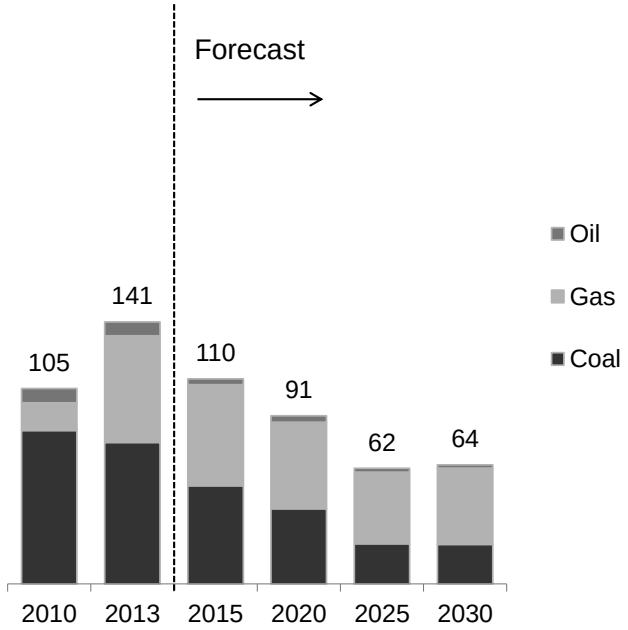
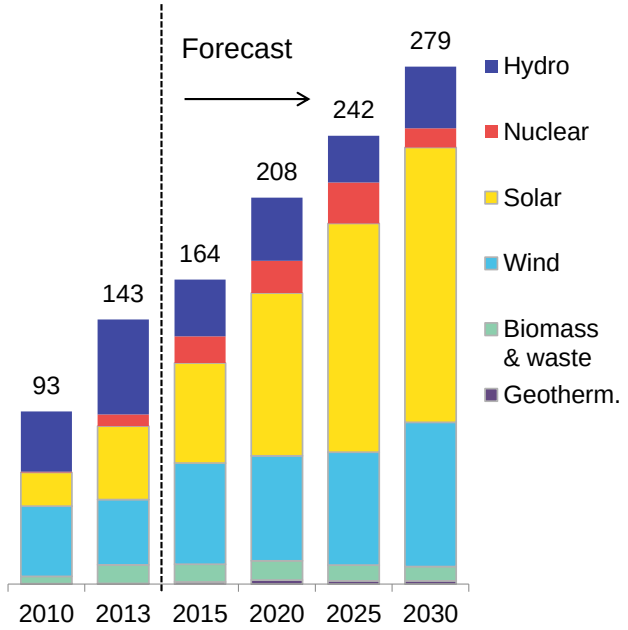
FOSSIL FUEL



Note: Underlying data is from GREMO 2014

CLEAN ENERGY



Source: Bloomberg New Energy Finance

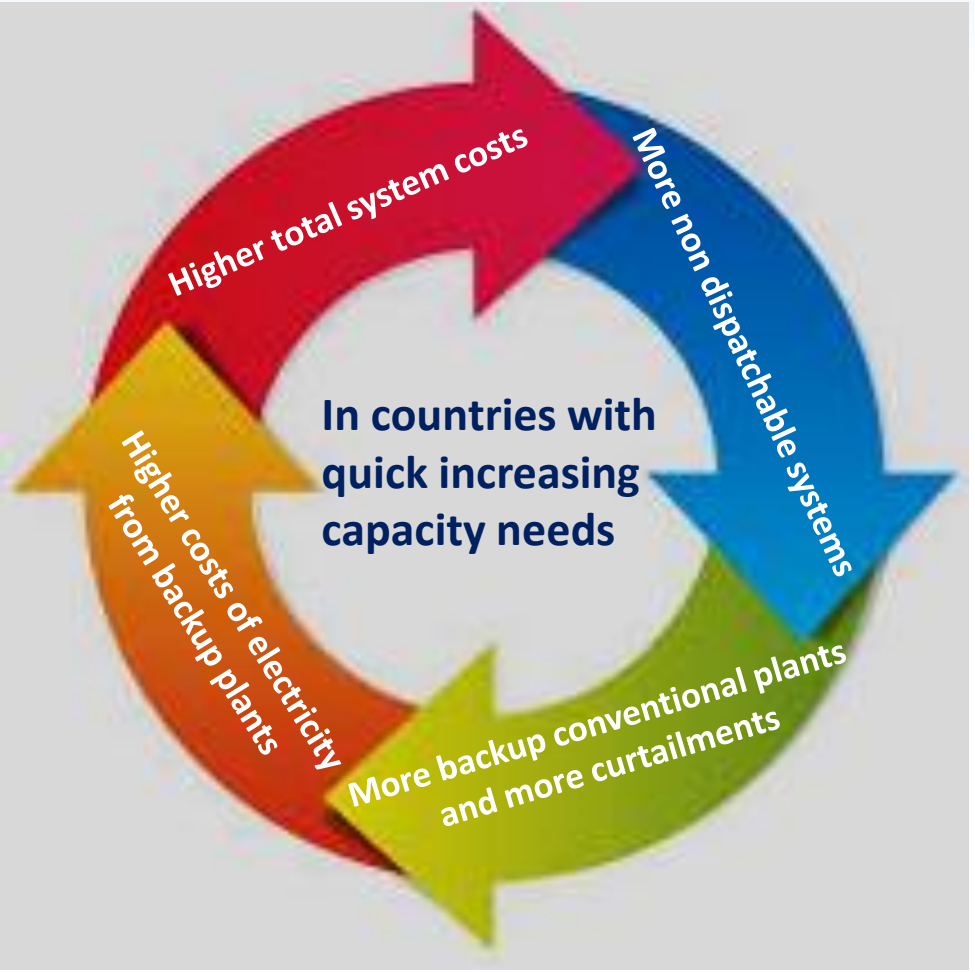
RES technologies account for most of the new capacity additions in the last years at world level and this trend will increase exponentially in the near future

- Who can ever promote – on a pure commercial basis - a new coal, gas combined cycle or nuclear power plant in most of the countries in the world?
- Which financing organization could take the risk of uncertain carbon taxes or even strong operational restrictions during the payback time of the loans?

