

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria dell'Energia

Relazione per la prova finale
Impianti solari a concentrazione: potenziale
contributo per un futuro energetico sostenibile

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Padova, 21/09/2023

- SDS (Sustainable Development Scenario)
- NZE2050 (Net Zero Emissions by 2050)
- 2030 Climate and Energy Framework

- panoramica degli impianti CSP
- importanza dell'accumulo termico
- impatto ambientale
- aspetti economici e competitività
- impatto sulla curva di potenza
- ruolo nel mix energetico odierno e futuro

- costante solare: 1367 W/m^2
- radiazione solare diretta

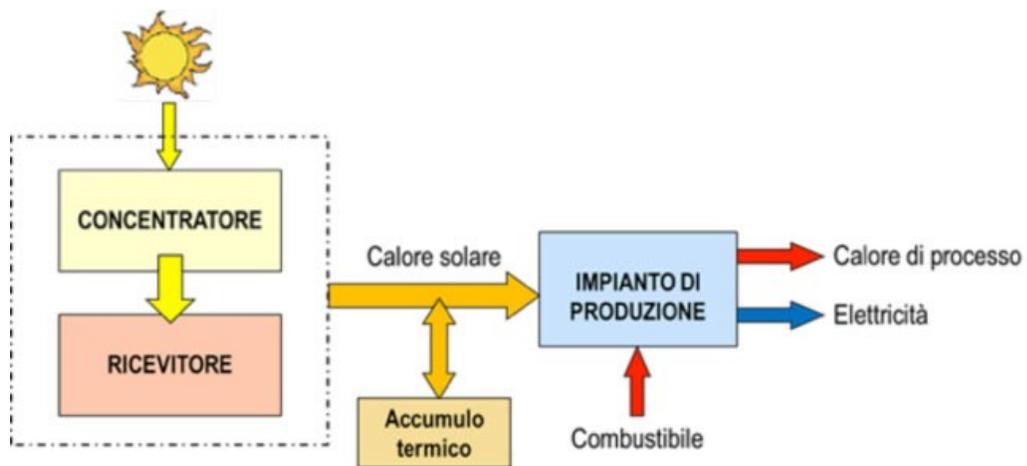


Figura 2: schema concettuale degli impianti solari a concentrazione

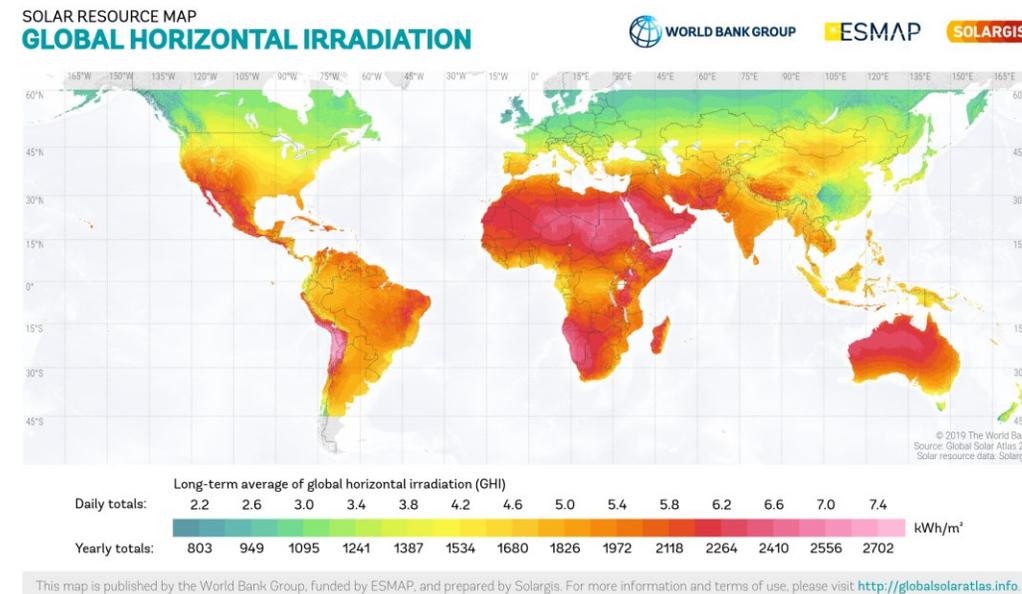


Figura 1: radiazione solare diretta incidente all'anno in kWh/m²

FOCALIZZAZIONE LINEARE



parabolic trough:
 $C = 30-80$
 $T_{max} = 400 - 600^{\circ}\text{C}$



linear Fresnel:
 $C = 30-80$
 $T_{max} = 400 - 600^{\circ}\text{C}$

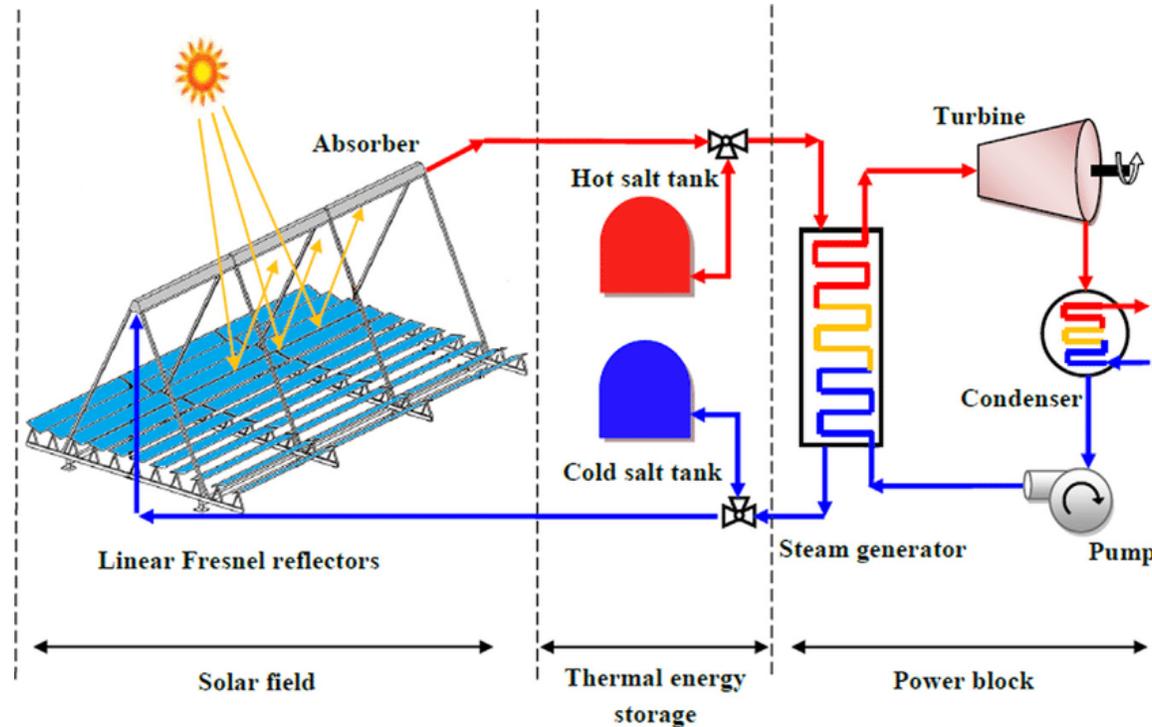
FOCALIZZAZIONE PUNTUALE



