Hybridization of CSP technologies with PV.

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European Research Area Chair.

23/06/2020

Webinar: Hybridization: How to accelerate the transition to renewables with Hybrid PV-CSP systems

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 667942.

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  - The Climate Crisis and the urgent need for an Energy Transition to a sustainable, environmentally friendly and renewable energy based World Energy System.
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- Overview of CSP technologies
  - Main characteristics
  - Value proposition

- Hybridization of CSP with PV
  - Rationale
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- Conclusions

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Context

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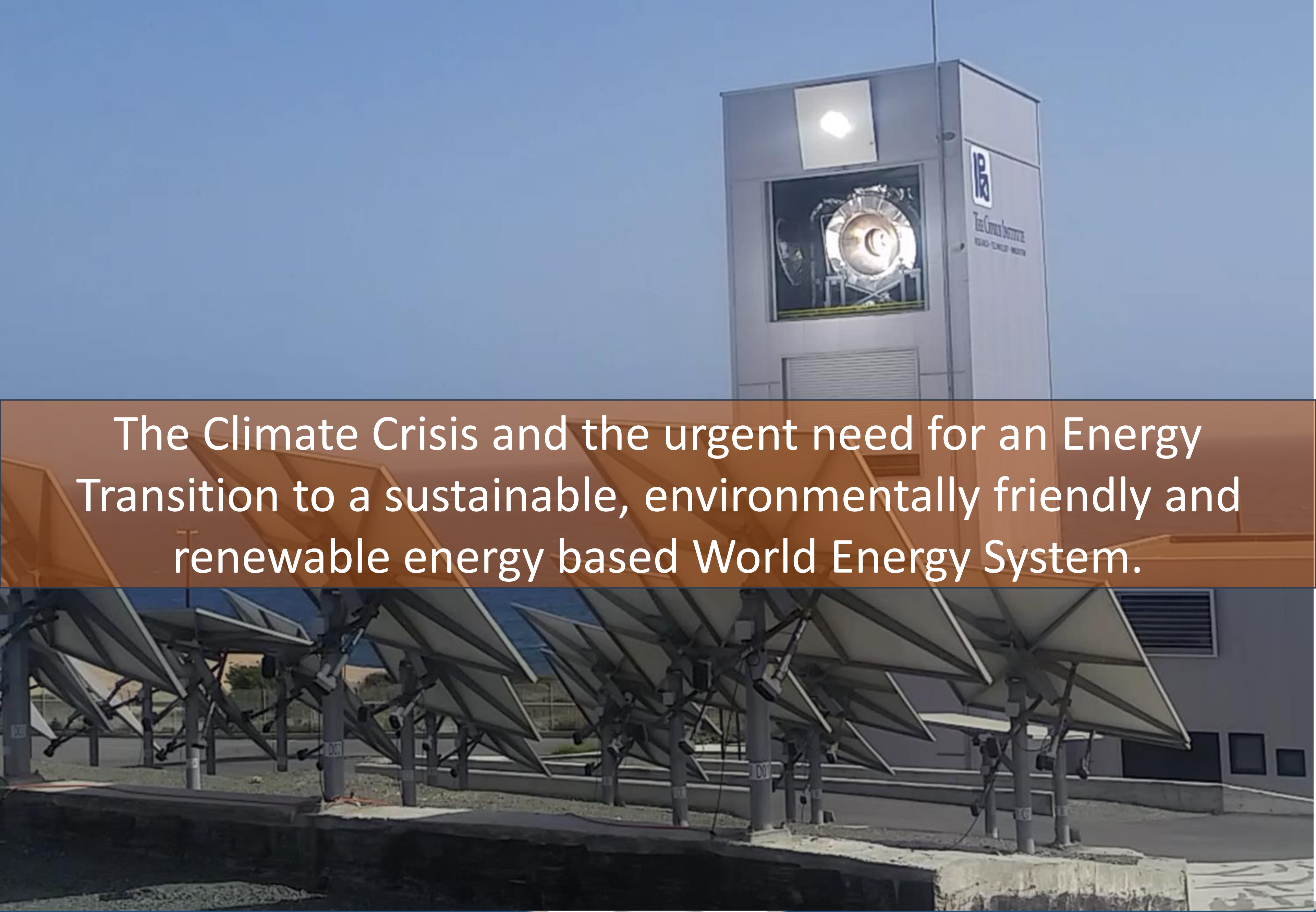

The Climate Crisis and the urgent need for an Energy Transition to a sustainable, environmentally friendly and renewable energy based World Energy System.

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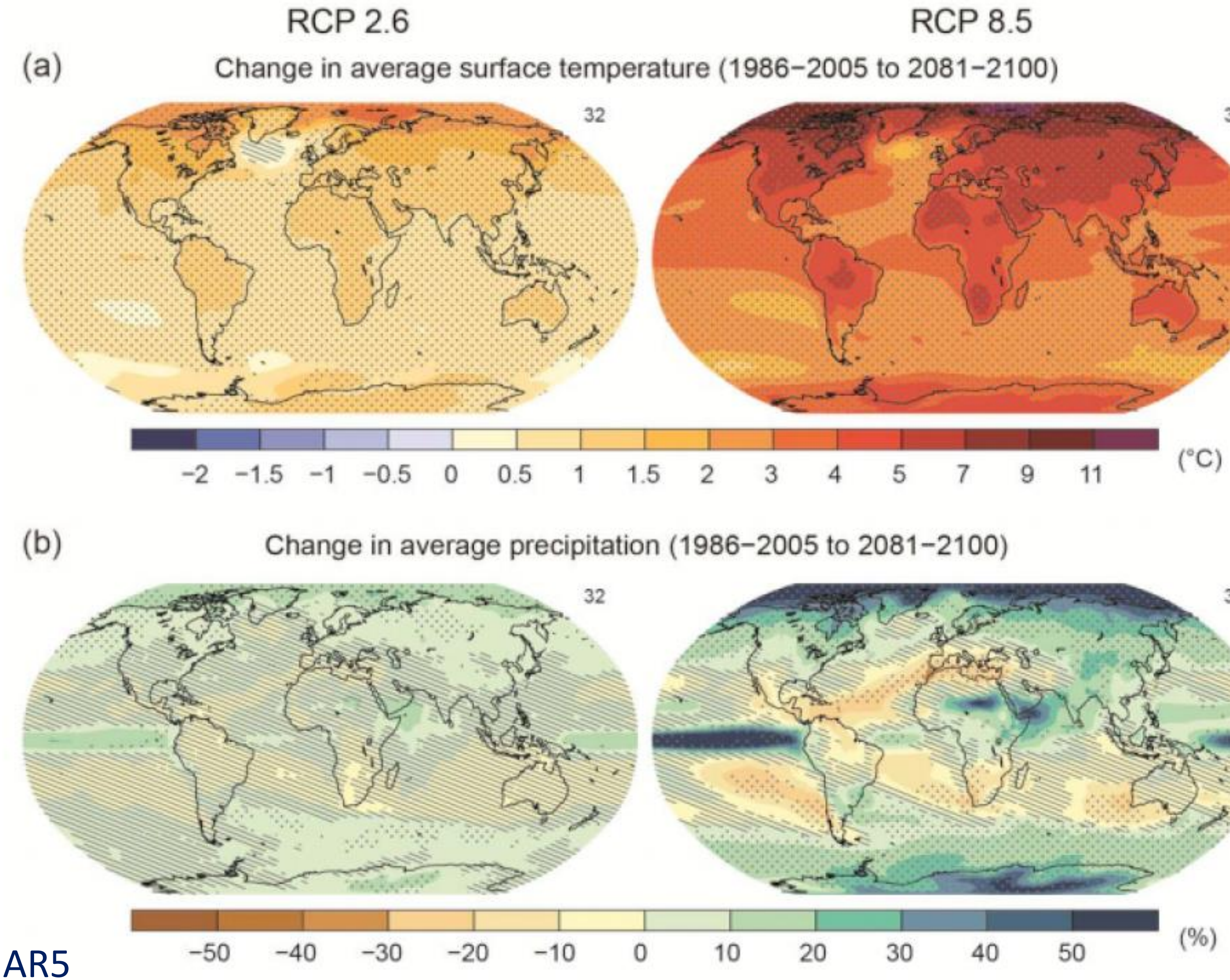
Projections - Global Climate Models



IPCC AR5

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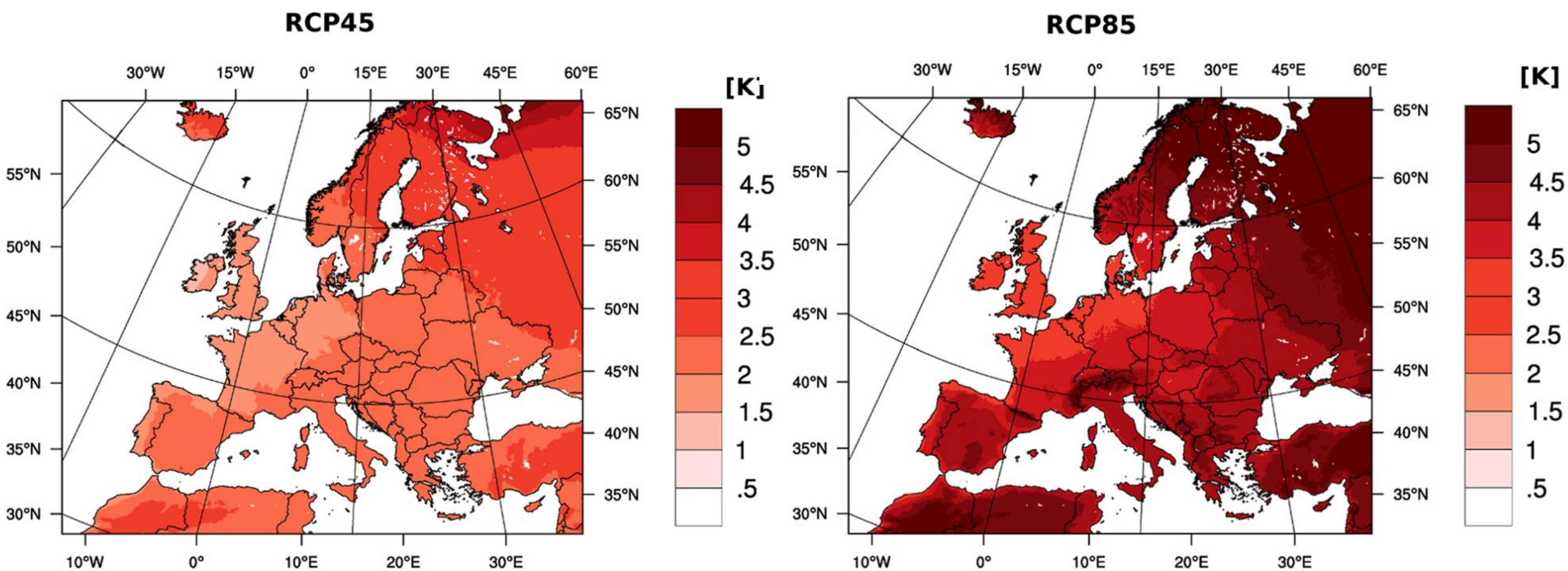
Mean Climate Projections for Europe (Temperature)

According to all scenarios European Climate will likely get warmer.



Projected changes of annual mean temperature [K] for 2071–2100 compared to1971–2000, for RCP4.5 (left) and RCP8.5 (right) based on EURO-CORDEX simulations (Jacob et al. 2014)

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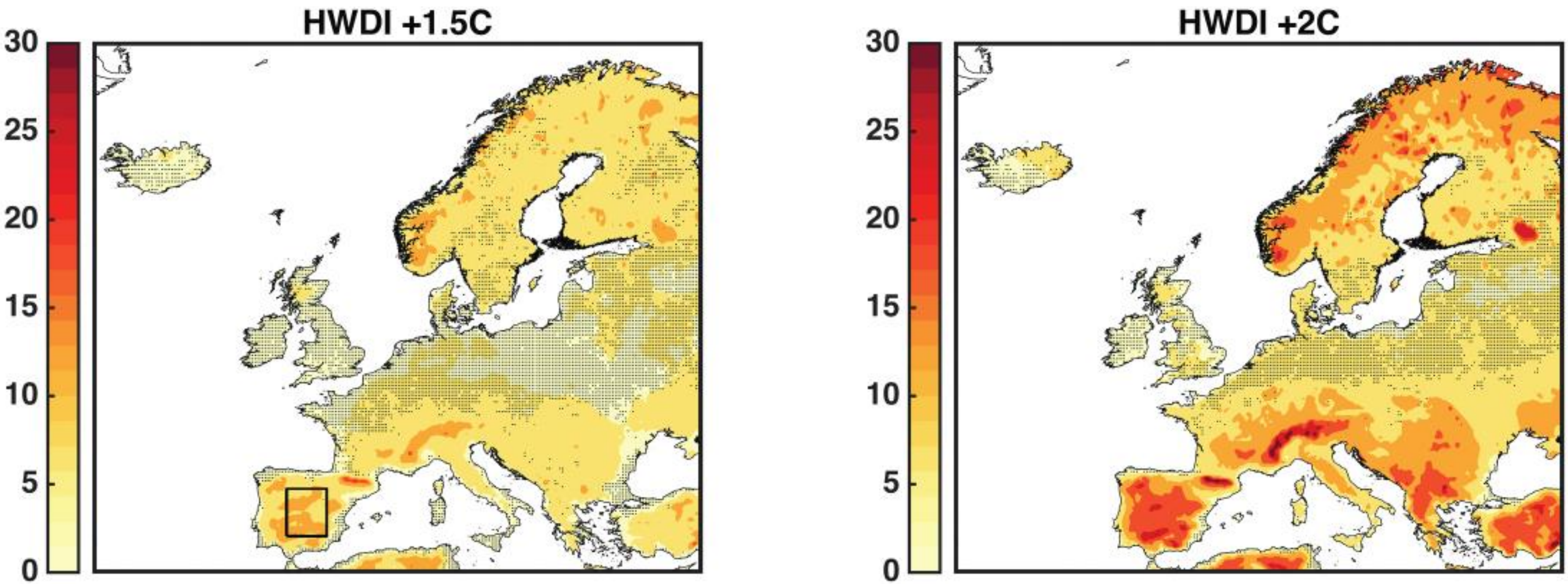
Heat Waves

Besides changes in mean climate we expect to have more frequent and severe extreme events (e.g. heat waves, droughts).



