Usos de água concorrentes para a agricultura e geração de eletricidade: quantificação dos impactos das alterações climáticas no setor eletroprodutor Português

Webinar / Palestra LNEG ONLINE

17 março 2022

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CENSE | Center for Environmental and Sustainable Research

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3

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5

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Energy Transition

Sustainable Urban Systems

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Agradecimentos

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Os resultados apresentados são da exclusiva responsabilidade das autoras.

Já em 2022 estamos a enfrentar seca extrema que levou à interrupção de produção hidroelétrica em fevereiro deste ano.

Neste webinar apresentamos os resultados de um estudo do LNEG e do CENSE – NOVA para 2050 focando o impacto combinado das alterações climáticas segundo o Representative Concentration Pathway 8.5 e a variação expectável na utilização de água para agricultura tanto em Portugal como em Espanha.

A análise estuda as bacias do Douro e Tejo e o impacto que se poderá sentir no sistema eletroprodutor nacional como um todo.

Será que vamos ter água suficiente para cumprir os objetivos do Roteiro de Neutralidade Carbónica para o setor energético? Qual o papel de outras tecnologias como o solar e a eólica??

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Outline

I. Context

II. Methods

Impact on RES sources
eTIMES_PT model
Future water demand for irrigation and CF

III. Results

IV. Final remarks and limitations

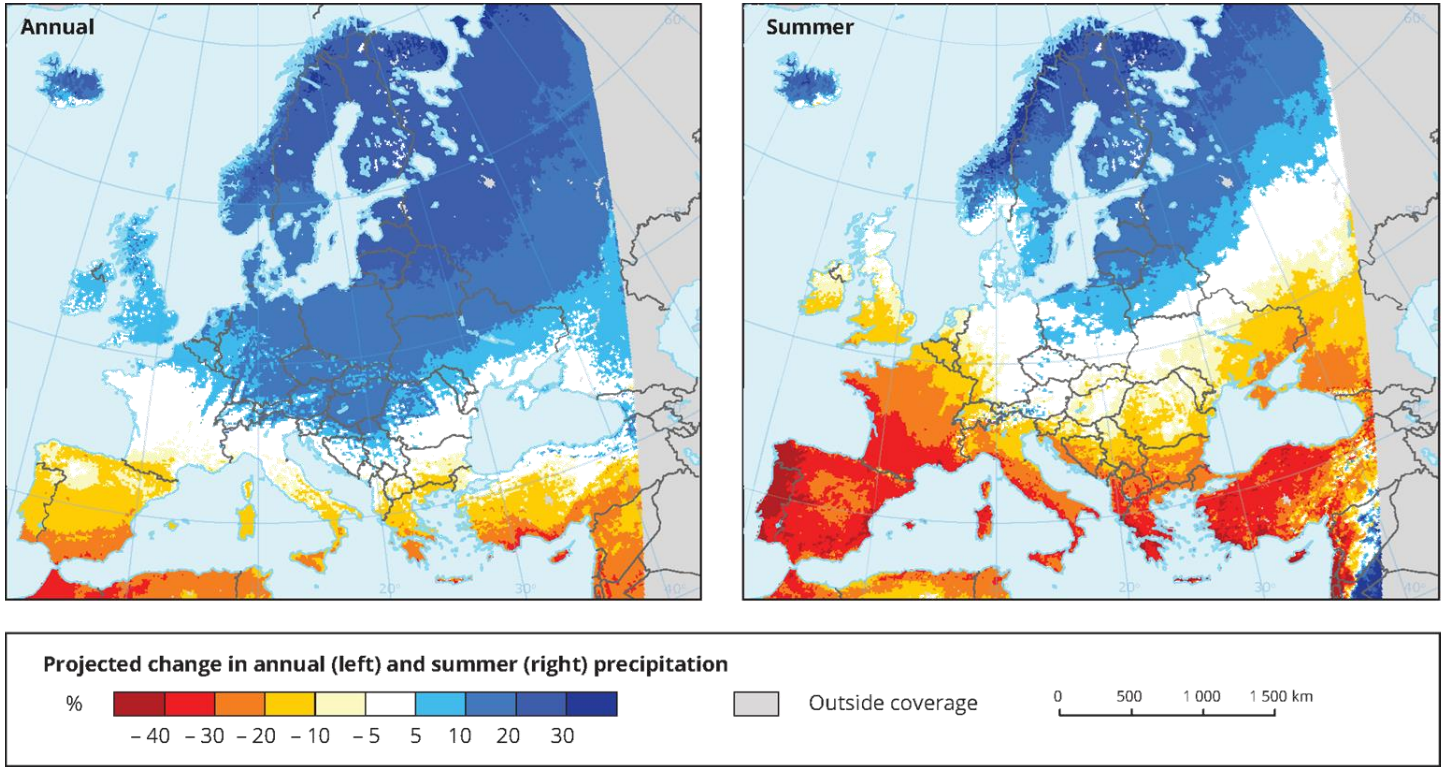
Fortes, P., Simoes, S.G., Brás, T. A., Amorim, F. (n.d.) **Competing water uses between agriculture and energy: Quantifying future climate change impacts for the Portuguese power sector.** Journal for Cleaner Production (under revision – conditionally accepted)

