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ESTELA

The Value of Thermal Storage in STE Plants

The Issue of Integrating Intermittent Renewable Generation into Power System Operation

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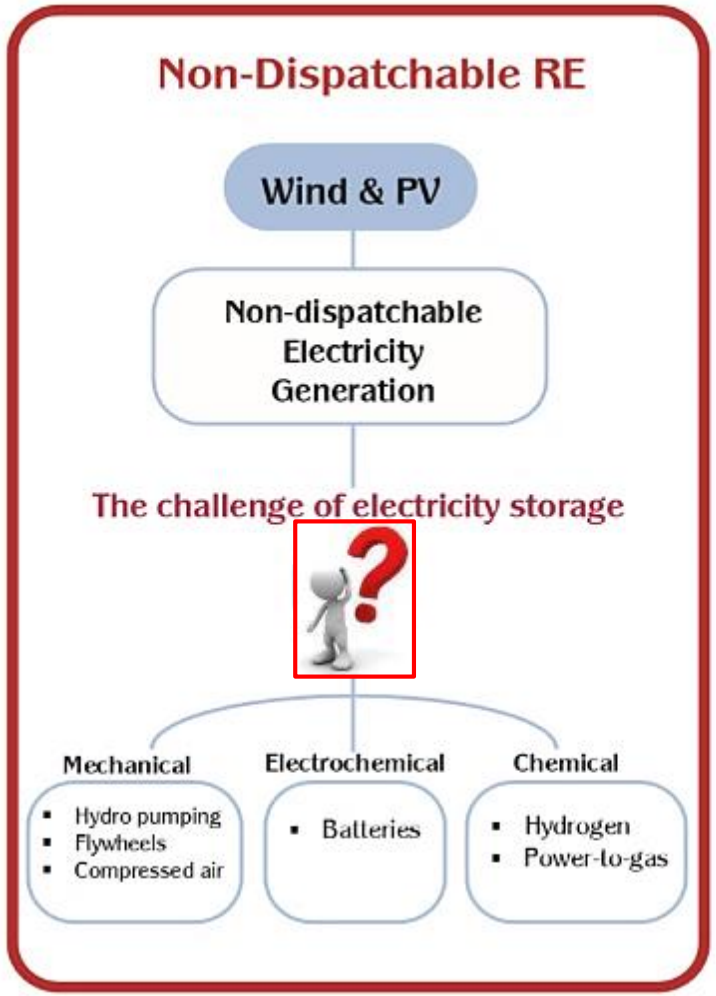
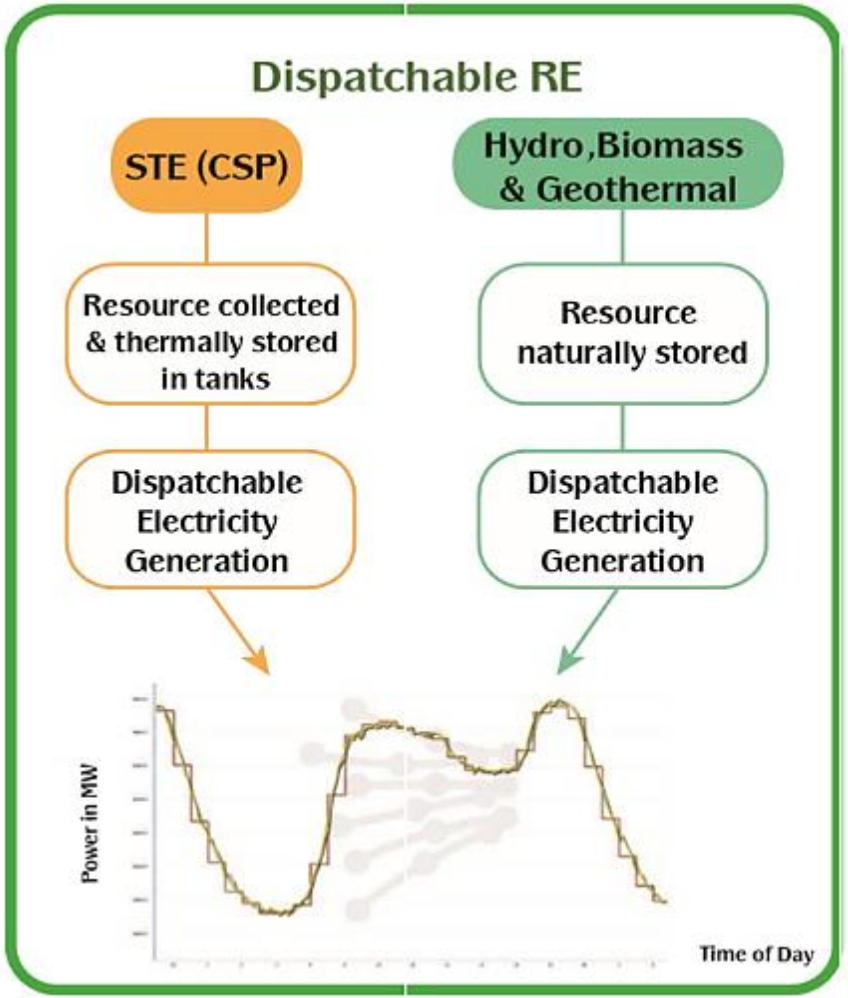
After the current the initial phase of RES deployment -reaching now about 450 GW of Wind and 250 GW of PV worldwide- time has come to face an **essential fact**





