Central Asian Regional Workshop on Sharing Best Practices to Promote Renewable Energy

Session V: Solar energy technology
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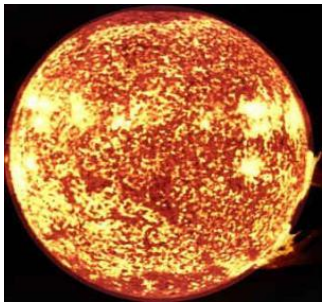
Basic ideas

- Solar heat and electricity is clean,
- Solar energy supply is local, no critical energy supplies.
- Solar electricity is available to nearly everyone worldwide
- Solar resources are thousands of times more than human society consumes each year,

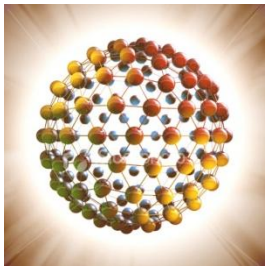
Oportunity to harmoniously increasing per capita energy use in a world while increasing population and wealth.

Life needs energy



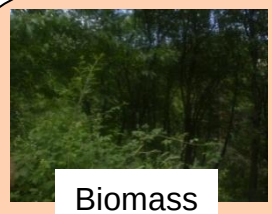
Sun

Gravity



Nuclear

Geothermal

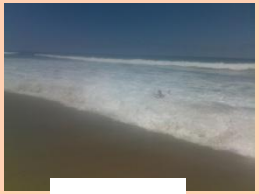


Biomass

Sun

Oil, Gas, Coal

Wind

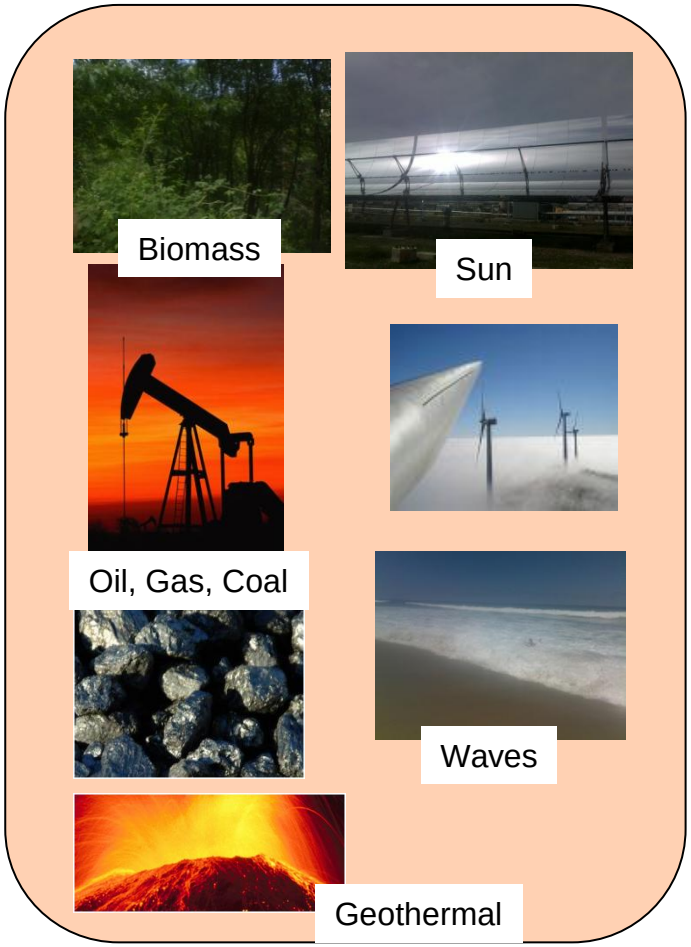


Waves

Sun energy creates: wind, waves, biomass, oil, coal.

Goal

- Increase global efficiency
- Lower the cost
- Dispatchability
- Increase capacity factor
- Use efficiently locally available resources
- Reduce water needs



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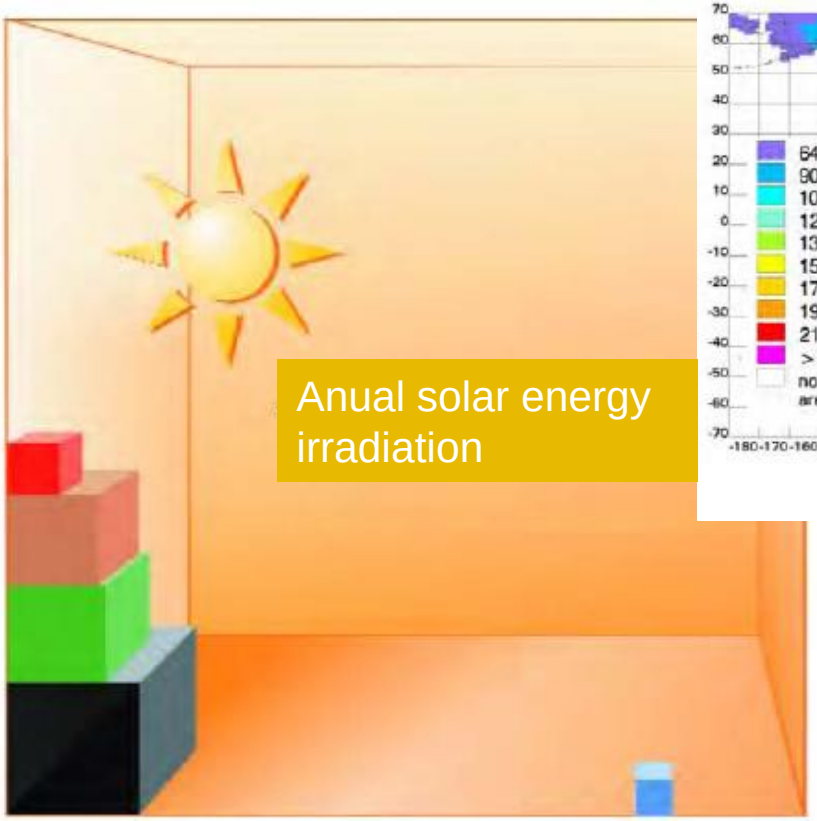
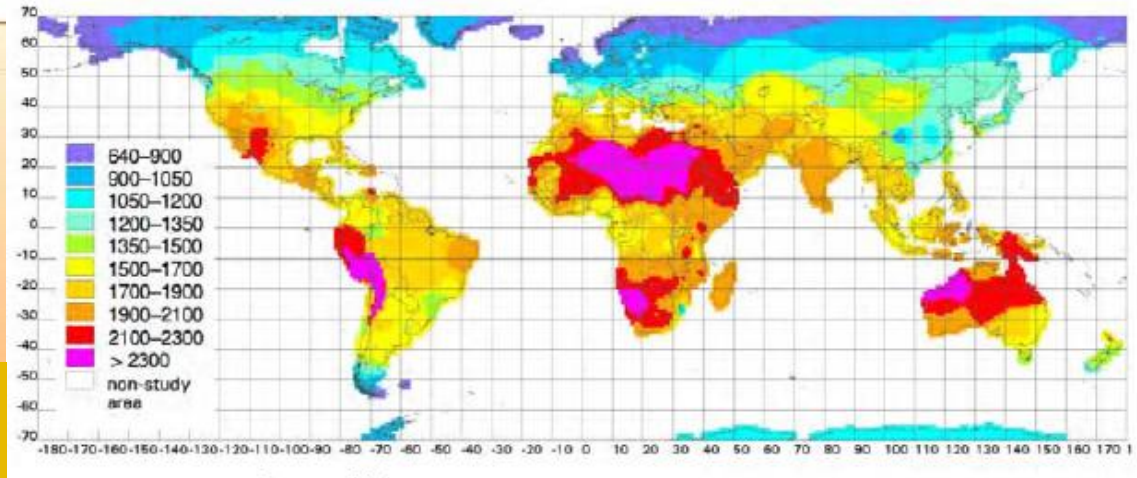
Energy source



Anual solar energy irradiation



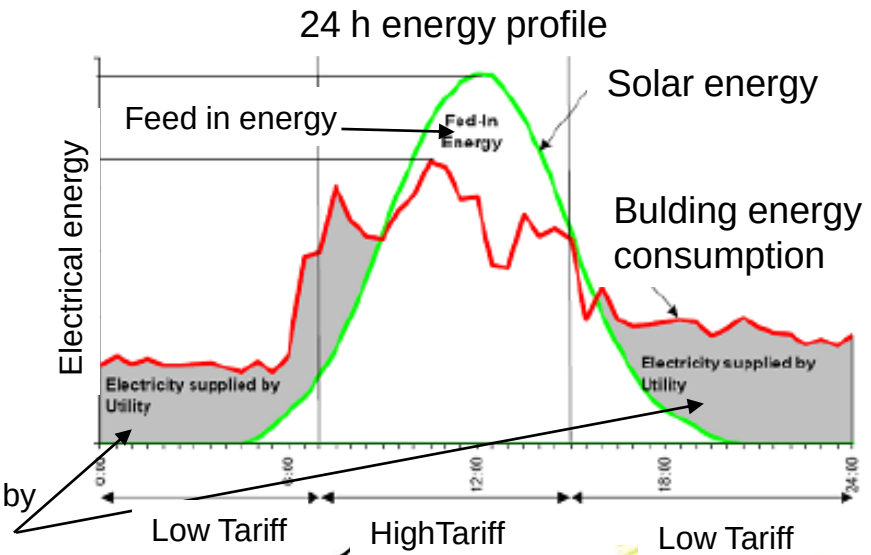
Source: Meteonorm

Uranium | Gas

Oil | Coal

Anual energy consumption

Source: BMI 2000

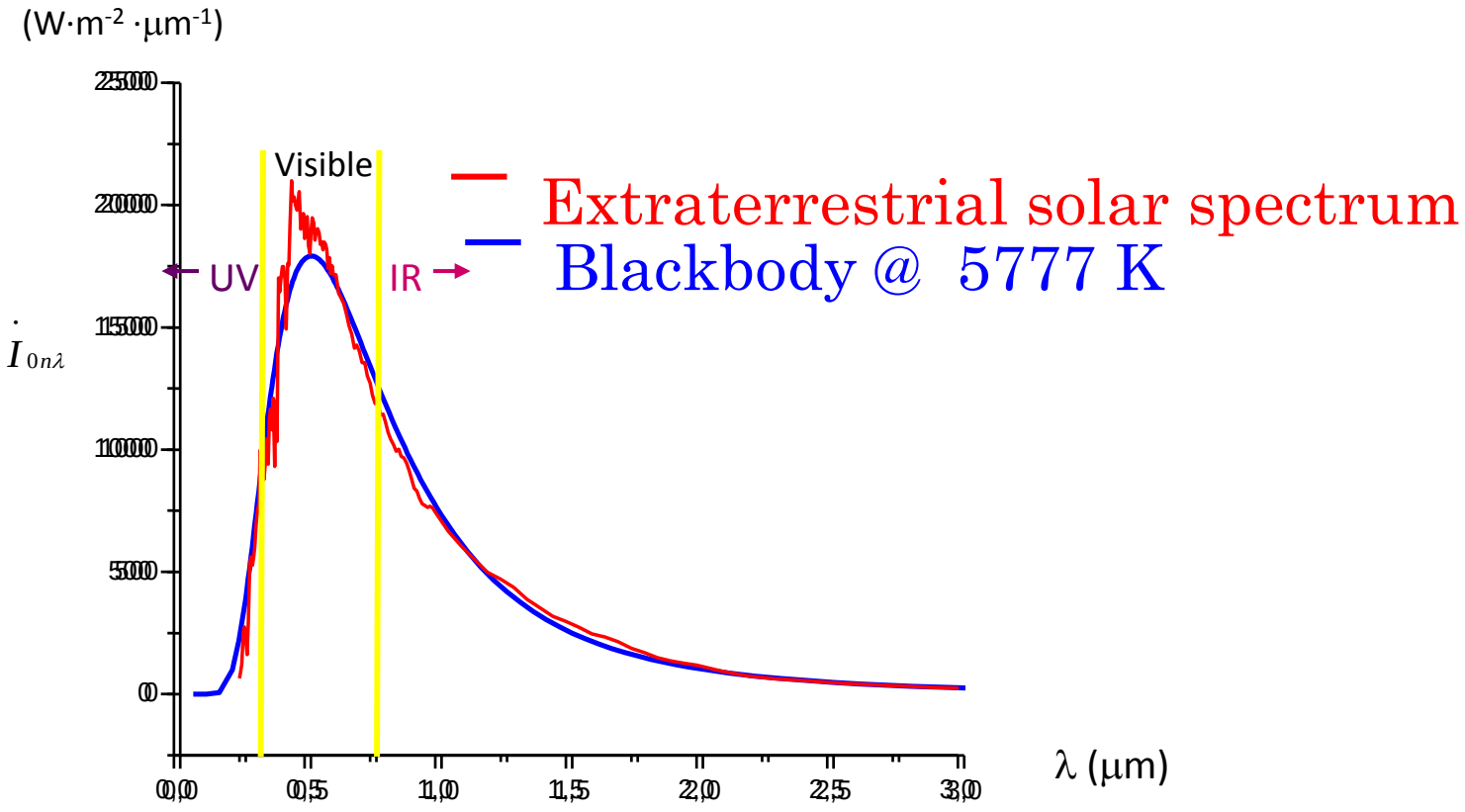


The Sun as an energy source

Mass:	$1{,}99 \times 10^{30}$ kg
Diameter:	$1{,}392 \times 10^{9}$ m
Area:	$6{,}087 \times 10^{18}$ m^2
Volume:	$1{,}412 \times 10^{27}$ m^3
Average density:	$1{,}41 \times 10^{3}$ kg/m^3
Angular diameter:	31’ 59,3’’
Average distance to earth:	$1{,}496 \times 10^{11}$ m = 1 AU
Equivalent Temperature:	5777 K
Power:	$3{,}86 \times 10^{26}$ W
Irradiance:	$6{,}35 \times 10^{7}$ W/m^2

http://www.leonardo-energy.org/csp-training-course-lesson-5-assessing-solar-resource-csp-plants