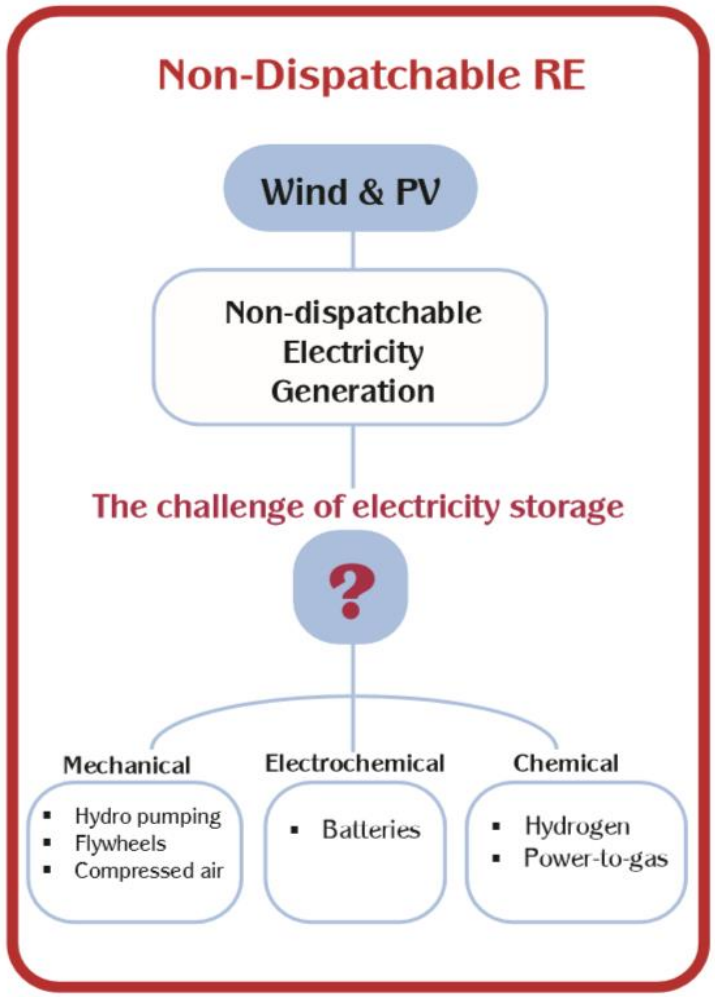
Therefore RES will in the future rarely compete with conventional power plants …

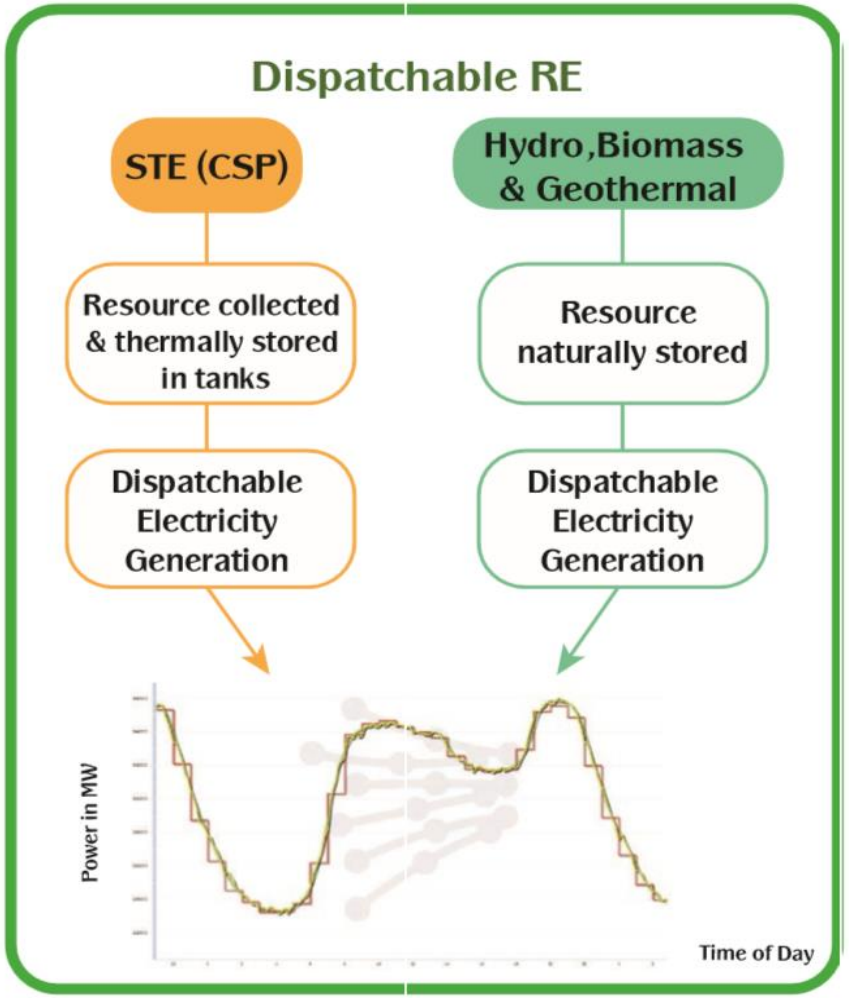
… but high penetration of non dispatchable technologies in simply unsustainable

- The increase of the share of intermittent electricity generation is due to the fact that in many countries additional generation is auctioned so as to secure a long-term PPA
- This approach leads to situations in which the offer could exceed the demand and the subsequent issues: what to do with electricity surpluses and how to fairly compensate the old conventional plants, effectively providing the necessary back up, but operating only few hours a year?
- It is also foreseeable that markets will - at a given moment - send investors signals about foreseeable low investment yield for a product offered by most market actors at the same time, which will certainly reduce the resulting marginal prices and challenge the business cases for such investments.