There are two types of renewables

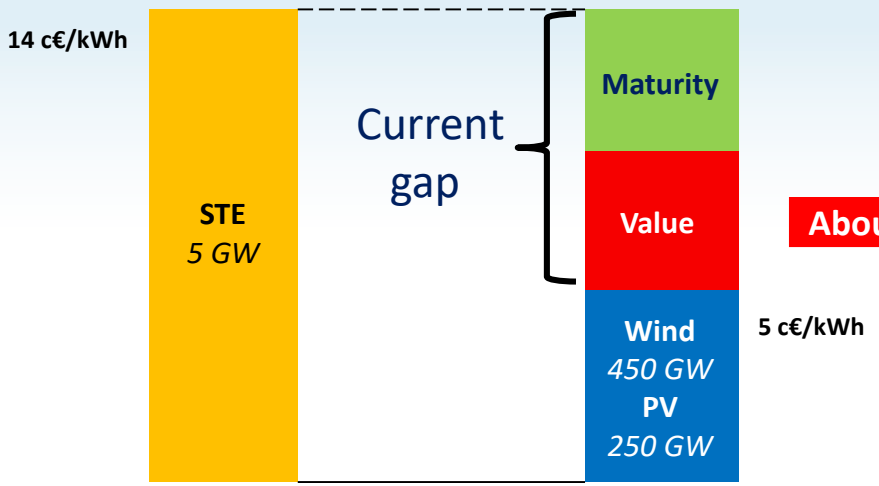
- ✓ One, which is the cheaper but non-dispatchable
- ✓ The other one is the "still" more expensive but dispatchable technology - such as solar thermal electricity STE/CSP

Achieving a CO_2-free power system will be only possible with a larger share on dispatchable renewables

Regarding the issue of electrical storage,

why not prevent the causes of the problem instead of having to cure its effects?

Explaining the current gap on costs between non dispatchable RE technologies and STE



About "Value"

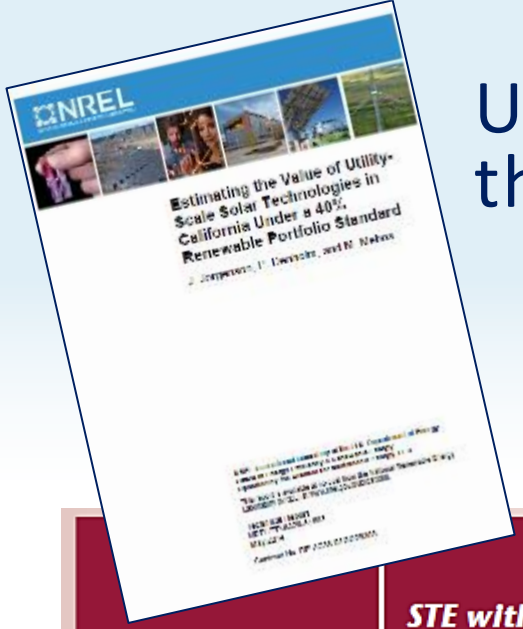
About "Maturity"

$64/MWh has been offered by an STE plant in the recent auction in Chile

- ✓ 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.



Understanding the value of solar power according to the Renewable Electricity penetration share

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

http://www.nrel.gov/docs/fy14osti/61685.pdf

	33% renewables		40% renewables	
Value component	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 50 USD/MWh to PV than 100 to STE with storage
This difference will become larger as RE penetration increases

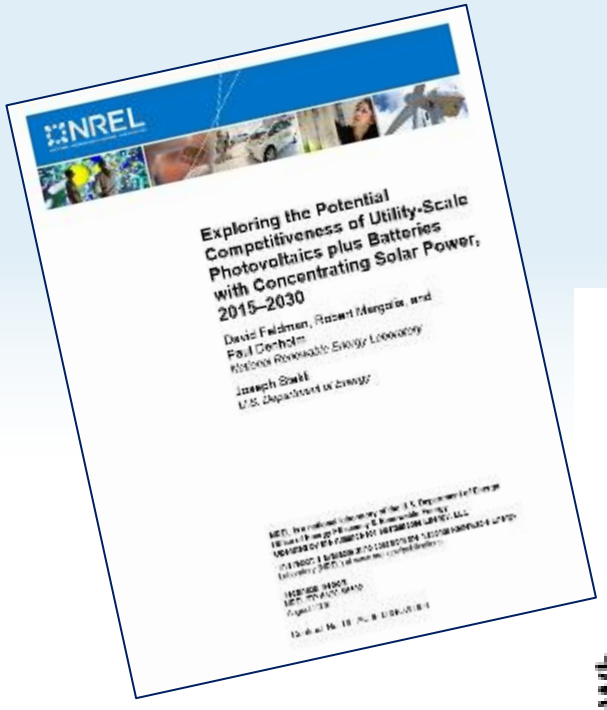
- **What does operational value means:**
  Operational value represents the avoided costs of conventional generation at their respective dispatching times along with related ancillary services costs, such as spinning reserve, etc. Savings on emission costs are also accounted