Heat Wave Duration Index in a 1.5°C and 2°C warmer world (Jacob et al. 2018)

*HWDI: Annual count of days with at least 6 consecutive with T_{max} > mean(T_{max}) + 5°C

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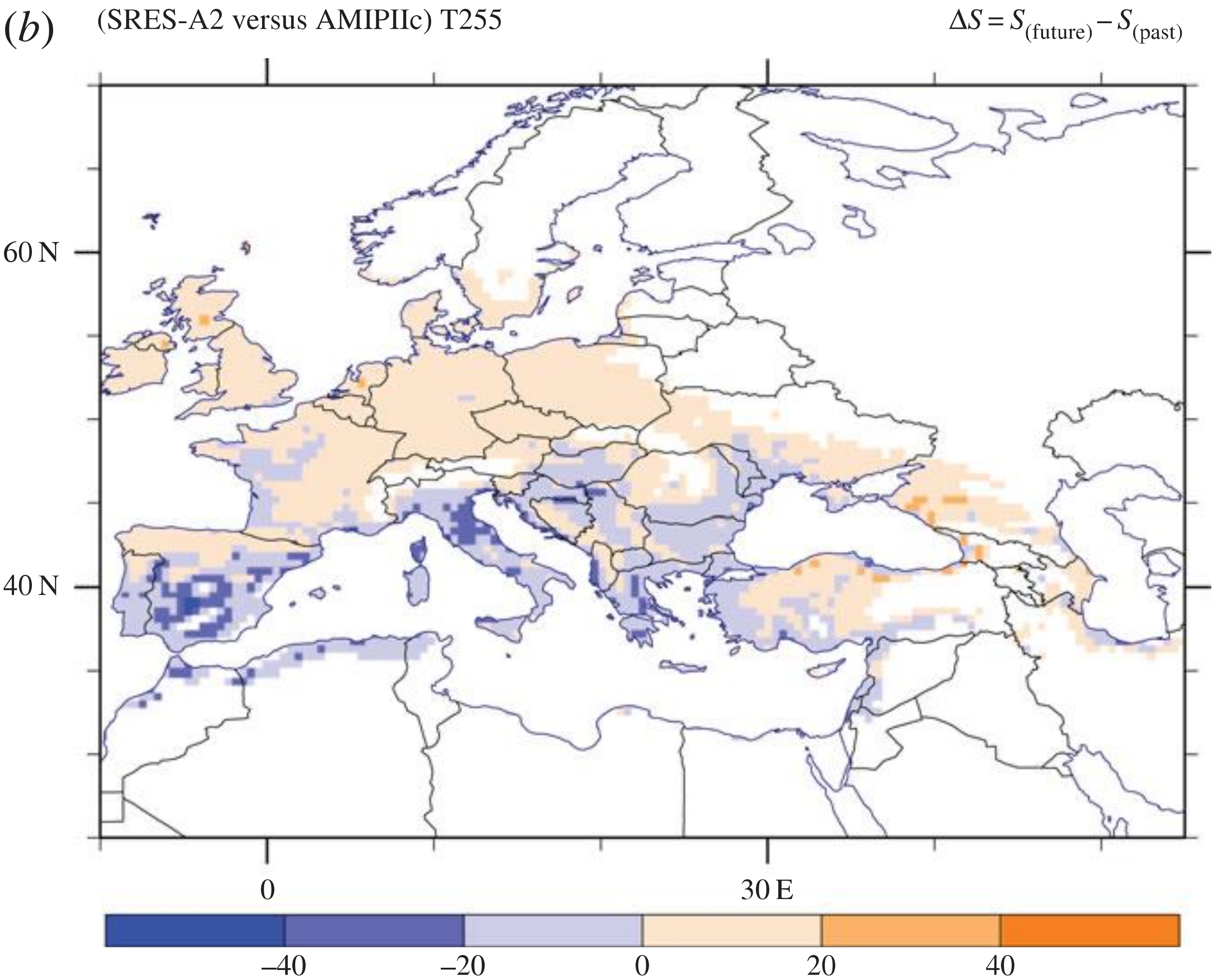
Vector-borne diseases



European maps of the **habitat suitability change of Asian Tiger Mosquito** between the future and reference periods. Areas with hsi less than 10% have not been considered.

Proestos et al. 2015

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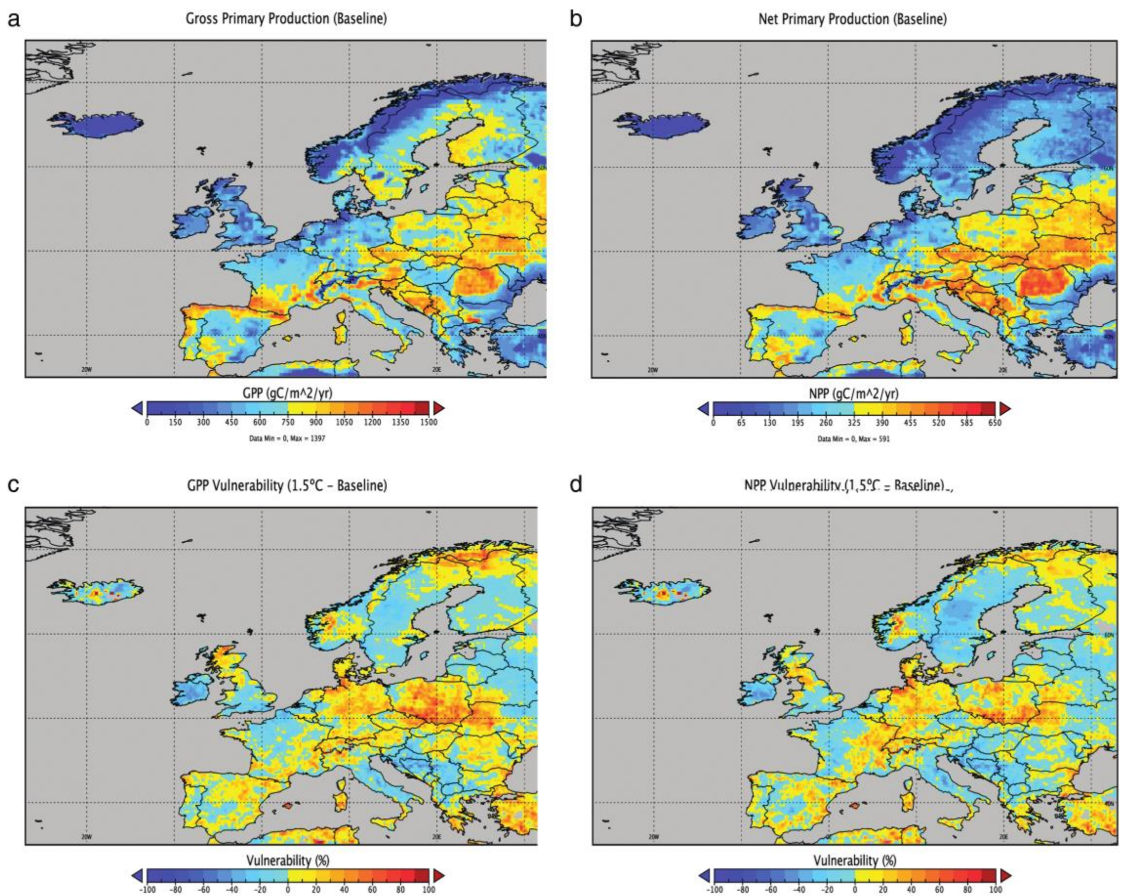
Impact on Ecosystems

The impacts are expected to be widespread and several socio-economic sectors will be affected.



Baseline Gross (GPP) and Net Primary Production (NPP) and climate change signal in a 1.5℃ warmer world.

Jacob et al. 2018

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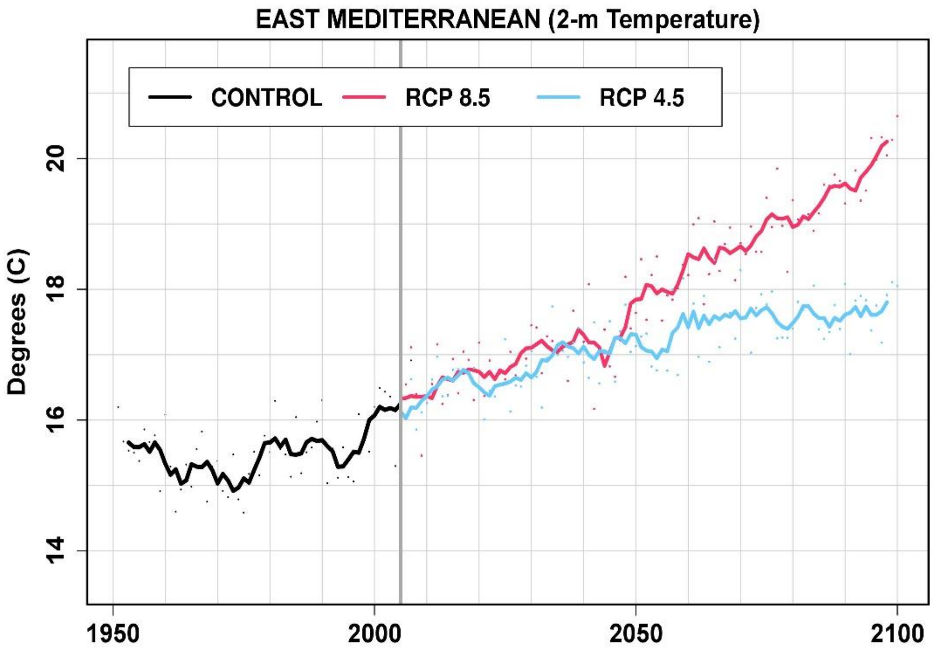
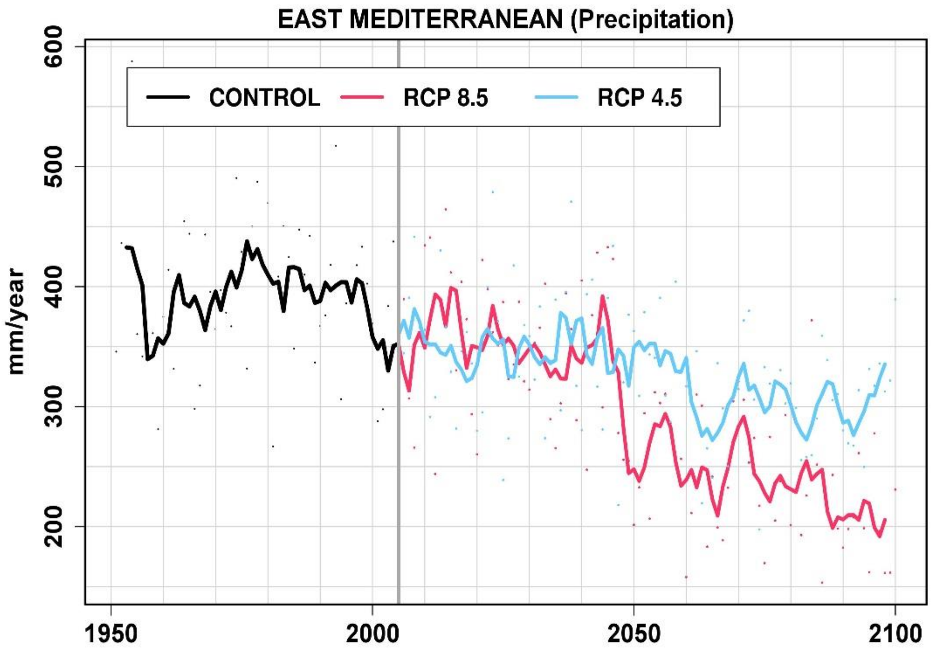
Projections – Eastern Mediterranean