Following the initial phase of RES deployment – reaching now about 400 GW of Wind and 200 GW of PV worldwide- time has come to face an **essential fact**

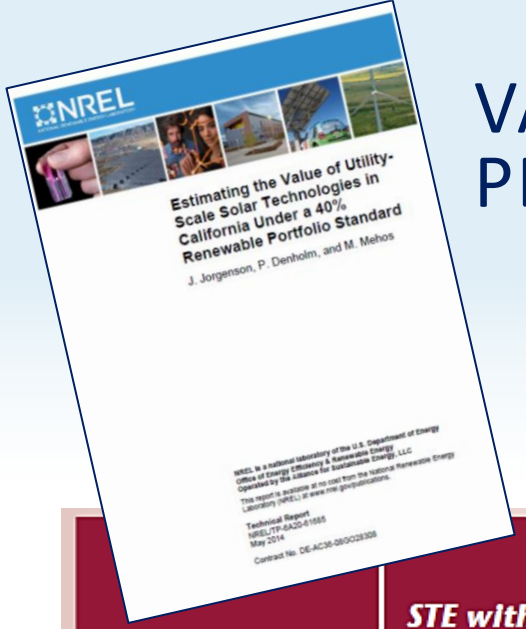




There are two types of renewables

- ✓ One is the cheaper non-dispatchable
- ✓ The other one is the still-more-expensive but dispatchable technology - such as solar thermal electricity STE/CSP

Achieving a CO2-free power system will be only possible with a larger share on dispatchable renewables



VALUE OF SOLAR POWER ACCORDING TO RE PENETRATION SHARE

Example for 33% and 40% RE shares in California (NREL, May 2014)

Value component	33% renewables		40% renewables	
	STE with storage value (USD/MWh)	PV Value (USD/MWh)	STE with storage value (USD/MWh)	PV Value (USD/MWh)
Operational	46.6	31.9	46.2	29.8
Capacity	47.9-60.8	15.2-26.3	49.8-63.1	2.4-17.6
Total	94.6-107	47.1-58.2	96.0-109	32.2-47.4

Conclusion:

It is equivalent for the total cost of the system to pay 5 to PV than 10 to STE

- **What does operational value means:**

  Operational value represents the avoided costs of conventional generation at their respective dispatching times along with related ancillary services costs, such as spinning reserve, etc. Savings on emission costs are also accounted

- **What does capacity value means:**

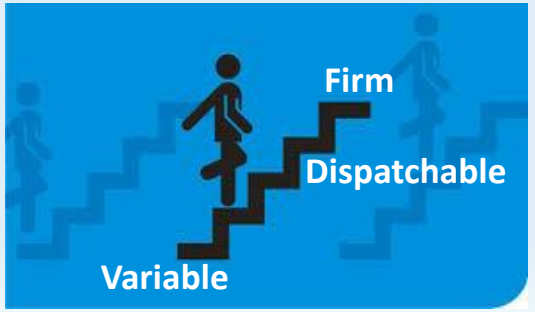
  Capacity value reflects the ability to avoid the costs of building new conventional generation in response to growing energy demands or plant retirements

LCOE is not a valid metric any longer

The guiding principle for further investment steps towards a sustainable energy transition should not only be how much a generated kWh in a given power plant costs based in CAPEX/OPEX. Instead, the value it effectively adds to the system should be from now on the essential factor for deciding on investments. The metric of LCOE may be useful for academic purposes, but it is no longer supportive of a longer-term energy policy-making resulting in system planning decisions and support schemes.

The “Value” versus “Cost” approach is being understood by more and more policy makers and reference organizations although it will take a while to abandon unspecific auctioning when supporting the deployment of new RE capacity in the different countries