- **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

Comparison among different storage technologies

Storage Technology	Hydraulic Pump	Compressed Air	Batteries	Flywheels	SMES	Super Condensers	Molten Salt Tanks (STE Plant)
Storage Capacity	500-8000 GWh	580-2860 MWh	0.001-250 MWh	0.0052-5 MWh	0.01-0.001 MWh	0.01 MWh	1 – 10 GWh
Duration of Discharge at Maximum Power	1-24h	1-24h	1-8h	15s to 15 min	10s	10s	1 – 24h
Nominal Power	10-1000 MW	50-300 MW	0.015-50 MW	0.1-20 MW	1-10 MW	0.05-0.1 MW	10 – 300 MW
Response Time	minutes	3-15 min (big scale)	30 ms	5 ms	5 ms	5 ms	minutes
Auto Discharge	Very small	Small	0,1-20%	100%	10-15%	20-40%	Very small
Effective Lifetime (years)	50-100	30	02-10	20+	20	20+	40
Energy Density (Wh/kg)	0.5-1.5	3.2-5.5	20-200	5-00	10-75	0.1/30	30 - 100

Source: DOE / CIEMAT



Cost estimates of Li-ion batteries

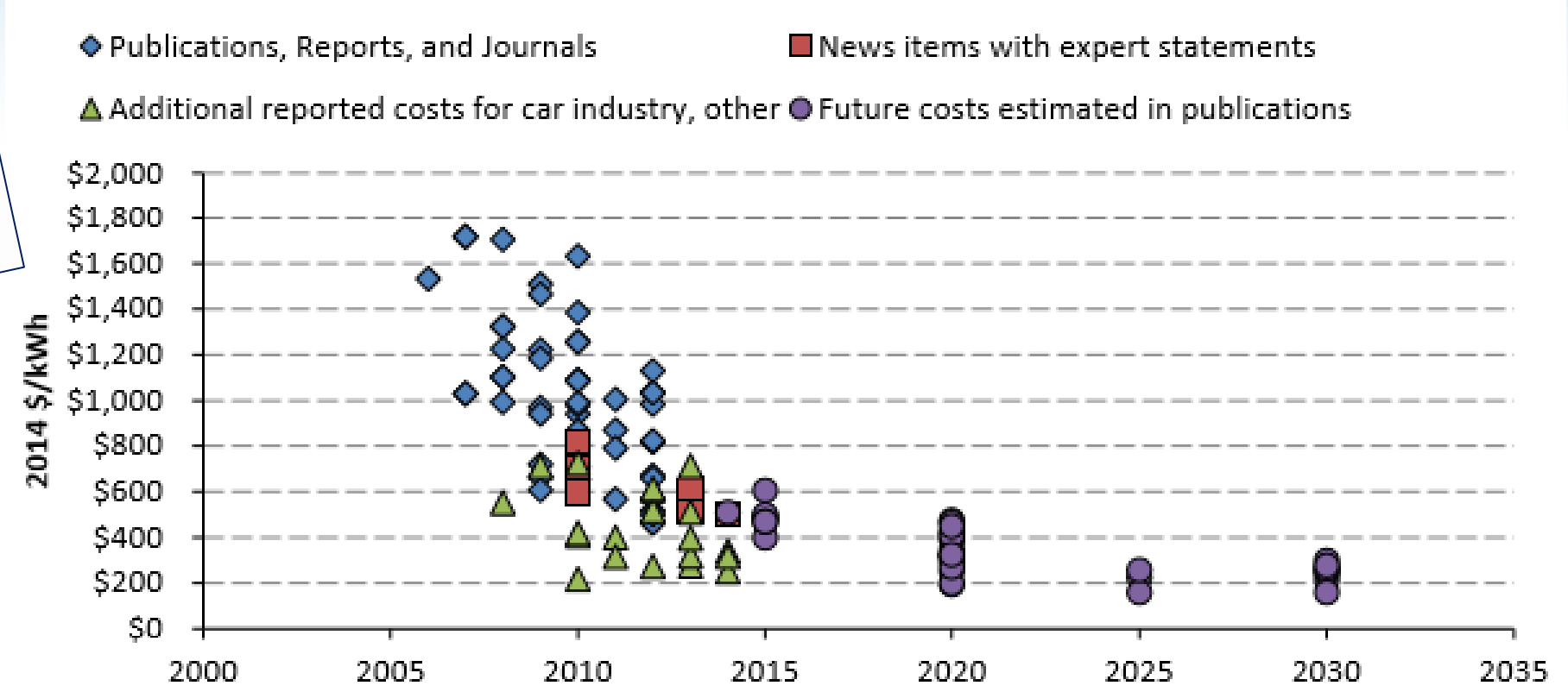


Figure 13. Cost of Li-ion battery packs

Source: Nykvist and Nilson 2015

Approaches and forecasts to Li-ion battery cost projections

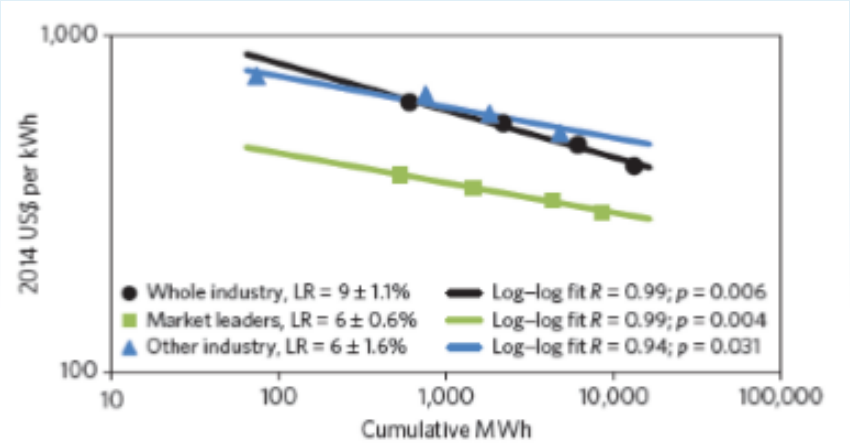


Figure 14. Modelled experience curves for battery packs

Source: Nykvist and Nilson 2015

Could other potentially better concepts show quicker experience curves?

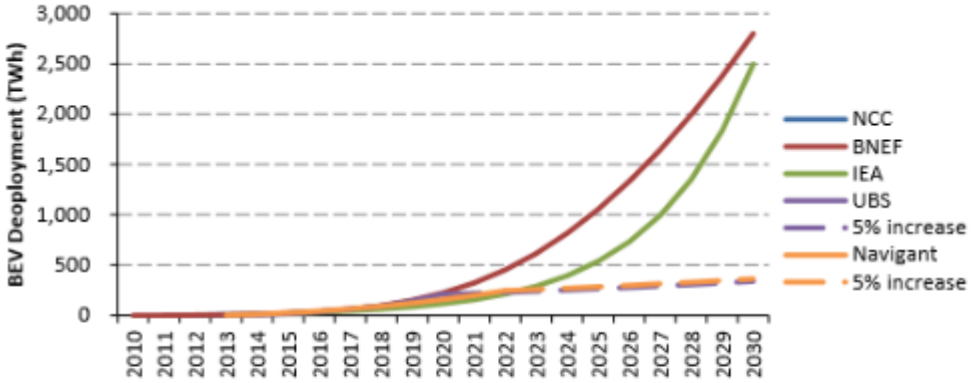


Figure 15. Projected battery-pack deployment, 2010–2030

Sources: Gandolfie et al. 2015; BNEF 2015b; IEA 2015; UNFCCC 2016; Navigant 2013; Nykvist and Nilson 2015

analyst forecasts that only project car sales, this analysis assumes an average battery size for a of 25 kWh.

