Spatiotemporal characteristics of solar resource and photovoltaic productivity over the Euro-Mediterranean area

A climate perspective

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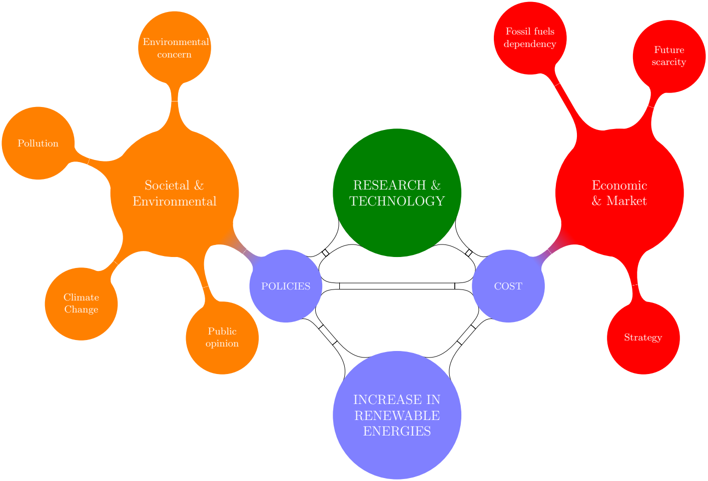
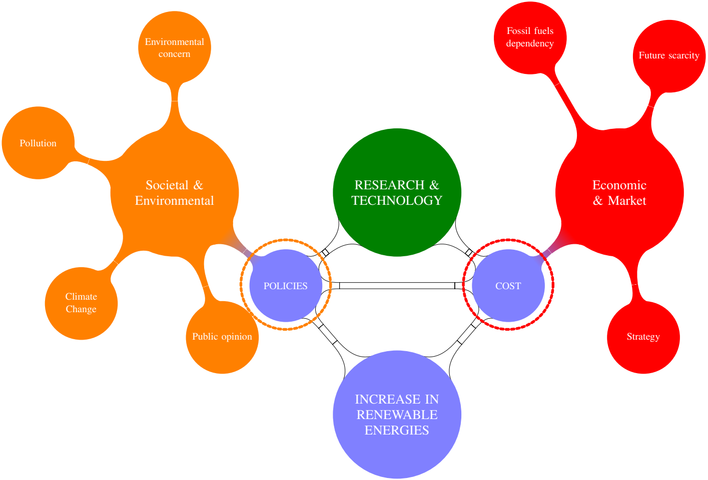
Index

Context and introduction

Energy transition



Energy transition



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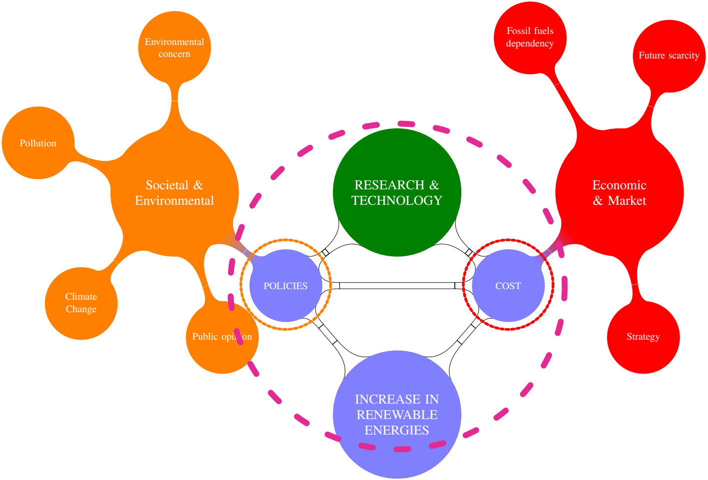
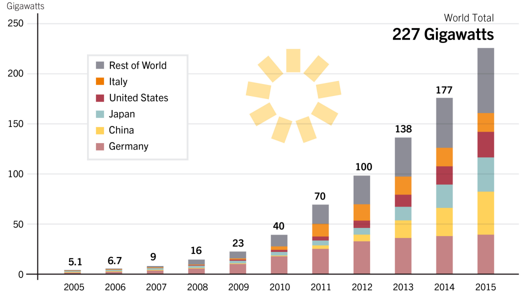