tower:
 $C = 200 - 1000$
 $T_{max} = 600 - 1000^{\circ}\text{C}$



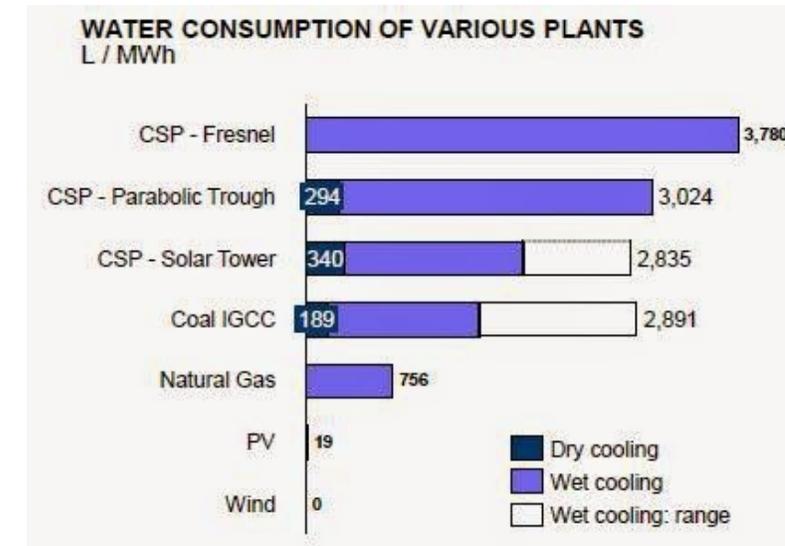
solar dish:
 $C = 1000 - 4000$
 $T_{max} = 800 - 900^{\circ}\text{C}$



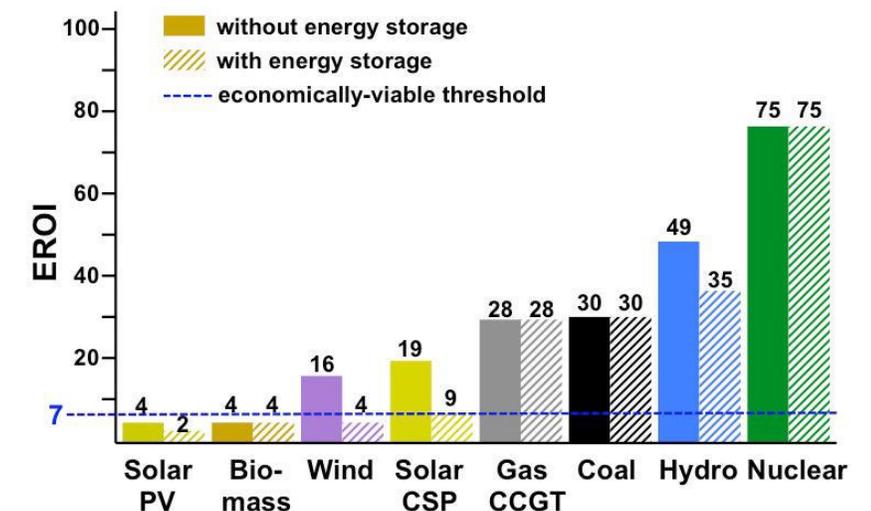
- permette di disaccoppiare la raccolta dell'energia solare dall'immissione dell'energia elettrica in rete
- solar multiple:= dimensioni del campo solare effettivo/dimensioni del campo solare sufficiente per alimentare il blocco di potenza alla potenza nominale senza calore in eccesso
- solar multiple per base load: 3 - 4