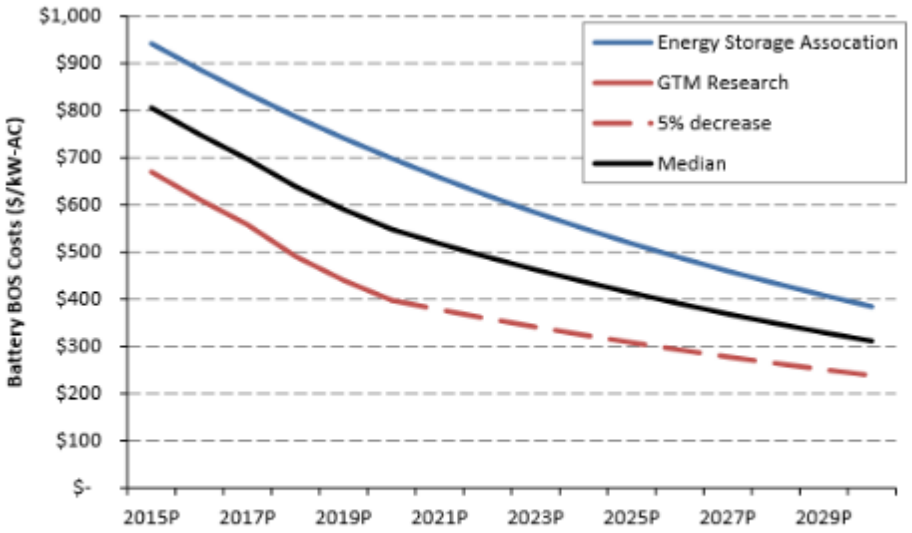


Figure 18. Estimated battery BOS costs, 2015–2030

Sources: GTM Research 2016; Roberts 2015