Temperature



Rainfall



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CYI – Modelling of City Temperatures

City	Number of hot days per year with T_{max} > 35 C		Change
	Current	End of Century	
Ankara	10	50	400 %
Athens	29	52	79 %
Bahrain	105	161	53 %
Beirut	7	57	714 %
Cairo	116	163	41 %
Istanbul	8	56	600 %
Nicosia	57	110	93 %

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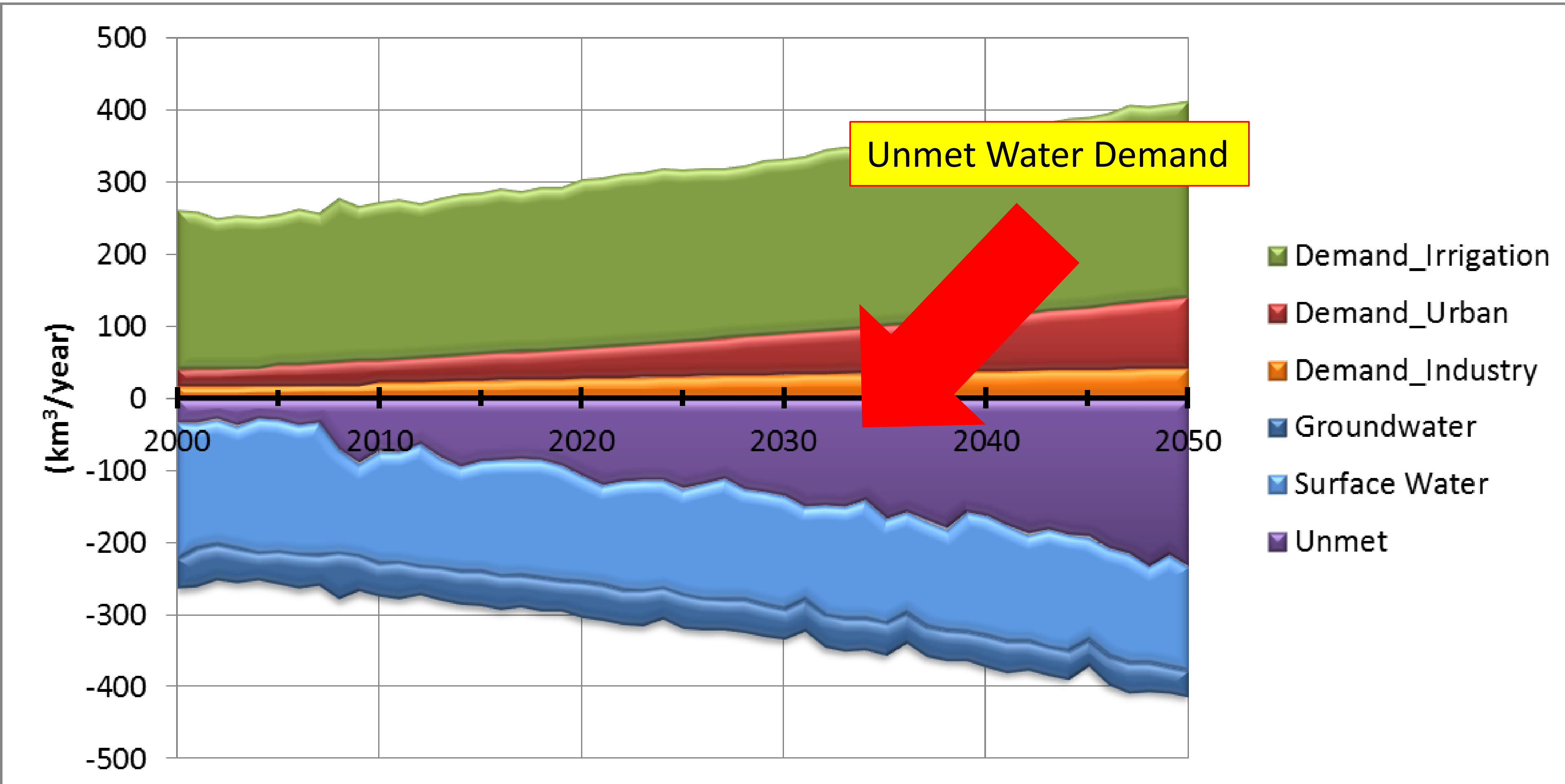
Projections – Water Budget in the Mena Region



Water shortage for the MENA region will be 25 to 50% of the total demand by 2040-2050.

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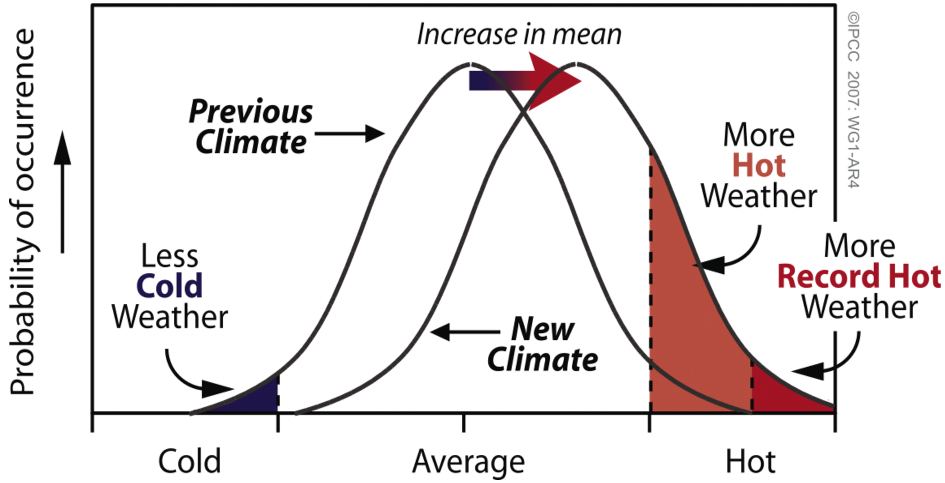
Mass Exodus? Emigration Crisis? Security Thread?



J. Lelieveld, et. al : ***Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century***. Climatic Change, 10.1007/s10584-016-1665-6, 2016

Likely to lead to mass exodus from the MENA region!

Will Extreme Heat Trigger a Refugee Crisis?

photo credit: © Molly John, Flickr, Creative Commons.

By the end of the century, climate change could make the Middle East and North Africa uninhabitable.

The prediction is based on a study recently published in the journal *Climatic Change* by researchers at the Max Planck Institute for Chemistry and the Cyprus Institute in Nicosia.

At last year's UN Climate Change Conference in Paris, a goal was set to keep a global temperature rise this century well below 2 degrees Celsius (3.6 degrees Fahrenheit). Hpwever, the new research estimates that even if this goal is met, the Middle East and North Africa could become uninhabitable by the end of the century.

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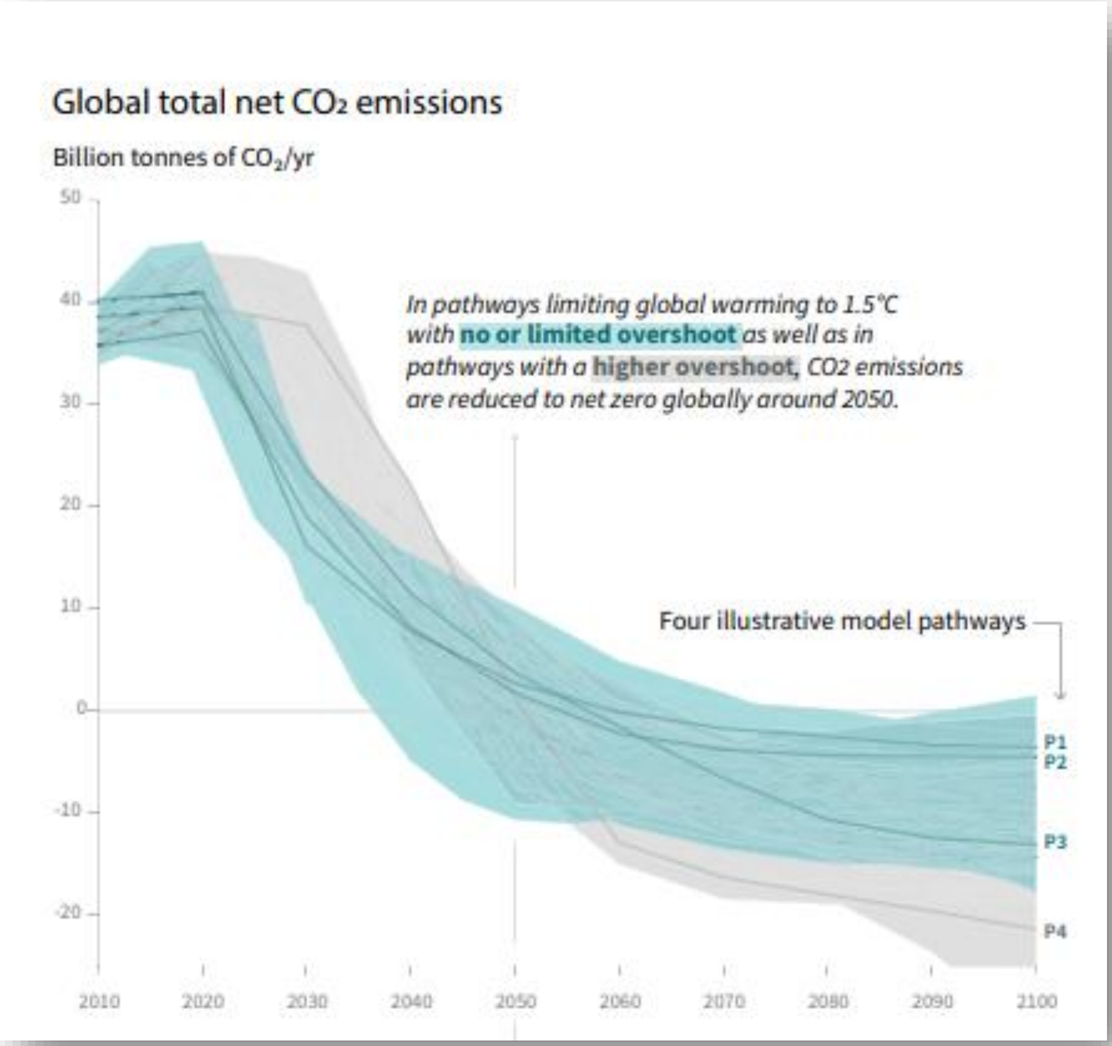
IPCC Recommendations

*"**Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems**. These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options."*



Global Warming of 1.5°C. IPCC Special Report

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The role of solar technologies in the new World Energy System and the implications for Europe

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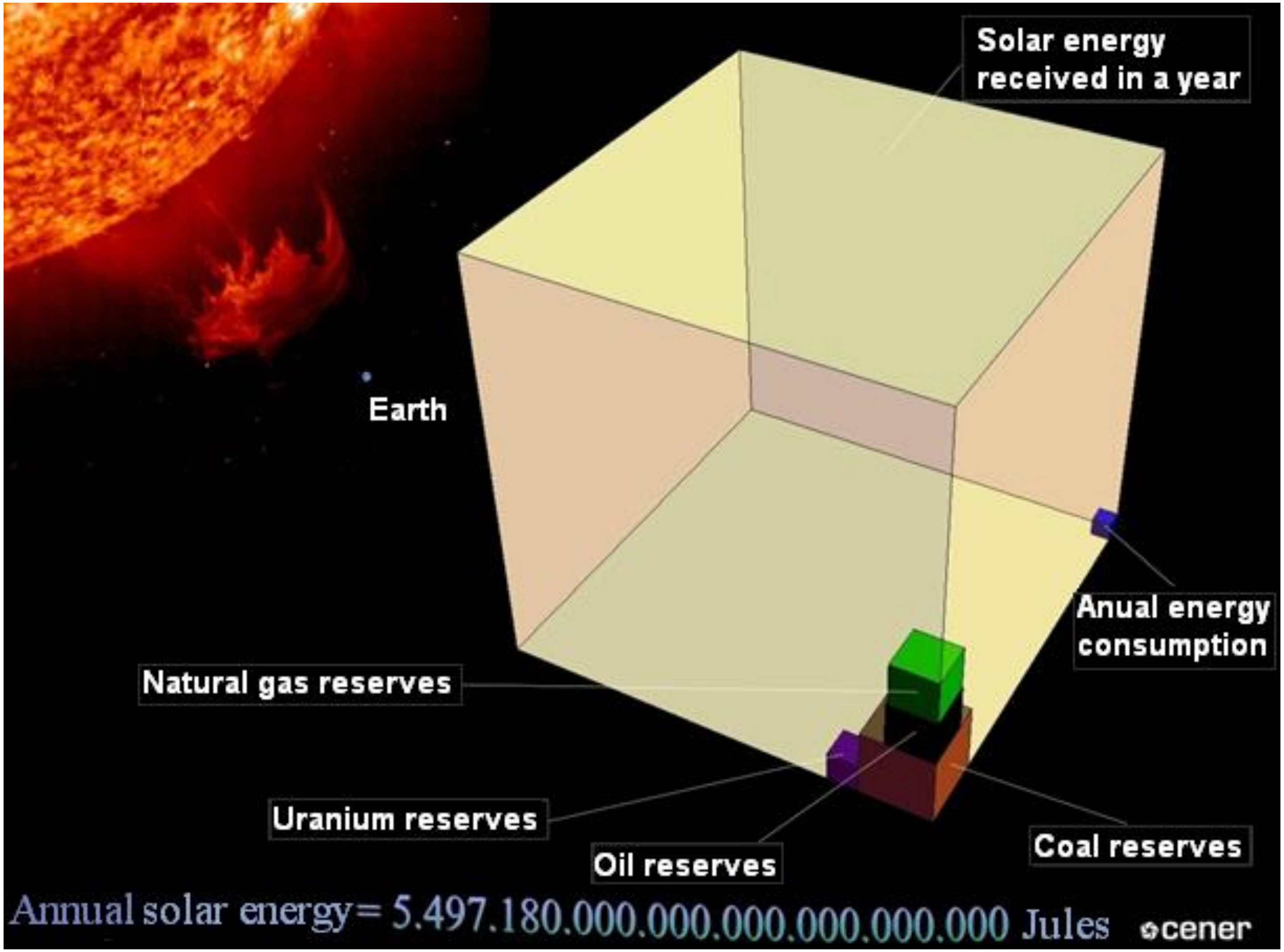
Solar Thermal Technologies



- Life on Earth is powered and modulated by the Sun.
- The Sun is by far the most important energy source available to us.