Context

- Climate change projections show that the **main Iberian international basins will likely suffer extreme multi-year droughts**
- In Southern Europe, **irrigation demand will increase up to 28%**

Projected changes in Annual and Summer precipitation (1971-2100) comparing with the baseline period 1971-2100

RCP 8.5 Multi-model ensemble



Source: European Environment Agency from COPERNICUS

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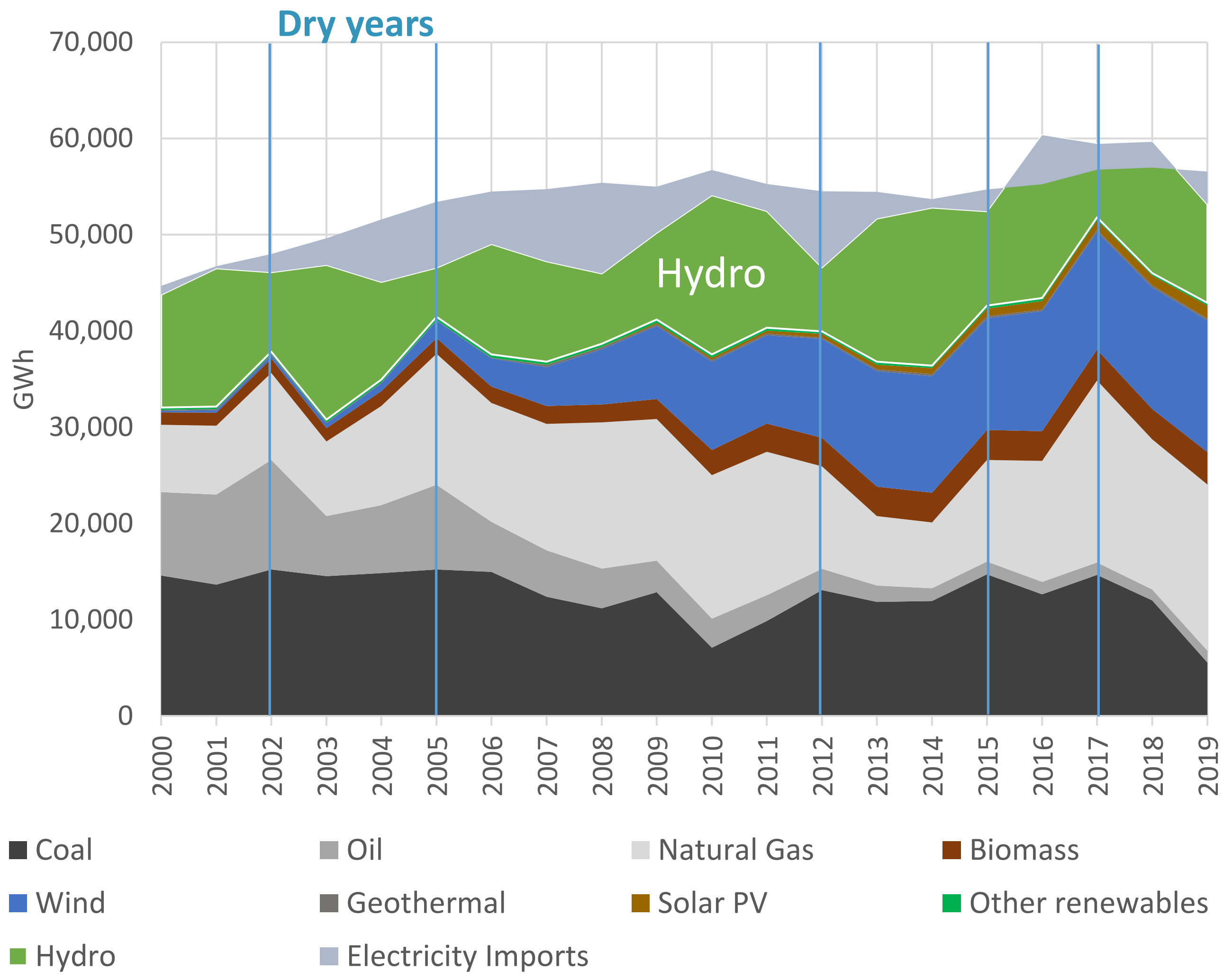
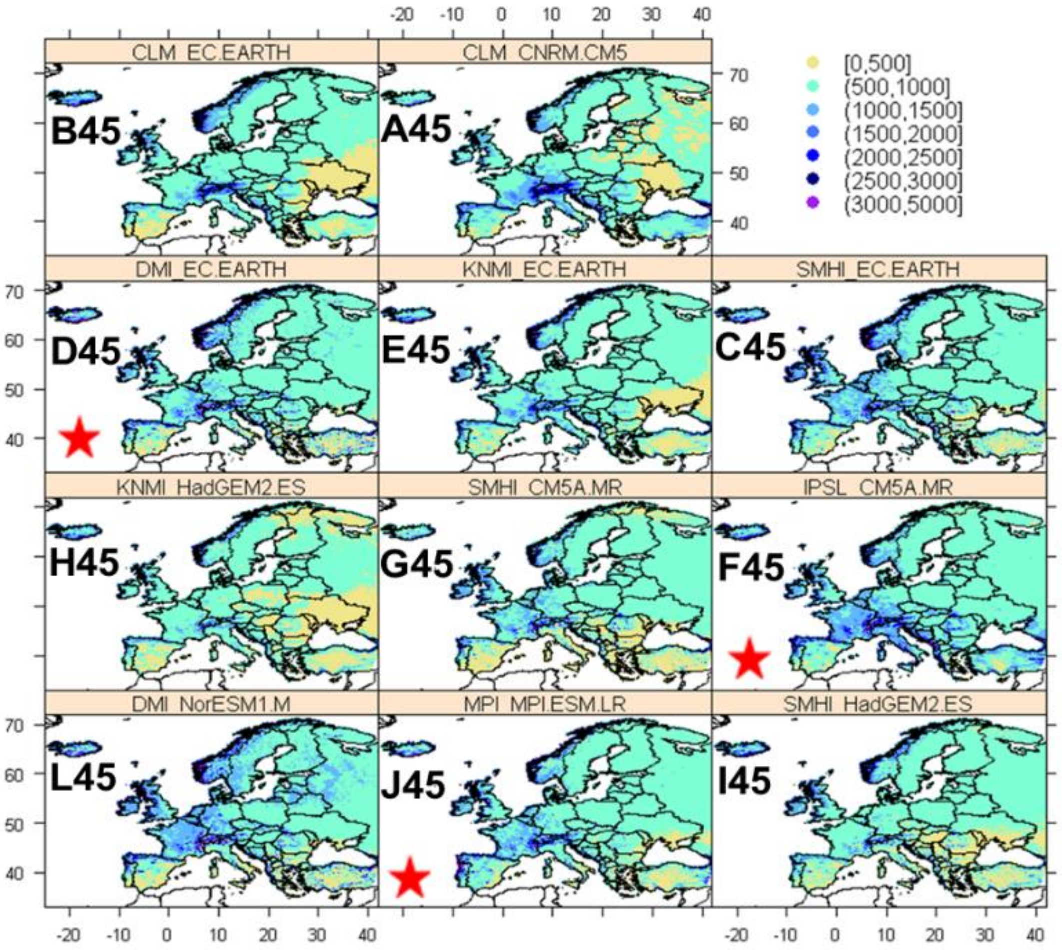
Context