Projected battery system prices

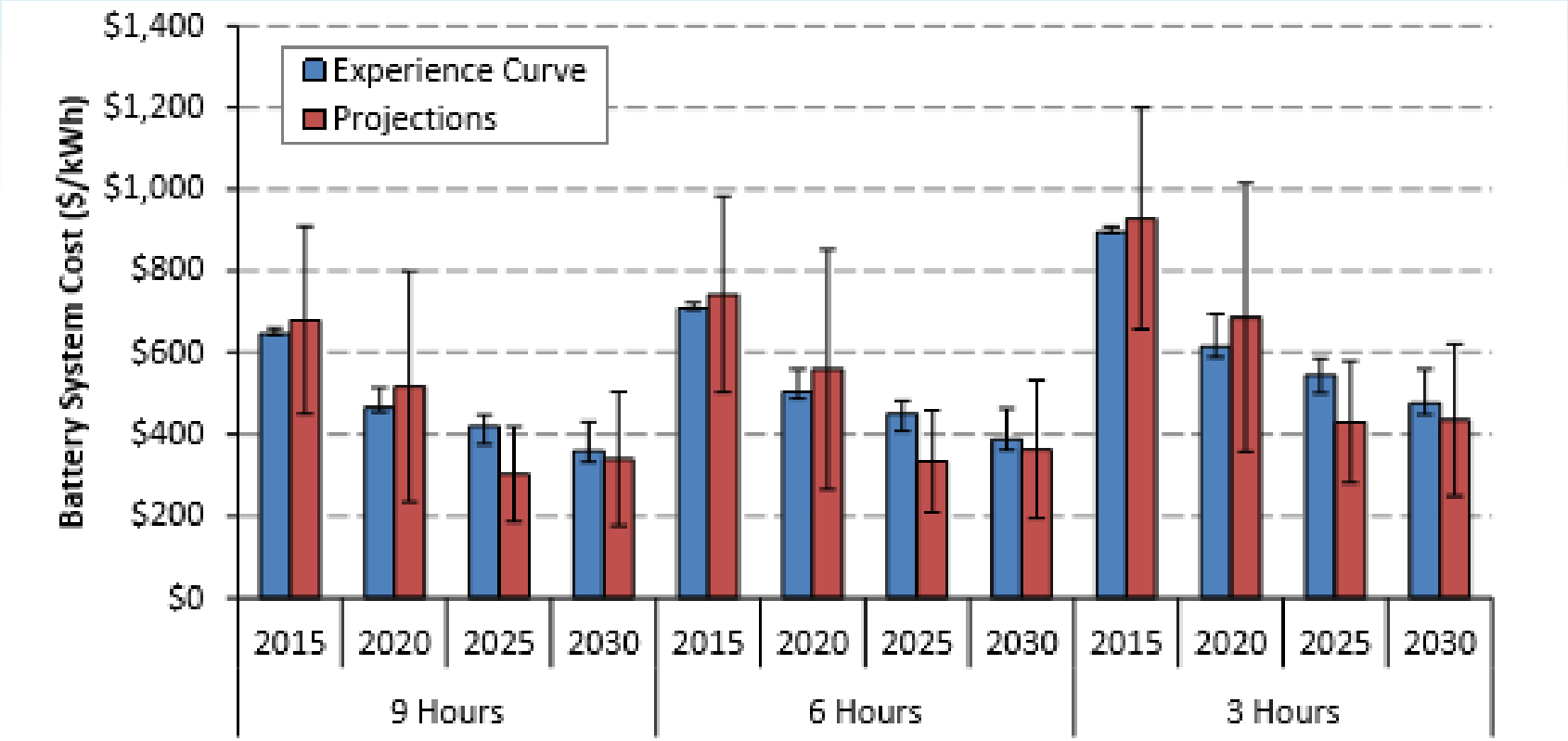
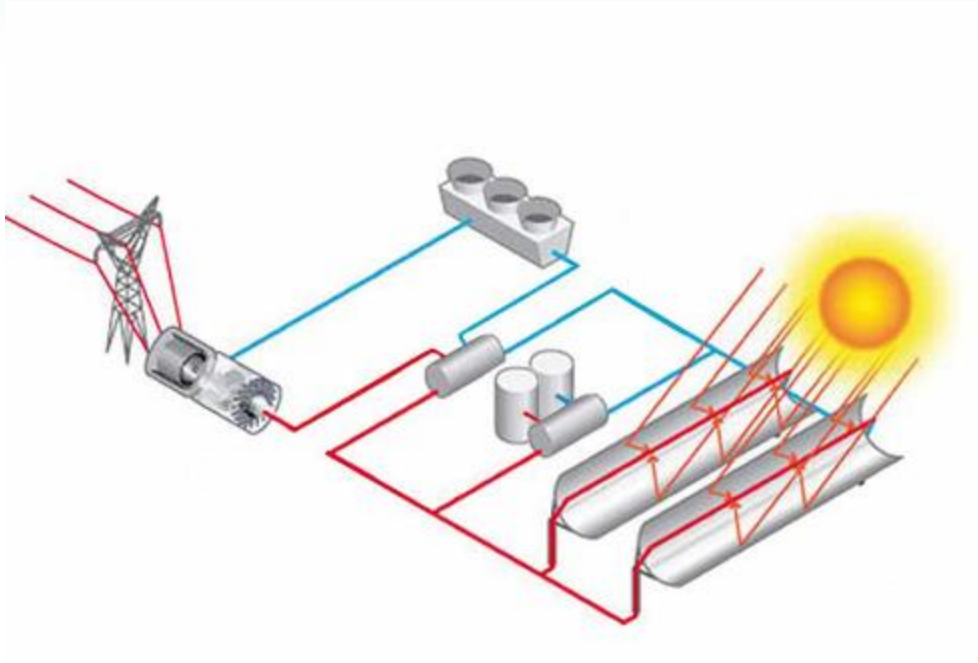
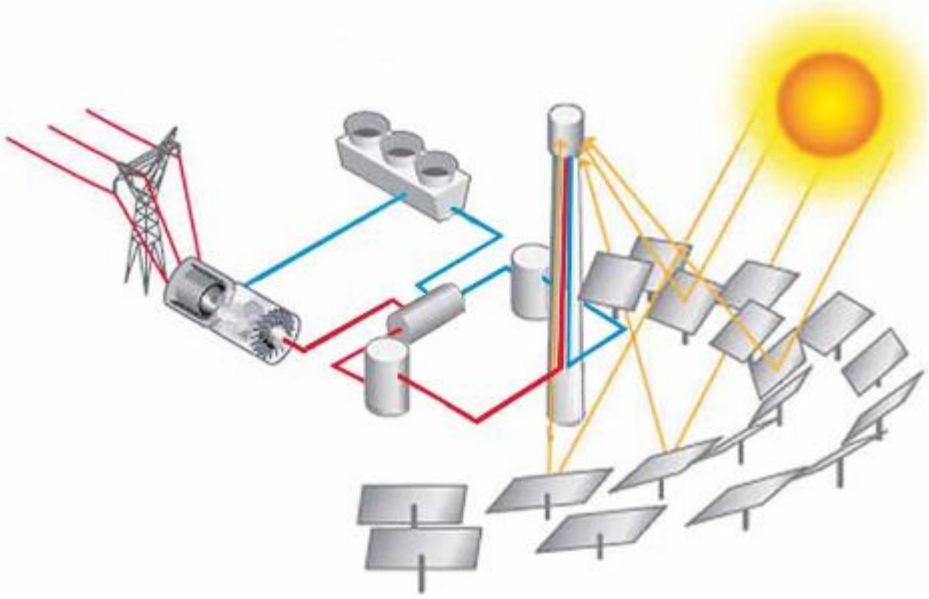