✓ Firmness of supply is a step beyond dispatchability



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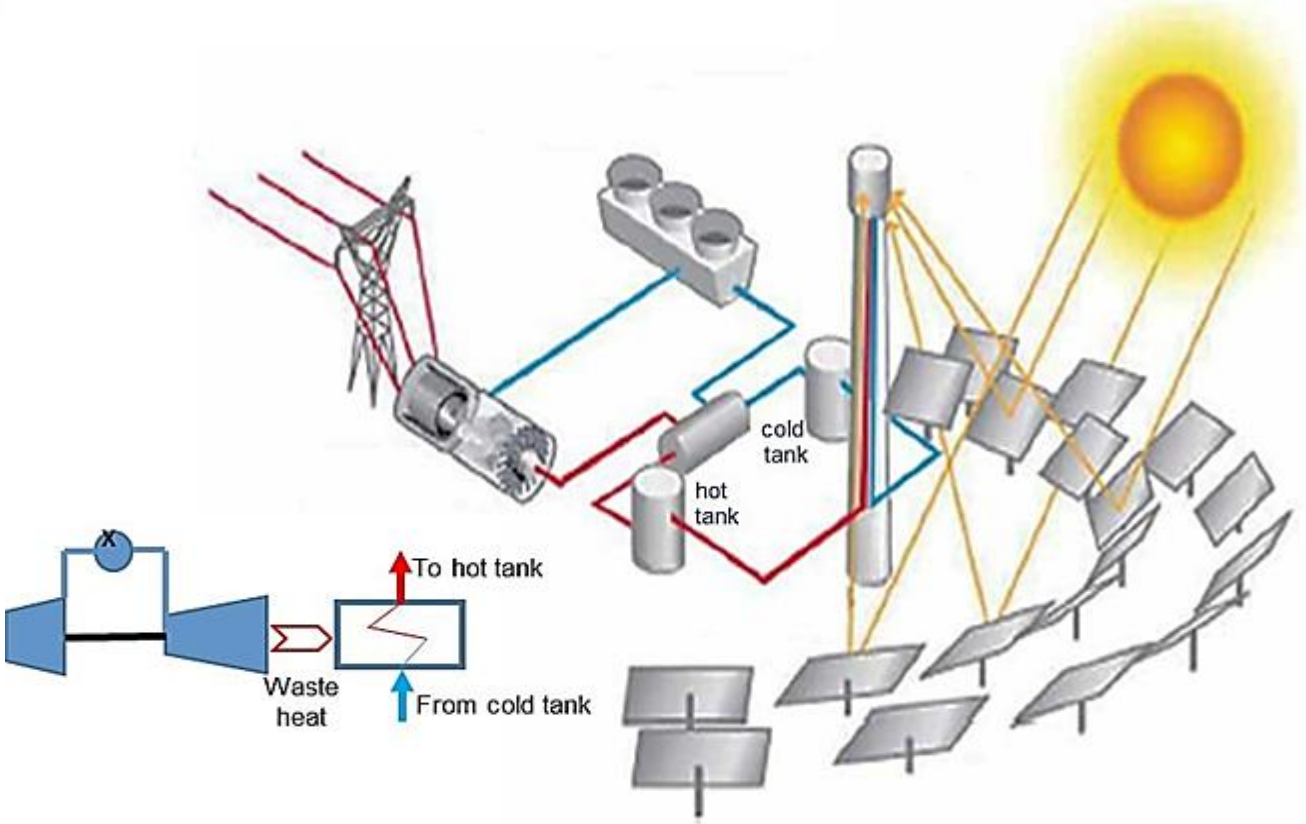
Gas and storage: the perfect combination of gas turbines with molten salt tower plants



This concept can be defined as “decoupled Integrated Solar Combined Cycle”. It has nothing to do with the ISCC since it provides a much higher share of the solar part.

It will have nearly the same efficiency than the combined cycles but its operation will be much easier and flexible.

Reference HYSOL project

STE plants could facilitate the deployment of variable RES power plants

Examples of existing co-location of plants

Andasol plants (150 MW) and wind parks (200 MW) in the province of Granada, Spain

Dispatching STE at the evening peak to complement PV plants will increase significantly the operational and capacity value of hybrid STE/PV plants

10 MW STE plant co-located with 1 MW PV in the Solucar complex, Seville, Spain

THE REASONS FOR A BRILLIANT STE FUTURE

1. Technical

STE is the only dispatch-able and grid-friendly renewable technology with potential enough to firmly meet the electricity needs worldwide in order to achieve an almost carbon free generation system.
A wise mix with other R.E. technologies will be the right choice.

2. Local Economic Development

Local content of STE plants - and conversely its GDP contribution - should be one of the main drivers behind the coming supporting policies in most countries of the Sunbelt.

3. Affordable cost with higher value

STE plants are currently a cost competitive choice to supply the increasing power demand of emerging countries compared with “investing twice” as it would be the case regarding other fluent R.E. technologies + CC backup. Furthermore STE plants will show important reductions when approaching similar values of Wind (400 GW) and PV (200 GW) from their current 5 GW

Some recent data on STE production in Spain

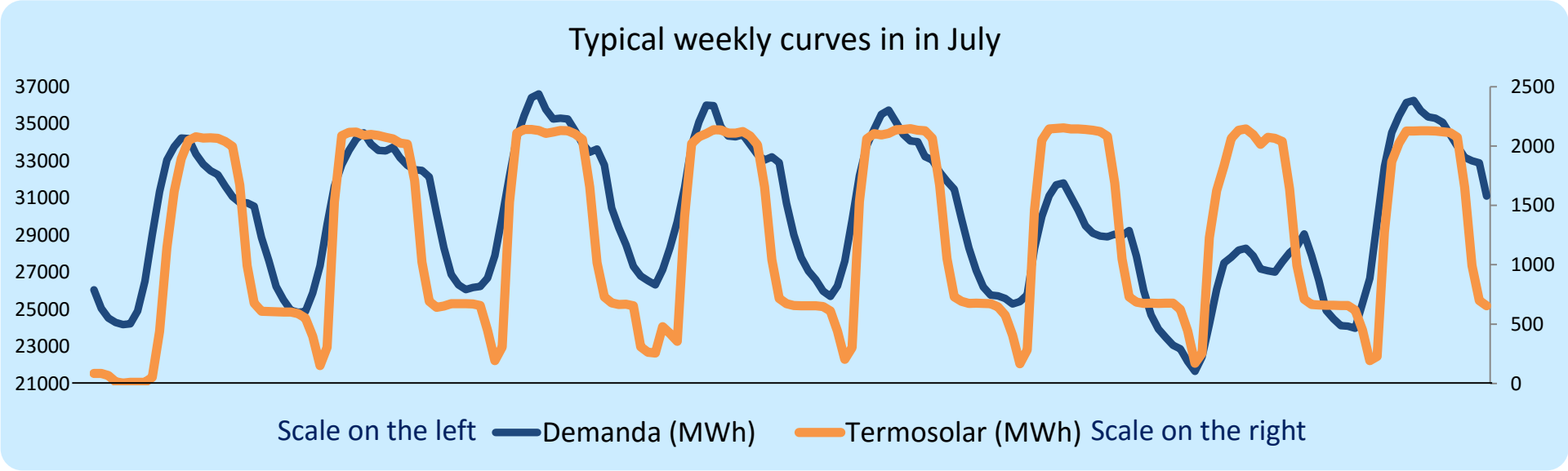
All the 50 STE Plants in Spain are performing according to the expectations
The learning curve took between 1 to 2 years depending on the plant but now all are working very well.