The sun spectrum



http://rredc.nrel.gov/solar/standards/am0/wehrli1985.new.html

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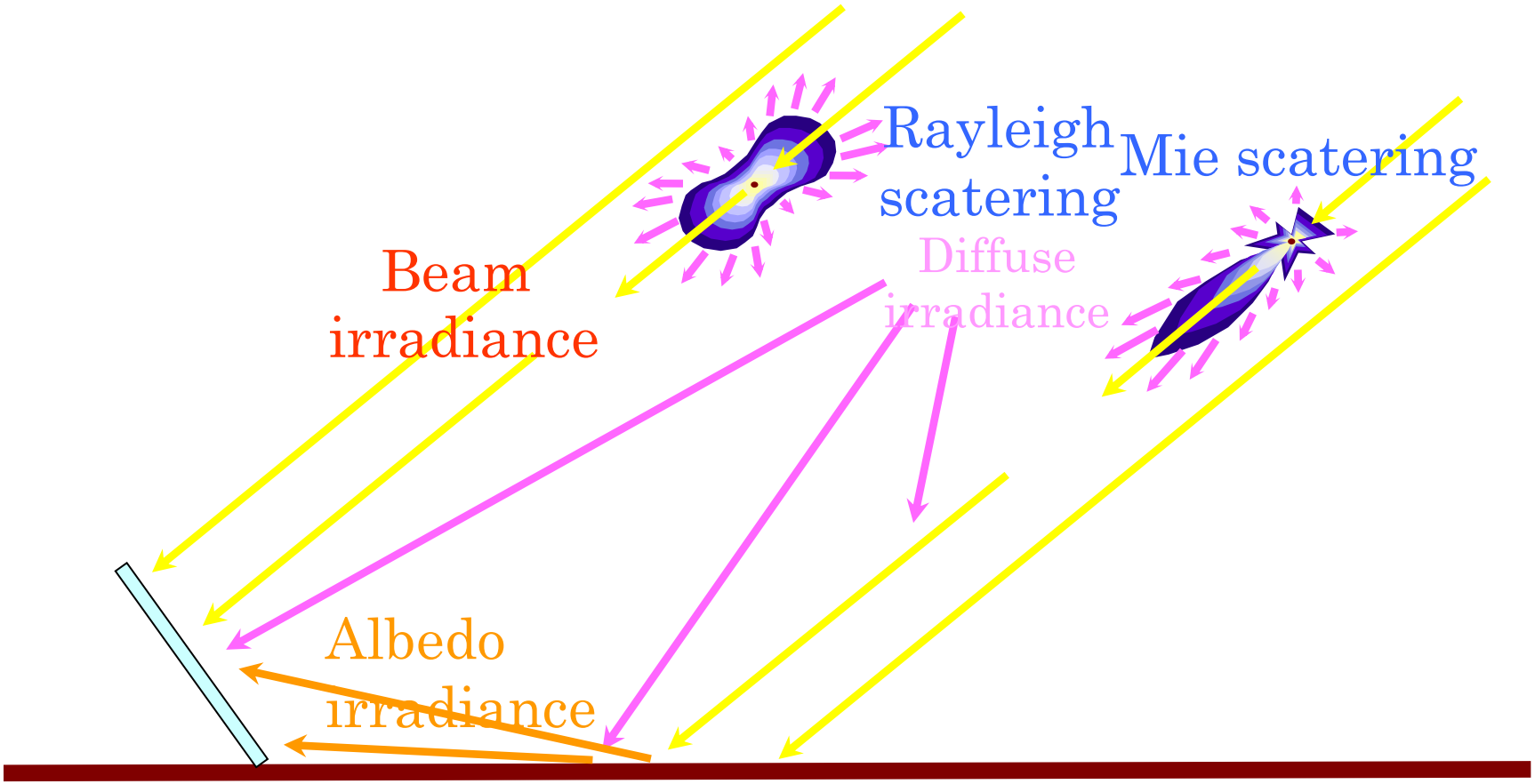
Light atmosphere



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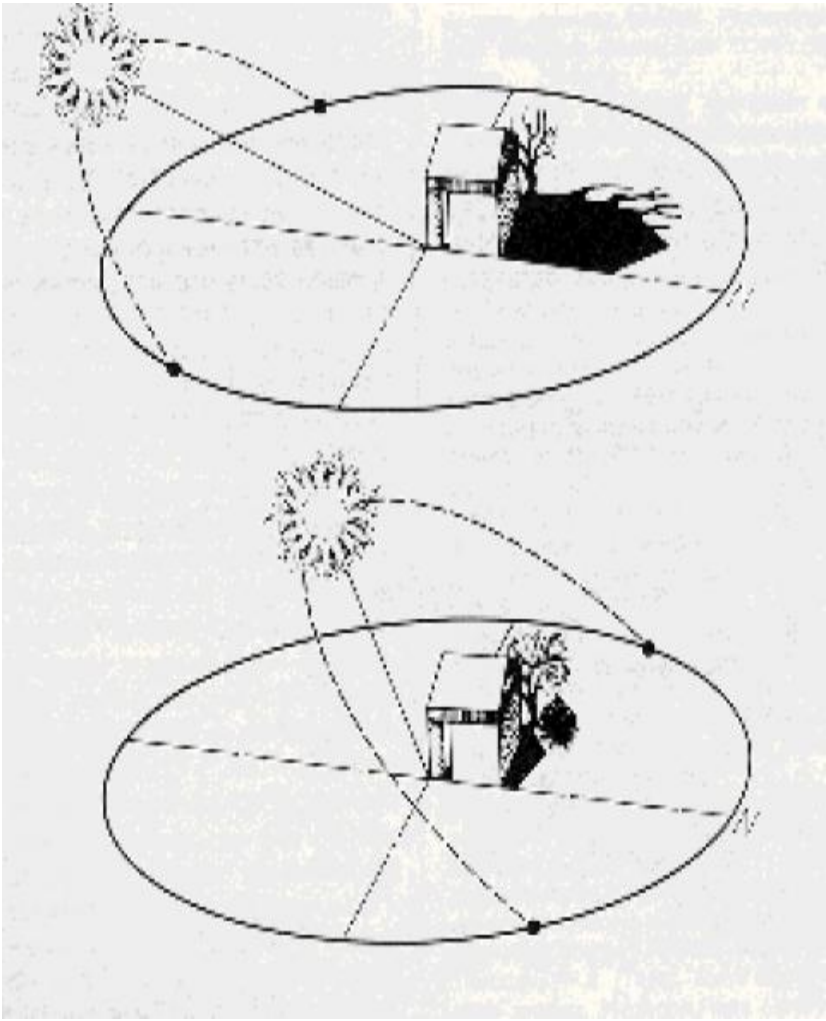
Solar Cycles

- Solar energy reaches the earth in a discontinuous form, showing cycles or periods:
- Daily cycle: accounts for 50% of the total availability of daily hours.
- Another effect of the daily cycle is the modulation of the received energy through out the day.
- Assessment and evaluation of solar resource
- Seasonal cycle: modulation of the received energy throughout the year.



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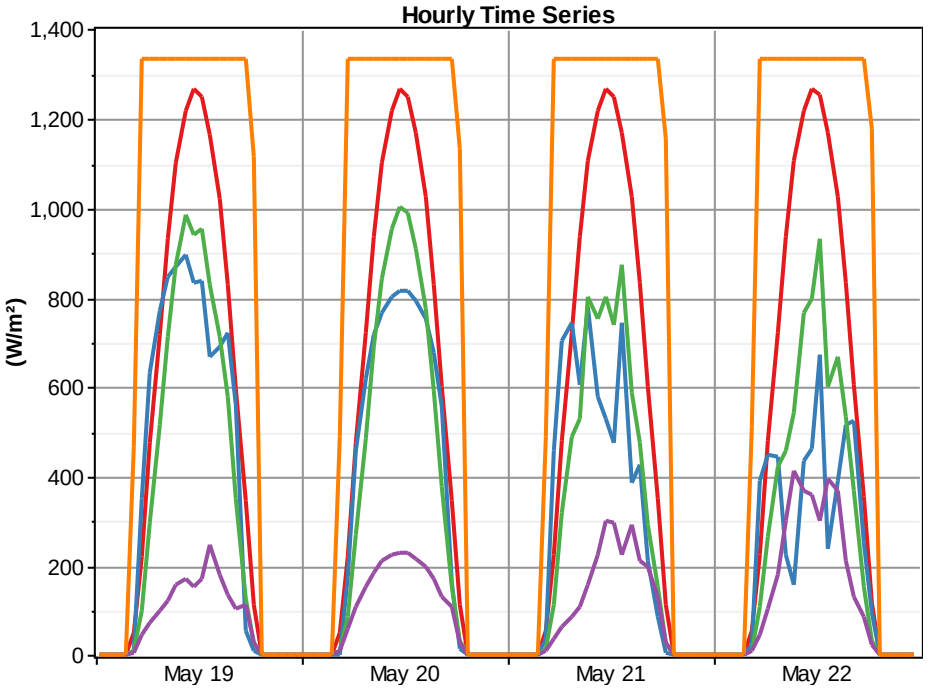
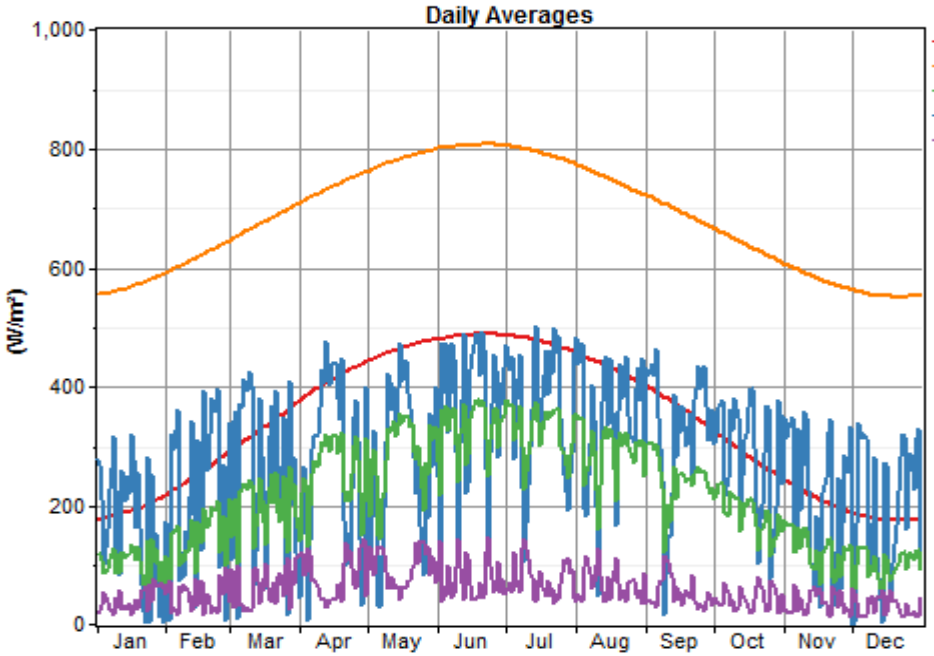
Typical profile(UZB)





Extraterrestrial Horizontal Radiation
Extraterrestrial Direct Normal Radiation
Global Horizontal Radiation
Direct Normal Radiation
Diffuse Horizontal Radiation

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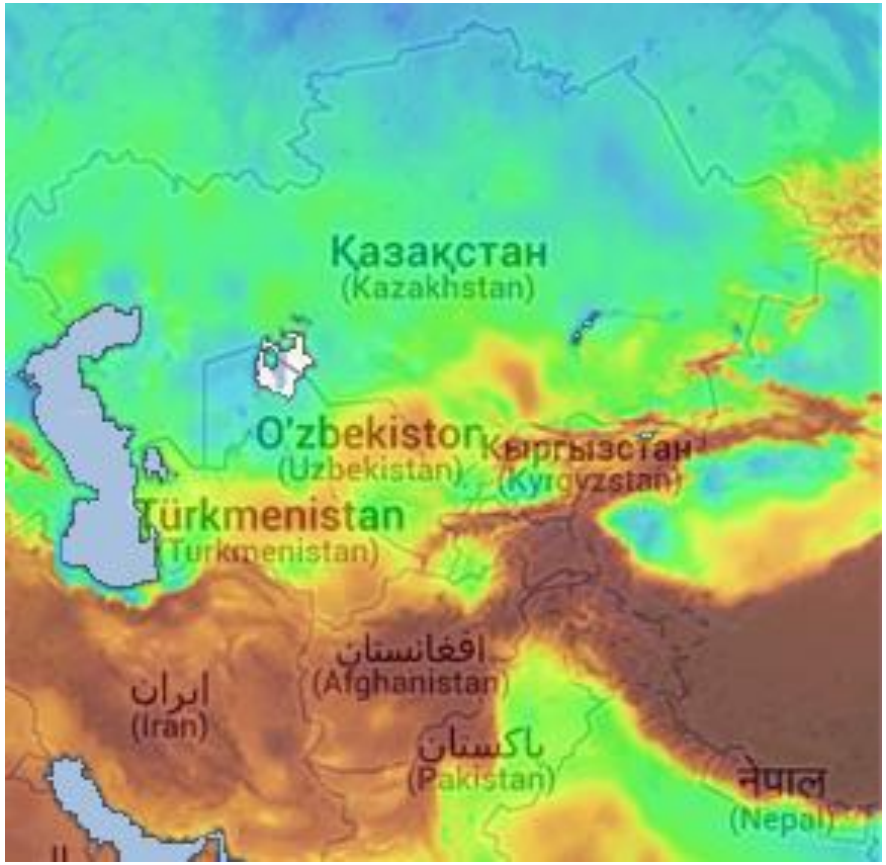
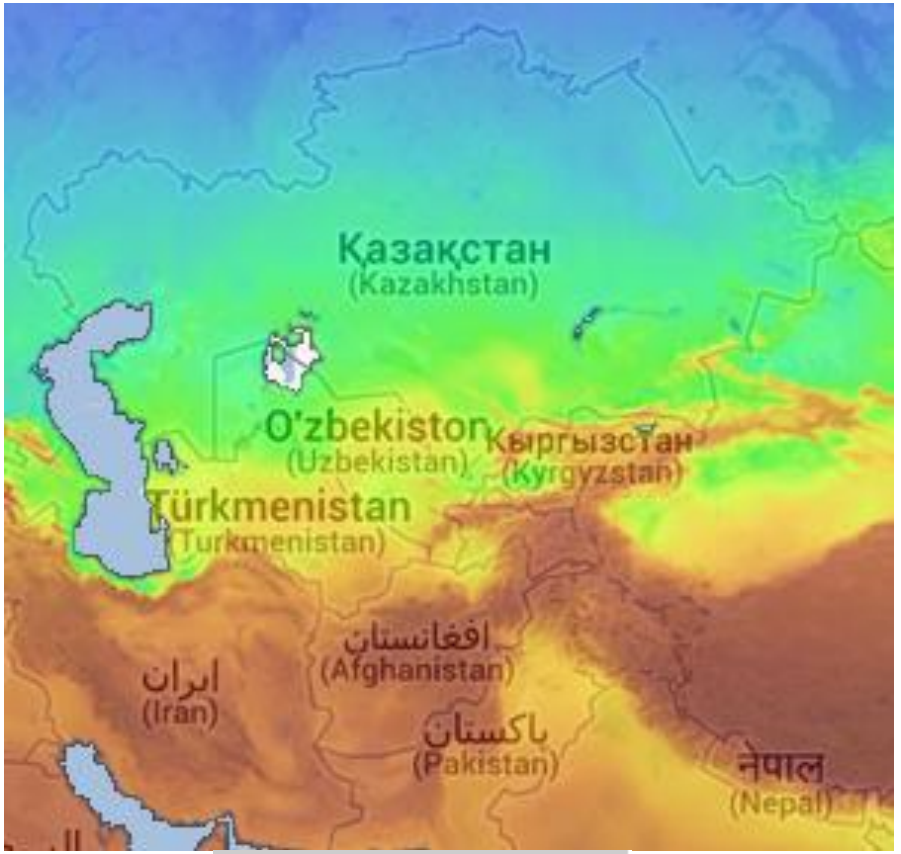
Direct Norma Irradiation (DNI)
Global Horizontal Irradiation (GHI)



