Vereniging voor Zonnekracht Centrales

Concentrated Solar Thermal for the energy transition

Utrecht, October 21st 2021

Solar Energy versus fossil fuels

About me

- Advisor Renewable Energy at Sweco
- Worked as Mechanical Engineer at Flagsol (EPC company Concentrated Solar Power)
- CSP Projects involved:
  - Andasol-3 (Spain)
  - Kuraymat (Egypt)
  - Shagaya (Kuwait)
  - Los Arenales (Spain)
  - Several R&D Projects at Plataforma Solar Almeria (Spain)

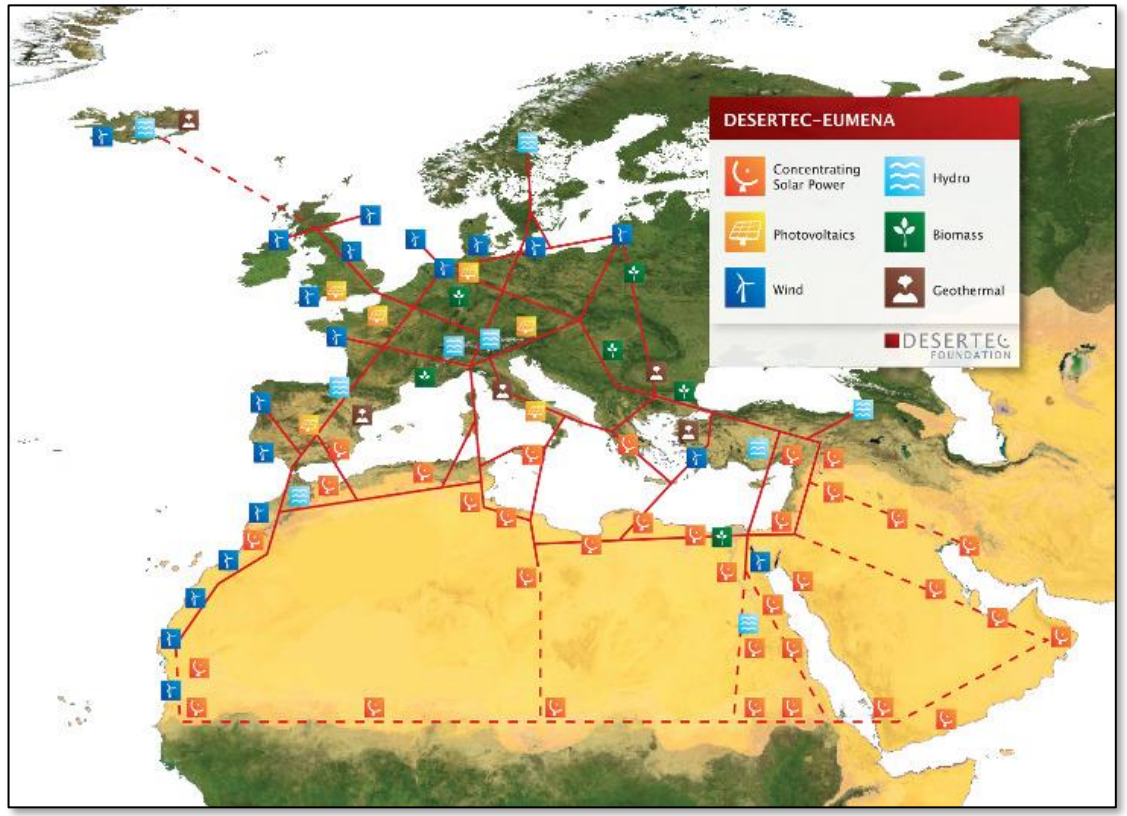
Dutch Association for Concentrated Solar Energy

Mission

- Realize sustainable energy generation based on Desertec
- Focus on Concentrated Solar Thermal/Power (CST/CSP)

Goals

- Promotion and dissemination of knowledge
- Lobby and support



Source: Desertec Foundation

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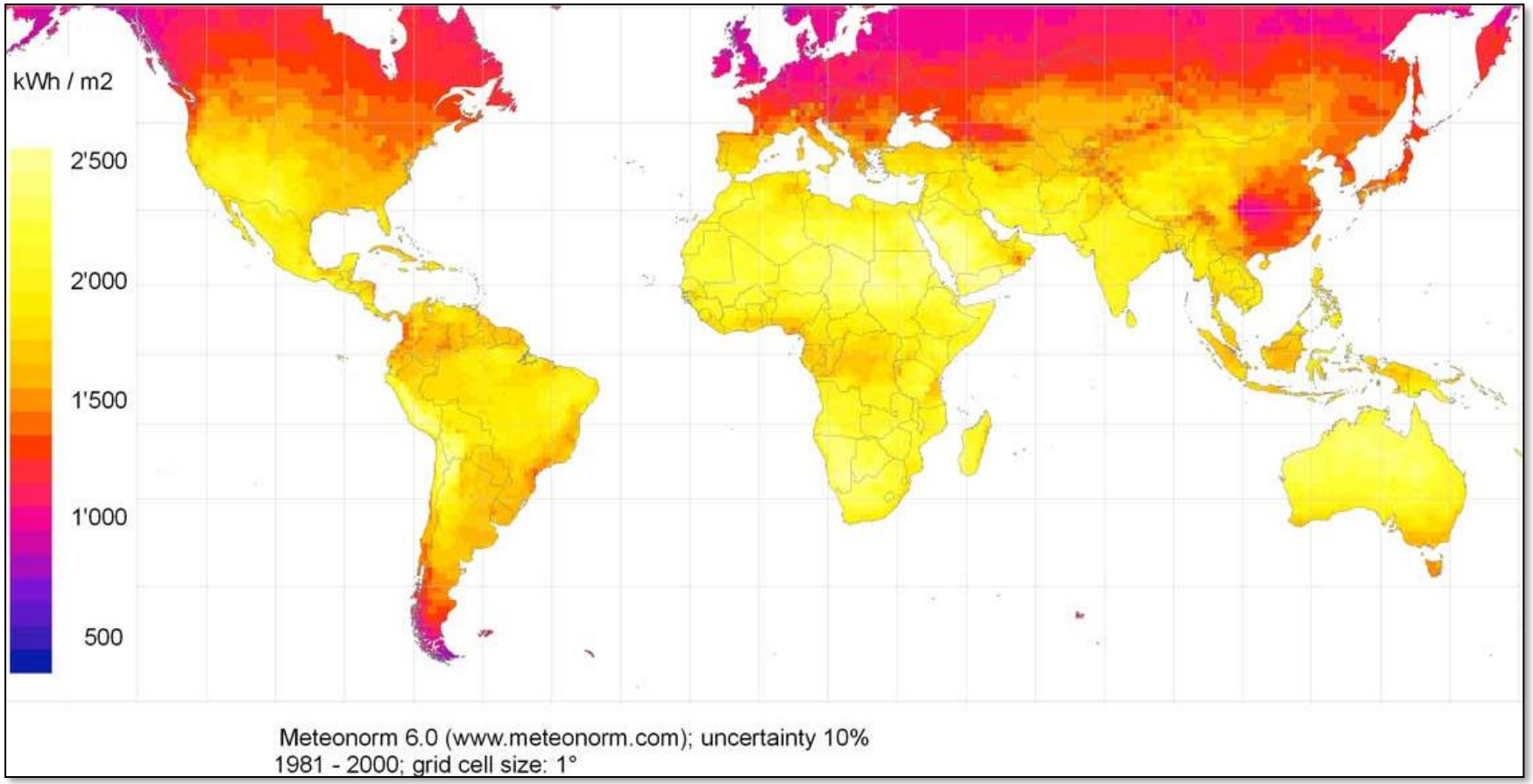
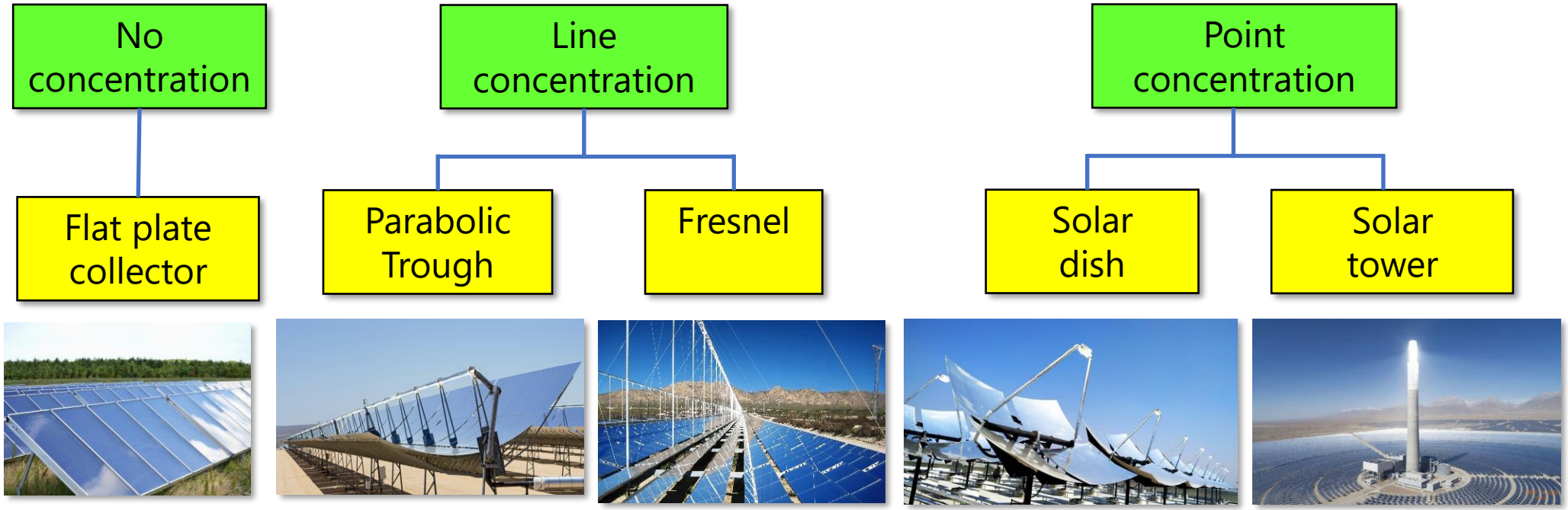
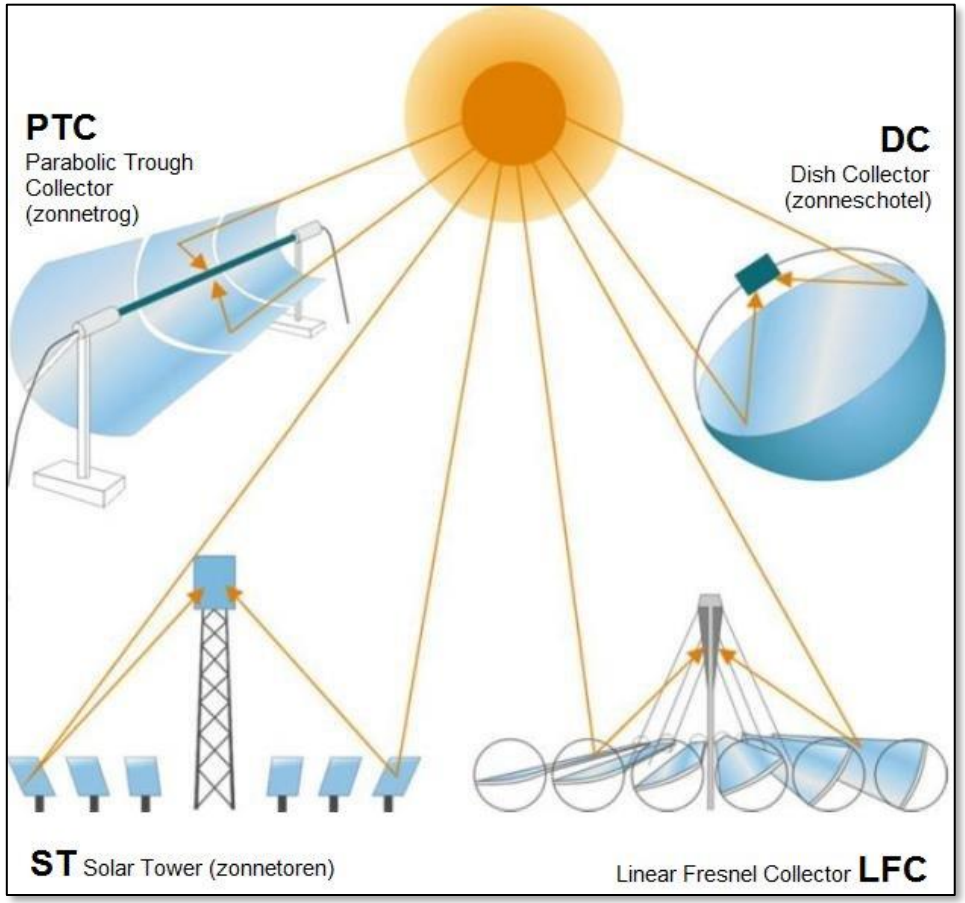
Solar Radiation Worldwide