Improvements in operation and O&M cost reductions are still being applied

Important milestones in 2015

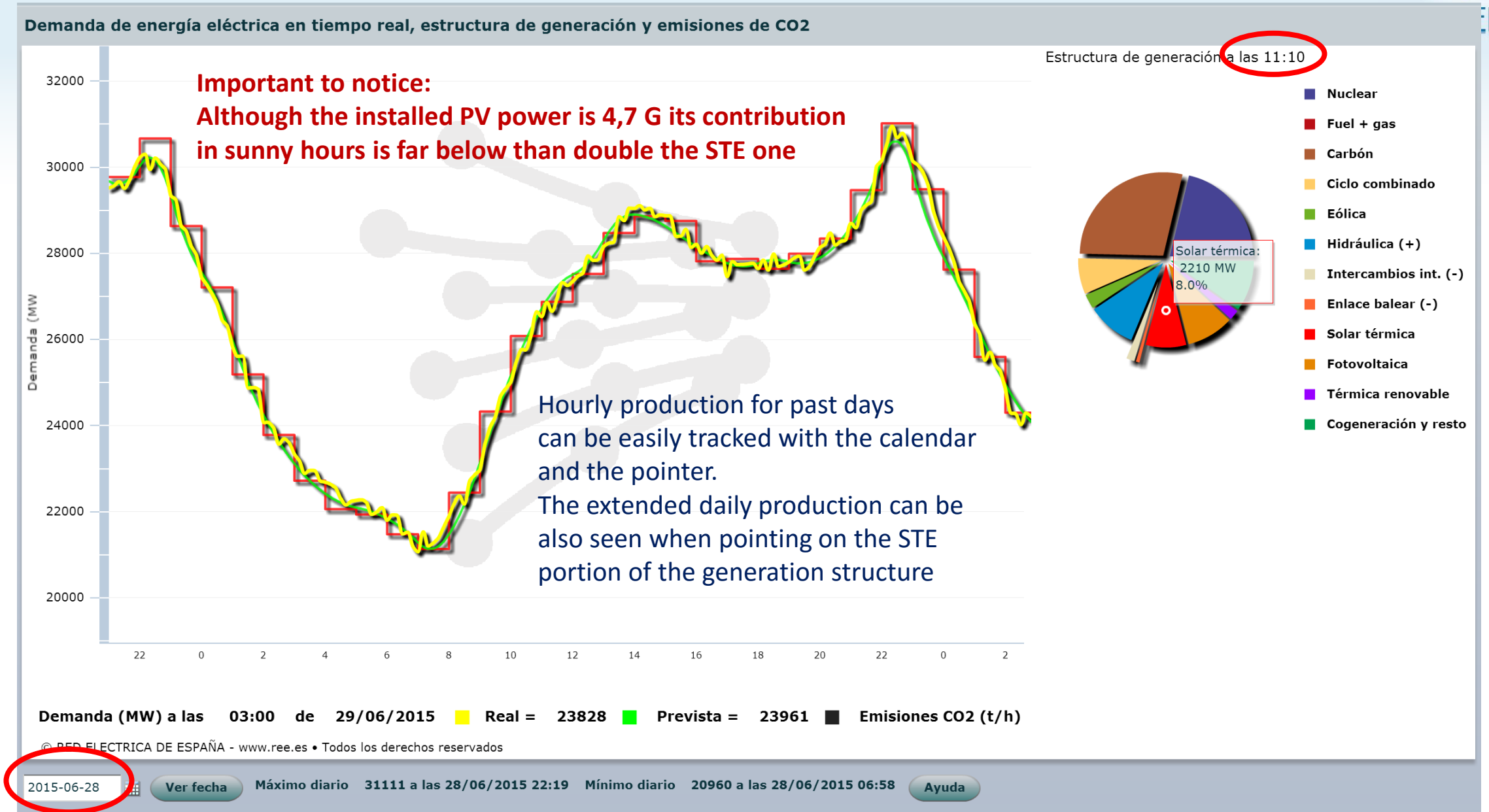
- ✓ Installed Power 2300 MW (50 plants)
- ✓ New yearly record 5,1 TWh
- ✓ Max. contribution > 8 %
  At many moments from May till September
- ✓ Max. daily contribution around 5%
  At many days in June, July and August
- ✓ Monthly production close to 4 %
  889 GWh in July