Solar DNI Overlay: W/m²

77.0 222.5 368.0



Solar GHI Overlay: W/m²

77.0 222.5 368.0

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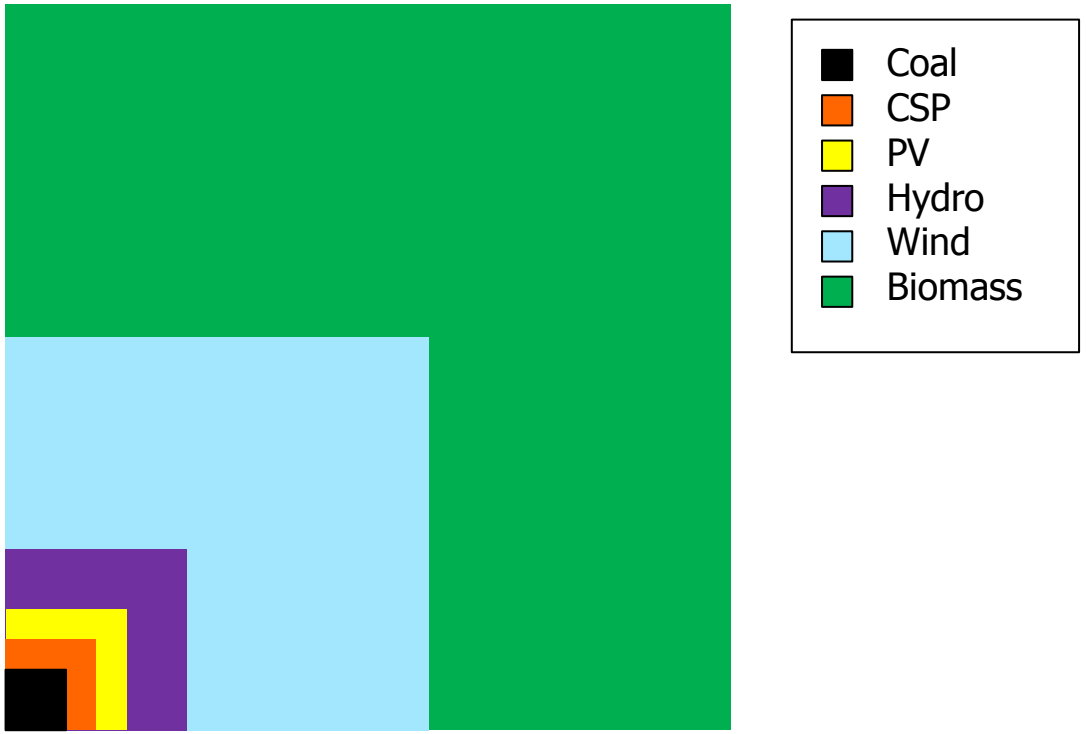
Possible combination

- Renewable:
  - Biomass
  - Wind
  - Hydro
  - Geothermal
- Fossil fuels



Comparison of land needed for energy production

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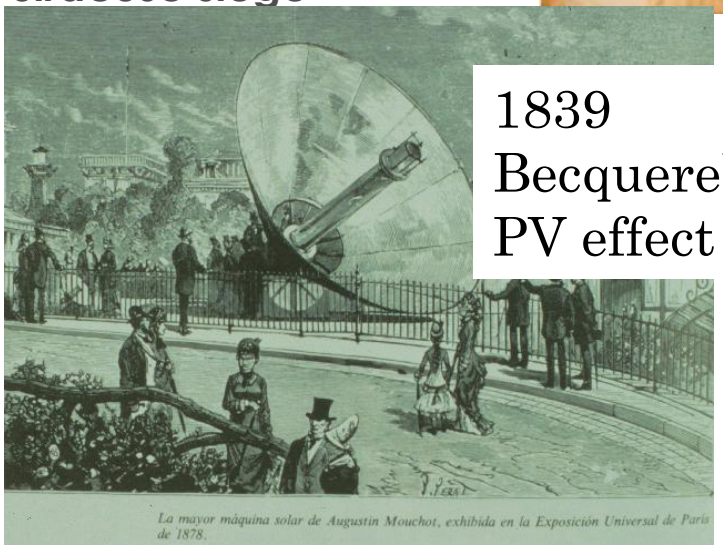
SOME HISTORICAL EXAMPLES OF THE USE OF SOLAR TECHNOLOGIES

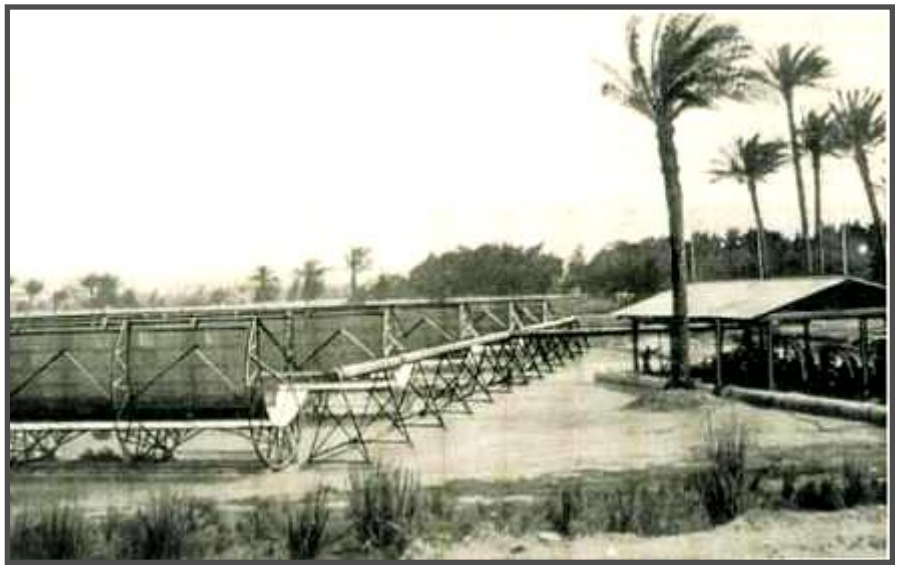
200 a.C.

Siracuse siege



1839
Becquerel
PV effect

Agustin Muchot France, Paris international expo 1878—1887

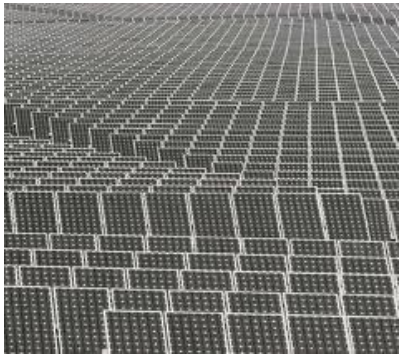


1914
First solar industrial parabolic through collector power plant in Shuman in Meadi, near Cairo (5 rows of 62 m each with a 120 HP steam turbine)

Solar Energy Generating Systems
SEGS 1984-1991
1984-1991（SEGS）

PV

PV on roof

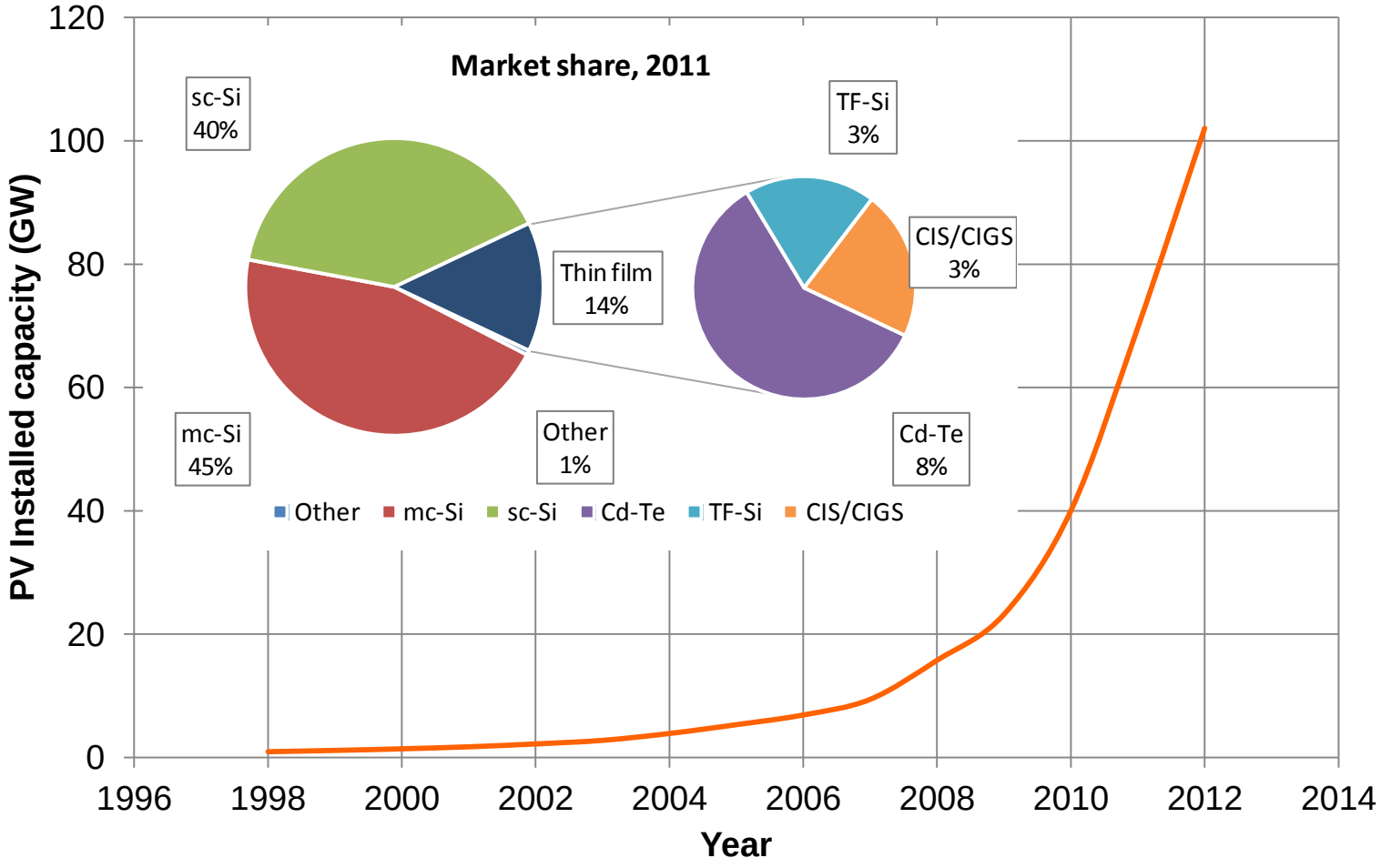


PV fixed

PV tracker

Concentration PV

PV current situation



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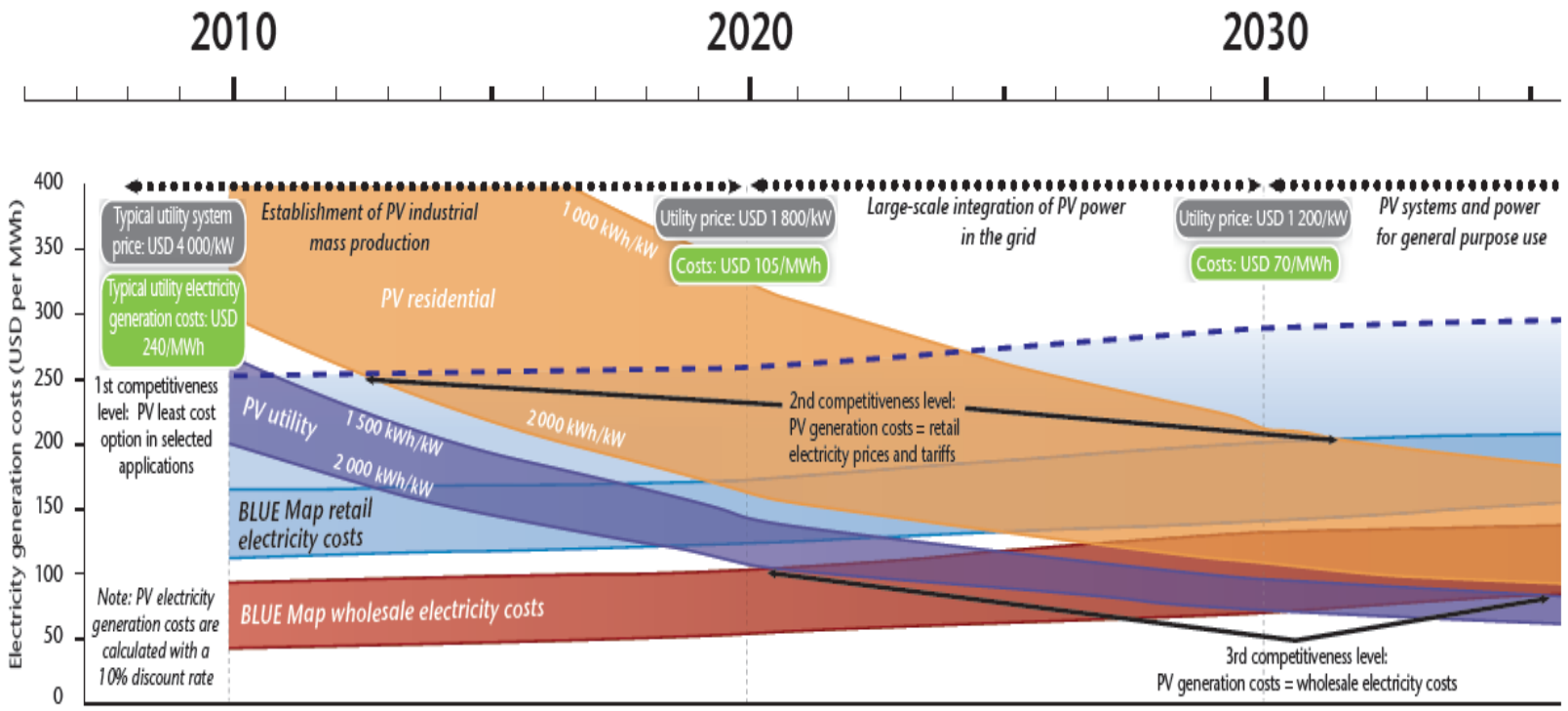
Leveraged Cost of Electricity

PV LCOE Variation IEA roadmap.