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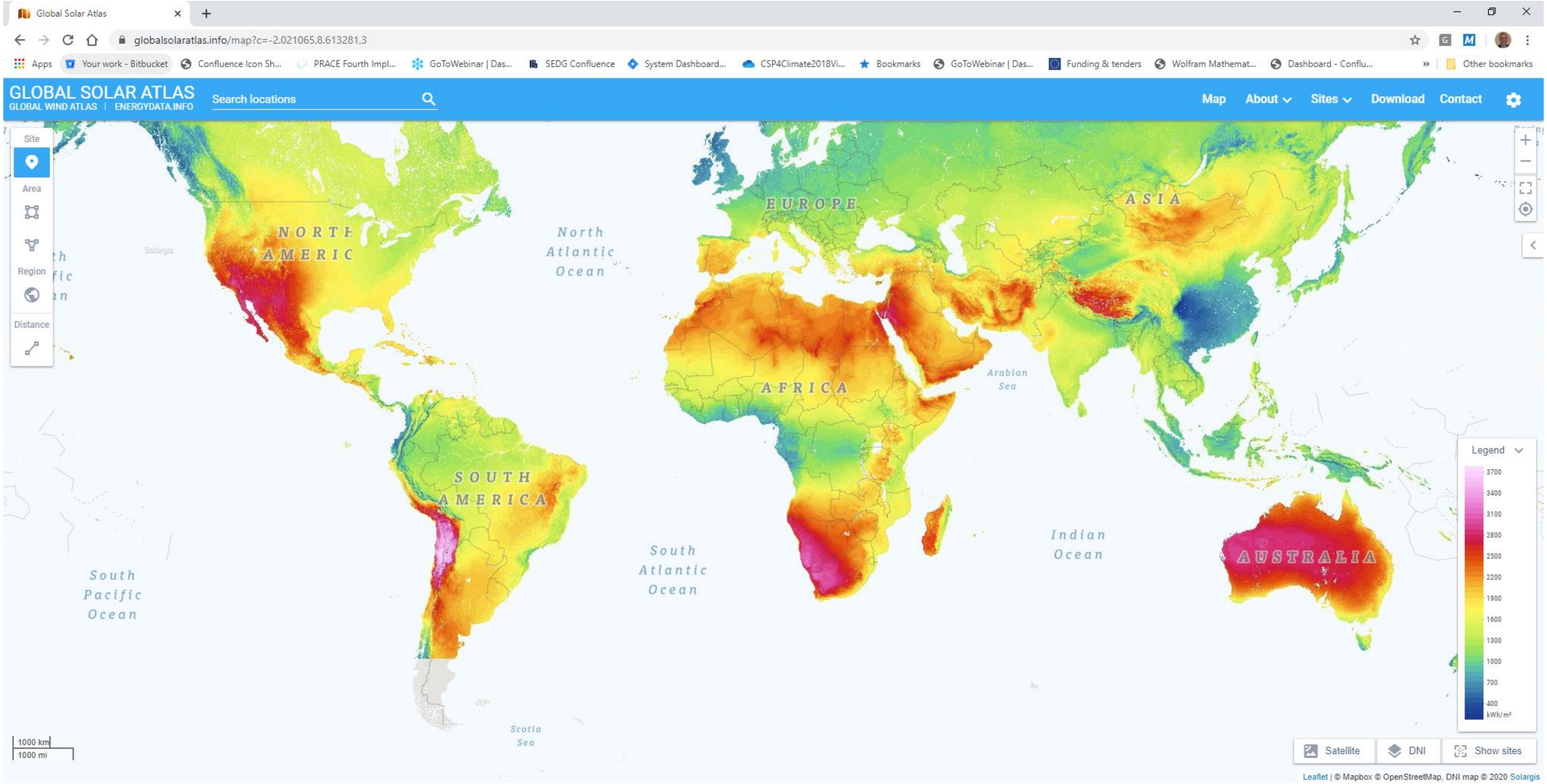
High Potential for Deployment Around the World



https://globalsolaratlas.info/

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High Potential for Deployment in Europe

Annual Direct Normal Irradiation (kWh/m^2-year)

https://globalsolaratlas.info/

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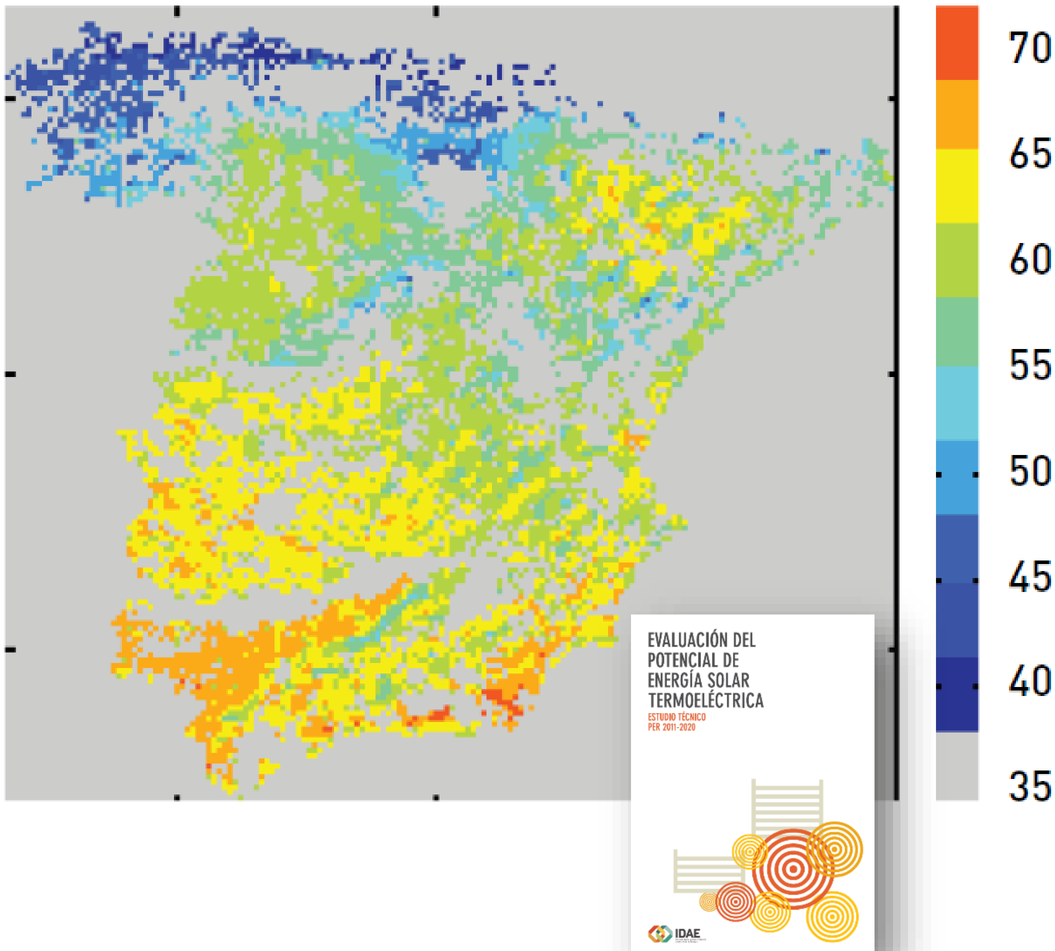
High Potential for Deployment in Europe

Annual Electricity Generation (kWh/m²-year)
50 MW Solar Tower with 6 hours TES



Available potential of solar tower electricity generation in Spain based on 50 MW + 6h TES power plants:

16,627 TWh/year

5.9 times the total energy consumption of E28 in 2018, which was 2,812 TWh.

https://ec.europa.eu/eurostat/web/energy/data/main-tables

And this is just Spain…

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However…

Foreseen contribution of CSP in member states' National Energy and Climate Plans (NECPs) is low.

- Italy and Spain have the highest outlook.
- Small deployments in Cyprus and Greece.

Country	Installed Capacity (MW)		
	2020	2025	2030
Cyprus	0	50	50
Greece	0	70	70
Italy	10	250	880
Spain	2,303	4,803	7,303

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High Potential for Deployment in Europe

FROM GREEN DEAL TO GREEN RECOVERY

An initiative of the European solar industry

MAY 2020

In early 2020, the proposal of the European Commission to launch a "Green Deal" set an ambitious double objective for the sake of European citizens' wealth and health: increasing the European contribution to fight climate change while boosting the European economy.

Within a few months, the COVID-19 crisis added a dramatic level of urgency to act – beyond single national interests. What is needed is no longer a "boost", but an unprecedented cooperation to "recover" the severely hit European economy under the unchanged or even increasing threat of climate change. European leaders are called to act and transform this urgency into an opportunity, without delay. This is also what the European Solar Industry is committed to.

In this context, the role of the European Solar Industry remains primarily to support the fight against climate change. It brings immediately available solutions to decarbonize energy systems while opening wide business opportunities and creating sustainable jobs – which are at the heart of a Green Recovery for the European continent.

The decarbonization challenge applies to three sectors: electricity, heating and cooling and transport. Electricity appears today as the relatively easier-to-reach target, while heat and even more transport, are facing complex challenges and will need more time and effort. However, a smart integration of Concentrated Solar Thermal Technologies (CST) in energy policies will result in innovative multi-technologies solutions impacting not just one, but the three above-mentioned sectors.

One solar industry for Europe

The times of industries competing for the deployment of single technologies is over. Solar PV and wind hold and will keep the larger share of installed capacity. The least cost substitution of fossil-based energies comes usually first when countries go through the initial first phase of their energy transition. Unfortunately, this shifted key know-how and essential industrial production capacities of components to non-EU competitors. This should not happen again. A smart integration of the best blend of European technologies will avoid this technological drain and provide sustainable solutions, i.e. adapted to real needs – at real costs.

Therefore, the European "solar industry" can no longer be addressed only as the PV sector, discarding the considerable assets of CST. Today, markets and regulations frame a competition between companies and economies, not between technologies. Presenting the "solar industry" as reduced to PV does not reflect the business reality: not only large corporations, but also many SMEs and research entities in many European countries are working in parallel on sustainable answers using solar technologies. This demonstrates that CST is not a competitor, but a driver for the further deployment of solar electricity generation in and outside Europe proving its competitiveness versus CCGT and even more, versus coal.

FROM GREEN DEAL TO GREEN RECOVERY: An initiative of the European solar industry 1

- Solar energy is by far the largest of the renewable energy source at our disposal.
- Just based purely in its sheer size, solar energy is called upon to play a pivotal role in the new world energy system.
- Because solar energy can play a very relevant role in the Energy Transition in Europe, and because of the leading role it will play worldwide, **Europe should support and promote the development of its solar energy industry and its research capabilities in all types of solar technologies to a much larger degree than it is currently doing**.
- Failing to do this, Europe risks continuing being a relevant actor in the international energy playground.