These curves show how good STE production matches the demand

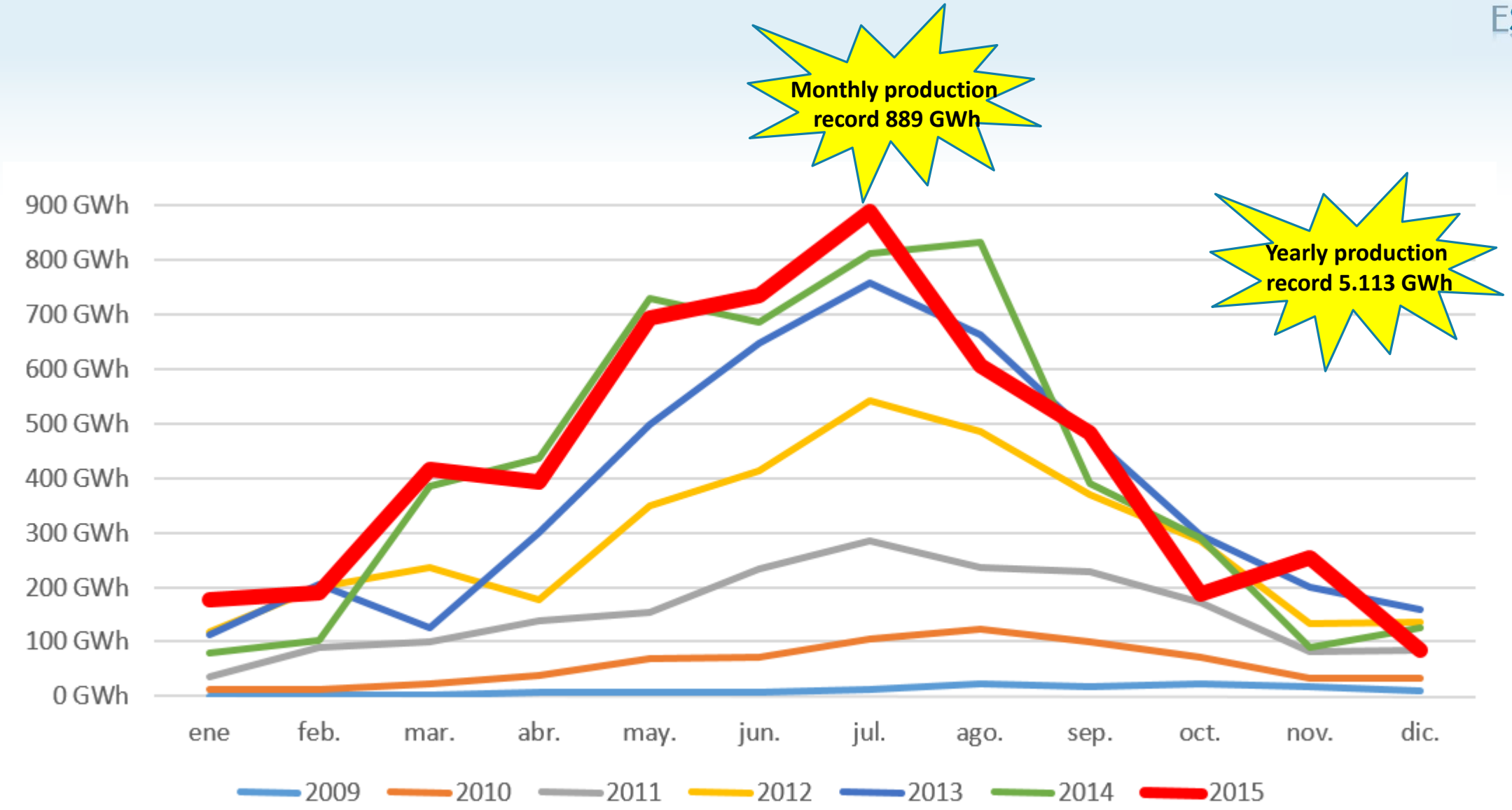


Typical production in a summer day

https://demanda.ree.es/demanda.html



Historic production of STE plants in Spain



Macroeconomic Benefits for the country's economy

Comparison between premiums and returns of a STE deployment program

+ Industrial development

+ Re-balancing the generation mix

+ Reinforcement of the grid

+ Attraction of foreigner investment

+ Regional economical convergence

Supports

Supporting STE was a wise decision for Spain and it will be so in all countries

Unemployment subsidies

Savings in CO2 rights

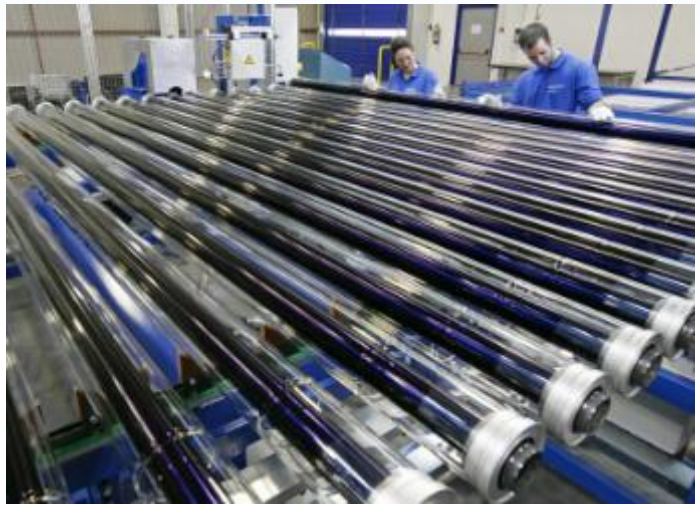
Savings from replacing imported fossil fuels

Fiscal contribution
(Social Security, Corporate, Personal and Local Taxes,)

Contribution to GDP

Industry localization in Spain for solar field components

Absorber tubes



Curved mirrors

Prerequisite:
Stable program of some few hundred MW per year

Collector structure

Other direct effects on Industry

Reorientation of other mature industries:

- Construction, civil works
- Engineering of conventional power plants
- Electricity Transmission Infrastructures
- Galvanizers, …

Reinforcement of some industry sectors:

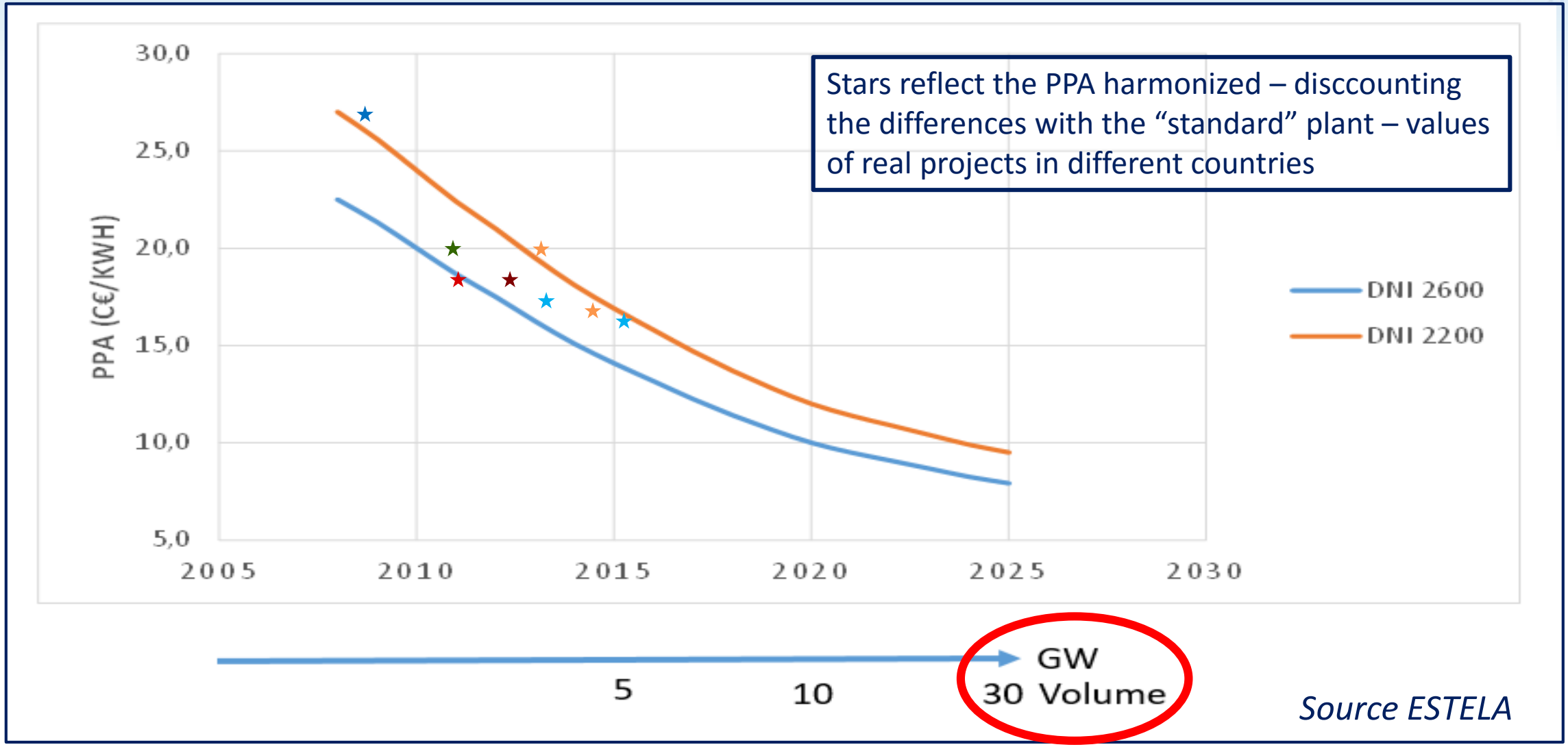
- Piping and tanks
- Heat exchangers
- Boilers
- Cabling
- Telecommunication and control

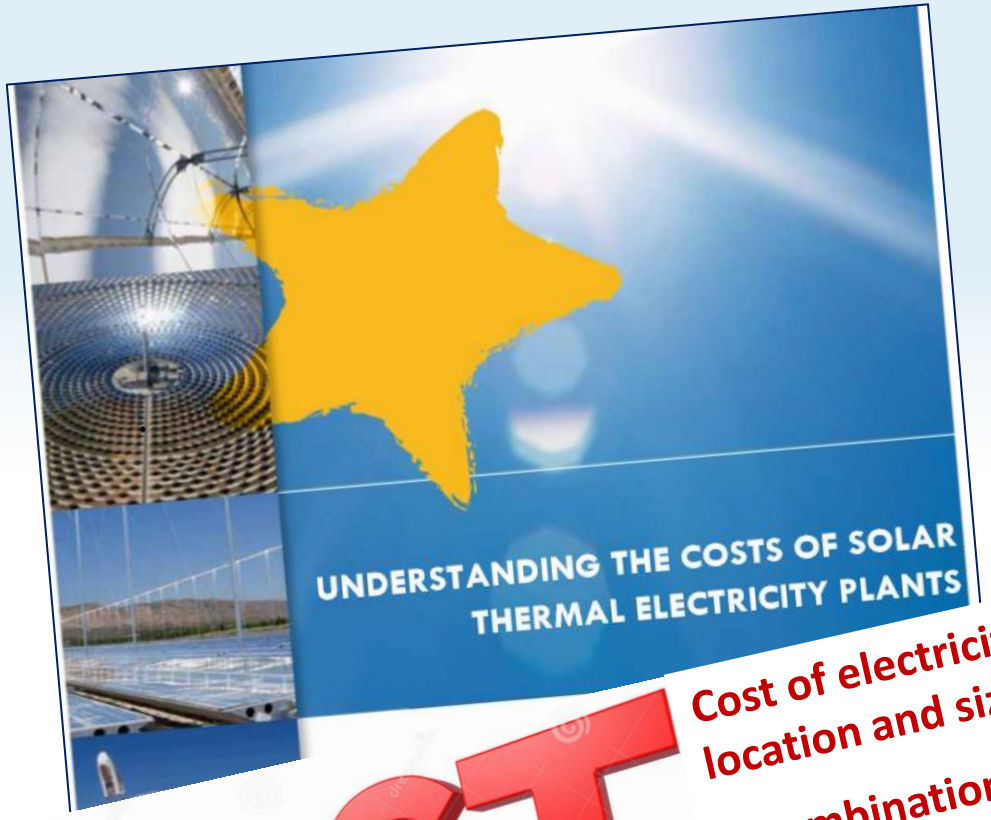
Huge impact in auxiliary sectors

- Cleaning, environmentalists, labs, …
- Road transport
- Training, …

+ Reinforcement of supplier's subsidiaries in the country:
Promotion, Maintenance, Spare parts, …