Figure 19. Projected battery system prices from historical experience curves and analy estimates, 2015–2030

Mid case is shown with uncertainty bars representing the span of the low to high cases.

The current most efficient solution for Solar Energy Systems: Dispatchable Solar Thermal Electricity (STE/CSP)





The two tank molten salt storage system is working very efficiently since 2008
(One decade almost without degradation signs)

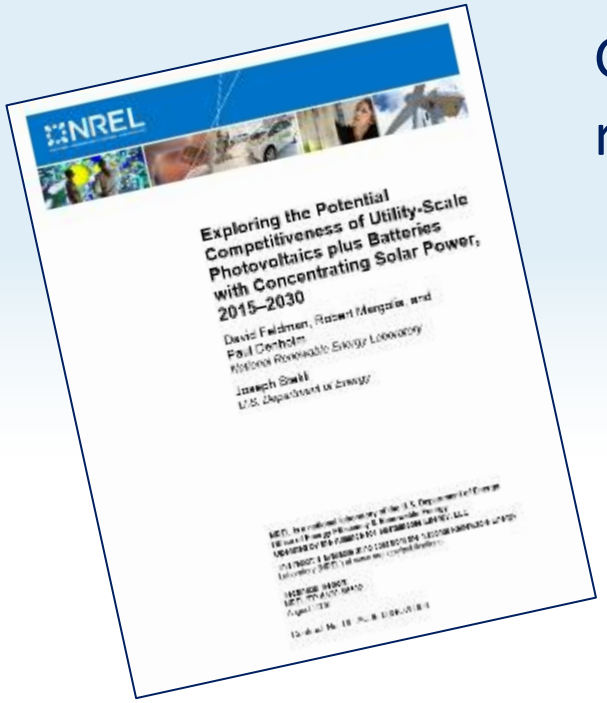
Molten salt tower plants require 3 time less volume of storage than the parabolic trough plants with thermal oil and no HTF/Salt heat exchanger

17 STE PT plants in Spain with 7,5 hours Storage

1 GWh_{th} equiv. 375 MWh_e

Cost 35 M€ aprox.
Ratio 90 €/kWh_e aprox.