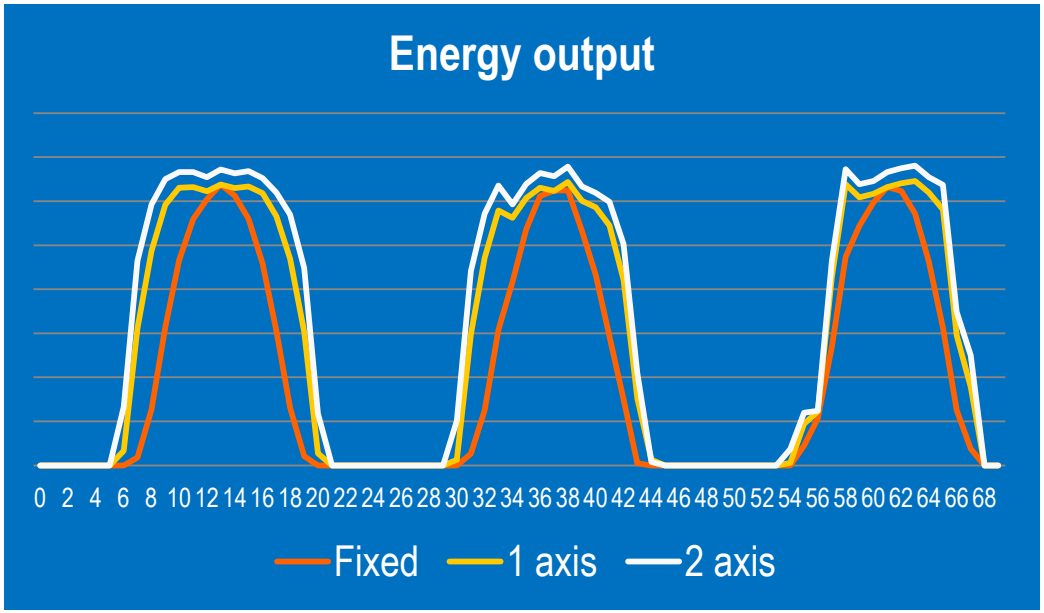
$LCOE_{PV}$ Source: IEA, PV Technology road map, oct2010

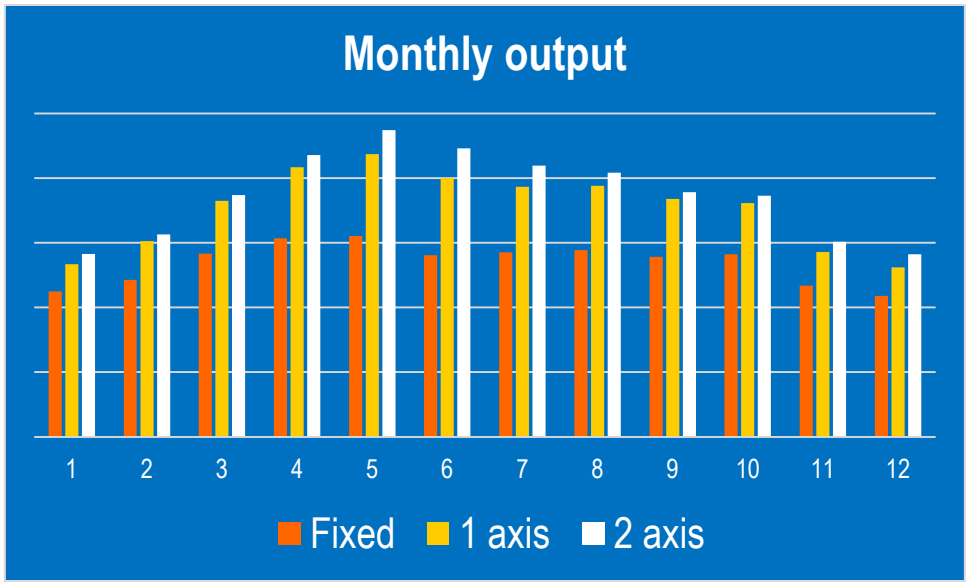
Technologies

- PV modules established technologies are:
  - Crystalline
  - Polycrystalline
  - Thin-Film

- And for the tracking system:
  - 1 axis
  - 2 axes
  - Fixed Structure

Samarkand





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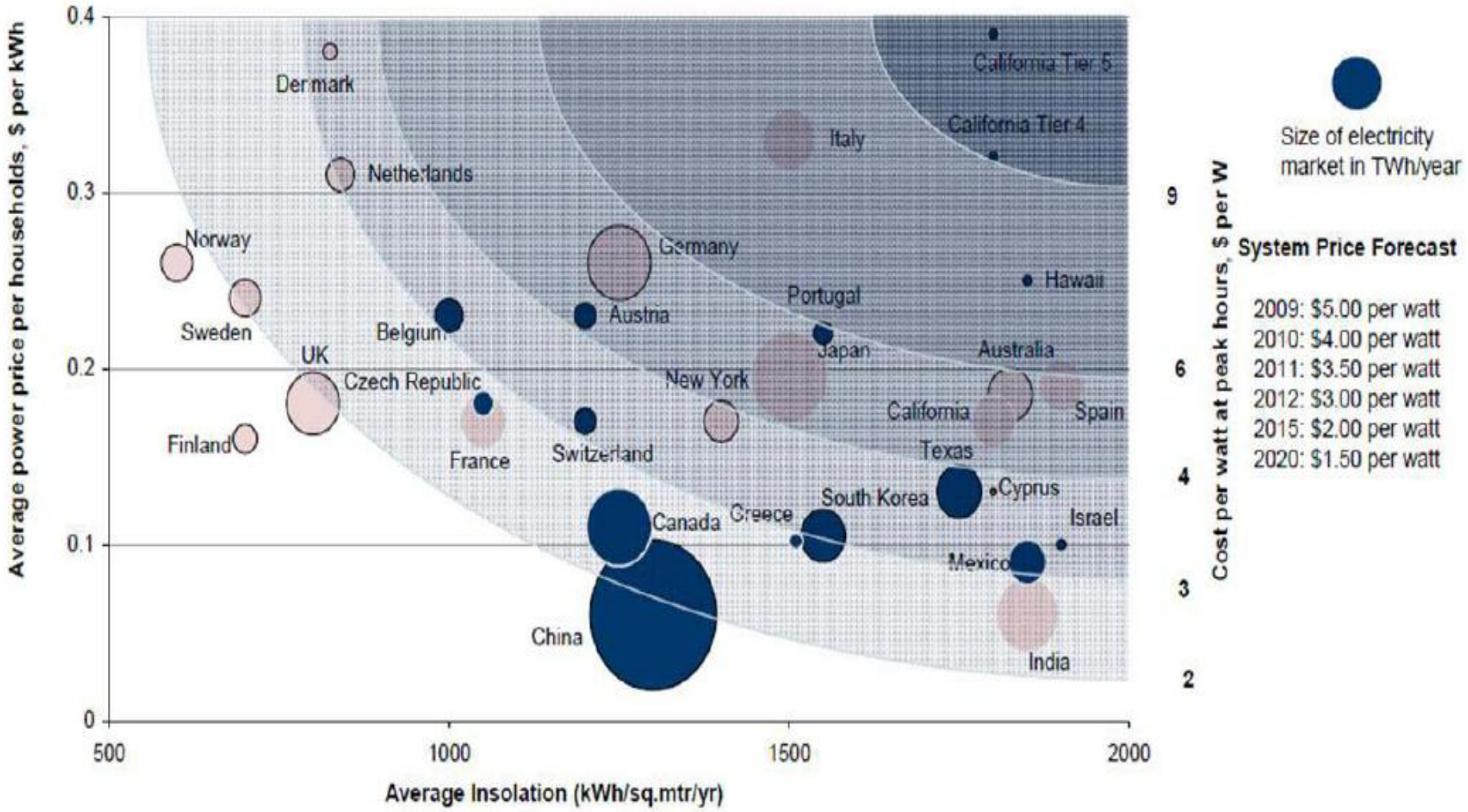
Grip parity



Source: Barclays Capital research, McKinsey Global Institute, CIA country files, European Photovoltaic Policy Group, Pacific Gas & Electric, Public Policy Institute of New York State

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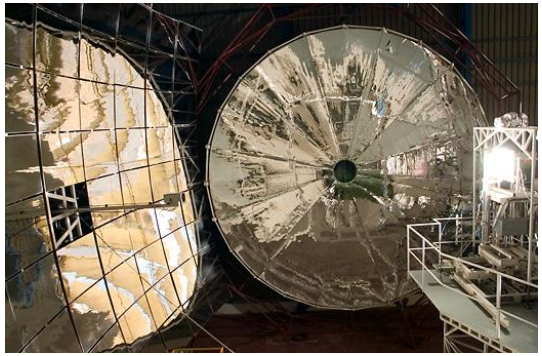
CSP



Solar furnace

Tower

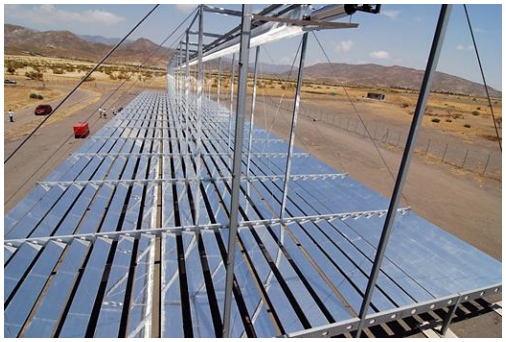
Stirling dish

Point concentration

Temperature

Linear concentration

Parabolic trough



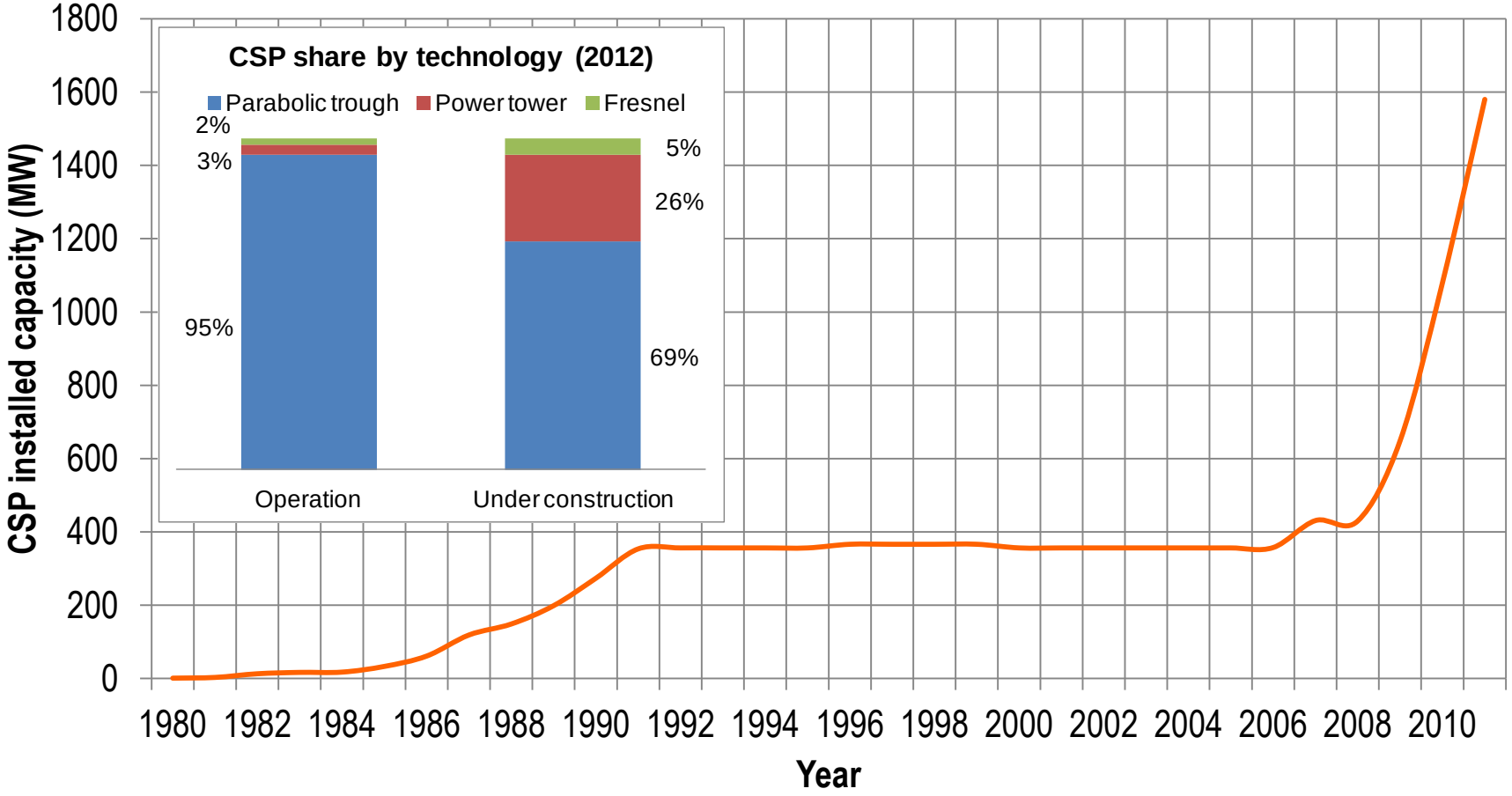
Fresnel linear

Desalinization

Cooling and heating

All pictures from Plataforma Solar de Almería, Spain

CSP current situation by technology



Source: NREL and REN 21

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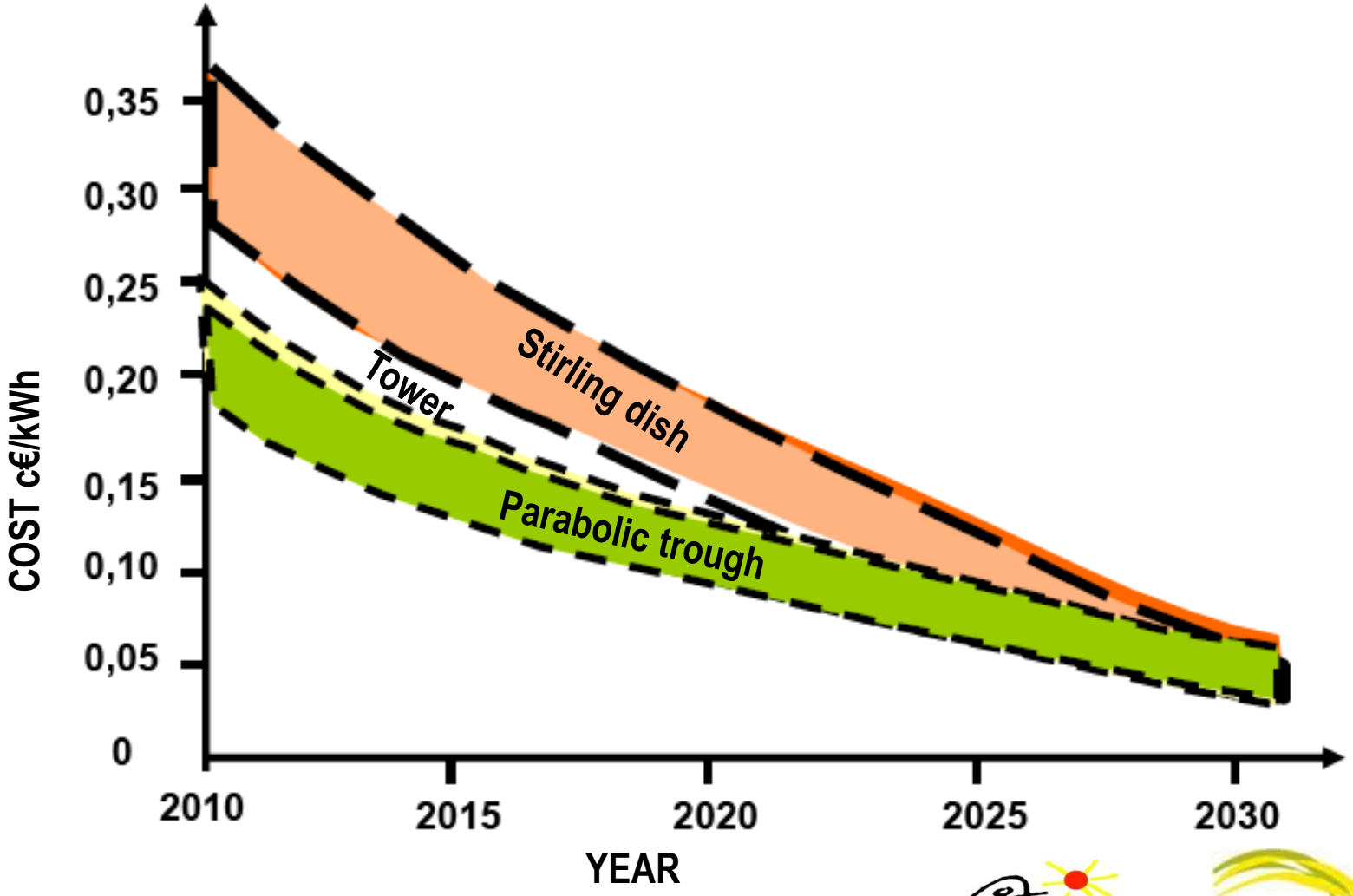
Cost