Solar Thermal Overview



CSP Technology

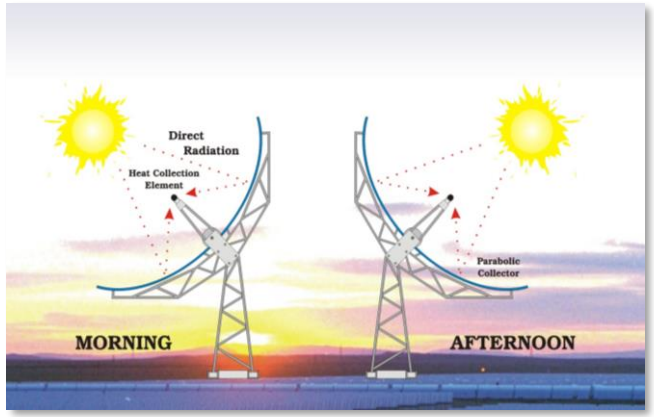


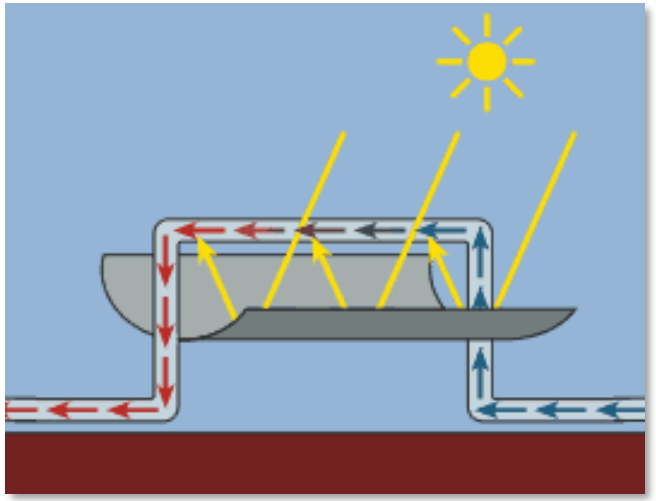
Source: https://www.joostdevree.nl

Technology	Temp. Range [˚C]	Power [MWel]	Storage	Average efficiency solar-electric [%]
PTC	160-550	10-250	Yes	14-17
LFC	280-450	5-250	No	10-11
DC	750	5-25 kW	No	16-32
ST	550-600	10-200	Yes	15-16

Parabolic Trough Working Principle

Collectors track the sun from sunrise to sunset for optimal collector efficiency





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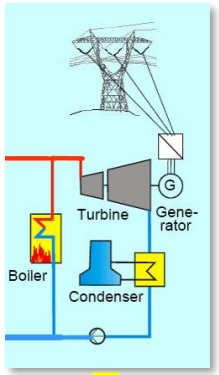
CSP/CST Applications

Concentrating Solar Collectors

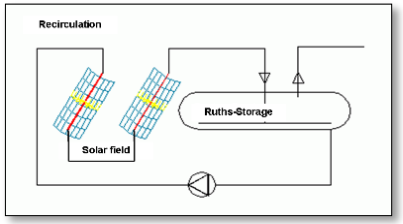
High Temp.

Power Generation (CSP)

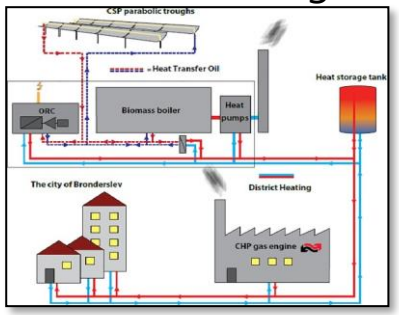


Low/Mid Temp.