Current prices for CSP storage systems for central receiver plants are already around 35 €/kWh_e



Generation costs for a system with 6 hours of storage will remain lower at least until 2030 for CSP than for PV + batteries

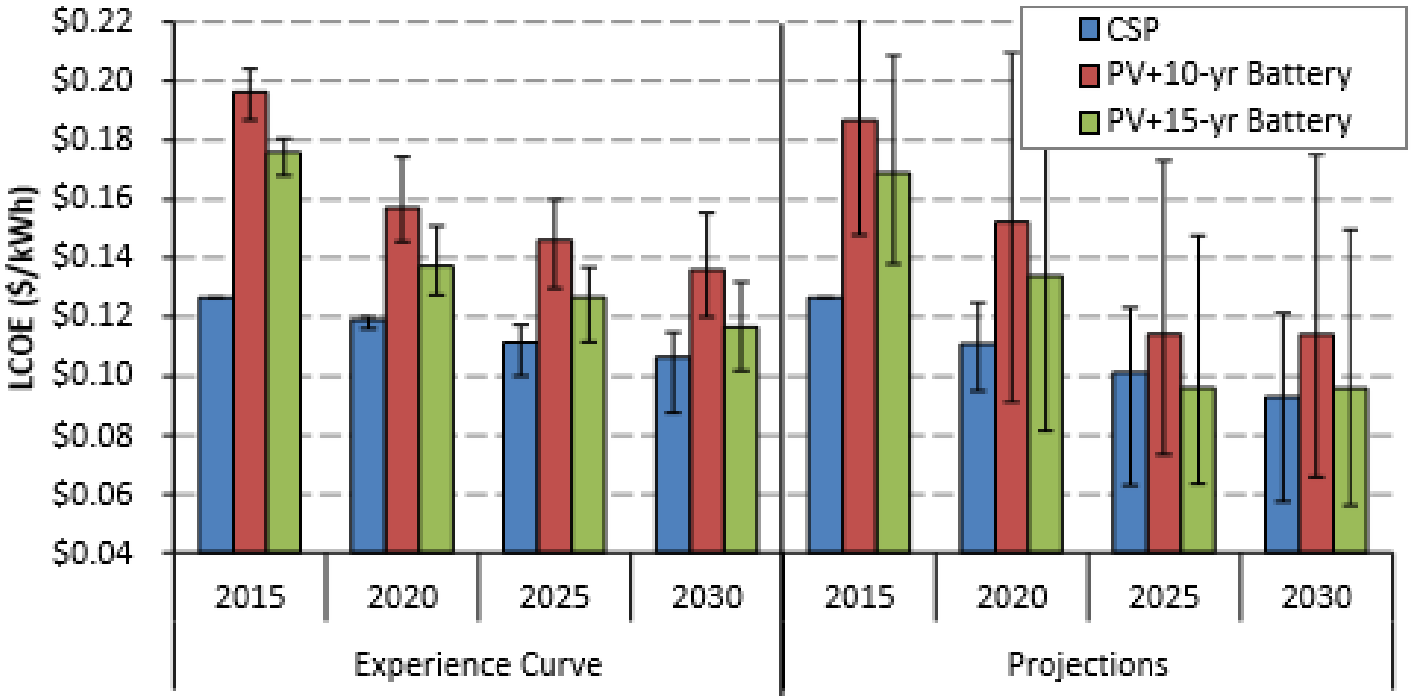
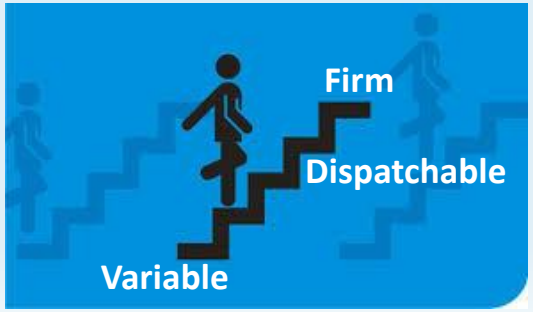


Figure 26. LCOE comparison: CSP versus PV (six hours of storage), 2015–2030

Mid case is shown with uncertainty bars representing the span of the low to high cases.