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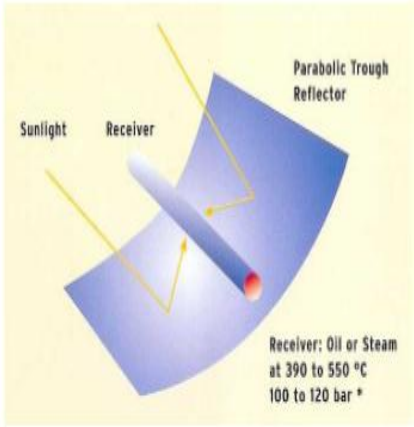
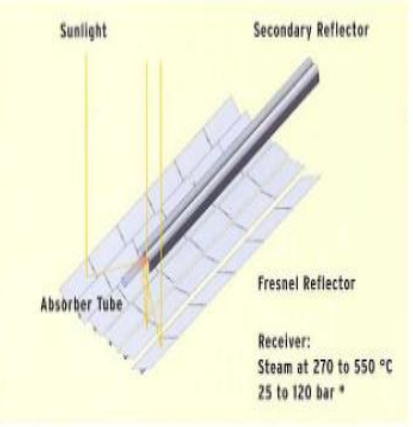
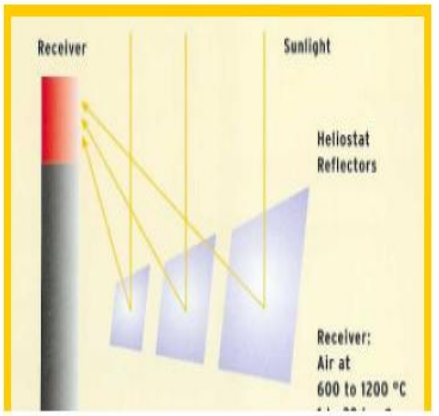
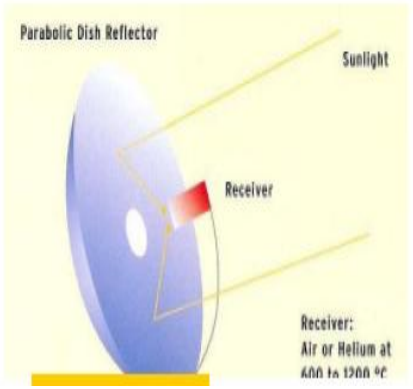
Clasification

- Linear receiver (or 1D concentration):
  - Parabolic troughs
  - Linear Fresnel
- Central Receiver (2D) on
  - Tower(movable concentrator, fixed receiver)
  - Parabolic Dishes (2D) (both concentrator and receiver are moved)









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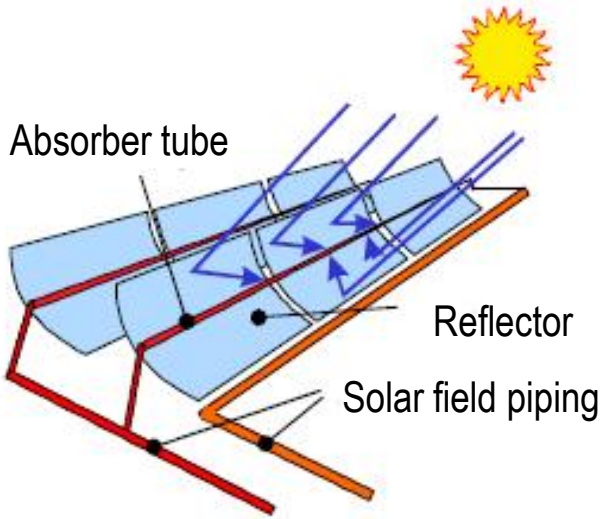
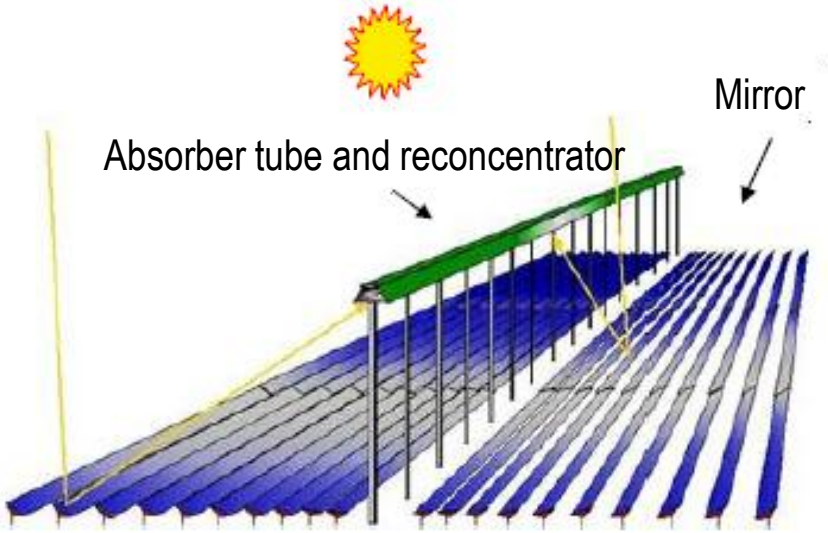
1-D concentration



Parabolic trough



Fresnel

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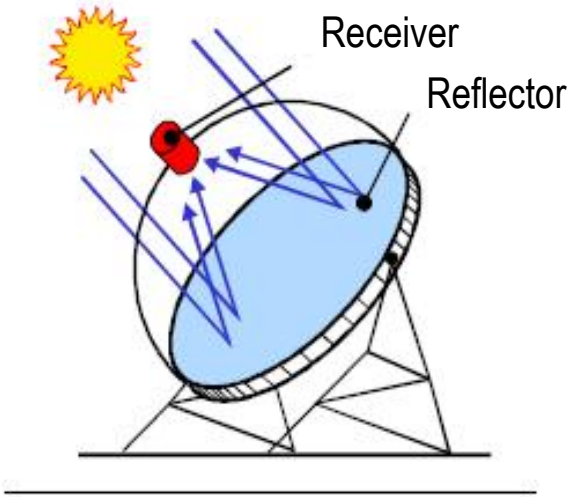
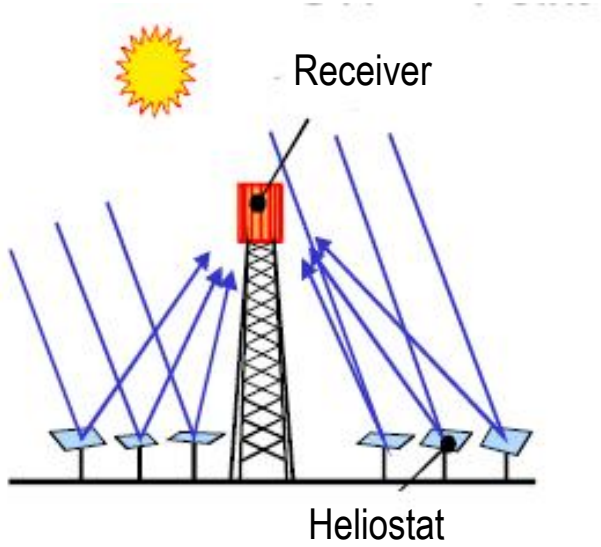
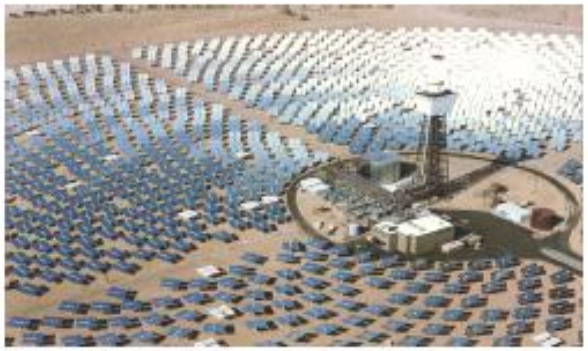
2-D Concentration



Stirling dish



Central Receiver System



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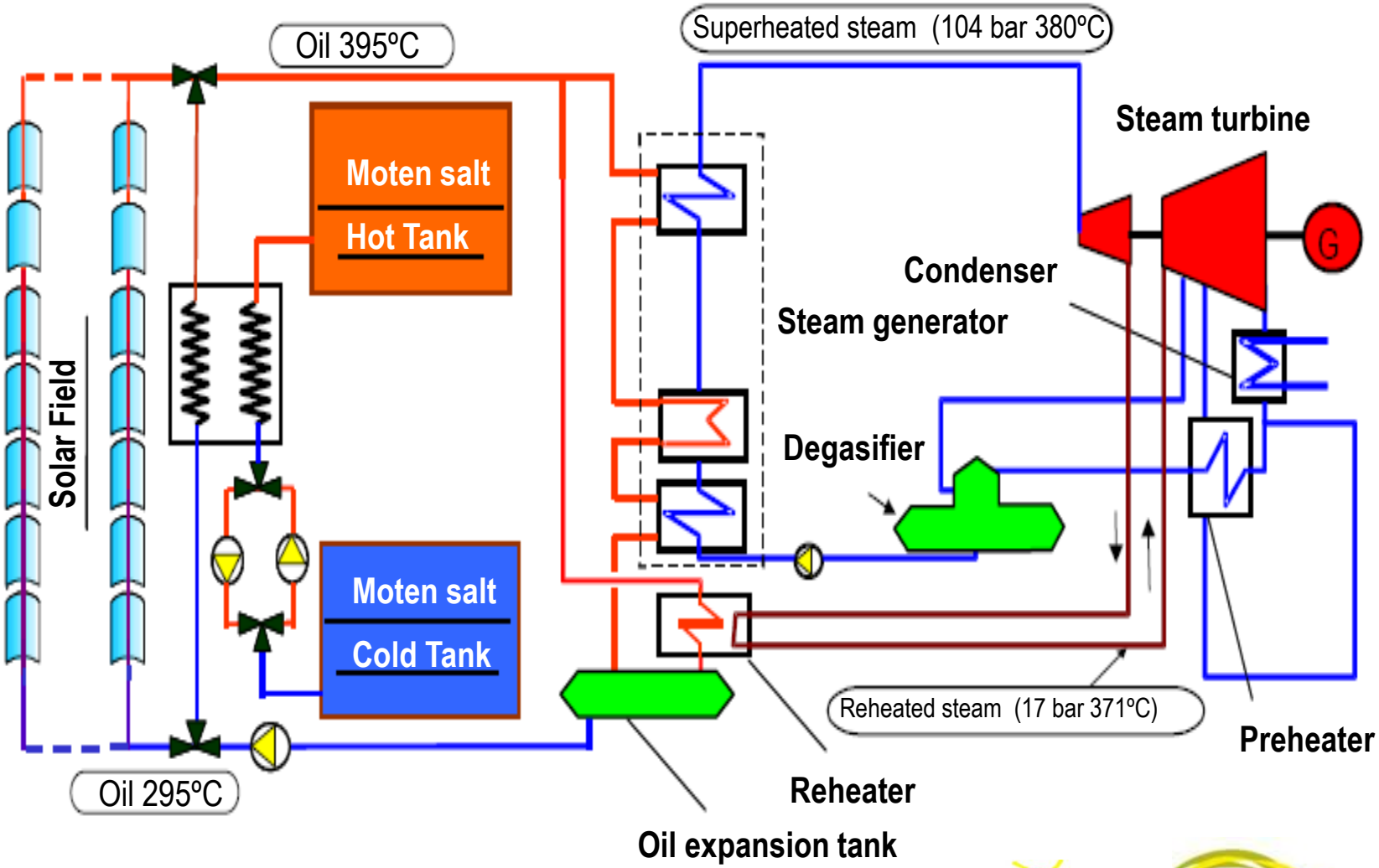
Typical PT HTF power plant



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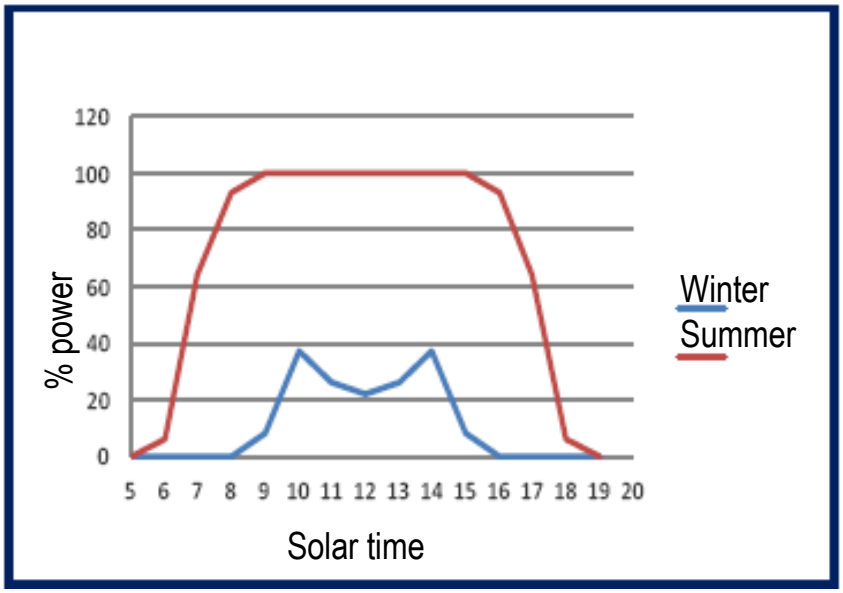
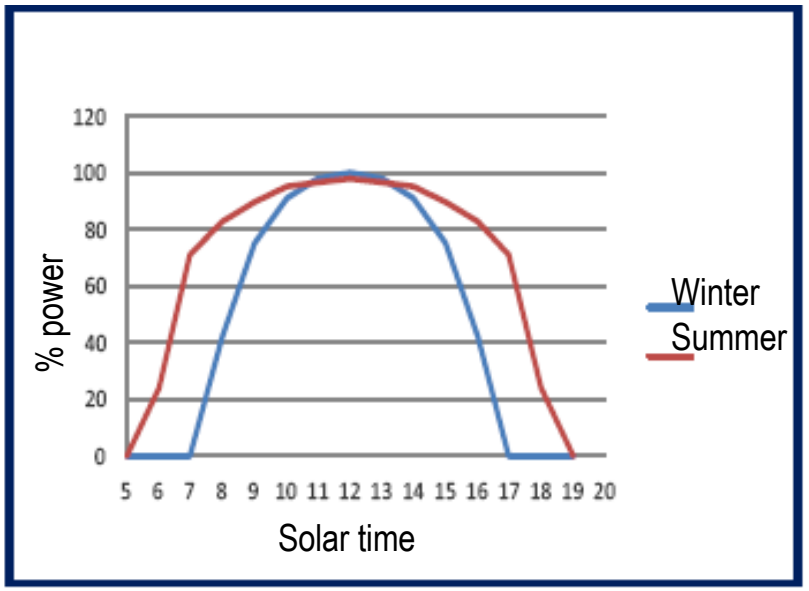
Production