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Overview of CSP technologies

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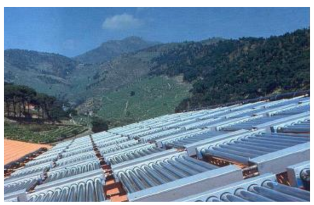
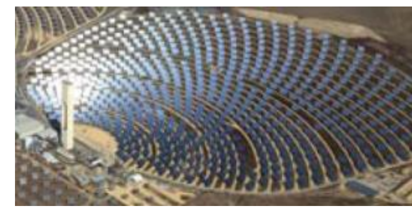
Solar Energy → **Heat** → Useful Energy




Temperature of heat is critical

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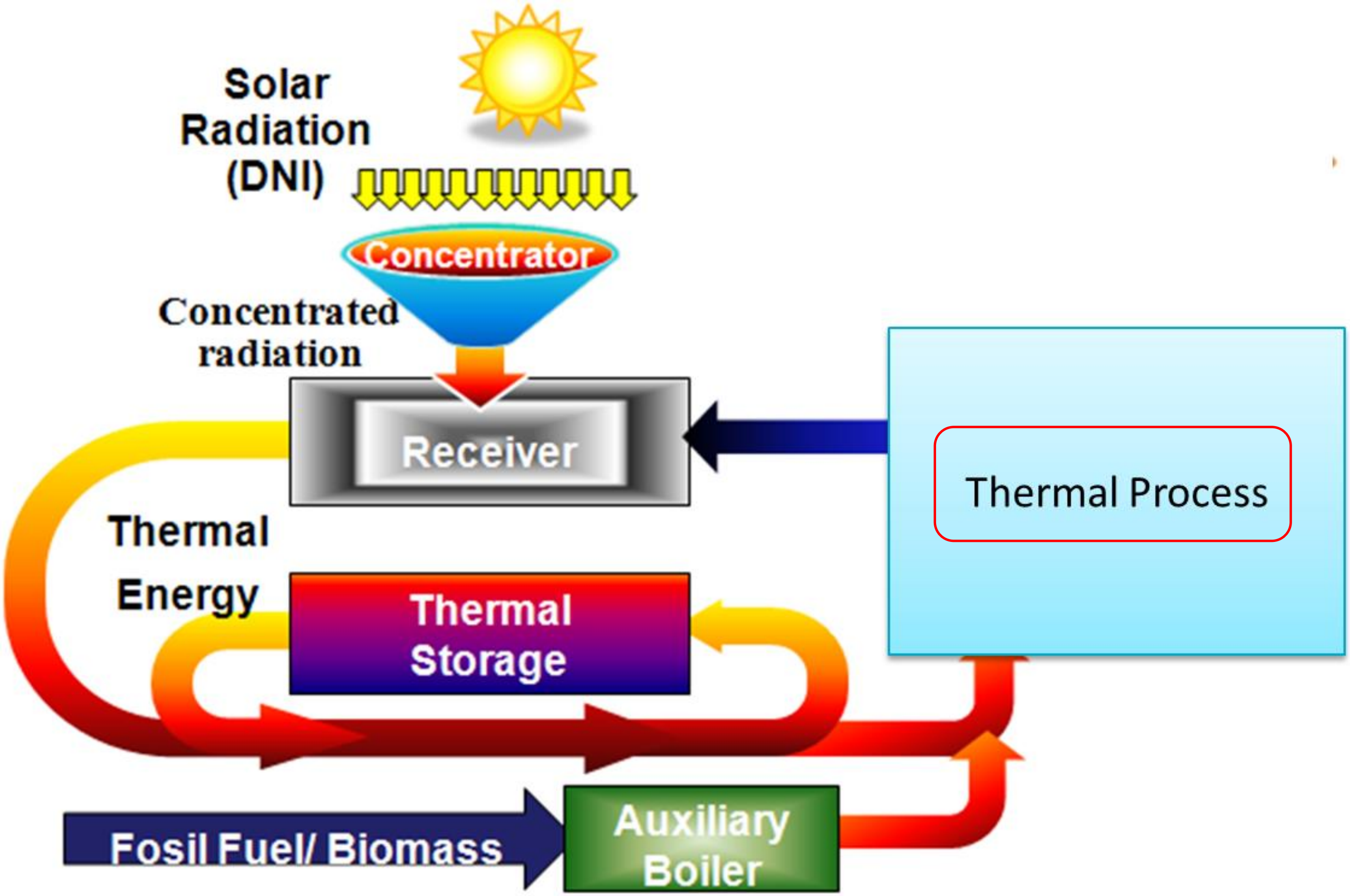
CST - Hybridization, Storage and Multiplicity of Use



Heat process

Electricity

Solar fuels

Solar desalination

Solar detoxification

Solar Oil Recovery

Solar mineralogy

……

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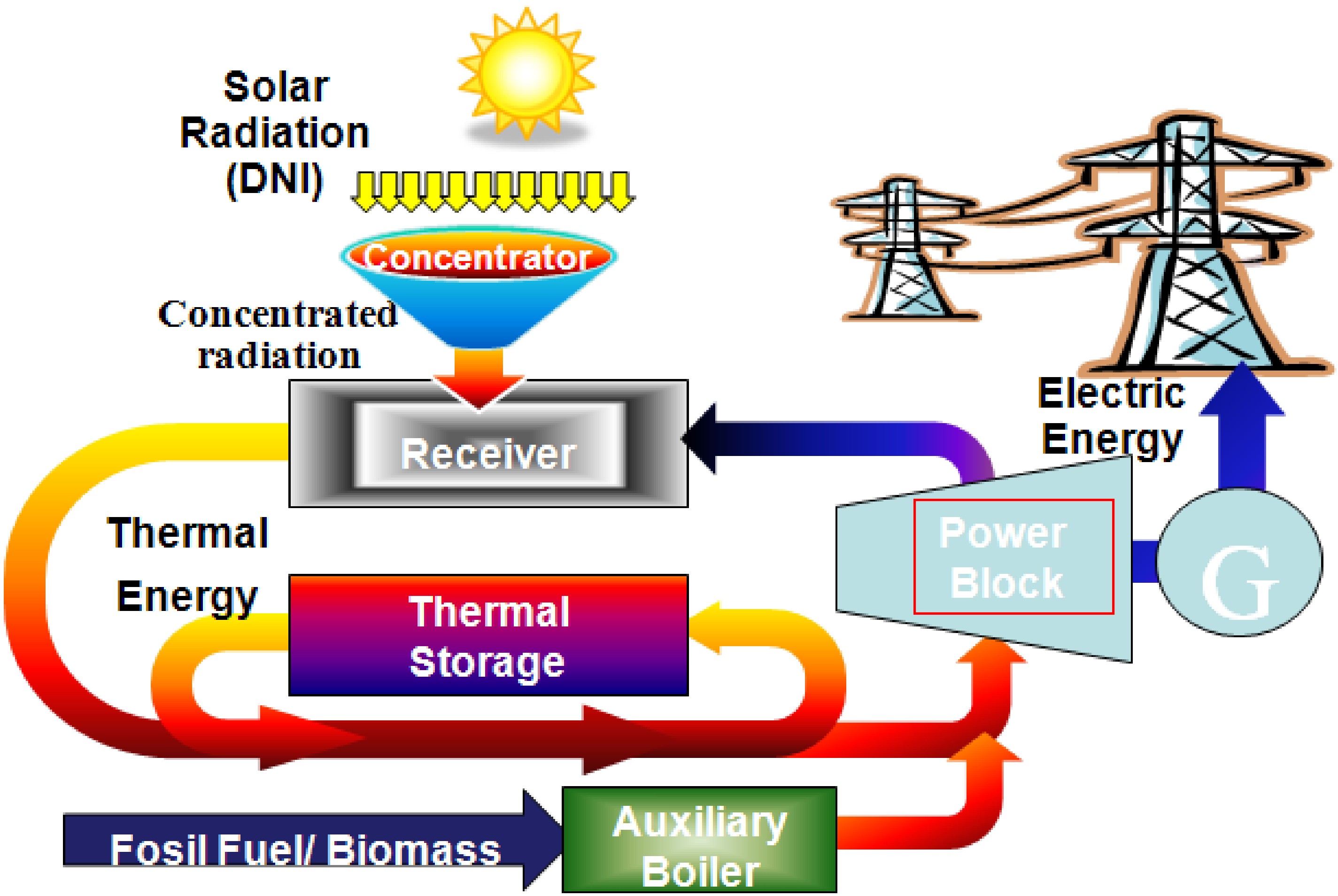
Concentrated Solar Power (CSP) Concept



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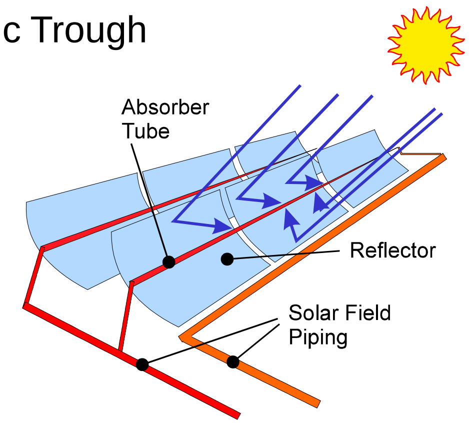
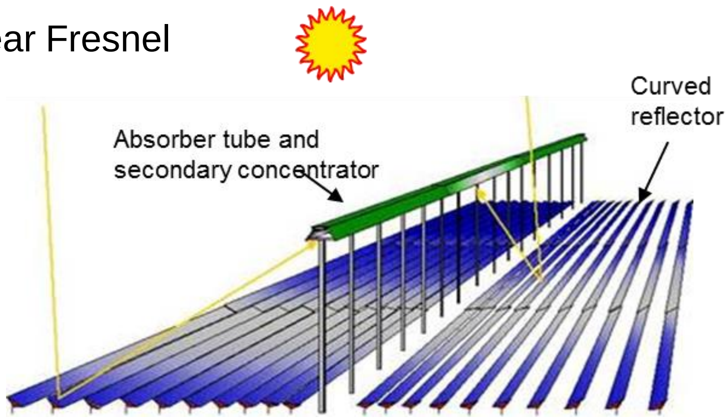
Several Technologies – Different Characteristics

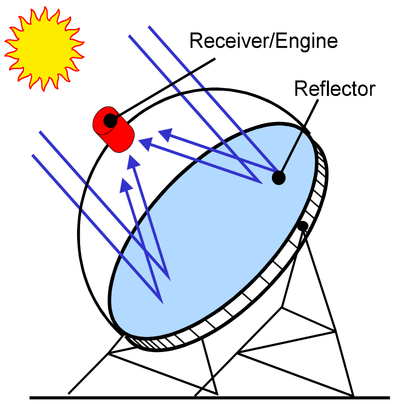
Parabolic Trough



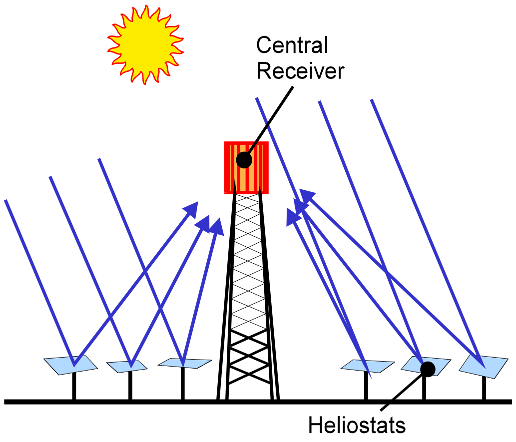
Linear Fresnel



Parabolic Dish



Central Receiver (tower) systems



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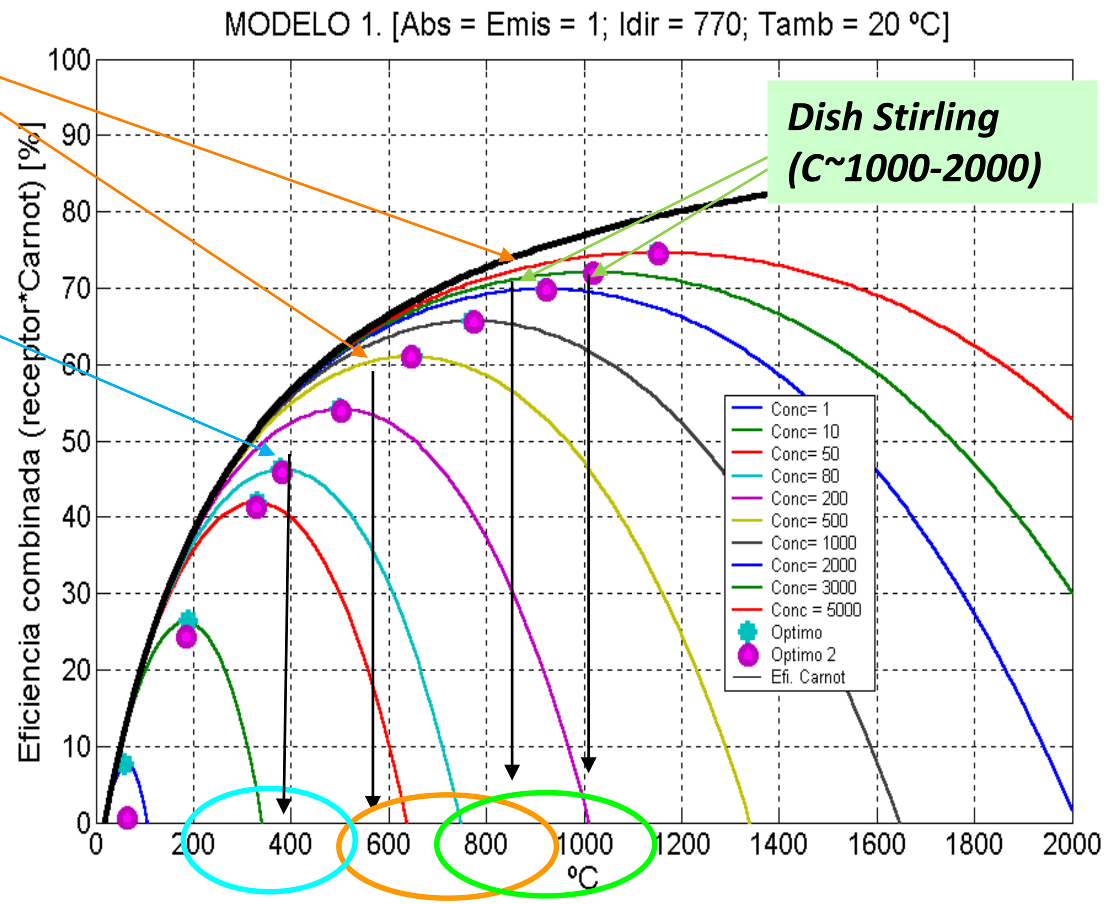
Several Technologies – Different Characteristics

Central receiver (C~200-1000)

Parabolic-Trough (C ~50)



Higher efficiency at higher temperatures

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Thermal Energy Storage

Thermal energy storage is:

- Feasible,
- Environmentally friendly,
- Cost effective.