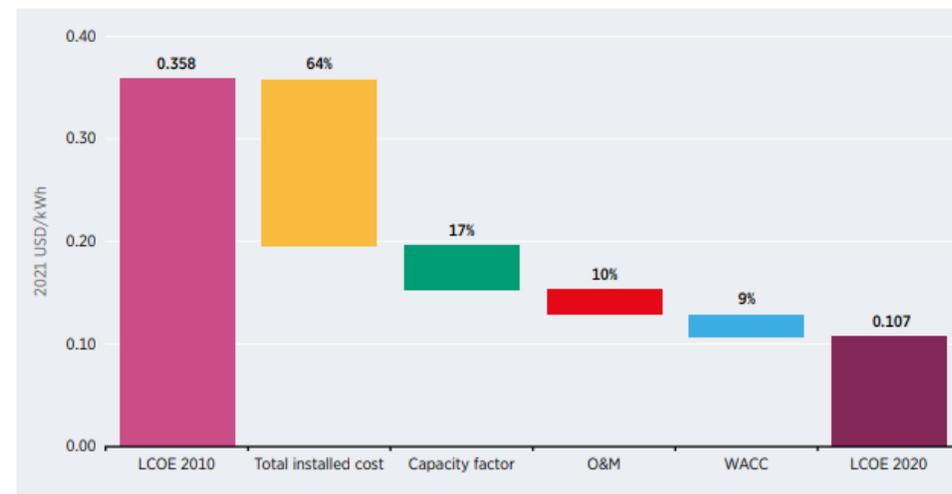
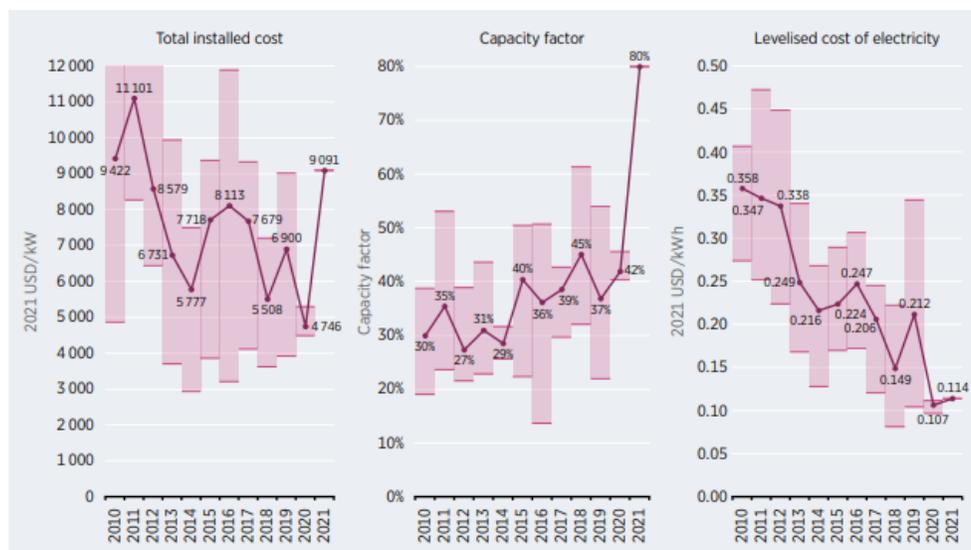
ciclo Rankine:
condensatori a torre: 2 - 4 m³/MWh.
condensatori ad aria: 0,2 - 0,34 m³/MWh

tecnologia	emissioni per la costruzione [g/kWh]		emissioni d'esercizio annuali [g/kWh]	
	CO ₂	CH ₄	CO ₂	CH ₄
carbone	41	0,04	936	3
carbone CCS (90%)	56	0,06	152	5
gas naturale	23	0,03	384	3,87
gas naturale CCS (90%)	30	0,04	69	4,53
PV	949	5,58	0,1	0
CSP	606	1,53	17	0
nucleare	89	0,18	4	0
eolico	97	0,32	0,1	0