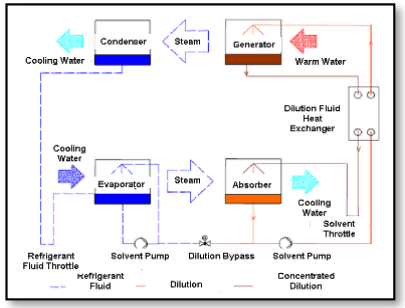
Process Heat



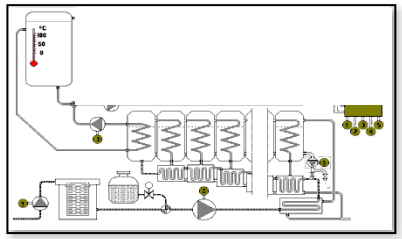
District Heating



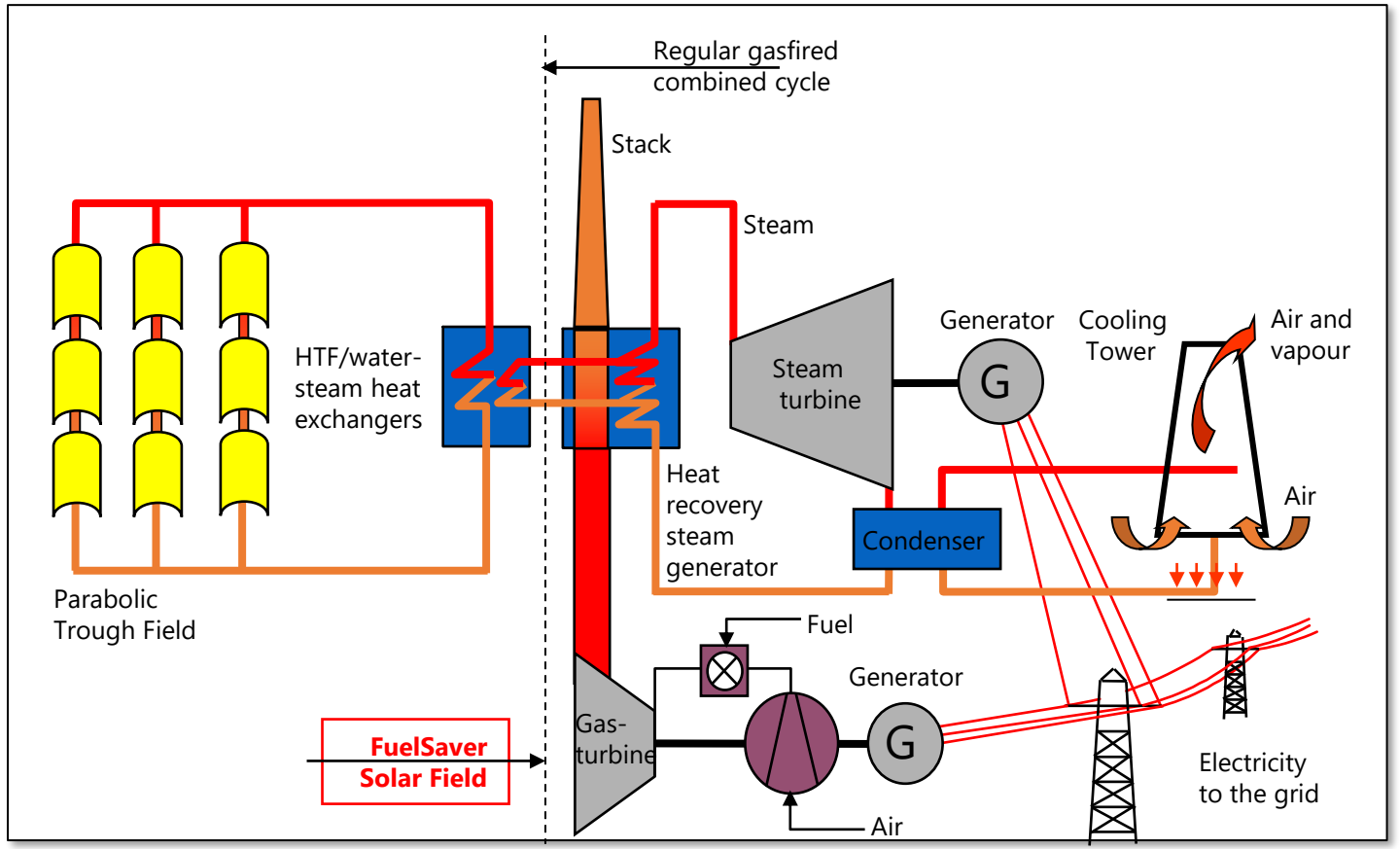
Solar Cooling



Desalination



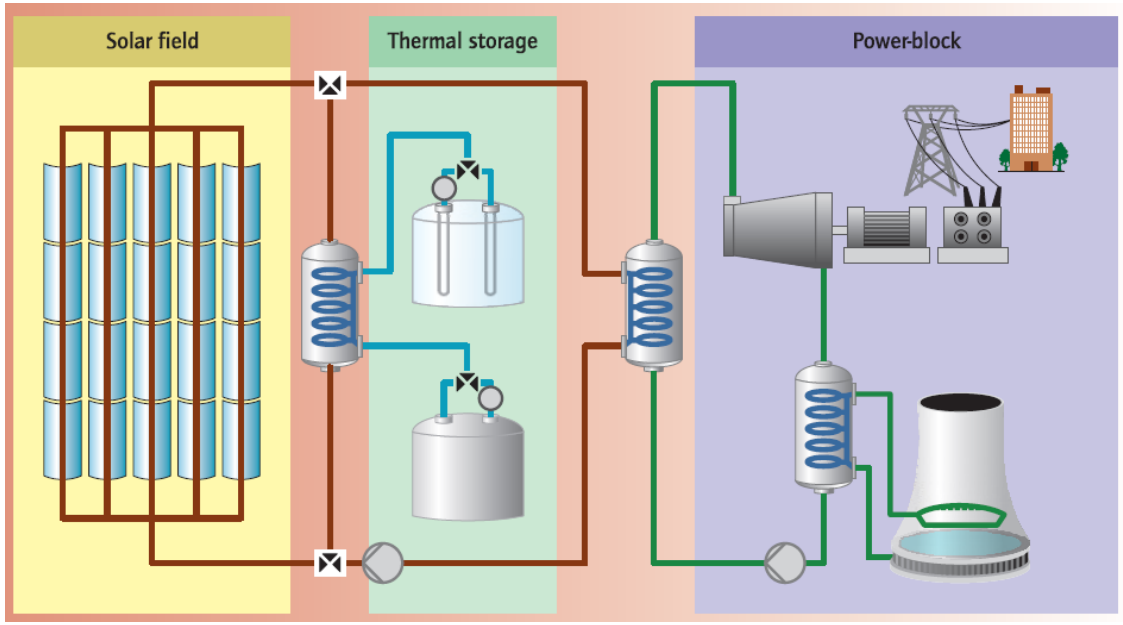
Integrated Solar Combined Cycle (ISCC)



- Heat from the solar field to generate steam
- Improve plant performance when solar radiation is sufficient → **Fuel Saver!**

CSP with Heat Storage

Thermal Storage ensures flexibility, stability and dispatchability

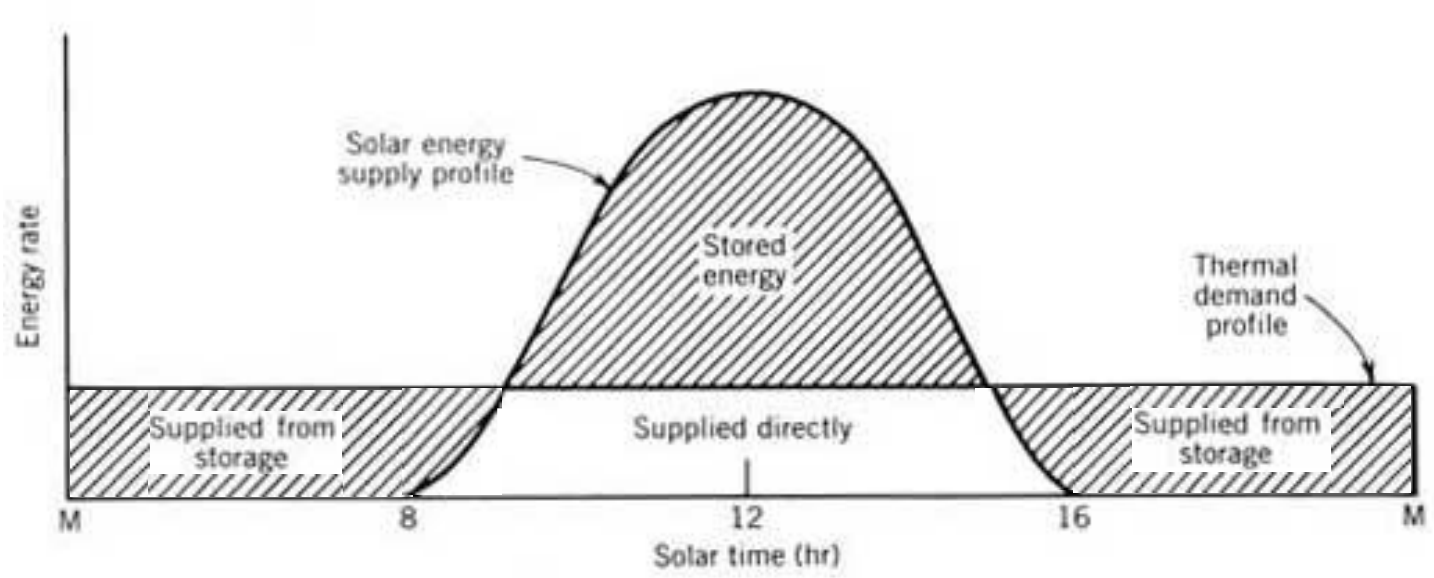


Andasol 3 Thermal Storage System

- 2 Tank storage tank system
- Molten Salt: mixture of $KaNO_3/NaNO_3$
- Heat capacity: ~ 1 GWh
- Thermal power: ~121 MWth
- Temp. Cold/Hot Tank: 286ºC/386ºC