- Reference plant: 150 GWh/year Spain
- Parabolic Trough Plant half year breakdown: Winter 25% / Summer 75%
- Central Receiver Plant half year breakdown: Winter 39% / Summer 61%

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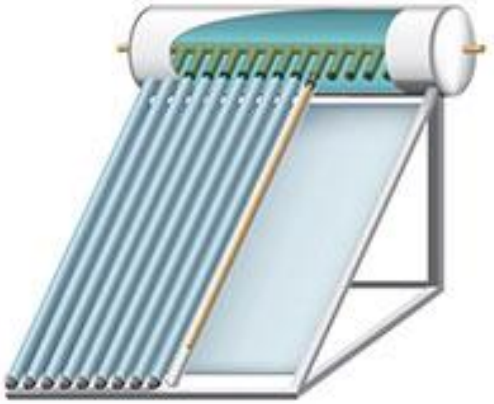
Solar Water heaters

Batch collectors

Flat plate collectors



Evacuated tube collectors

Source: Energy star

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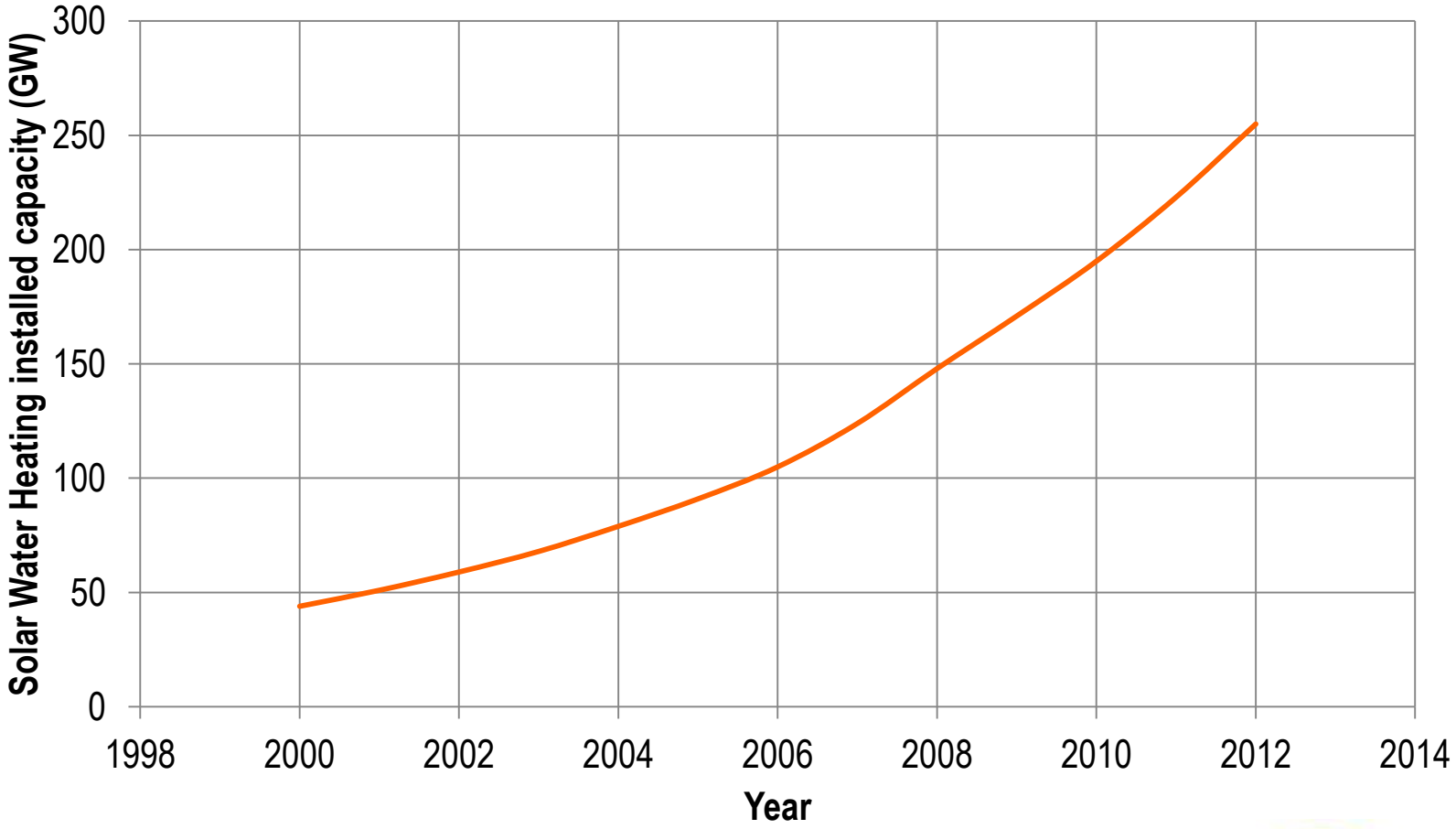
Solar Water heaters, current situation



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Comparison

Technology	Installed Capacity	Source
World electricity	5.200 Gwe	IEA
Photovoltaic (PV)	102 Gwe	REN 21
Concentrated solar power (CSP)	2.5 Gwe	REN 21
Solar water heaters	255 GWth	REN 21
Wind energy	283 Gwe	REN 21

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Comparison

Category			Small		Medium		Large	
Installation Size			< 10kW	10 to 100kW	100kW to 1 MW	1 to 10MW	10 to 100MW	> 100 MW
Technology Mix in Each Market			100% PV		99% PV, 1% CSP		50% PV, 50 %CSP	
2007 Share of Worldwide Solar Market (Installed Capacity and % of Installed Capacity)			14 GW (72%) 2010		3 GW (16%) 2010		2,5 GW (12%) 2010	
Installation Type			Distributed Generation			Central Generation		
Markets Served			Residential		Commercial	Utility	Base (50%). Intermediate (40%), Peak (10%)	
PV Based	Non Dispatchable	Non-Tracking PV	best suited	best suited	best suited	best suited	best suited	
		Tracking PV	suitable	suitable	best suited	best suited	best suited	
		CPV	suitable	suitable	best suited	best suited	best suited	suitable
Thermal Based	Dispatchable (with storage)	Dish-Engine		suitable	best suited	best suited	best suited	best suited
		Trough		suitable	suitable	best suited	best suited	best suited
		Tower				suitable	best suited	best suited
		LFR				best suited	best suited	best suited
Installation Size			<10kW	10 to 100 kW	100kW to 1MW	1 to 10 MW	10 to 100 MW	> 100 MW

Legend: best suited, suitable

Source: Prometeus institute, Concentrated Solar Power 2008

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Almería Solar Platform (PSA)

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Parkent, Uzbekistan

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CTS Puertollano

Solnova 1, PS 10 and PS 20

ANDASOL 1 and ANDASOL 2

EXTRESOL 1

LA RISCA

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LA DEHESA

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CASA DE LOS PINOS

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GEMASOLAR

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PV-CSP, Which?, Who?

Developer

Bank

EPC

Grid operator

Regional authority

Local authority

Local community

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Item	PV	CSP
Resource	Global Irradiance	Direct Irradiance
Shape, slope	Any	Rectangular, <2%
Surface	2-3 ha/MW	2-5 ha/MW (storage)
Water	Cleaning	Cleaning or 5-7 m3/MWh
Wind	Fix over 100 km/hr	20 Km/hr, 50 stow
Erection	Simple (6month-1 year)	Complicated (2 years)
O&M	Low cualification	Cualification
Capacity factor	10-20%	20%-85%
Energy storage	No	3-18 hours
Hybridation	No	Yes
Stability	Unstable	Stable
Supply safety	No	Yes
Daily energy patern	Maximum at noon	Shift to the afternoon
Cost	8-7 €/Wp – 2-3€/Wp	4 €/Wp – 6 €/Wp
FIT, PPA	45 c€/kWh-0,9 rmb/kWh	27c€/kWh-0,9 rmb/kWh

Developer, Bank, EPC, Grid operator, Regional authority, Local authority, Local community

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Why Solar is Attractive for Investors?	What are the main concerns?
Low risk technology •Proven technology •Easy construction •Variance of the resource Low working capital Government support •FIT •Renewable Energy Certificates •Tax Incentives Scalability Low environmental impact •Limited visual impact •Inert materials	Administrative and regulatory risks • Lack of support •Risk of certain retroactivity High Capital Expenditures •High capital allocation per Mw Low technical complexity •Number of players: Fragmentized market •Small barriers to entry •Misjudgments of the technical assumptions

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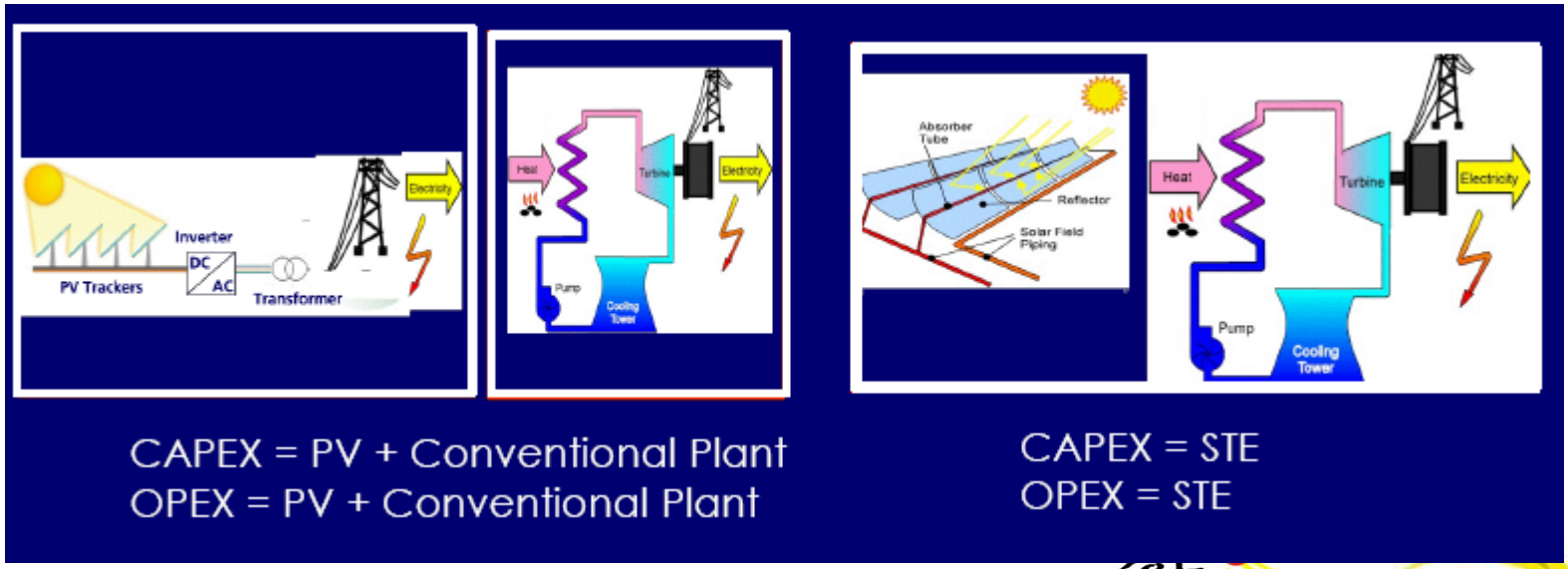
Energy supply

- Fluent source:
  - PV capacity factor around 20%
- Dispatchable sources capacity factor up to 100%



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Storage alternatives

	Type of storage	Cost for a 200 MW plant USD/kWhe	Operation lifetime (years)	Storage efficiency (%)	Operating temperature (ºC)
Molten salt	Heat	30	30	99	567
Synthetic Oil	Heat	200	30	95	390
Pumped hydro	Gravity	500-1600	30	70	N/A
Compressed air	Pressure		30	60	N/A
Superconducting	Electrical	Larger 1,000	30	90	Cryogenic
Battery Storage	Electrical	500-800	5-10	76	N/A