Photovoltaic

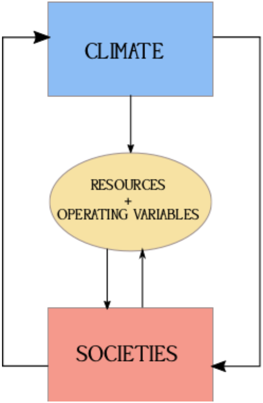
- Increase in **photovoltaic (PV) capacity**
- Continous growth in projected **trends**.
- Global increase leaded by China

Solar PV Global Capacity, by Country/Region, 2005–2015



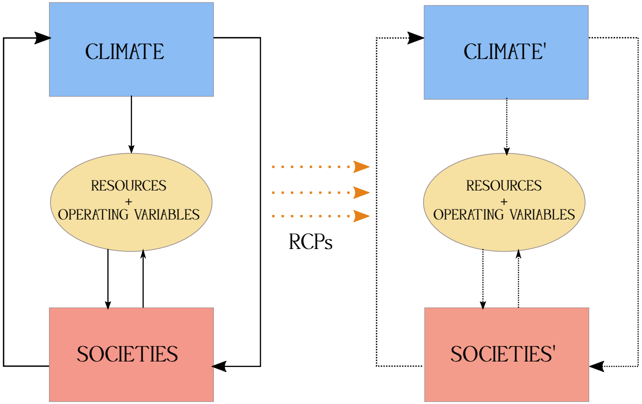
REN21 *Renewables 2016 Global Status Report*

Links between climate/weather and the power sector



- Highly dependent on the state of the atmosphere.
  - Potential energy produced/ mean resource (**supply side**)
- Modulate the electricity demand (**demand side**)
- Operation atmospheric variables like temperature

Links between climate/weather and renewables



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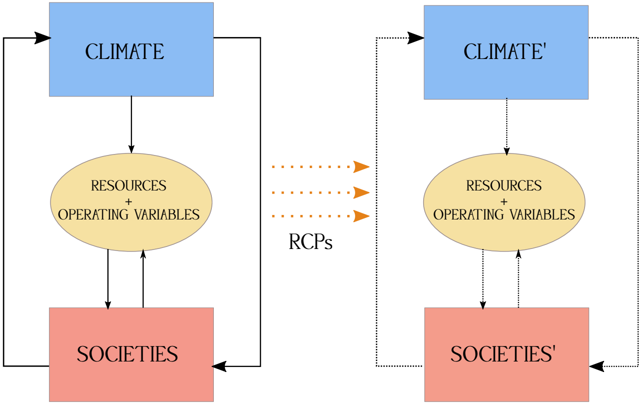
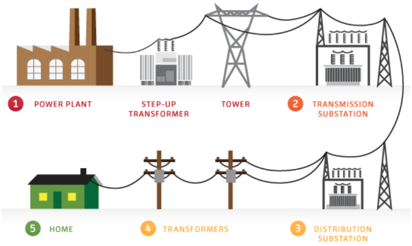


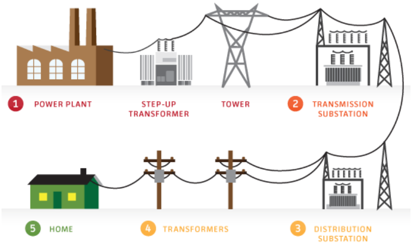
- Changes in the supply side
- Changes in the demand side

Electricity systems features:



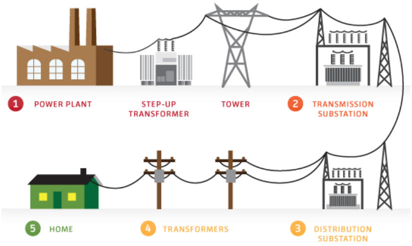
Electricity systems features:

- Demand and supply need to be **balanced**.



Electricity systems features:

- Demand and supply need to be **balanced**.
- Electricity systems are designed for centralized conventional power plants.