CSP with Heat Storage

- Solar field designed for steam turbine and heat storage
- Increase operating hours turbine

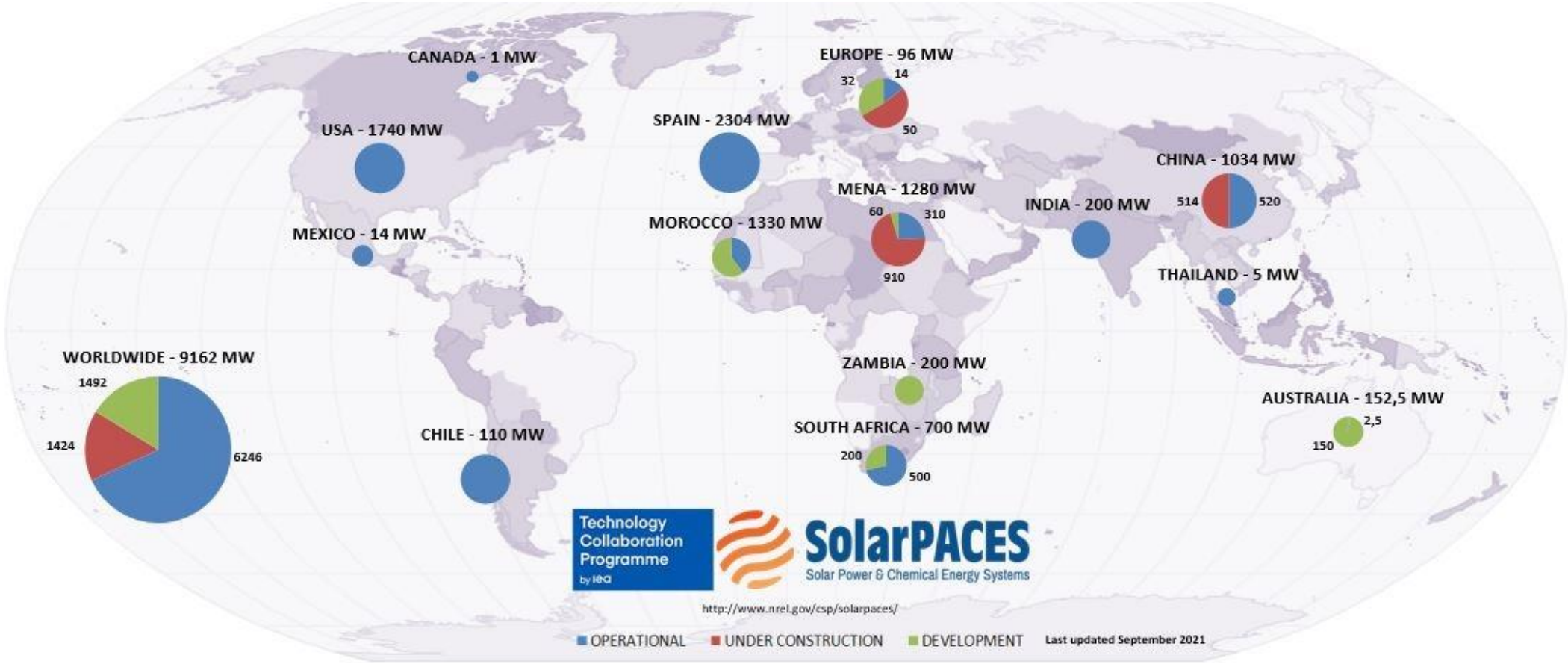


Source: https://http://www.powerfromthesun.net

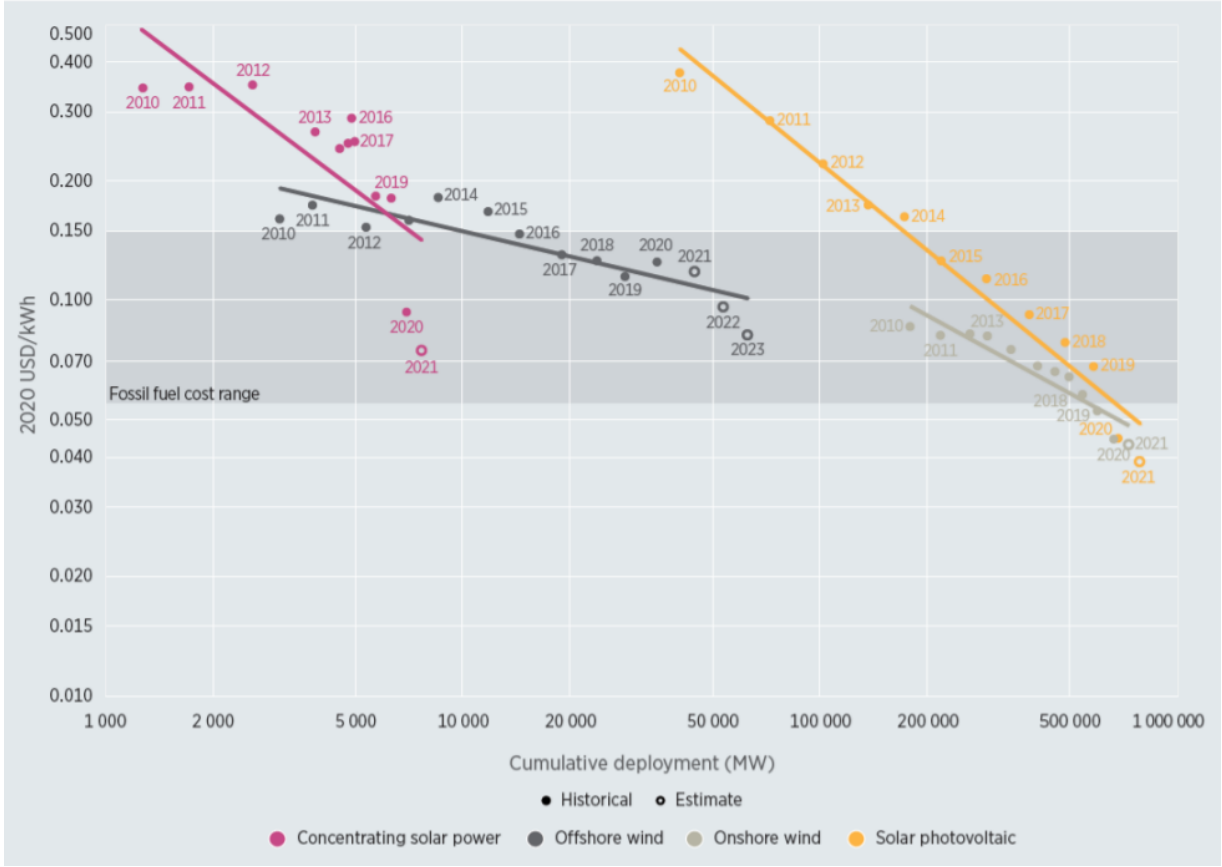
Key Requirements for CSP Plants

- Financing - Primary challenge for any utility-scale energy generating facility is project financing
- Areas of high solar radiation (DNI: Direct Normal Irradation)
- Contiguous parcels of land with limited cloud cover – Land needs vary by technology, typical CSP plant requires 5-10 acres of land per MW
- Access to water resources - most CSP systems require cooling water
- Available and proximate transmission access - Access HV transmission lines key for development of utility-scale CSP projects to move electricity from the solar plant to end users