Source: Carlo Rubia communication

Full system costs included

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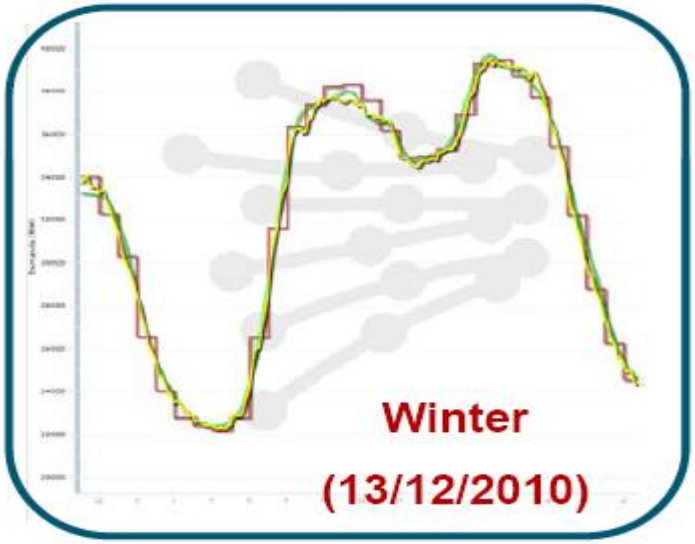
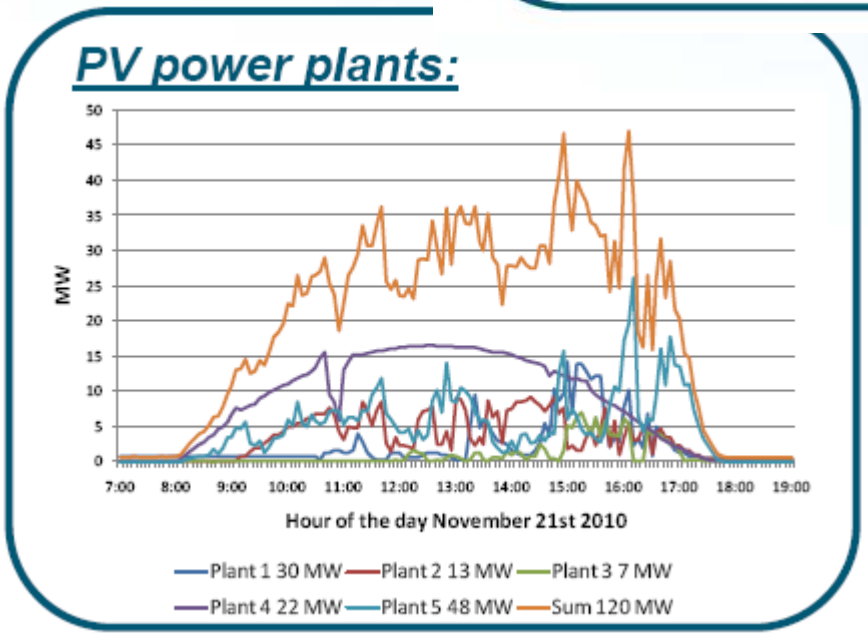
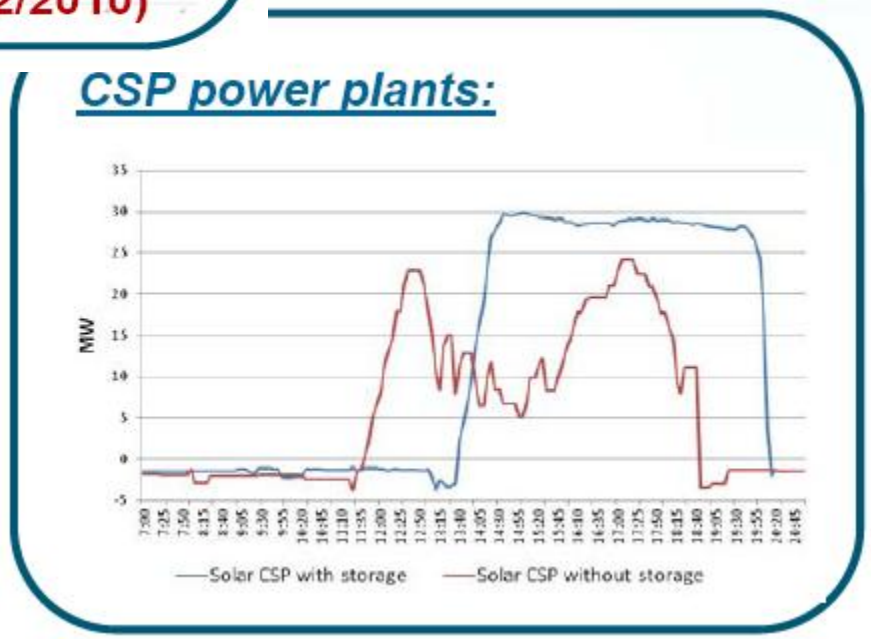




PV power plants



Multi-hour storage matches load profile

Source: DOE

Uzbekistan Roadmap

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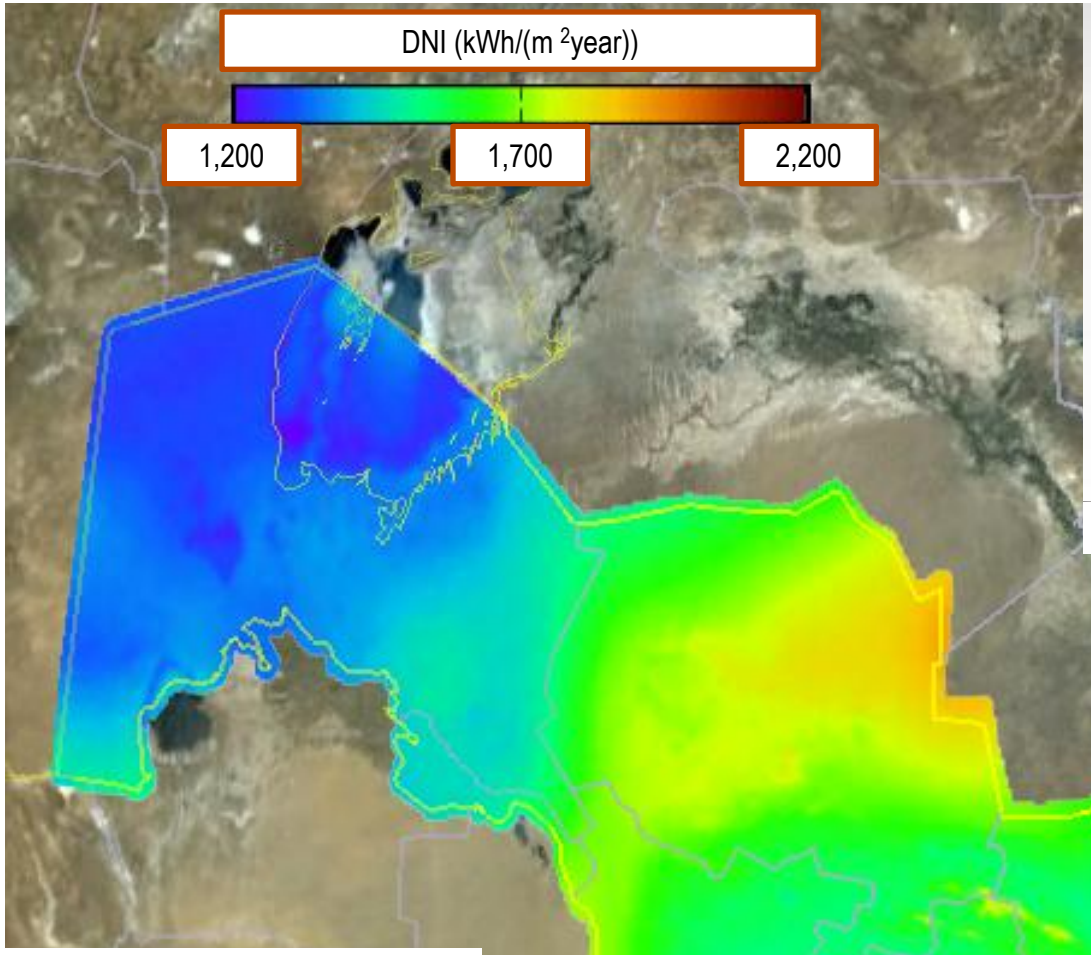
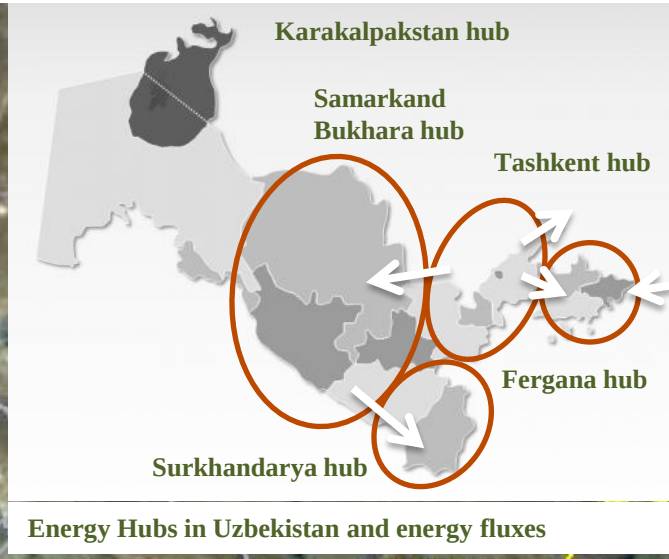




Energy Hubs in Uzbekistan and energy fluxes

Direct Normal Irradiation (DNI).
Source: ·own elaboration from 3 Tier data

CSP technology yearly energy output and needed land

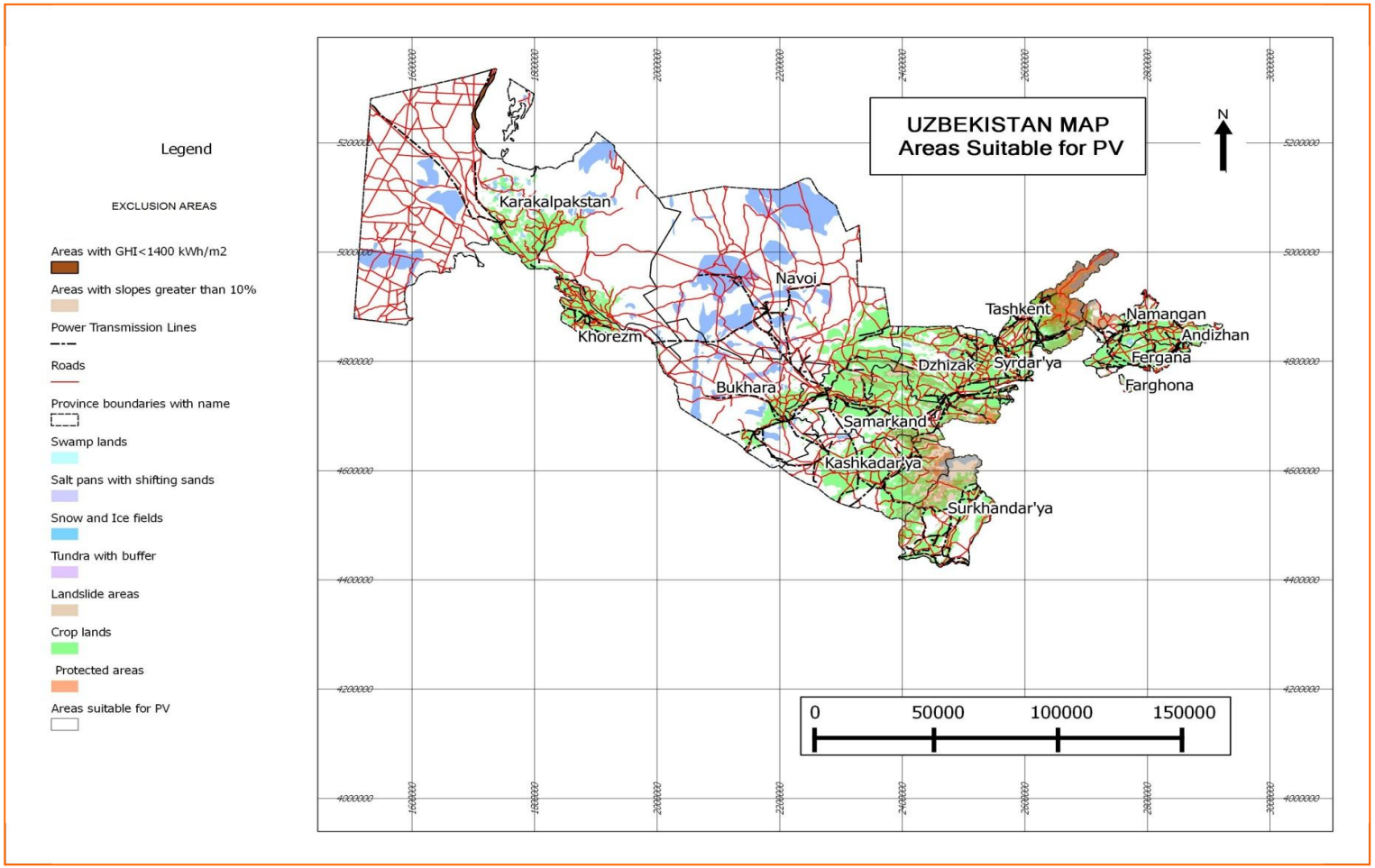
- **Optimistic scenario**
  4 TWh/year, 120 Km^2
- **Neutral scenario**
  1 TWh/year, 35 Km^2
- **Pessimistic scenario**
  0.4 TWh/year, 13 Km^2

PV tecnology yearly energy output and needed land:

- **Optimistic scenario**
  12 TWh/year, 190 **Km^2**
- **Neutral scenario**
  3 TWh/year, 50 Km^2
- **Pessimistic scenario**
  1 TWh/year, 20 Km^2