Required value for a 25-year PPA without escalation for a standard 150 MW 5-hour storage STE plant without any kind of financial public support





Drivers for Cost reduction in STE

	Today	2025
A) Solar field ind. HTF [€/m²]	160 - 250	100 - 160
B) Storage [€/kWhth]	26 - 30	18 - 21
C) PowerBlock [€/kWe]	720 - 765	700 – 790
D) System Efficiency	15-17%	18-20%

A) Solar Field

1. Collector with larger Apertur
2. Improved optics th
3. Advan

- layout (Tower)

- orage Medium)
- erance
- orage materials
- ndardized Design; Sub-Supplier design standards
5. Advanced charging and discharging, improved operation strategies in general

C) Power Block

1. Higher Cycle efficiency
2. Improved hybridization concept
3. Larger Power Block
4. Standardized Design

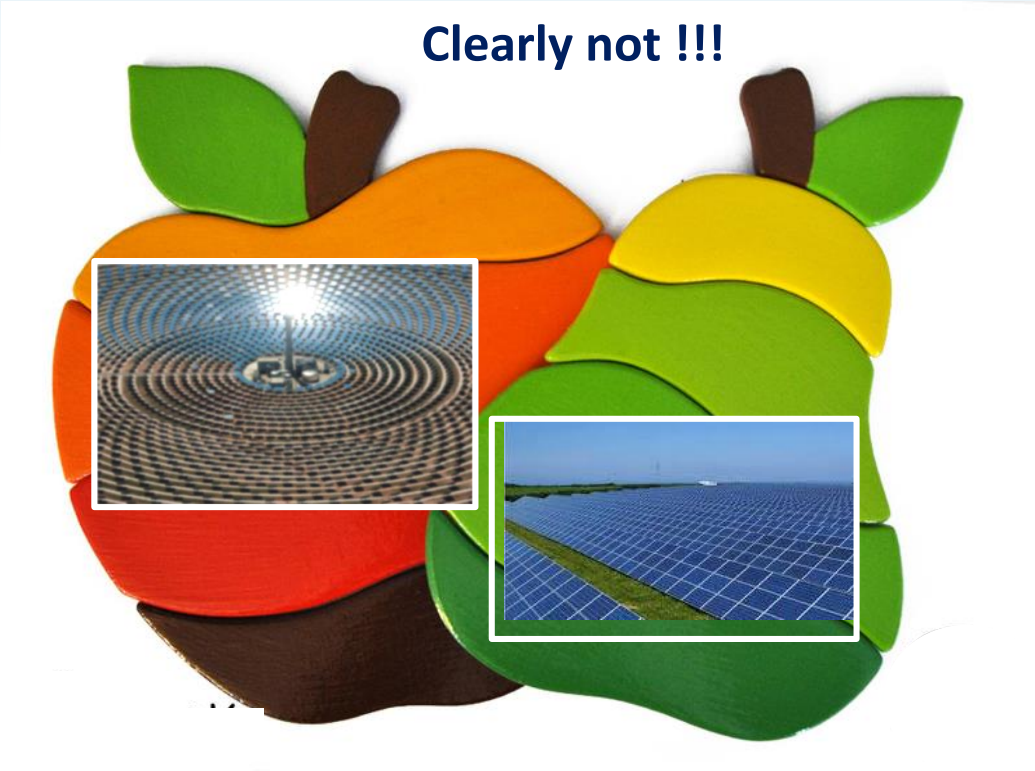
D) System Efficiency

1. Higher process temperature
2. Lower Parasitic consumption (higher temperature; through: larger aperture and other HTF; Tower: gravitational pressure loss recovery)
3. Adapted Turbine Design (for daily start-up)
4. Improved control and O&M strategies / procedures

Cost of electricity from STE plants is highly dependent on the location and size along with PPA terms and financing conditions

A combination of innovation, component prices and soft costs (permitting, financing, engineering, …) reduction will be key for competitiveness

Are we comparing apples to apples?



Cost/kW is not the right indicator. Comparisons must be - at least - made in terms of investment for the same yearly production.

When talking at system level **what matters is not simply generation cost** but **system costs and benefits**, which comprise its “value”.

Apart from **dispatchability and grid integration** issues, which provide a clear and accountable “plus” to STE and **macroeconomic** impacts, which policy makers should take into account, there are other aspects which are usually disregarded such as:

Life of components, performance degradation, impact of temperature on performance, iosses in charging and discharging batteries or pumping stations, etc.

Time has come to realize that it is not enough establishing global goals on the share of RE by 2030 or 2050. **Linking the necessary high contribution of dispatchable generation technologies to these goals is already a must**. Otherwise a CO_2 free generation system will not be feasible and business cases for *any* RES investments will no longer be given.

- ✓ **STE is** - and will continue to be - the **necessary choice** when planning addition of new capacity in sunny countries.
- ✓ **STE would be** also the **preferred choice** for policy makers when all the impacts - technical and economical - are duly taken into account

Thank you for your attention

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