CSP Projects around the World



Levelized Cost of Electricity CSP, PV and Wind



Source: IRENA

Note:
PV without storage

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CSP LCOE Trends

Source: IRENA

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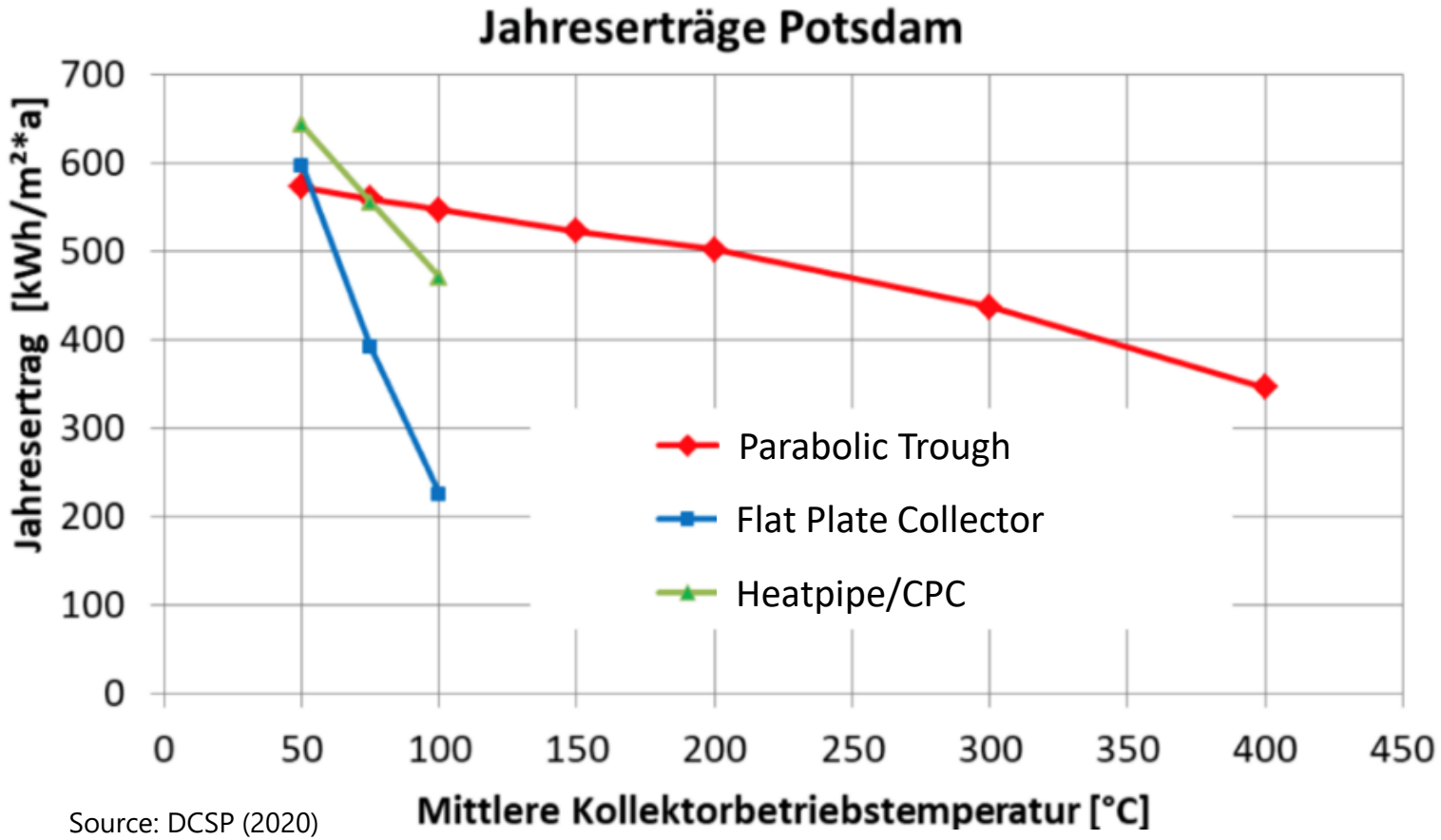
Focusdocument Published March 2021

More information?

https://www.zonnekrachtcentrales.nl/wp-content/uploads/2021/03/VZKC-Focusdocument-warmtetransitie-final-11-maart-2021.pdf

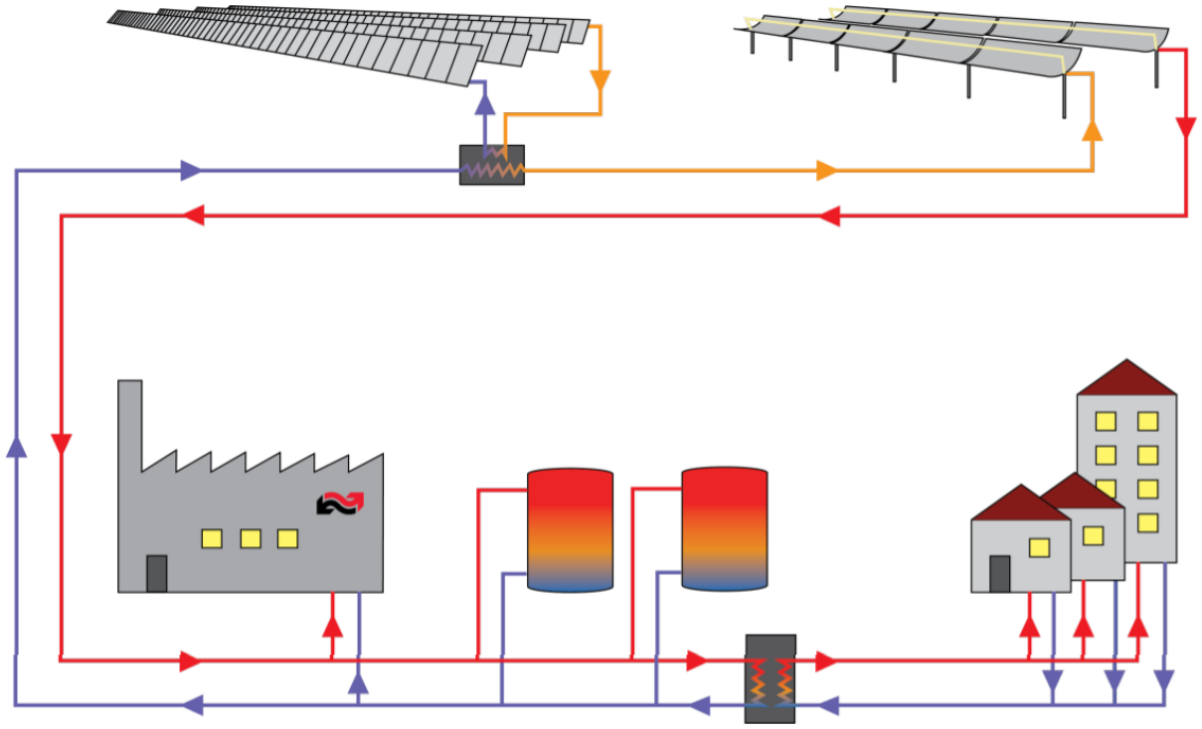
CST Yield [kWh/m²a] and Temperature range



Source: DCSP (2020)

CST District Heating Application

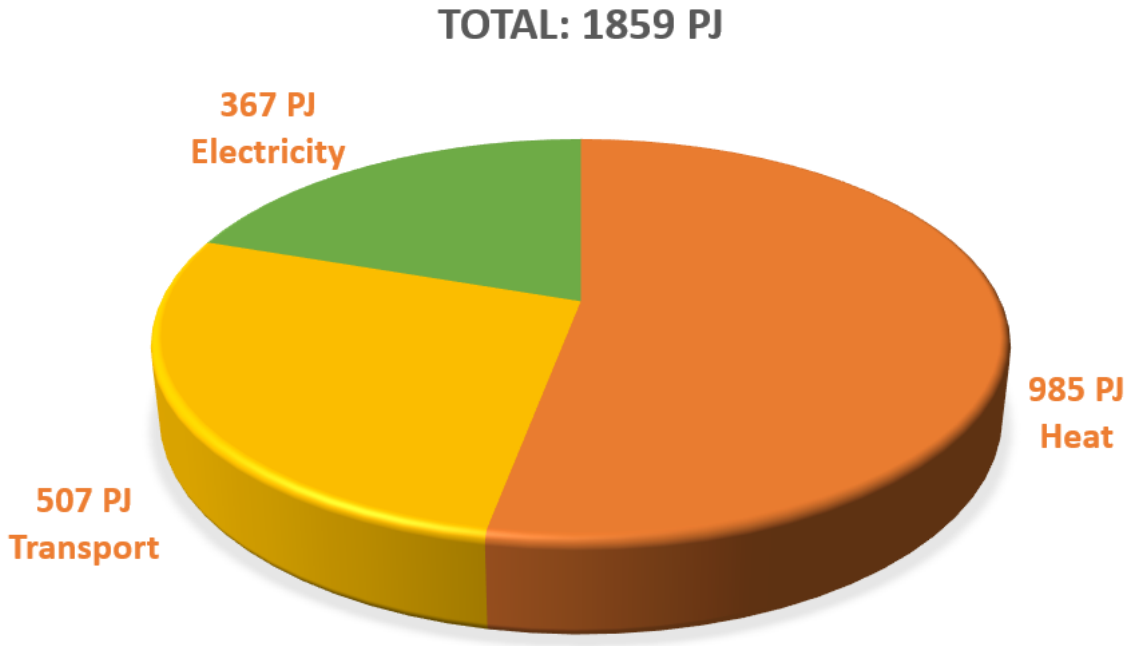
Combination Flat Plate Collector and Parabolic Trough