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Value Proposition

- **CST provides a very large range of energy service options**
  - Heating and cooling
  - Heat processes at high temperatures
  - Electricity
  - Solar fuels and other chemistry applications
- **CST is easily hybridized and stored**
  - If hybridized with biomass can provide a continuous 24/7 clean and renewable heat process or electricity production operation
  - If combined with a thermal storage system can provide the heat for the heat process application or for the deliver of electricity when is most needed or most economically profitable.
- **When deployed with conventional power block**
  - CST delivers dispatchable clean and renewable electricity and ancillary services to the grid

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- **CST utilises expertise already available in many countries**
  - High potential for conversion or expansion of existing manufacturing capabilities in a country to serve the CST sector
  - Local content of CST projects
  - Positive impact on employment, tax revenues and GDP
- **CST has all the attributes to become the backbone of the highly decarbonized energy system of the future**
  - Electricity sector:
    - don't need any conventional backup
    - roles as needed; from base-load to peaking plants
    - provide critical grid stability to increase penetration of non-dispatchable renewable technologies
  - Industrial and transport sectors:
    - provide process heat, fuel and solar chemistry solutions needed to highly decarbonize these sectors

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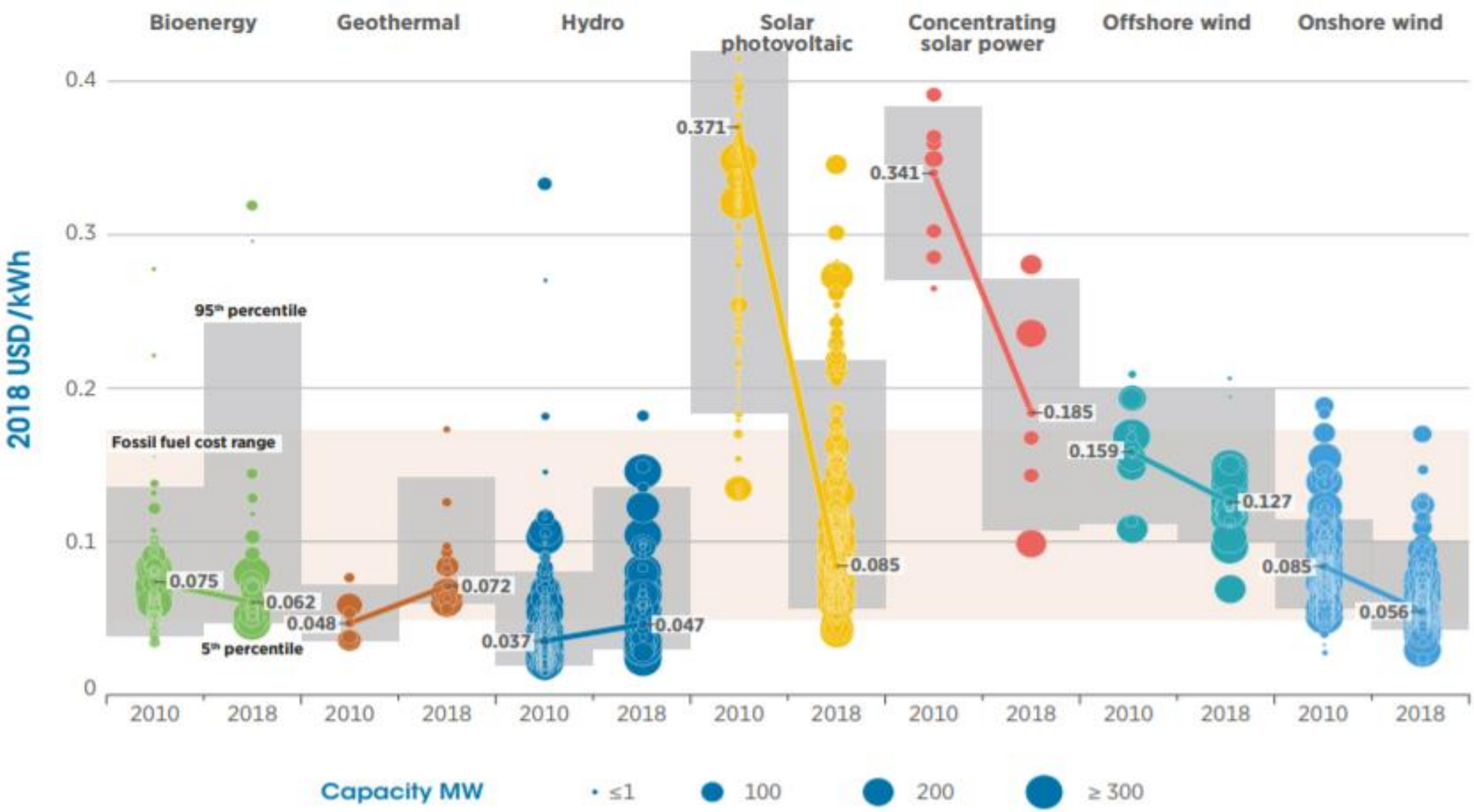
46% Reduction in LCOE from 2010 to 2018

Global LCOE of utility-scale renewable power generation technologies



IRENA, 2019

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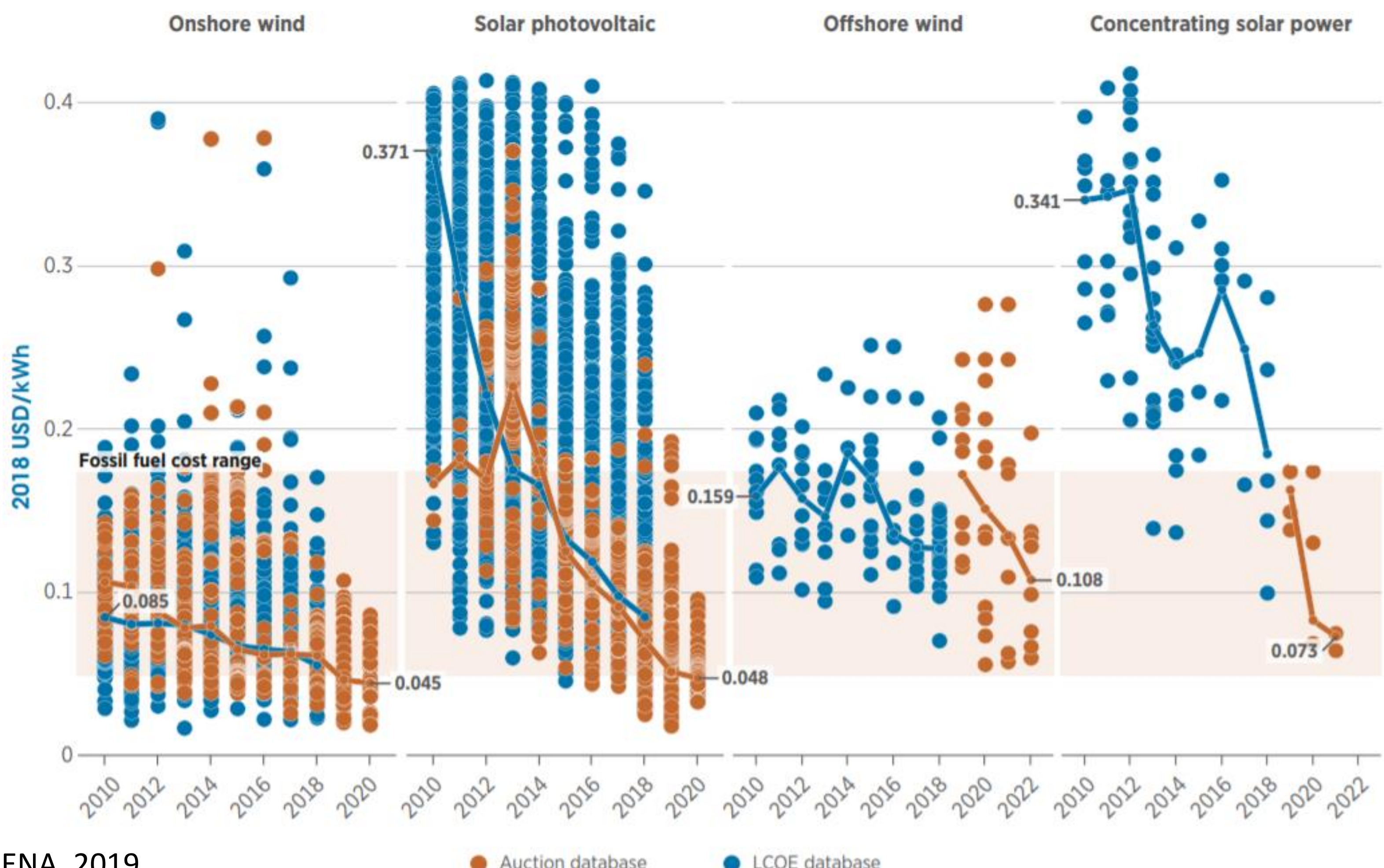
High Potential for Further Cost Reductions

LCOE for projects and global weighted average values RE technologies (2010-2022)



IRENA, 2019

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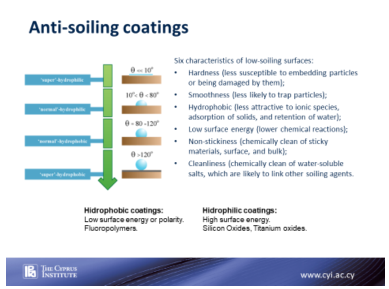
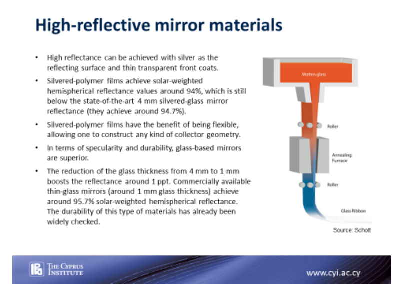
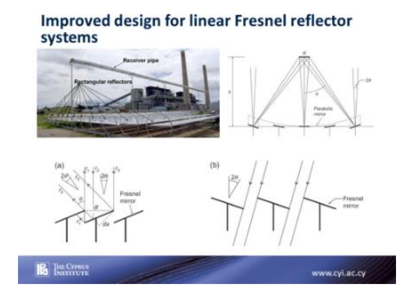
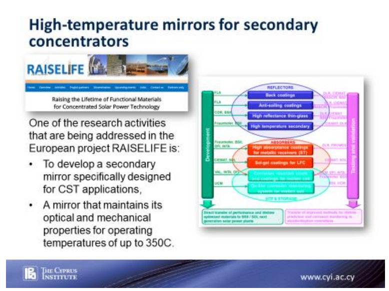
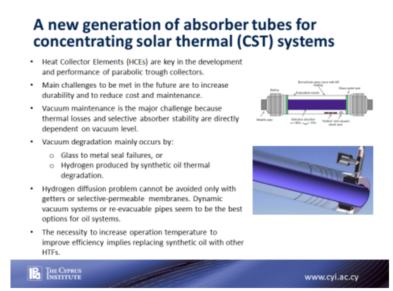
High Potential for Further Innovation