- Electricity generation in Portugal is highly affected by **hydrological conditions**
- 3 main watersheds, represent around **60% of total hydropower** capacity in Portugal, and are shared with Spain
- Portugal has set a carbon-neutral target and an almost **100% renewable electricity** by 2050
- In the future, climate change may affect the **availability of other renewable sources**

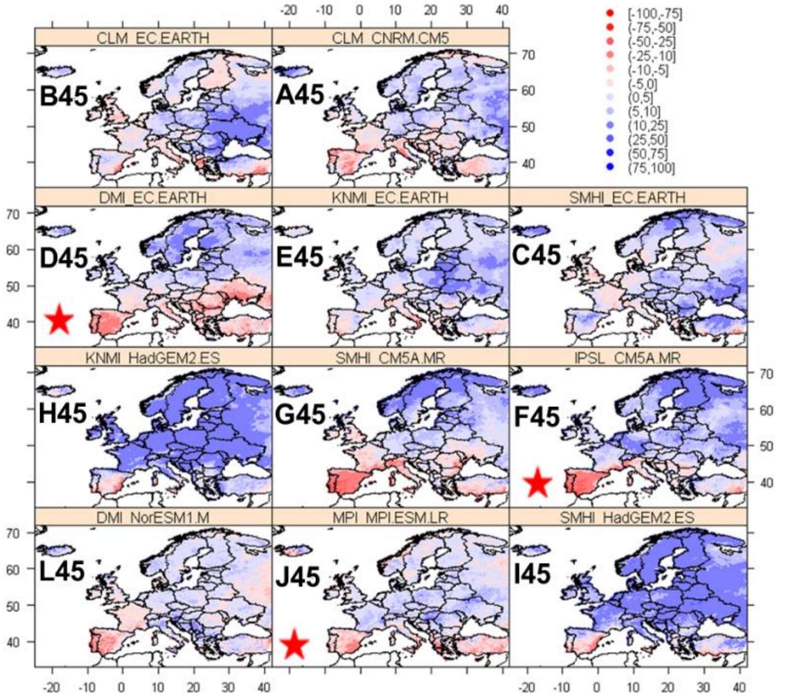


Uncertainty - precipitation over Europe