Source: Aalborg CSP

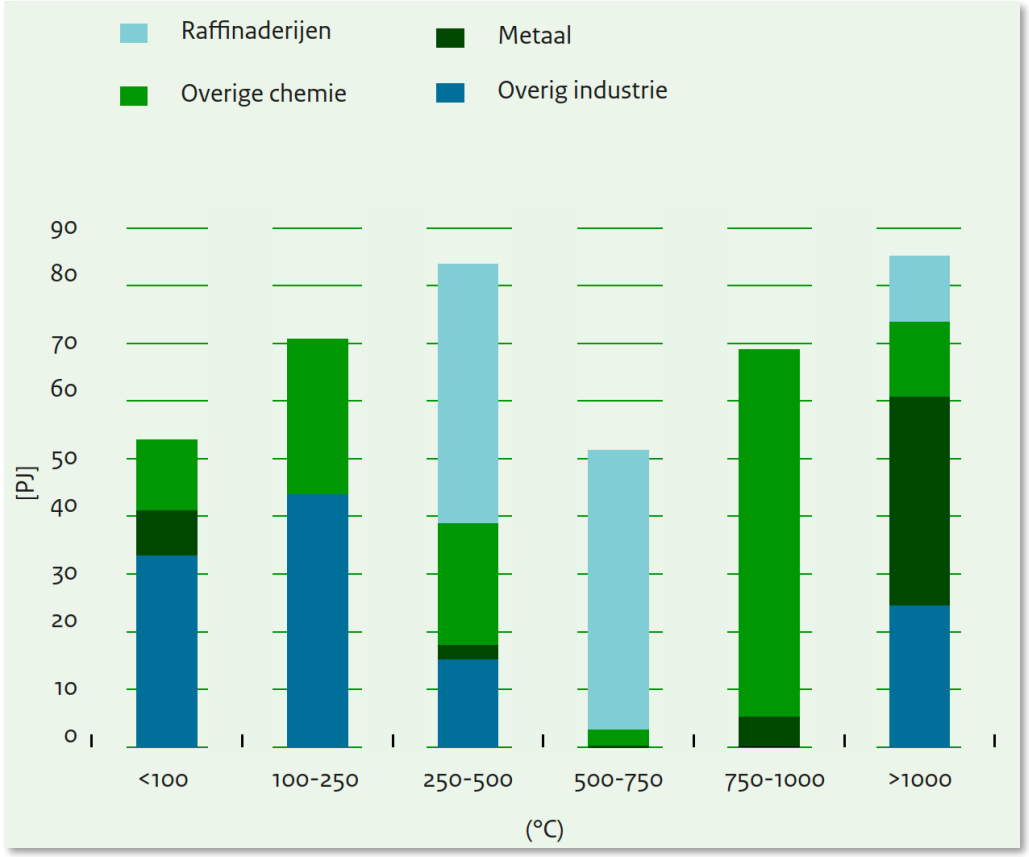
Heat Demand

Heat demand as part of total energy demand



Source: TNO (2020), Warmtemonitor (2019) o.b.v. CBS

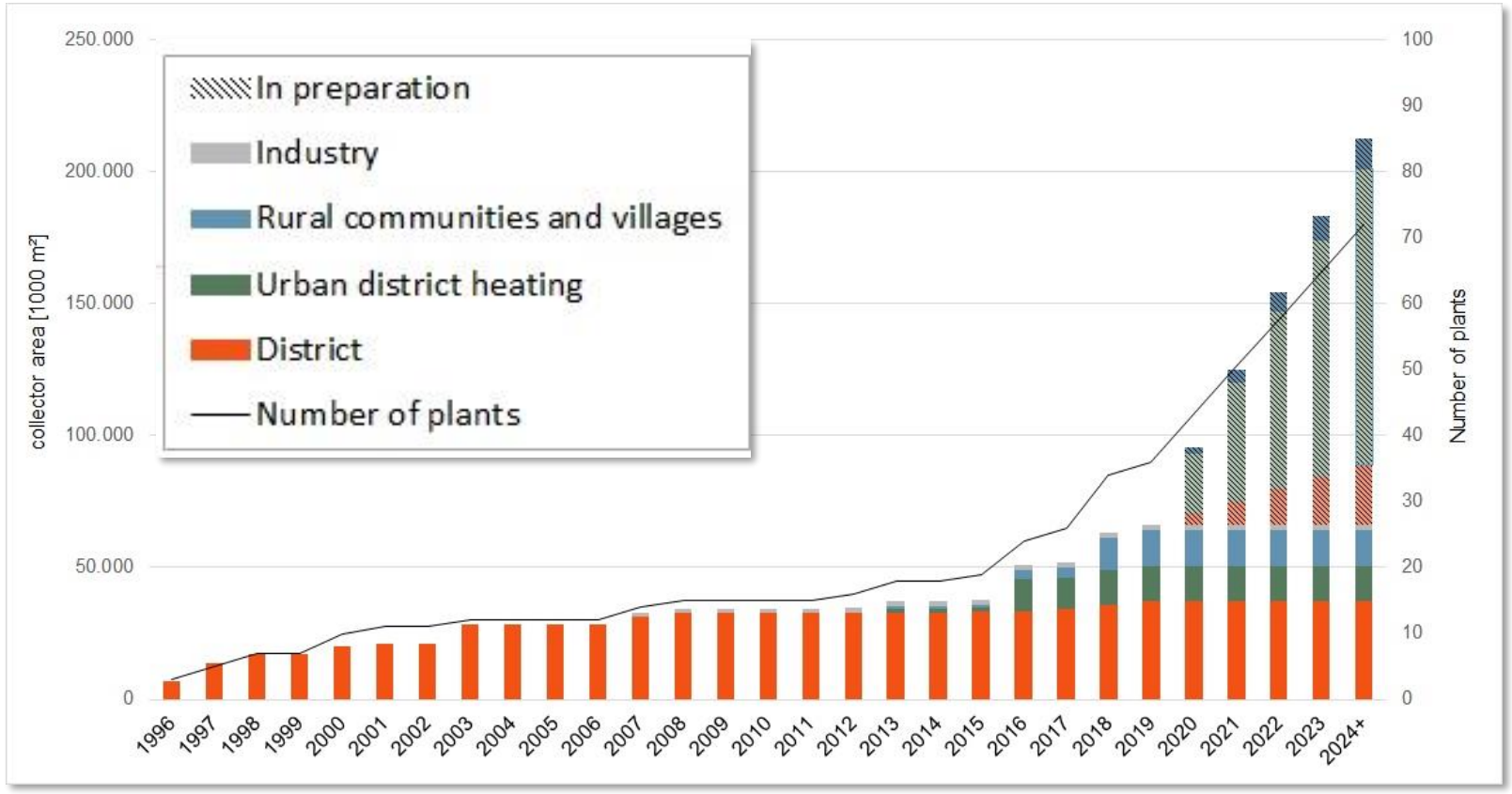
Heat Demand Industry



Source: AgentschapNL (2013)

- Total heat demand: 416 PJ
- German study shows half heat demand can be supplied by CST
- CST can deliver 200 PJ

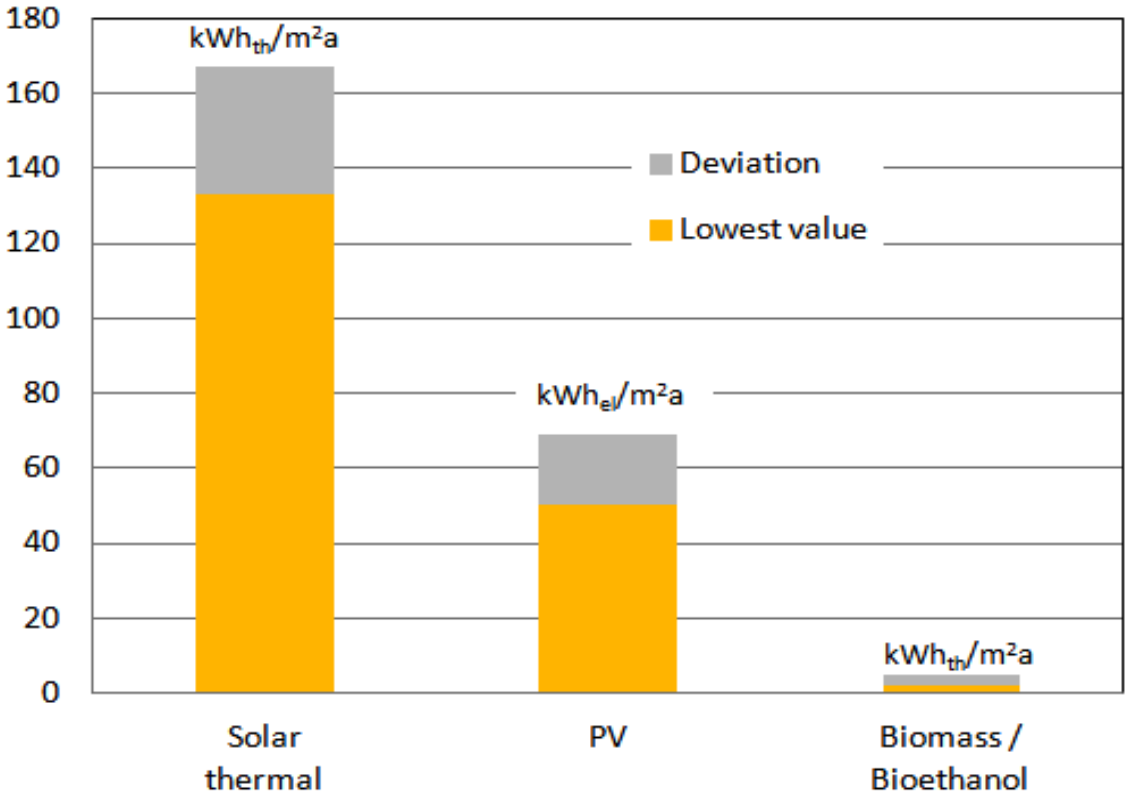
Solar Thermal Forecast



Source: Solites (2019)

Forecast solar thermal road map in Germany.