Energy Returned On Investment relative to the breakeven value of 1

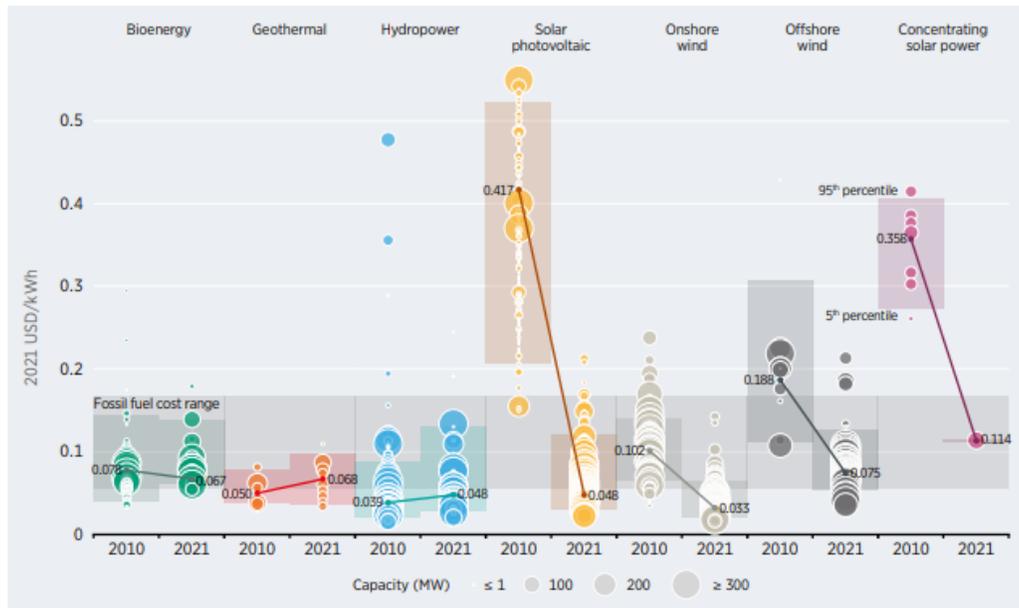




Source: IRENA Renewable Cost Database.

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anno	LCOE globale medio [\$/kWh]	costo d'installazione globale medio [\$/kW]
2010	0,358	9.422
2020	0,107	4.746



Source: IRENA Renewable Cost Database.

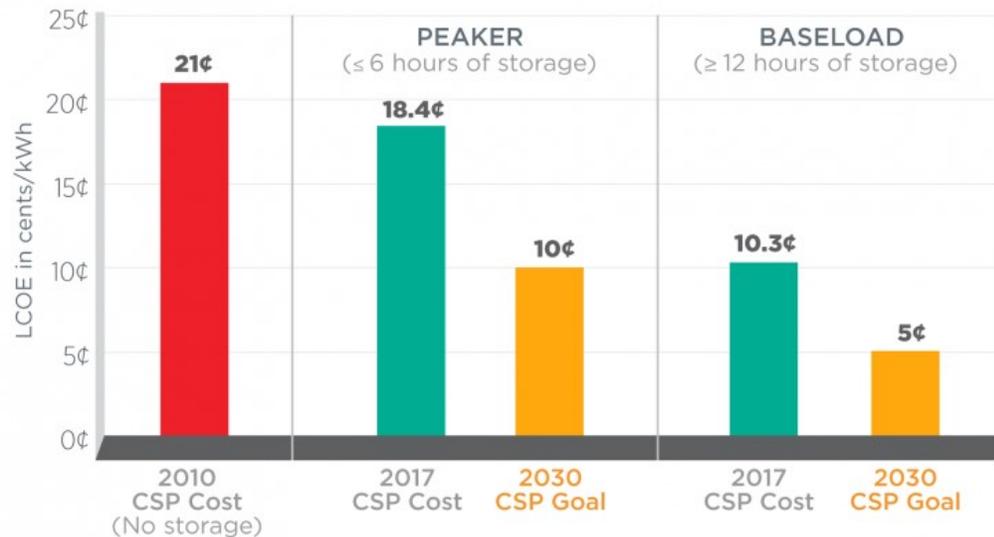
Note: This data is for the year of commissioning. The thick lines are the global weighted average LCOE value derived from the individual plants commissioned in each year. The LCOE is calculated with project-specific installed costs and capacity factors, while the other assumptions are detailed in Annex I. The single band represents the fossil fuel-fired power generation cost range, while the bands for each technology and year represent the 5th and 95th percentile bands for renewable projects.