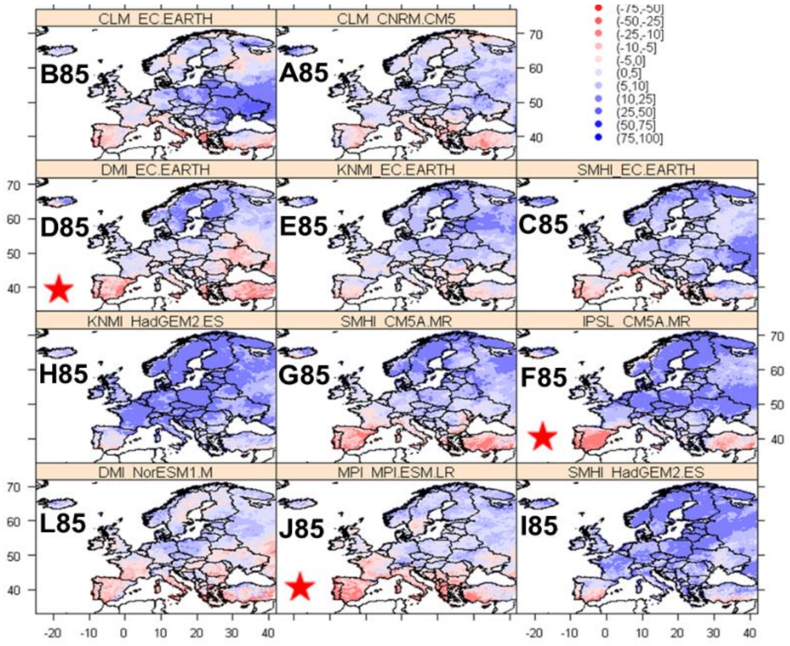
1976-2005

RCP4.5



% anomalies 2016-2045

RCP8.5

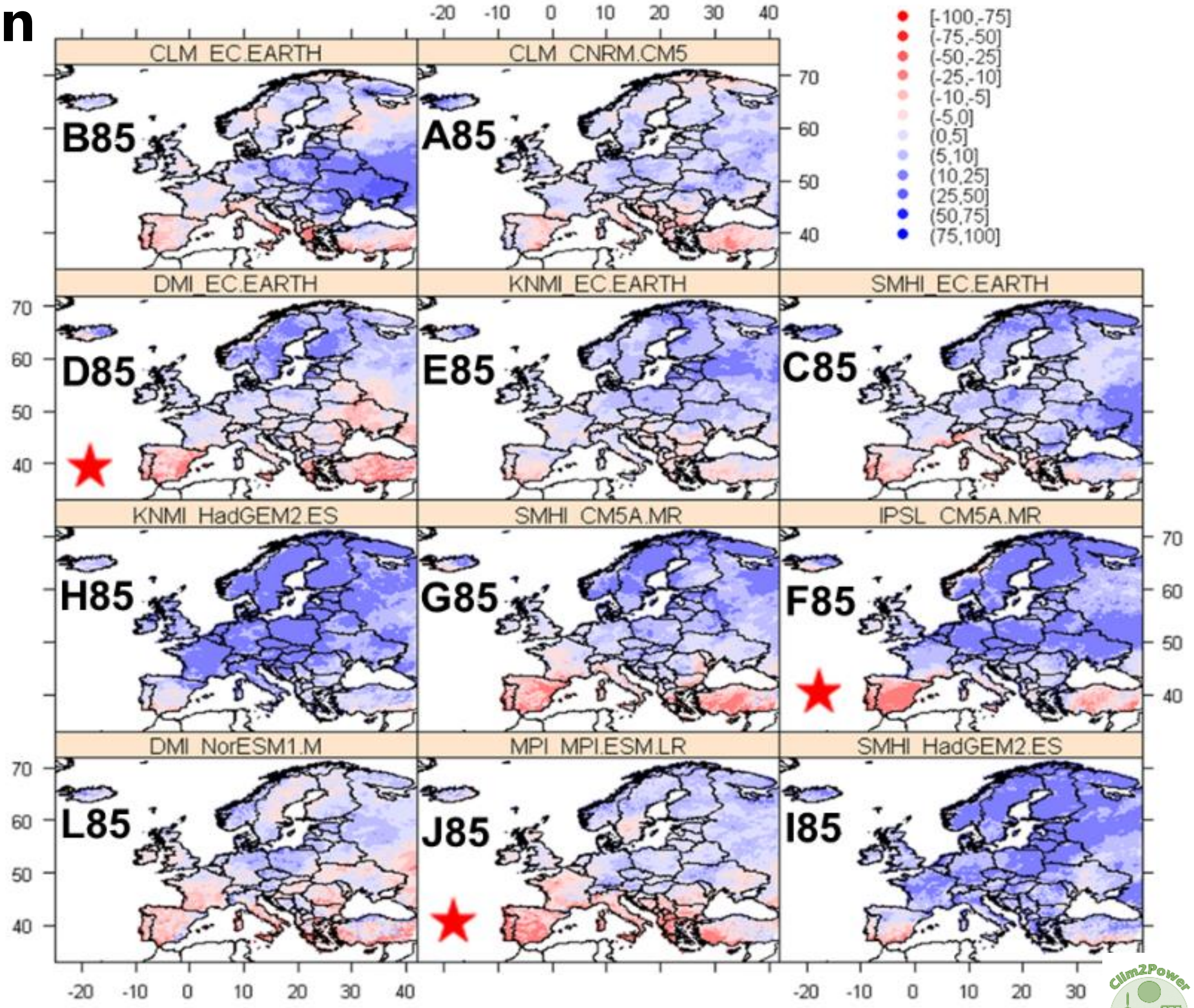


Uncertainty - precipitation over Europe in 2050

% anomalies 2016-2045

Red – lower precipitation

Blue - higher precipitation



RCP8.5

Objective

To which extent the **competition for water resources** between water demand for **agriculture** and **hydropower** may affect the future **Portuguese carbon-neutral power sector** under RCP8.5 climate scenario?