Yield [kW/m²a] Comparison PV vs Solar Thermal



Source: Fraunhofer, 2017

Fraunhofer study shows solar thermal collectors produce an average of **three** times more kilowatt hours energy per square meter than solar photovoltaics

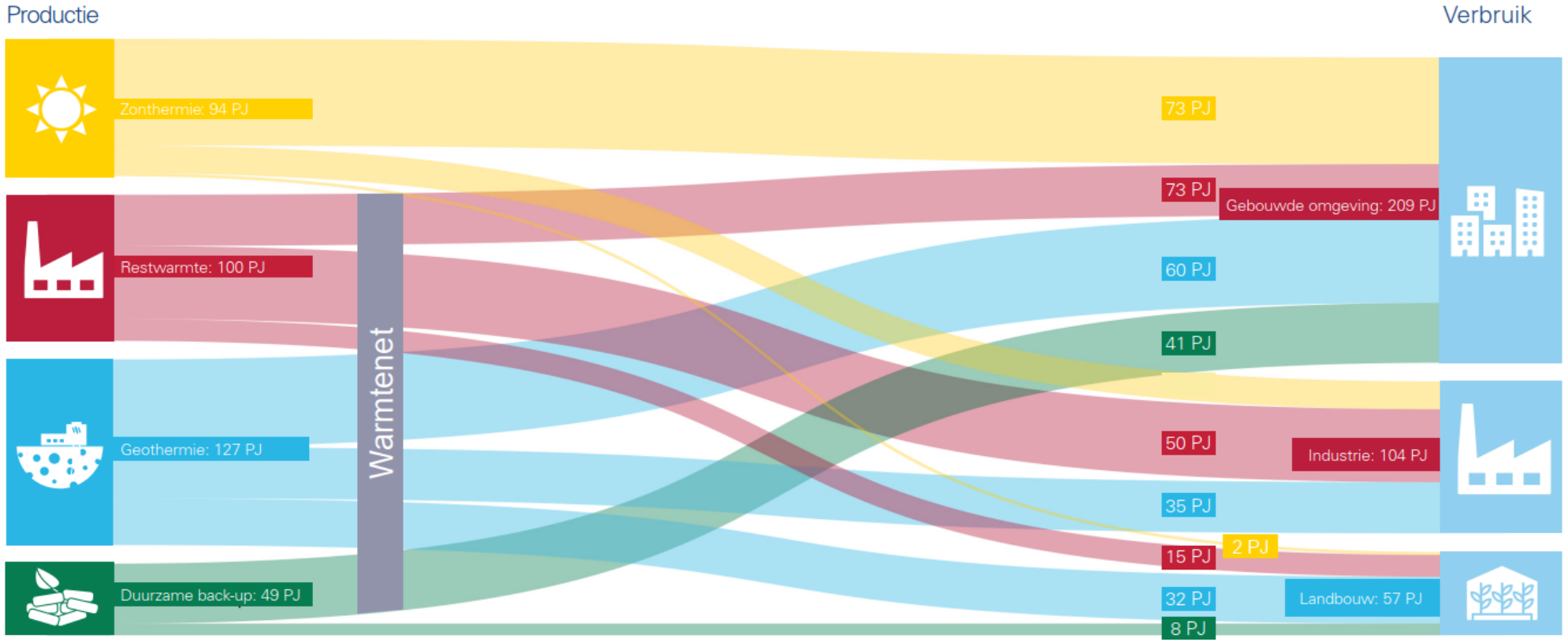
Performance Solar Thermal Systems

	YIELD (APERTURE AREA)	YIELD (SURFACE AREA)	YIELD (APERTURE AREA)	CONCENTRATION FACTOR	TEMP. RANGE	DOUBLE USE GROUND AREA	HEAT STORAGE	RATIO SURFACE-APERTURE AREA	REFERENCE
	kWh/m^{2}a	kWh/m^{2}a	GJ/m^{2}a	-	˚C				
TROUGH	550	185	2,0	10-85	50-400	Yes	Yes	3	DTU (2015)
FRESNEL	For NL unknown	Least space require-ment	For NL unknown	10-80	<300	Yes	Yes	1,5	Areva (SUPPLIER)
DISH	530	210	2,5	600–2000	<200	Yes	Yes	2,5	Axe (SUPPLIER)
FLAT PLATE	360	160	1,3	1	30-80	Yes	Yes	2,3	Netherlands
PV	170	65	0,6	1	n/a	Yes	No	3	Netherlands

Source: Focusdocument warmtetransitie met geconcentreerde zonthermie, Vereniging voor Zonnekrachtcentrales, 2021

Berenschot Study Solar Thermal: 94 PJ

With CST: potential additional 50 PJ



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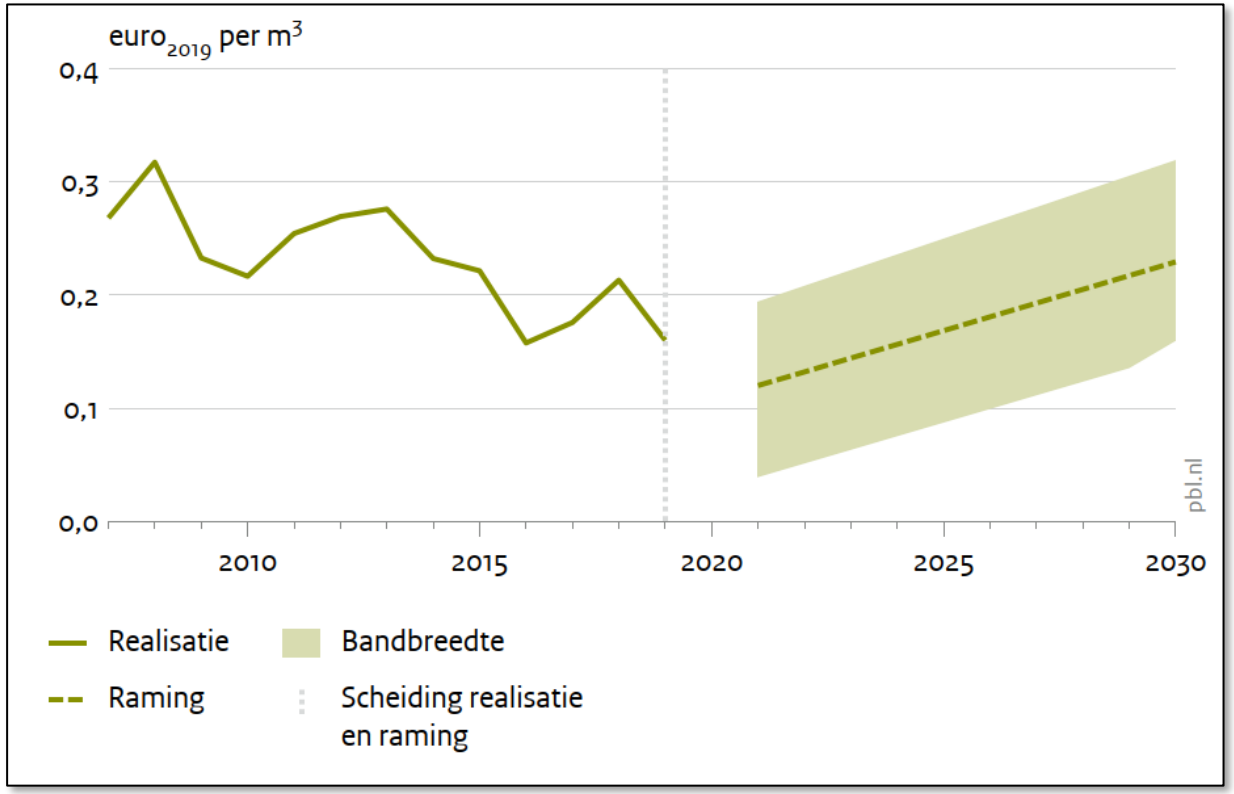
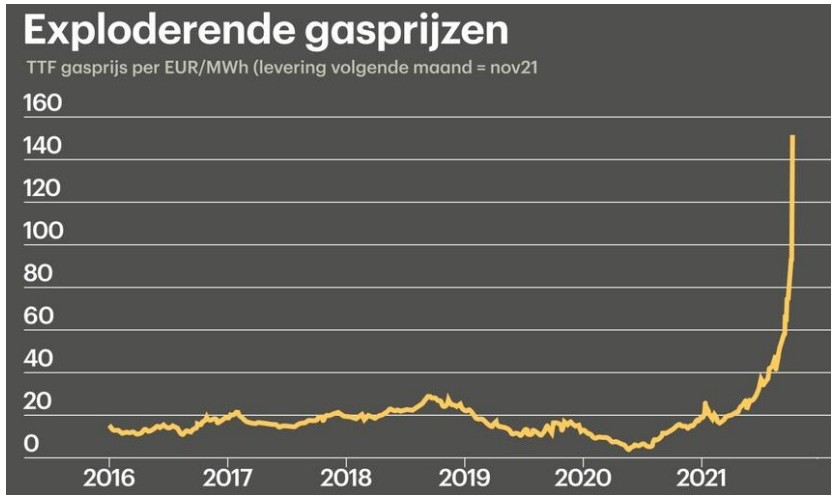
Price Development Natural Gas