	Total installed costs			Capacity factor			Levelised cost of electricity		
	(2021 USD/kW)			(%)			(2021 USD/kWh)		
	2010	2021	Percent change	2010	2021	Percent change	2010	2021	Percent change
Bioenergy	2 714	2 353	-13%	72	68	-6%	0.078	0.067	-14%
Geothermal	2 714	3 991	47%	87	77	-11%	0.050	0.068	34%
Hydropower	1 315	2 135	62%	44	45	2%	0.039	0.048	24%
Solar PV	4 808	857	-82%	14	17	25%	0.417	0.048	-88%
CSP	9 422	9 091	-4%	30	80	167%	0.358	0.114	-68%
Onshore wind	2 042	1 325	-35%	27	39	44%	0.102	0.033	-68%
Offshore wind	4 876	2 858	-41%	38	39	3%	0.188	0.075	-60%

- costo d'installazione medio globale nel 2020: 4.746 \$/kW
- LCOE medio globale nel 2020: 0,107 \$/kWh

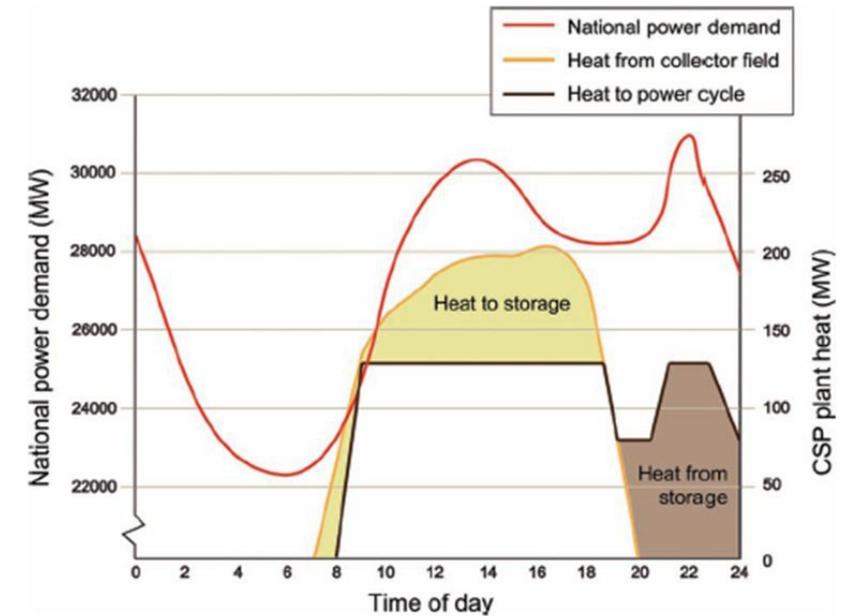
- peak load: capacità di stoccaggio termico bassa
- base load: capacità di stoccaggio termico elevata