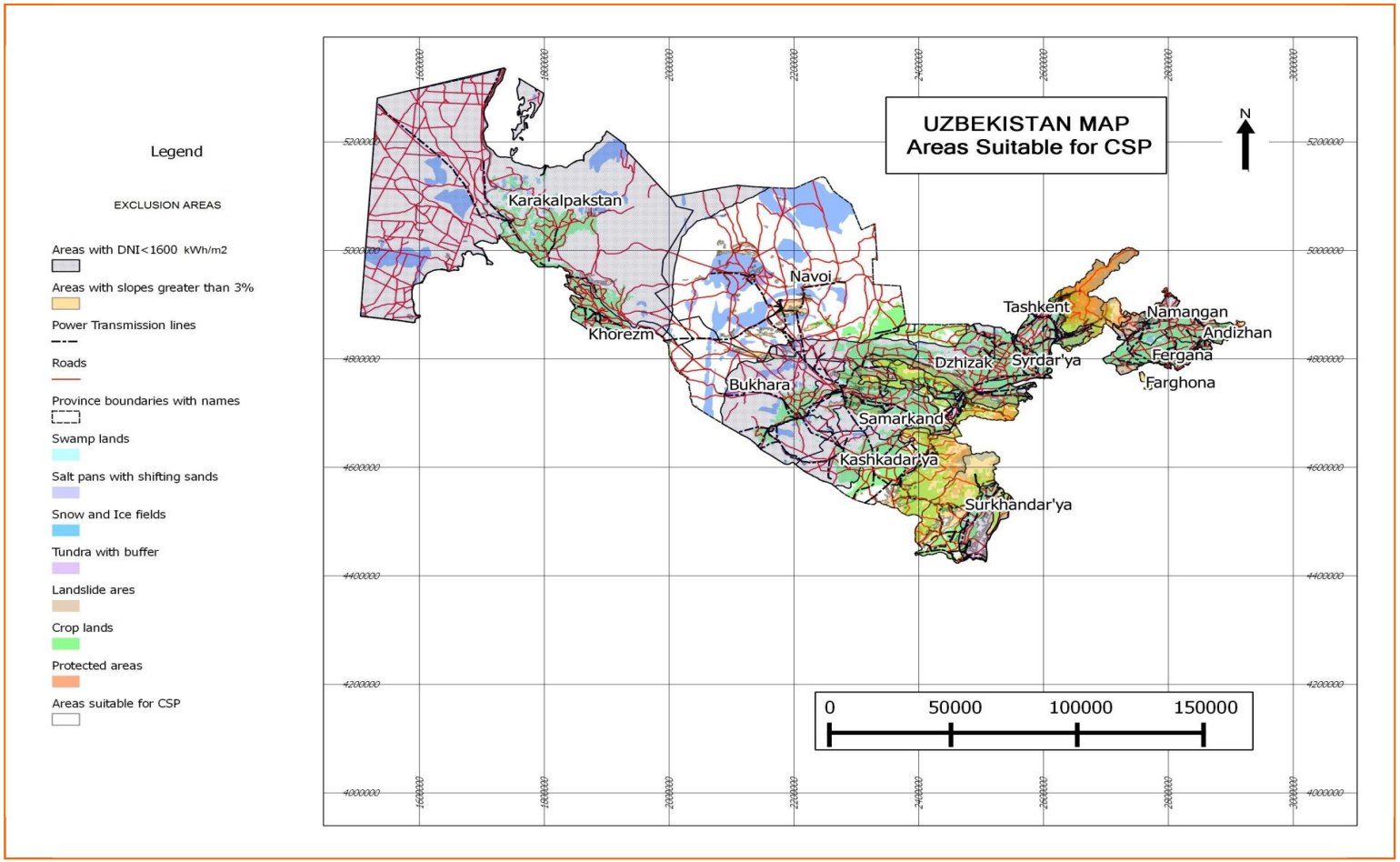
Restrictions

Suitable Area for PV

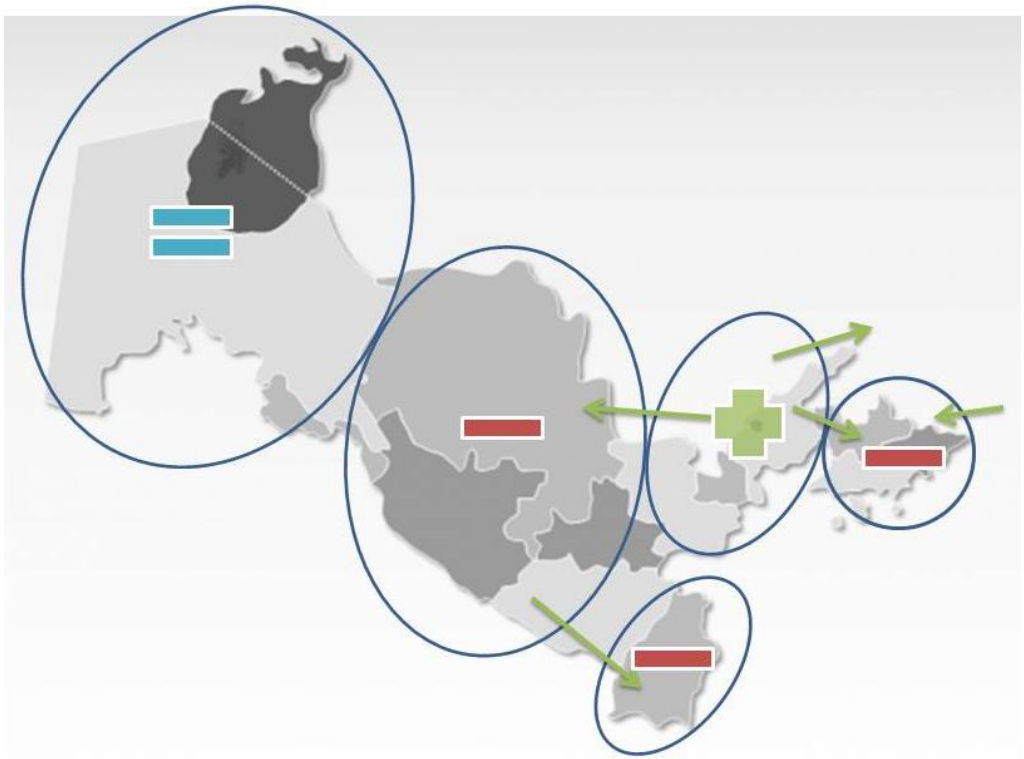


Restrictions

Suitable Area for CSP



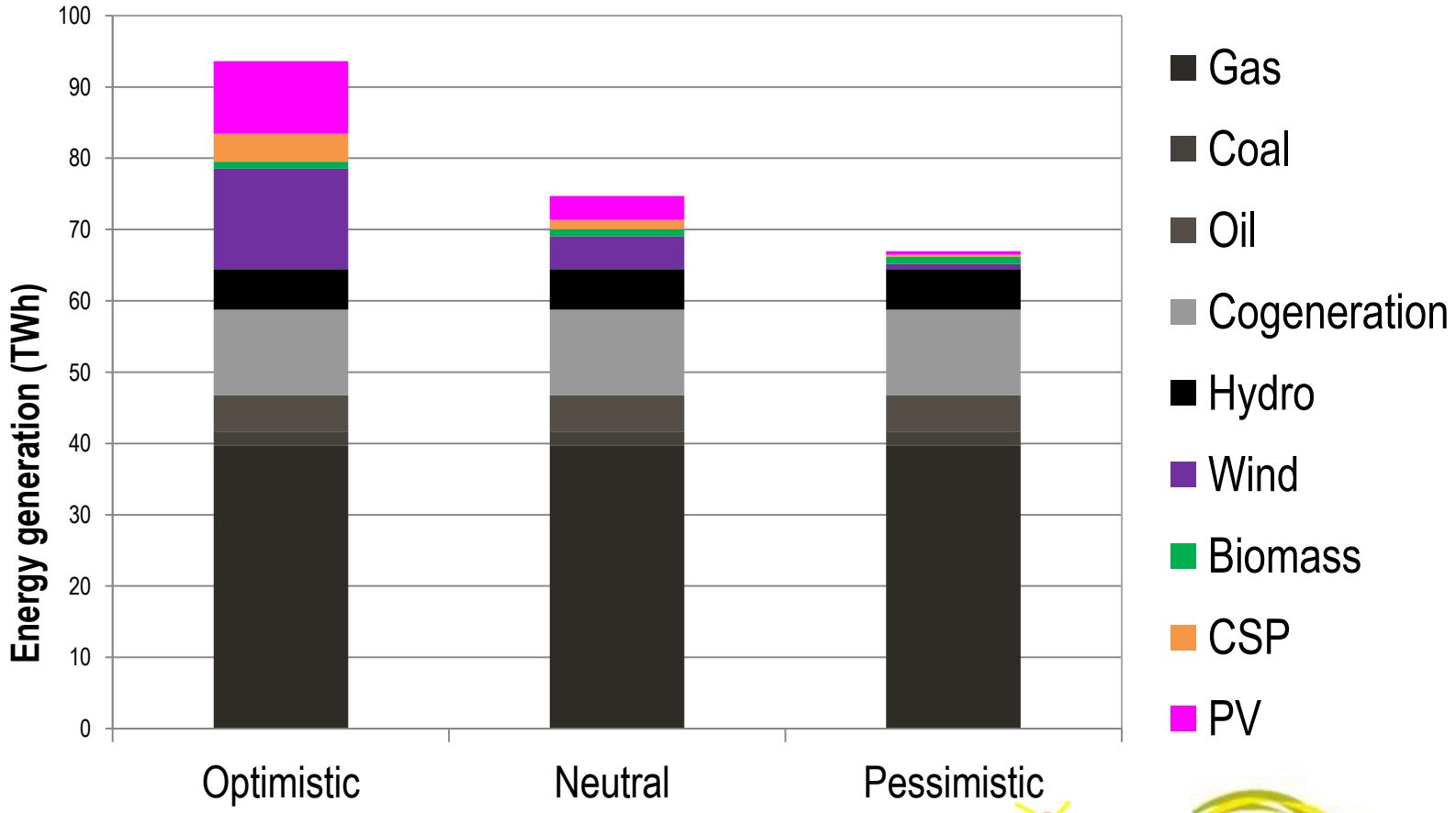
Location of solar power plants



Strategic location of solar power plants may improve the national energy consumtion/generation scheme.

Supply - Results

Forecasted electrical energy mix in 2031



Water

CSP+PV Consumption in 2031	% of Energy Generation Water Consumption
Optimistic scenario	10%
Neutral scenario	4%
Pessimistic scenario	1%

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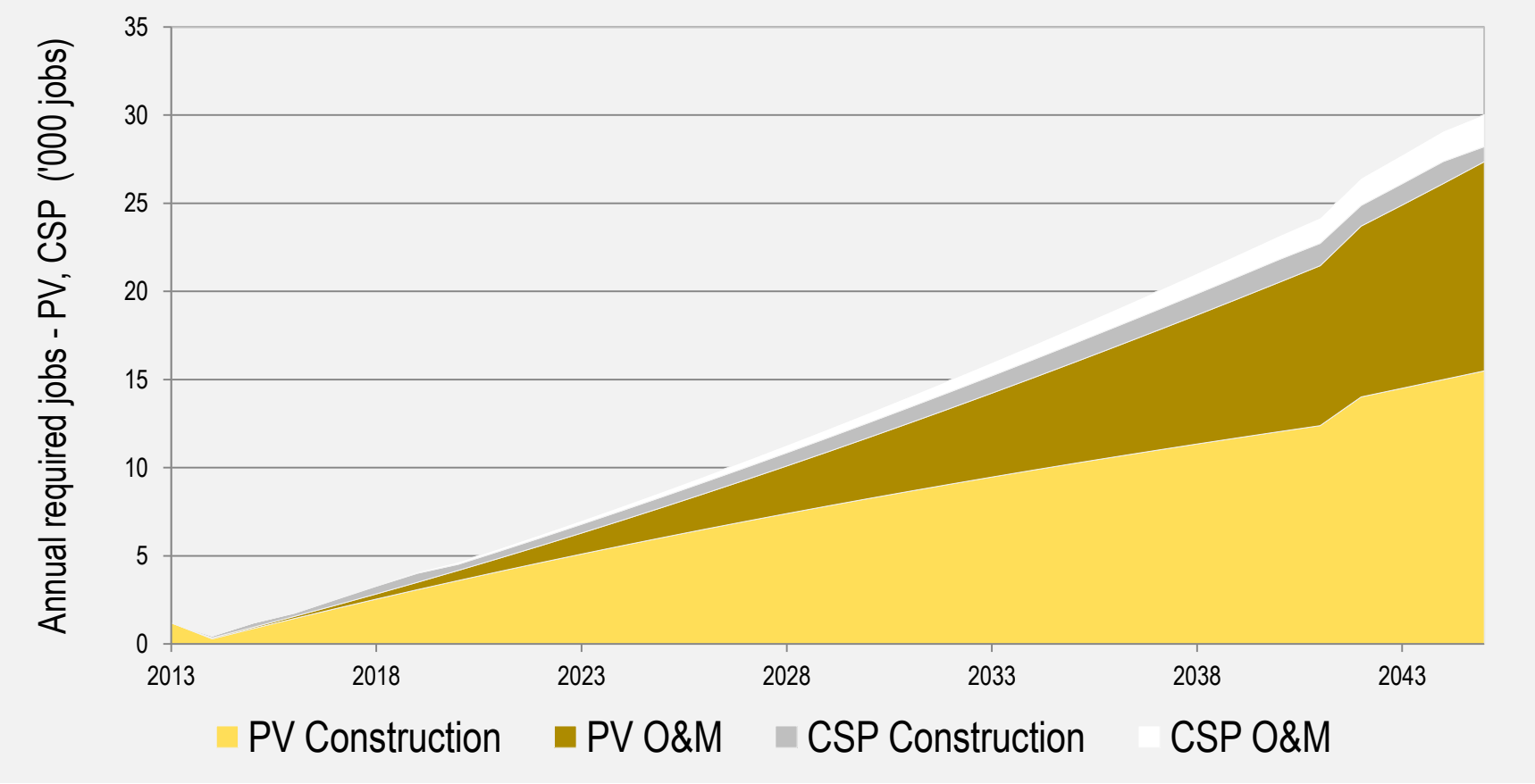
Employment



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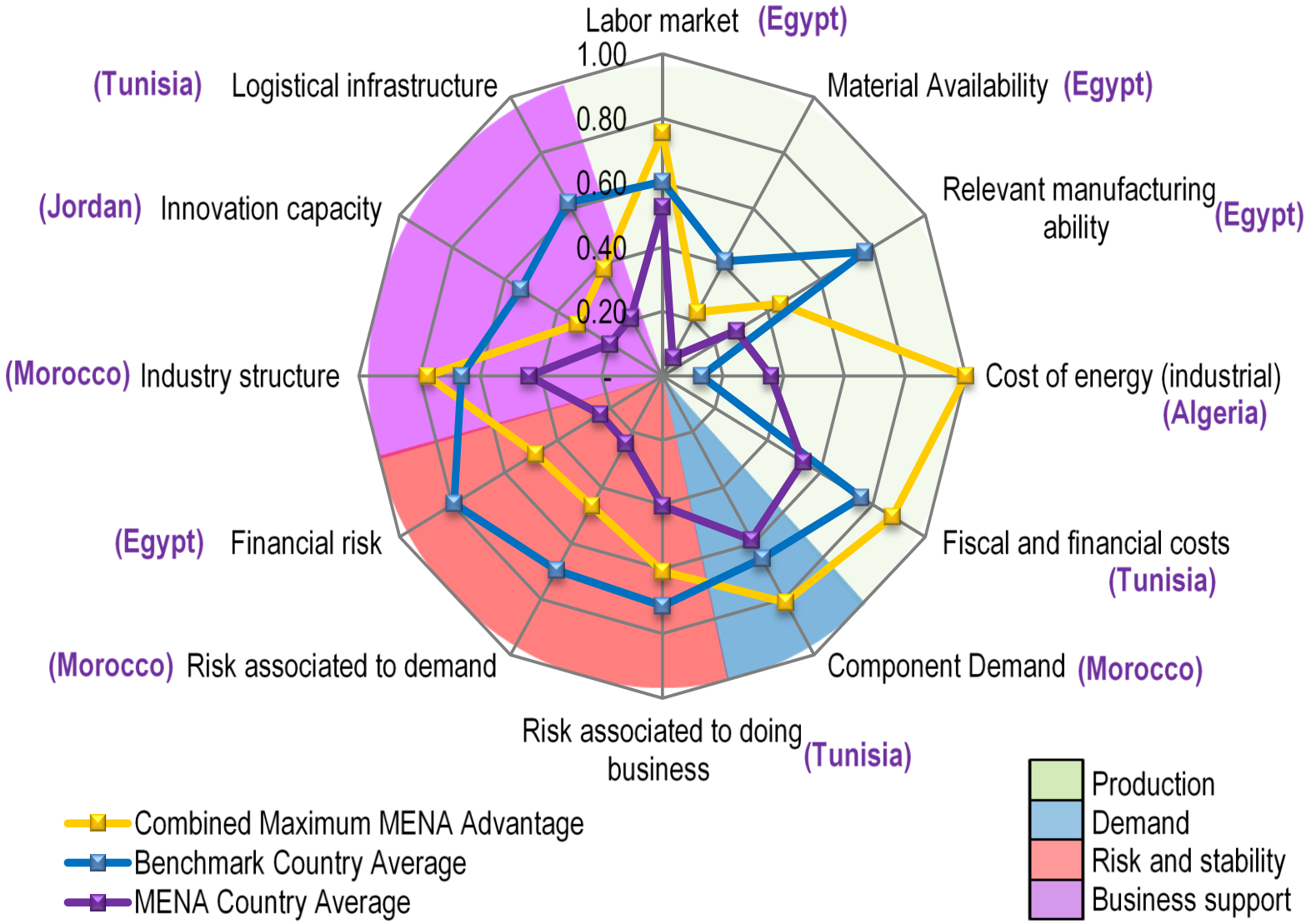

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Solar energy can play a role in Central Asia

Cofete beach at Fuerteventura, Canary Islands, Spain

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