Source: CBS (realisatie); ICE TTF, IEA WEO (2019) en WLO (2015) (raming)



Source: https://www.rtlnieuws.nl

SDE++ Subsidy Program 2022

Source: Solarmagazine (June 2021)

CST systems are eligible for subsidy in the solar thermal category starting in 2022

CST Reference Belgium

- Azteq
- Industrial Application
- Temp. outlet > 140°C
- Output: 0,5 MW_{th}
- Yield: 500 MWh/a

Source: Azteq

CST Referenties Denmark

- Aalborg CSP
- Solar District Heating (SDH)
- Temp. outlet: 98°C
- Daily Buffer
- Output: 6,8 MW_{th}
- Yield: 6,1 GWh/a

Source: Aalborg CSP

CST Referenties Sweden

- Absolicon
- 400 km above Stockholm
- Solar District Heating (SDH)
- Temp. Outlet: 110°C
- Output: 0,5 MW_{th}
- Yield: 1,1 GWh

Source: Absolicon

CST Referenties Germany

- Sunoyster
- Two Axis Collector
- Temp.outlet up to 170˚C
- Foldable (windload)
- Roof installation possible
- Output: 10 kW_{th}
- Optional PV: 4,8 kW_e

Source: Sunoyster

CST Reference Germany

- Protarget
- Industrial Application
- Output: 320 kW_{th}

Source: Protarget

Conclusions

- CST suitable source for both district heating networks and industry
- District heating network: CST can be combined with flat plate collectors and/or vacuum tubes
- Built environment: potential due to expansion with CST 50 PJ higher than calculated 94 PJ from Berenschot
- Additionally: 200 PJ heat can be supplied for industry
- In total, CST can account for 250 PJ (25% of the total heat demand 985 PJ), with the challenge of taking up space.


Thank you for your attention.
Do you have any questions?
Contact data: Christian Bartels cjbartels@aol.nl
https://www.zonnekrachtcentrales.nl

Extra slides

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Energy content of various energy sources

Energy Source	Quantity	Energy Content
Uranium	0,000001 ton	1 TCE (Tons Coal Equivalent)
Crude oil1	0,7 ton	1 TCE
Pit-coal	1 ton	1 TCE
Lignite	3,7 ton	1 TCE
Natural Gas	900 m^3	1 TCE
Wood	4 ton	1 TCE
Solar Energy	≈ 8000 hours on 1 m^2	1 TCE

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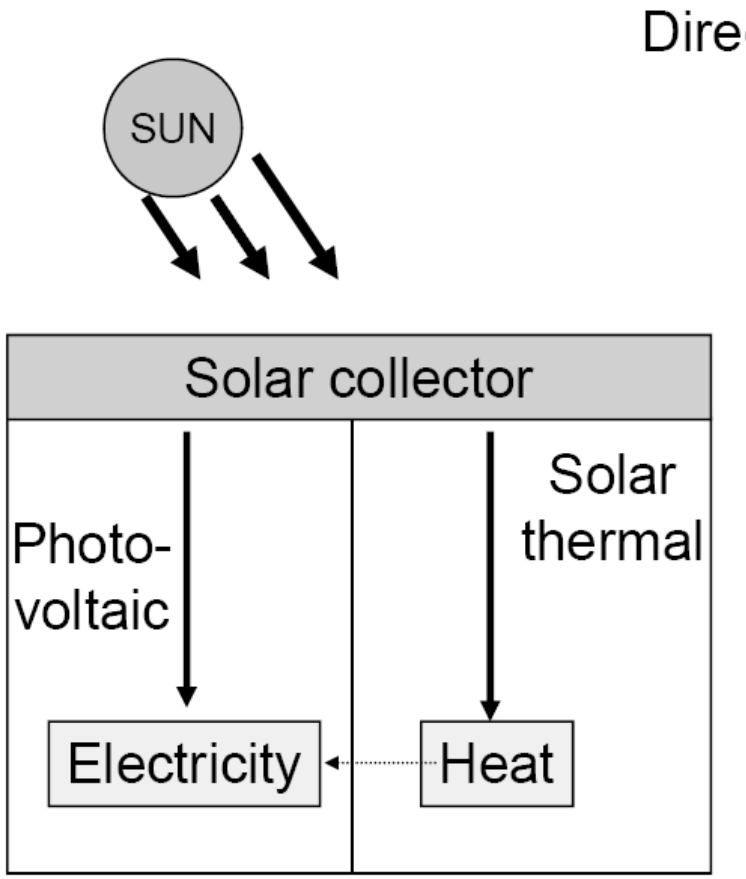
Direct use energy from the sun



- Solar radiation is primary source of energy
- direct conversion into useful energy
  - Photo effect (discret interval of solar spectrum is used)
    - Photovoltaic
    - (Photochemistry)
  - Thermal use (broadband interval of solar spectrum is used)

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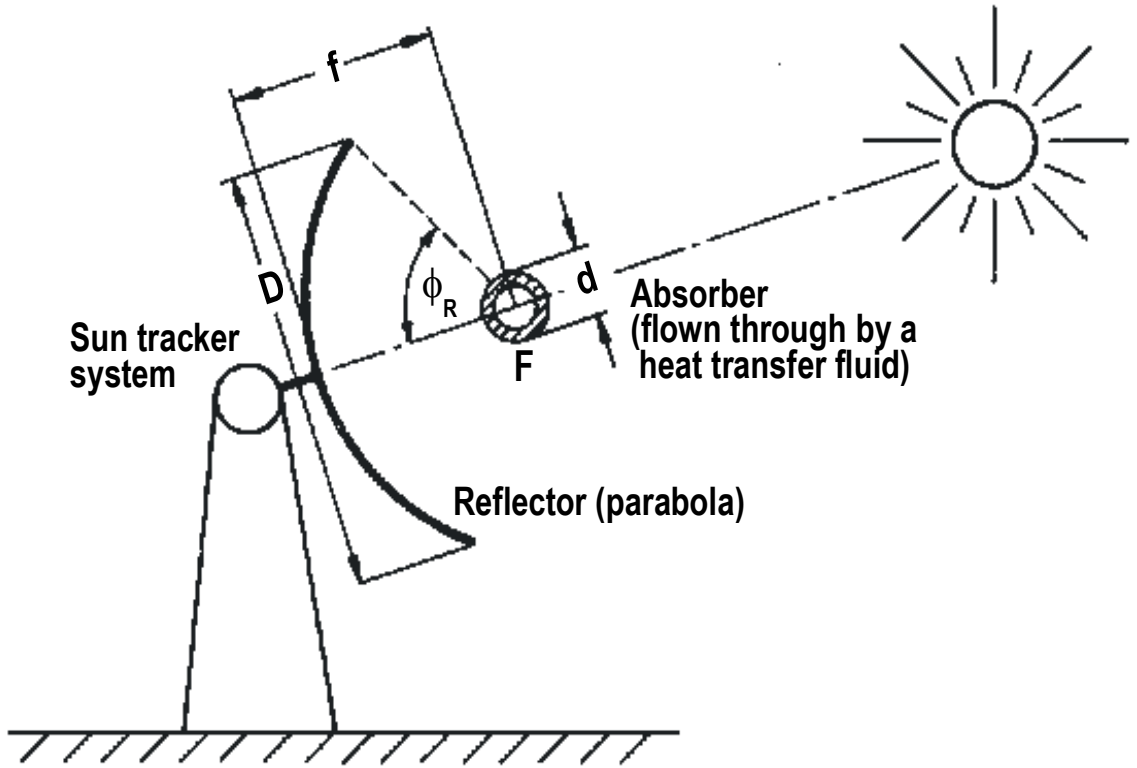
Parabolic Trough Collector - components



Main components:

- Concentrator (cylindrical parabolic reflector, structure)
- Receiver (tubular absorber, glass envelop)
- Tracking system

Main Parameters:

D: aperture width [m]
(resp. Paraboloid diam.)
f: focal length [m]
Φ_R: rim angle [degree]
d: absorber diameter [m]

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