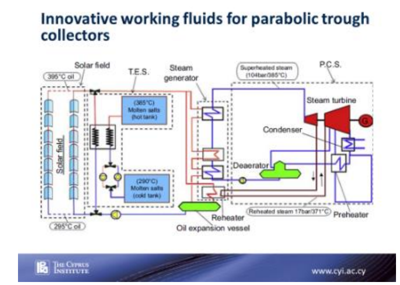


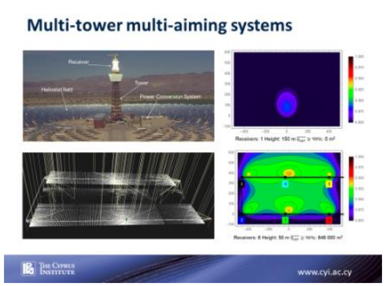


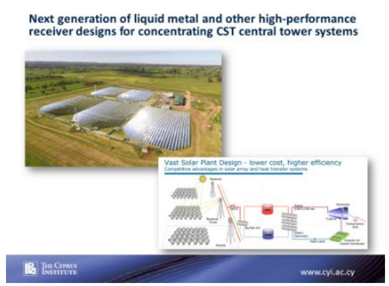


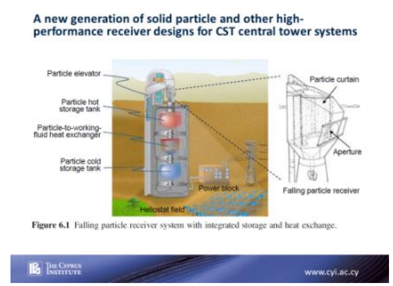












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Hybridization of CSP with PV

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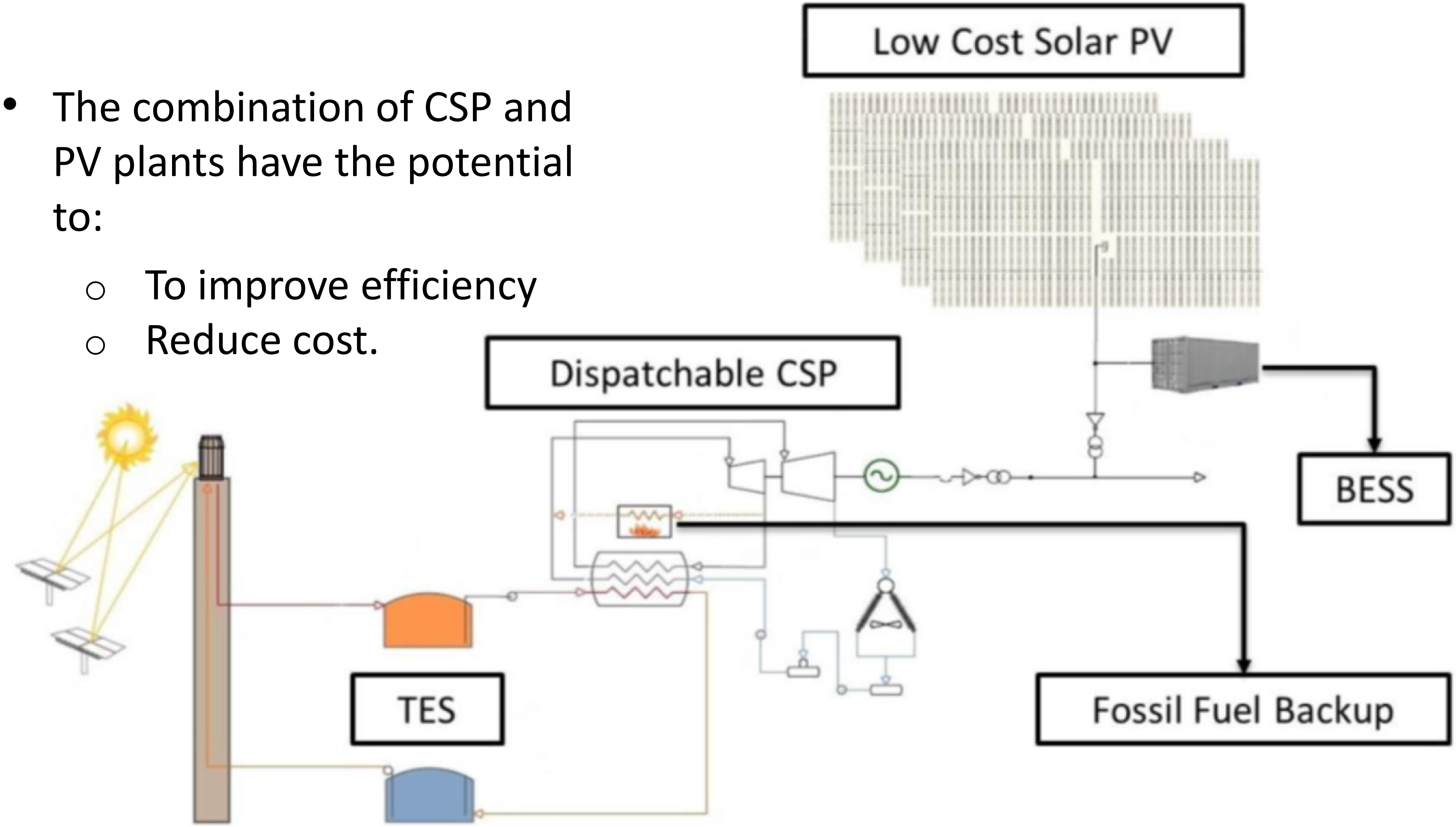
Rationale

- The combination of CSP and PV plants have the potential to:
  - To improve efficiency
  - Reduce cost.



Source: Ju, X., Xu, C., Han, X., Zhang, H., Wei, G., Chen, L., 2017. Recent advances in the PV-CSP hybrid solar power technology, in: AIP Conference Proceedings. https://doi.org/10.1063/1.4984480

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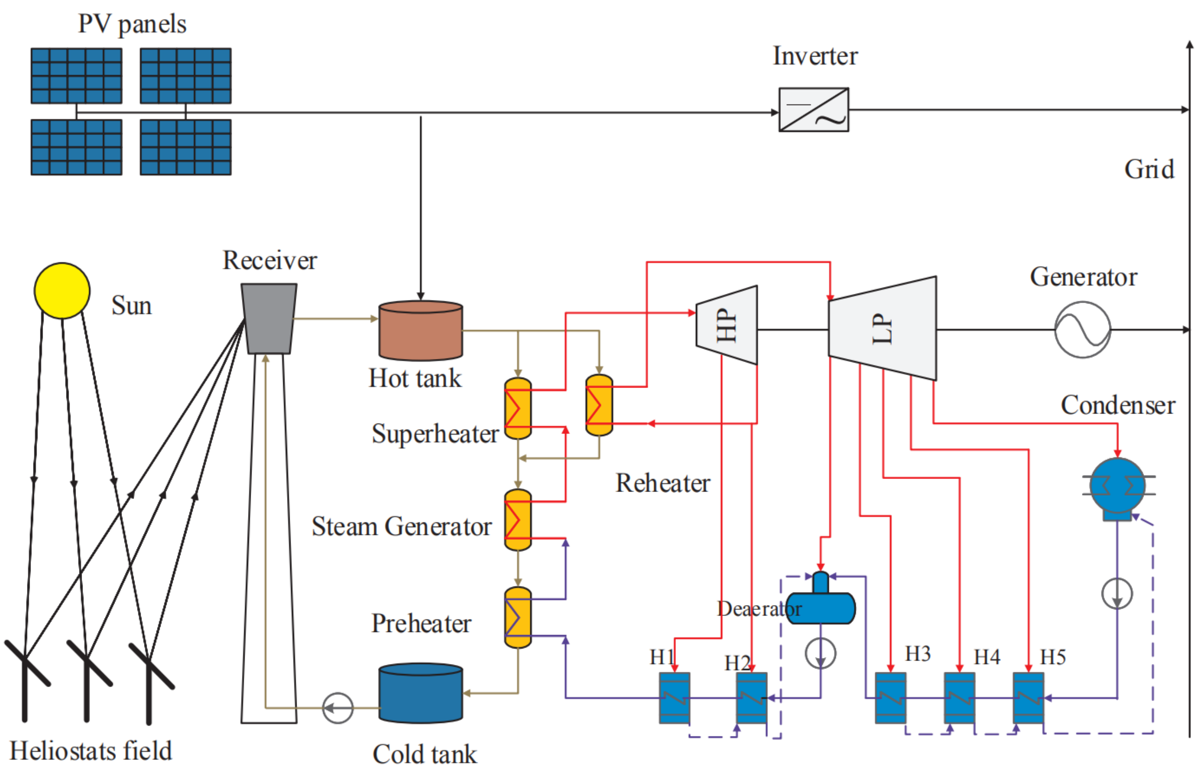
Advanced Hybrid CSP-PV Power Plant



Source: Liu, H., Zhai, R., Fu, J., Wang, Y., Yang, Y., 2019. *"Optimization study of thermal-storage PV-CSP integrated system based on GA-PSO algorithm."* Sol. Energy 184, 391–409. https://doi.org/10.1016/j.solener.2019.04.017

- Depending on the cost of the cost of the different components of the plant (heliostats, thermal storage, PV panesl, batteries, etc.) and on the operating strategies, different sizing of the different plant subsystems are in order and different savings can be obtained with regard to the plants operated and sized independently.
- Not only economic improvements are associated to the hybridization but also water savings.

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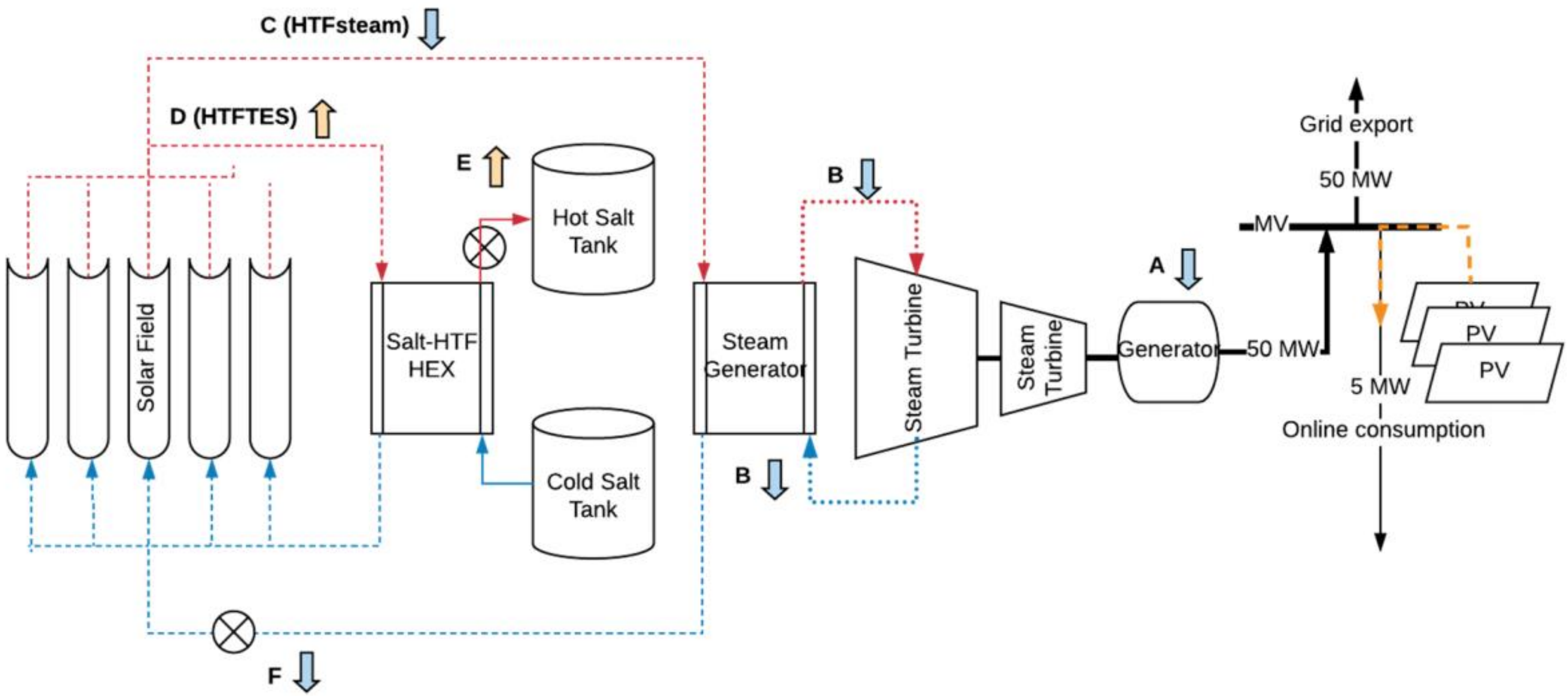
Hybrid CSP-PV Augmentation



Source: Bode, S.-J., Cuellar, A., Perez, I., 2019. "Retrofitting operating CSP plants with PV to power auxiliary loads - Technical consideration and case study", in: AIP Conference Proceedings. https://doi.org/10.1063/1.5117605