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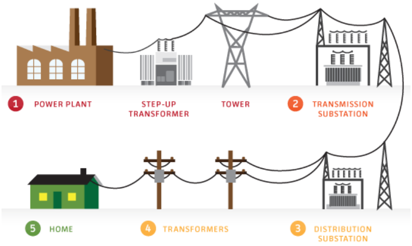
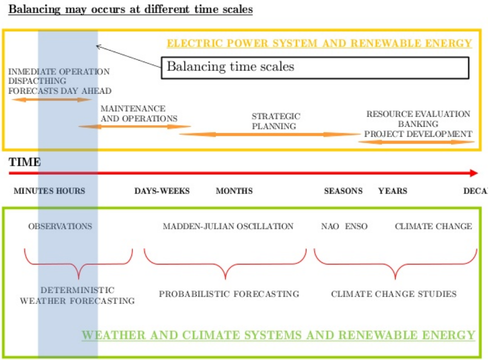
- **VRE**: variable renewable energy.

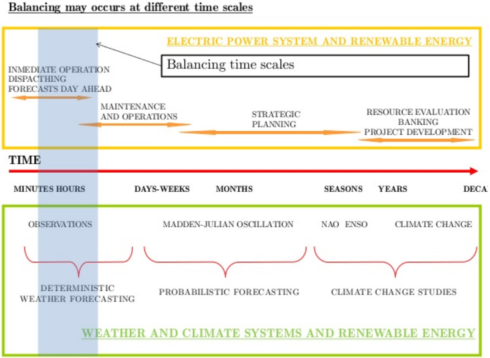


VRE: variable renewable energy



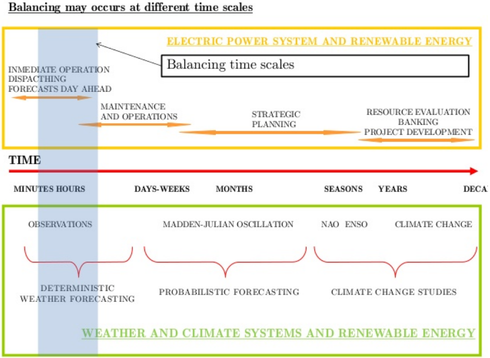
VRE: variable renewable energy

- **Intermittency**: not synchronized with the demand



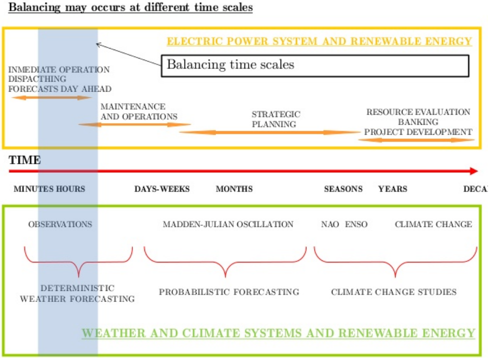
VRE: variable renewable energy

- **Intermittency**: not synchronized with the demand
- Need of forecasting, plannification and/or storage

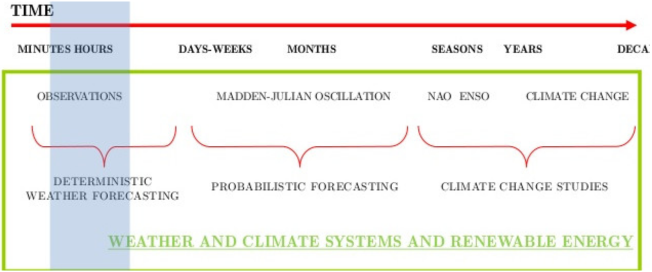


VRE: variable renewable energy

- **Intermittency**: not synchronized with the demand
- Need of forecasting, plannification and/or storage
- Variations **from short to long scales** (weather to climate)
  - short: operation
  - medium: planning, maintenance
  - long: resource assessment, financing, planning



Long scales: links between climate and renewables



Variability sources on PV

1. Astronomical factors
2. Atmospheric factors
   - clouds
   - aerosols
3. PV system factors
4. power plant size
5. distance between plants
6. Other factors
   - temperature
   - soiling

Need for long-term projections of **resource and PV potential**

Previous studies show a **discrepancy** between **GCMs** and **RCMs** surface solar radiation (SSR) over Europe:

- Increase projected by GCMs (*Wild et al. 2015, Solar Energy*).
- Decrease projected by RCMs (*Jerez et al. 2015, Nature Communications*).

Objectives and methodology

OBJECTIVE

- 1 To illustrate the **inconsistency** between **GCM** and **RCM** projections and to attribute it to missing aerosols forcing.