SunShot CSP Progress and Goals

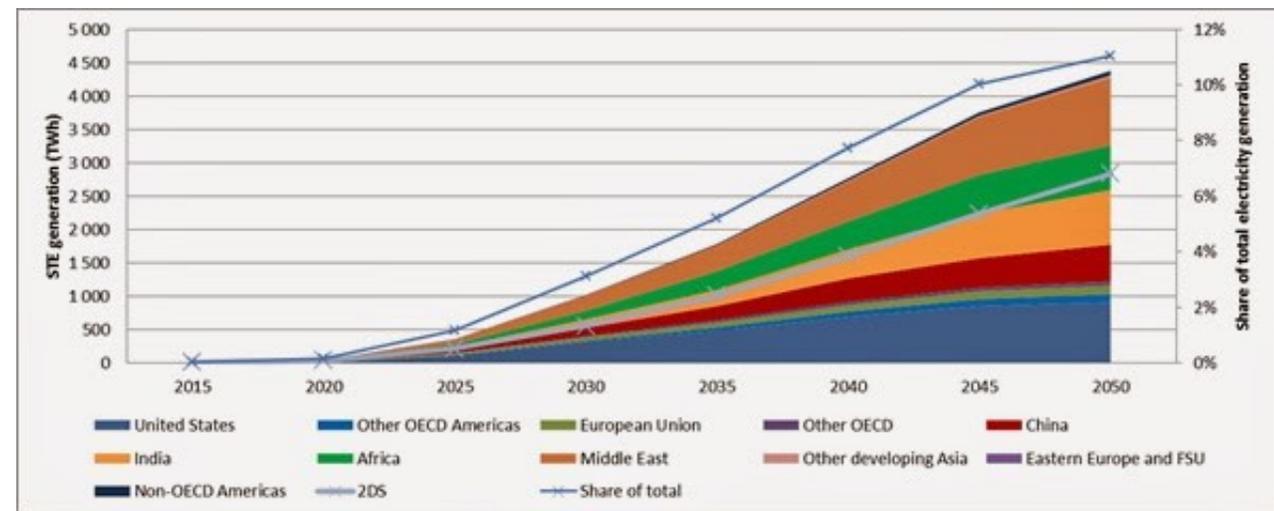


CSP and dispatchability

Figure 4.2 Extending operating hours of a 50 MWe CSP plant with thermal storage, to follow the demand curve of a normal mid-summer day in Spain. Demand curve derived from RED Elctrica de España (2011) and CSP load from computer simulation (<https://demanda.ree.es/demandaEng.html>)

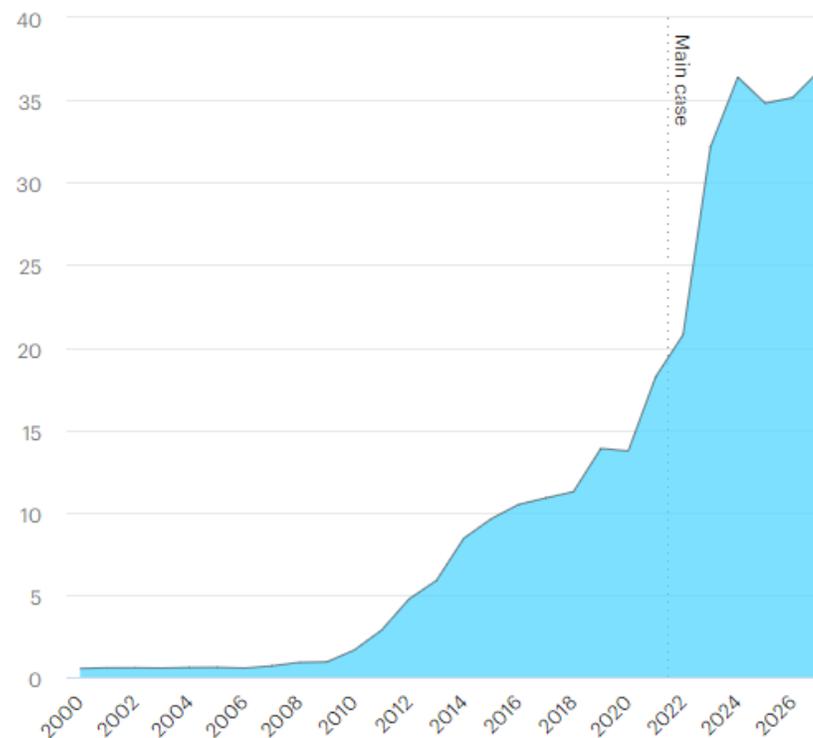


Generation	1 st gen.	2 nd gen.	3 rd gen.
Receiver outlet temp.	~250 - 450 °C	~500 - 565 °C	~720 °C
Typical plant or technology	PTC, SPT, LFR 	PTC, SPT, LFR ~500 - 565 °C 	PDC  Salt  Air, He, CO ₂ etc.
Heat transfer medium	Oil or steam	Steam or salt	Gas Salt Particle Gas
Thermal energy storage	Early designs: No or small Recent designs: Yes	Early designs: No or small Recent designs: Yes	No Yes
Power cycle	Steam Rankine cycle		Stirling Brayton cycle
Peak temp. of cycle	~240-440 °C	~480-550 °C	~720 °C
Design cycle eff.	~ 28-38%	~ 38-44%	~38%
Annual solar-electric eff.	~ 9-16%	~ 10-20%	~25%
			Expected to be >50%
			Expected to be >700 °C
			Expected to be >700 °C



2030: 1000 TWh all'anno

2050: 8 - 12% del mix energetico nella produzione di energia elettrica



2022: 7,5 GW potenza installata, 20,8 TWh energia elettrica generata

2027: 11,2 GW potenza installata, 36,6 TWh energia elettrica generata