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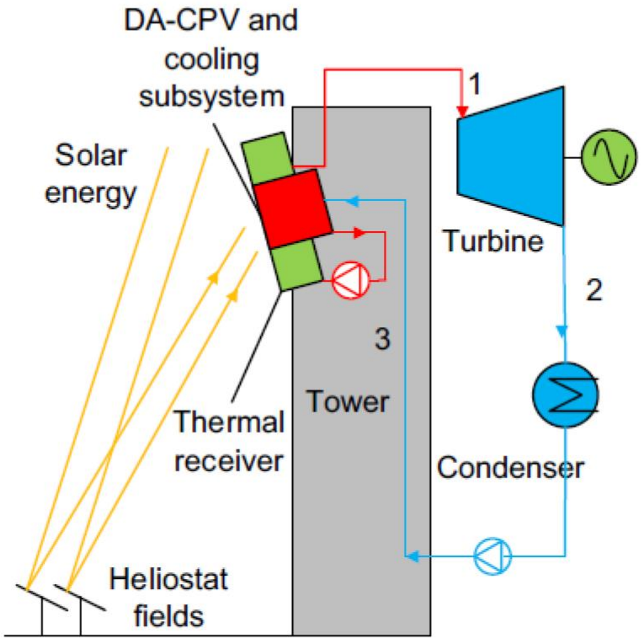
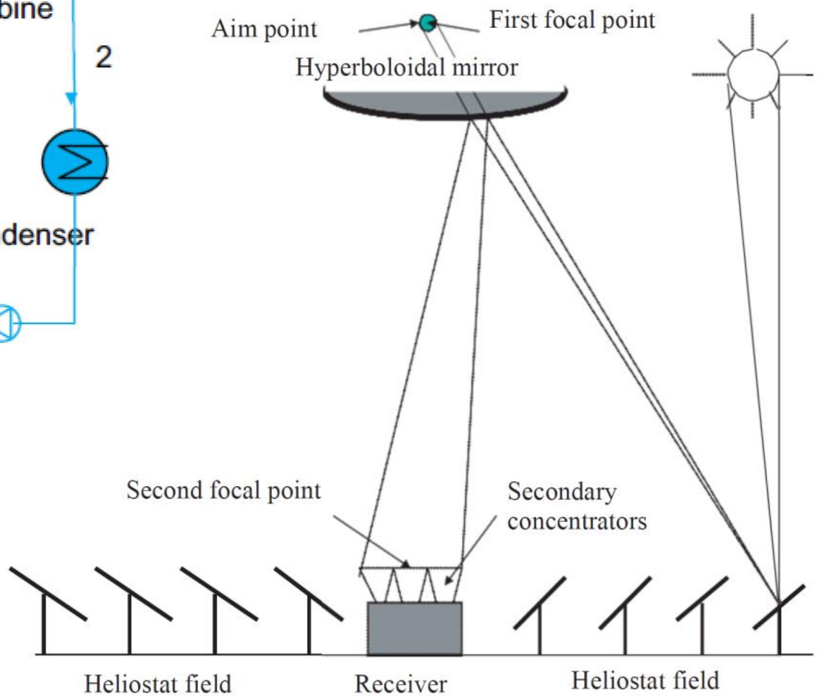
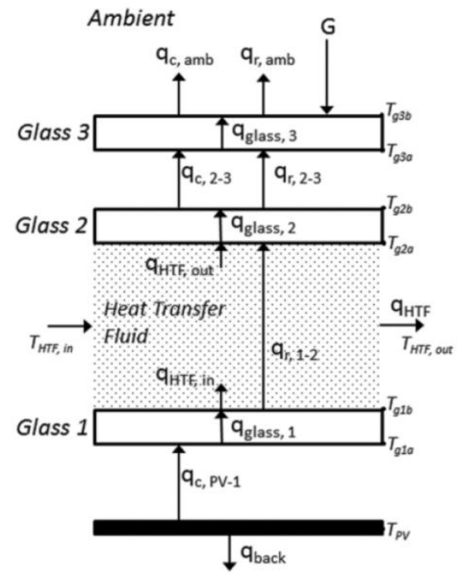
Compact Hybrid CSP-PV







Source: Ju, X., Xu, C., Han, X., Zhang, H., Wei, G., Chen, L., 2017. Recent advances in the PV-CSP hybrid solar power technology, in: AIP Conference Proceedings.
https://doi.org/10.1063/1.4984480

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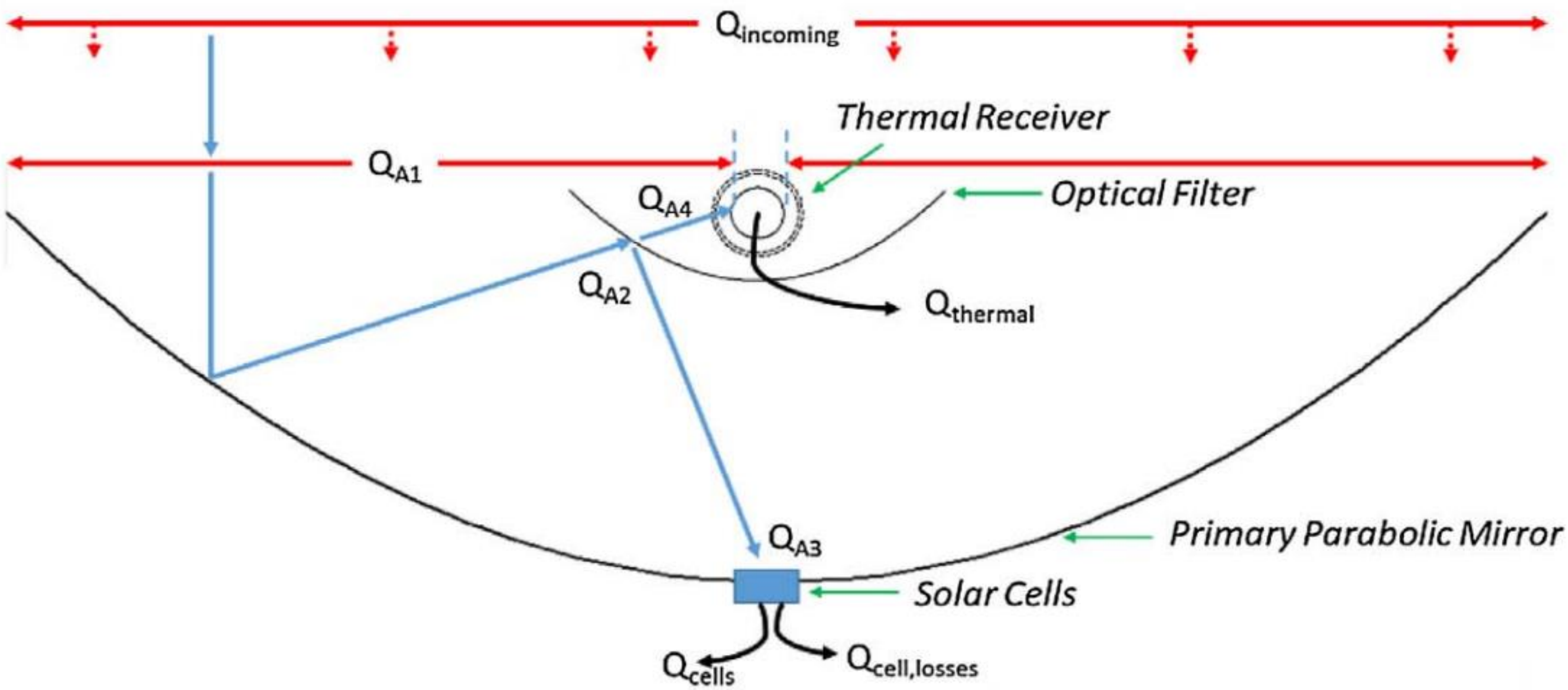
Hybrid CSP-PV with Spectral Beam Splitting



Source: Widyolar, B., Jiang, L., Winston, R., 2018. Spectral beam splitting in hybrid PV/T parabolic trough systems for power generation. Appl. Energy 209, 236–250. https://doi.org/10.1016/j.apenergy.2017.10.078

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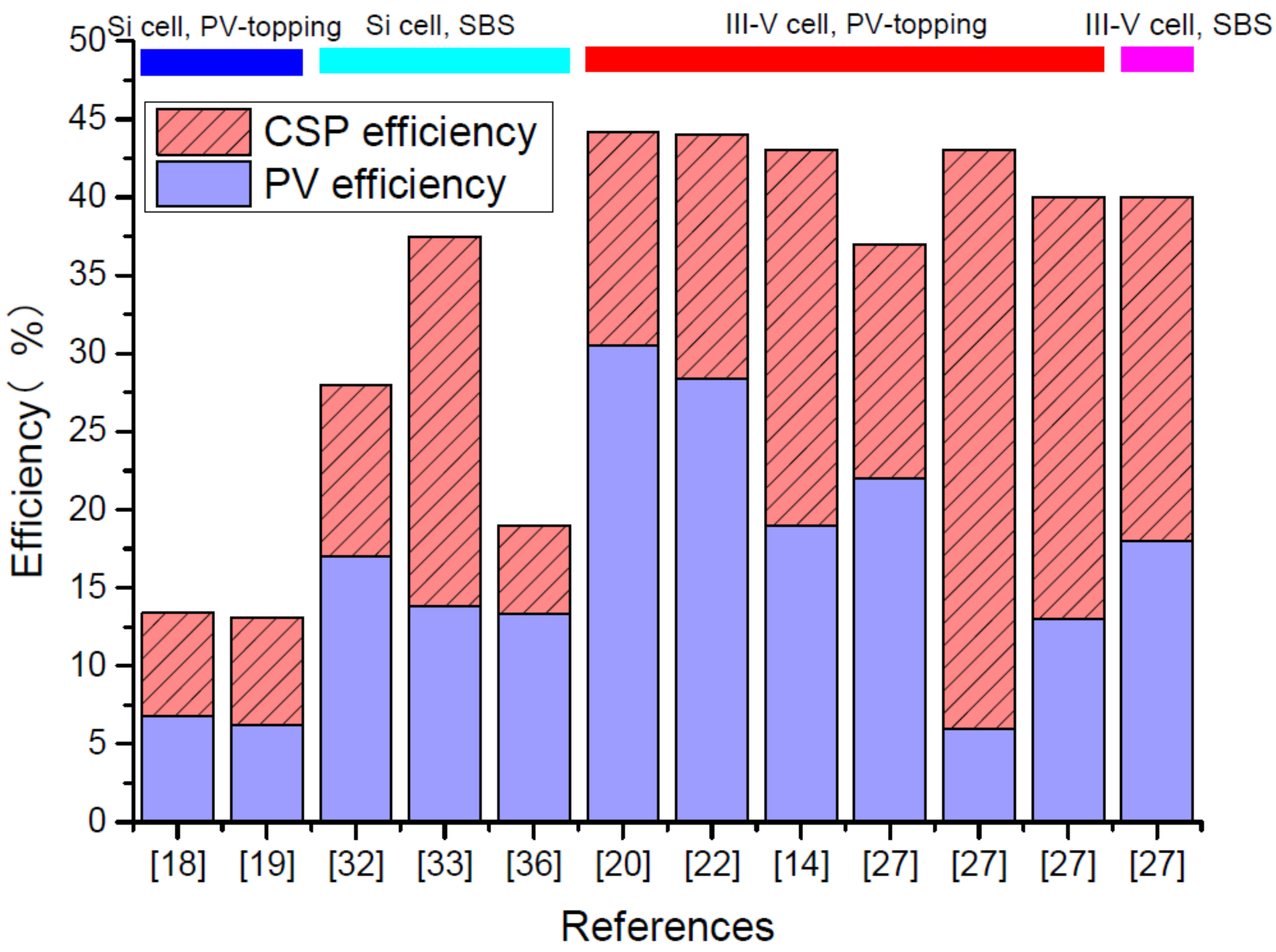
Hybrid CSP-PV Efficiencies Reported on Literature



Source: Ju, X., Xu, C., Han, X., Zhang, H., Wei, G., Chen, L., 2017. Recent advances in the PV-CSP hybrid solar power technology, in: AIP Conference Proceedings. https://doi.org/10.1063/1.4984480

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Conclusions

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Conclusions

- Climate Change and, more in general, the disruption of the environment and ecosystems at a global scale generated by prolonged an intensive non-rational human activity, is the most important challenge of our times.

- The Energy Transition, i.e., the full decarbonization of our energy systems at a global scale, is a critical component of our rational response to this challenge.

- Europe will be critically affected by the consequences of Climate Change if humanity will fail to keep it within the 1,5 – 2.0 C scenarios.

- Because of their characteristics and advantages, Concentrating Solar Thermal (CST) technologies are called to play a relevant role on the Energy Transition, together with the rest of renewable energy technologies.

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Conclusions

- Thanks mainly to the strong commercial deployment of CSP plants that took place in Spain from 2006 to 2012, and to the longstanding research activities in CST in many European Universities and National Laboratories, Europe is at the forefront of these technologies.
- However, even though European CSP companies are active around the world, the foreseen commercial deployment of CSP systems in Europe in the short to mid-term is extremely limited.
- If Europe wants to continue being a leader in the CSP/CSP field, it should find ways to substantially reactivate the commercial deployment of CST within its borders.
- Hybrid CSP-PV because of their key characteristics are expected to play a relevant role in the future.

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  - Different public presentations delivered by the author and colleagues when the author was:
    - Director of the Australian Solar Thermal Research Initiative and Science Leader at CSIRO.
    - Director of the Solar Thermal Energy Department of the National Renewable Energy Centre of Spain (CENER)
  - Summer courses delivered at the University of Colorado at Boulder during the years 2011 – 2013 in collaboration with Prof. Manuel Silva, University of Seville.
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Thank you!

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