- 2 To **deliver future projections of PV** potential production over Europe.

METHODS

- 1 To illustrate the **inconsistency** between **GCM** and **RCM** projections and to attribute it to missing aerosols forcing.

  - Use of well-chosen groups of GCM-RCM within the Euro-CORDEX ensemble.
  - **2021-2050** summer change in surface solar radiation, SSR, with respect of a reference period: **1971-2000**. Use of **RCP8.5** scenario.

GCM	RCM	Aerosols
CNRM-CM5	CCLM4-8-17	-
	ALADIN53	Szopa et al.
	RCA4	-
	CCLM4-8-17	-

METHODS

- 2 To **deliver future projections of PV** potential production over Europe.

solaR

Parametric PV model. **SSR** from **RCM** as input -> POA and electrical performance. Implemented in R (O. Perpiñán, 2013).

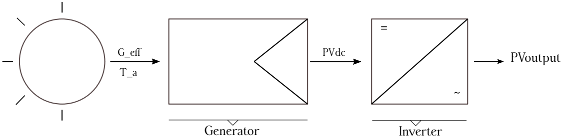


Figure 1: Squeme of a PV generator.

Results

SSR mean changes 2021-2050

GCM **RCM**

ssr_gimp4.png

Figure 2: SSR change (1971/2000)-(2021/2050) (W/m^2)

SSR mean changes 2021-2050

GCM **RCM**

ssr_gimp3.png

Figure 3: SSR change (1971/2000)-(2021/2050) (W/m^2)

- Only RCMs with evolving aerosols show the increase in SSR as GCMs.

CLT mean changes 2021-2050

GCM **RCM**

clt_gimp3.png

Figure 4: CLT change (1971/2000)-(2021/2050) (%)

CLT mean changes 2021-2050

GCM **RCM**

clt_gimp3.png

Figure 5: CLT change (1971/2000)-(2021/2050) (%)

- RCMs without evolving aerosols: CLT spatial pattern can explain SSR spatial pattern.
- CLT spatial pattern cannot explain SSR spatial pattern in models with evolving aerosols.

Mean changes 2021-2050

GCM	RCM	$\Delta SSR\ [W/m^2]$	$\Delta CLT\ [\%]$
CNRM-CM5		**9.9**	0.5
	CCLM4-8-17	-2.4	-0.8
	ALADIN53	**12.6**	0.3
	RCA4	-2.6	0.2
EC-EARTH		**5.6**	-0.3
	CCLM4-8-17	-2.7	-0.9
	RACMO22E	**4.8**	0.5
	RCA4	-2.1	0.1

Table 2: Spatial changes in SSR and CLT

AOD mean changes 2021-2050

Figure 6: AOD change (1971/2000)-(2021/2050)

- Spatial pattern of ΔAOD similar to ΔSSR when evolving aerosols considered.
- Higher correltation of SSR with AOD than with CLT.

GCM	RCM	ΔAOD	$\rho_{SSR,CLT}$	$\rho_{SSR,AOD}$
CNRM-CM5	CCLM4-8-17	-	-0.7	-
	ALADIN53	-0.2	-0.2	-0.9
	RCA4	-	-0.8	-
EC-EARTH	CCLM4-8-17	-	-0.8	-
	RACMO22E	-0.1	-0.3	-0.6
	RCA4	-	-0.8	-

$\triangle$PV relative JJA mean by country

Figure 7: Relative change in PV potential [%]

$\triangle$PV relative JJA mean by country

Figure 8: Relative change in PV potential [%]

- Decrease for models with no-evolving aerosols.

ΔPV relative JJA mean by country

Figure 9: Relative change in PV potential [%]

- Decrease for models with no-evolving aerosols.
- Increase for models with evolving aerosols.
- Central-Europe is the most impacted area.

Conclusions

Conclusions

- For the mid century, an **increase** in **photovoltaic potential** is projected over Europe when the **evolution** of **aerosols** over the area is considered.
- The **magnitude** depends on the country and the models.
- The most impacted areas are in Central-Europe, with an important potential increase of more than **10%** but large uncertainty between models.

Perspectives

- A **robust answer** is needed in order to deliver key messages for the solar industry.
- The FPS-aerosols could help to understand uncertainties and develop better projections for energy purposes.

Thank you for your attention.

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