> An integrated approach that also considers the impact of climate change on other renewable sources (wind, solar)

> Cost-optimal configuration of the power sector

Fortes, P., Simoes, S.G., Amorim, F, Siggini, G., Sessa, V., Saint-Drenan, Y-M., Carvalho, S., Diogo, P., Mujtaba, B., Assoumou, E. (2022) **How sensitive is a carbon neutral power sector to climate change? Interplay between hydro, solar and wind for Portugal.** Energy Journal (239) Part B, 122106.
https://doi.org/10.1016/j.energy.2021.122106

Methods

Future Climate Forecast

Climate Data

RCP8.5
11 climate models
Temperature
Solar Irradiation
Wind Speed
Precipitation

1

Additional Irrigation water demand

Variation on the volume of water demand for irrigation considering future climate and **12 crop types**

2

3

Changes in capacity factors

Load & Variable Res

- Solar PV
- Wind Onshore
- Wind Offshore
- Load

- Hydro Douro Dams
- Other Hydro (Dams | Run-of-river)

Optimisation model eTIMES_PT

Climate and Energy Policies

Municipal RES Potentials

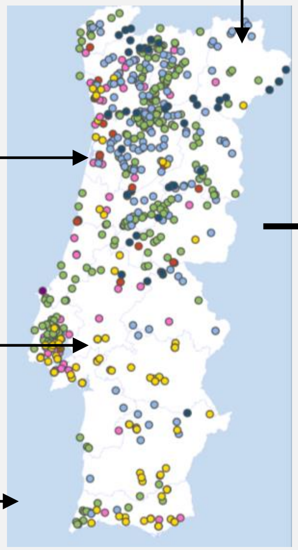
Technical Cost Development

Installed Capacity

Timing of Plants Decommissioning

4

Fossil fuel import prices



Optimal long term planning

Power production per technology

Installed Capacity per technology

Electricity costs

Results

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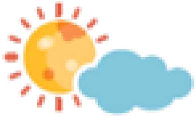
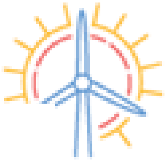
Future variation in wind, solar and hydro potential generation (capacity factors)



Climate Data

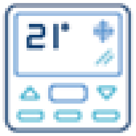
11 Future Climate Projections from EUROCORDEX RCP8.5

Hydrological modelling for Douro river



Physical wind and PV power simulation tools

Saint-Drenan, Y.M., Besseau, R., Jansen, M., Staell, I., Troccoli, A., Dubus, L., Schmidt, J., Gruber, K., Simoes, S.G., Heier, S. (2020) **A parametric model for wind turbine power curves incorporating environmental conditions**. Renewable Energy Journal (157) pp. 754-768 https://doi.org/10.1016/j.renene.2020.04.123



Machine learning for non-Douro river hydropower and electricity demand

Sessa, V., Assoumou, E., Bossy, M., Carvalho, S., Simoes, S.G. (2021) **Analyzing the Applicability of Random Forest-Based Models for the Forecast of Run-of-River Hydropower Generation.** Clean Technologies Journal, 3(4) 858-880. https://doi.org/10.3390/cleantechnol3040050

Fortes, P., Simoes, S.G., Amorim, F, Siggini, G., Sessa, V., Saint-Drenan, Y-M., Carvalho, S., Diogo, P., Mujtaba, B., Assoumou, E. (2022) **How sensitive is a carbon neutral power sector to climate change? Interplay between hydro, solar and wind for Portugal.** Energy Journal (239) Part B, 122106. https://doi.org/10.1016/j.energy.2021.122106