- Although batteries will continuously increase its role in electrical vehicles and distributed systems, it is not likely that they will be implemented in large power plants in the next 5 – 10 years
- **We mustn't forget that the generation fleet for 2030 have to start being constructed TODAY**

✓ Firmness of supply is a step beyond dispatchability



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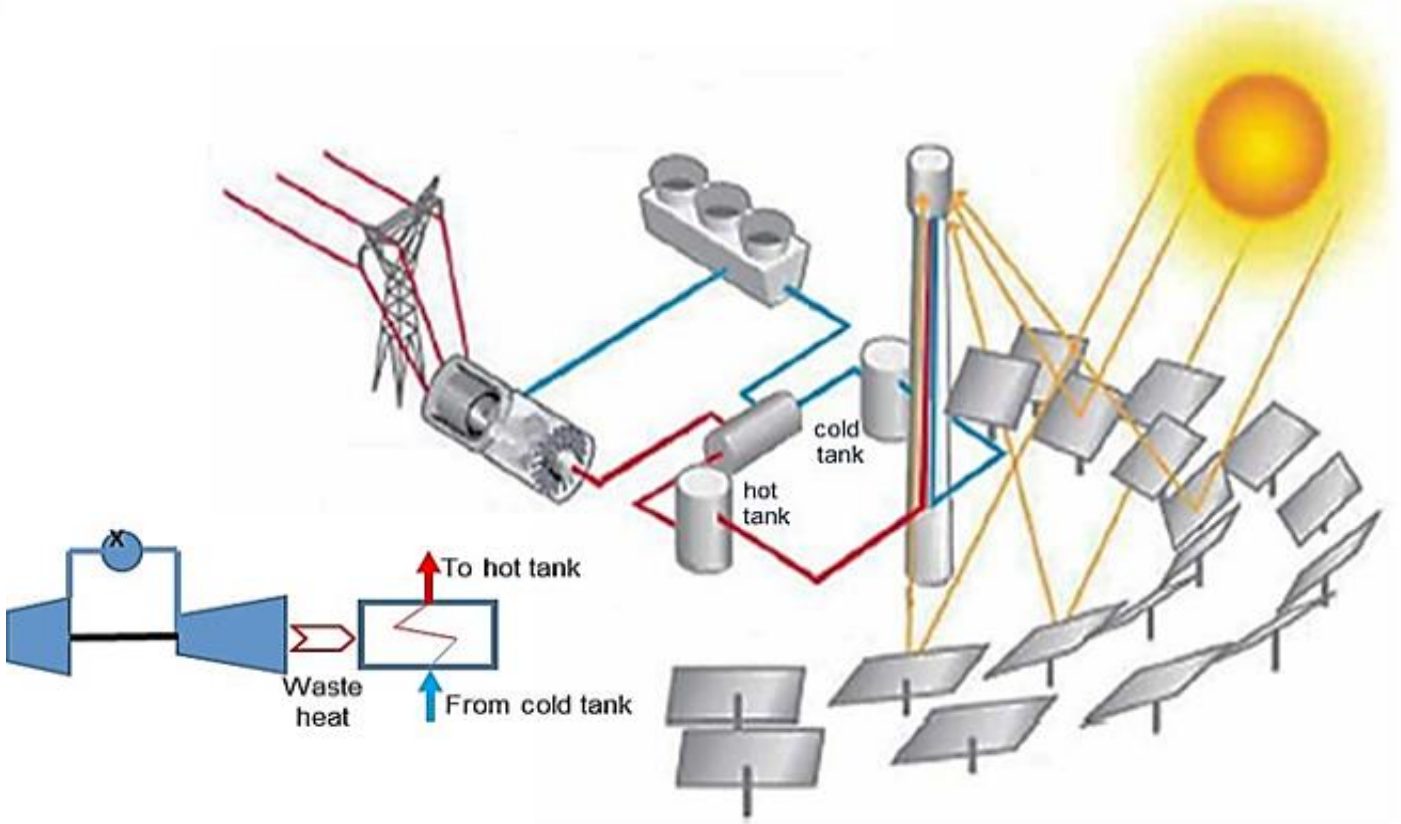
Gas and Storage: the perfect combination of gas turbines with molten salt tower plants



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

Conclusions

- ✓ LCOE of STE plants is - as of today - **much lower** that LCOE of PV plants with 6 hours battery storage. **And it will continue to be so at least in the next 10 years**

  Wherever you hear the simplistic argument that LCOE is much lower for PV than for STE, please raise your hand and say that it is not true, as STE will be always provided with thermal storage. Comparisons have to be made between "apples & apples"

  We must amplify this fact and educate policy makers and the general public to make them understand that current PV systems and STE plants with storage are two different products with very much different value for the system

- ❑ The current two tank concept is very robust and performs quite reliably and efficiently
- ❑ Innovations - medium, concepts - for cost reduction are welcome but they shouldn't result in performance degradation when discharging the storage and they shouldn't require significant auxiliary electrical consumption

Thank you for your attention

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