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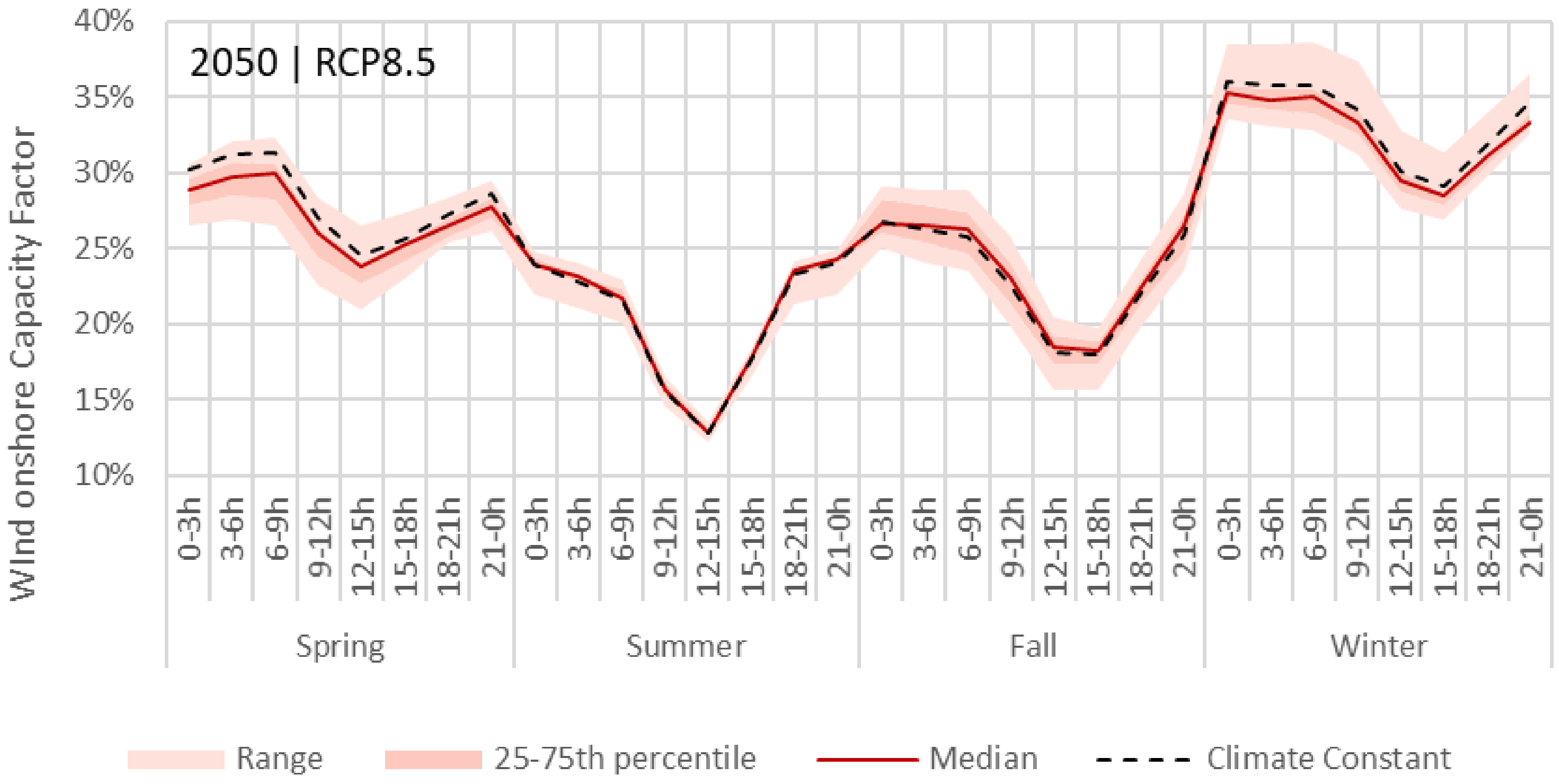
Future variation in wind potential generation (capacity factors)

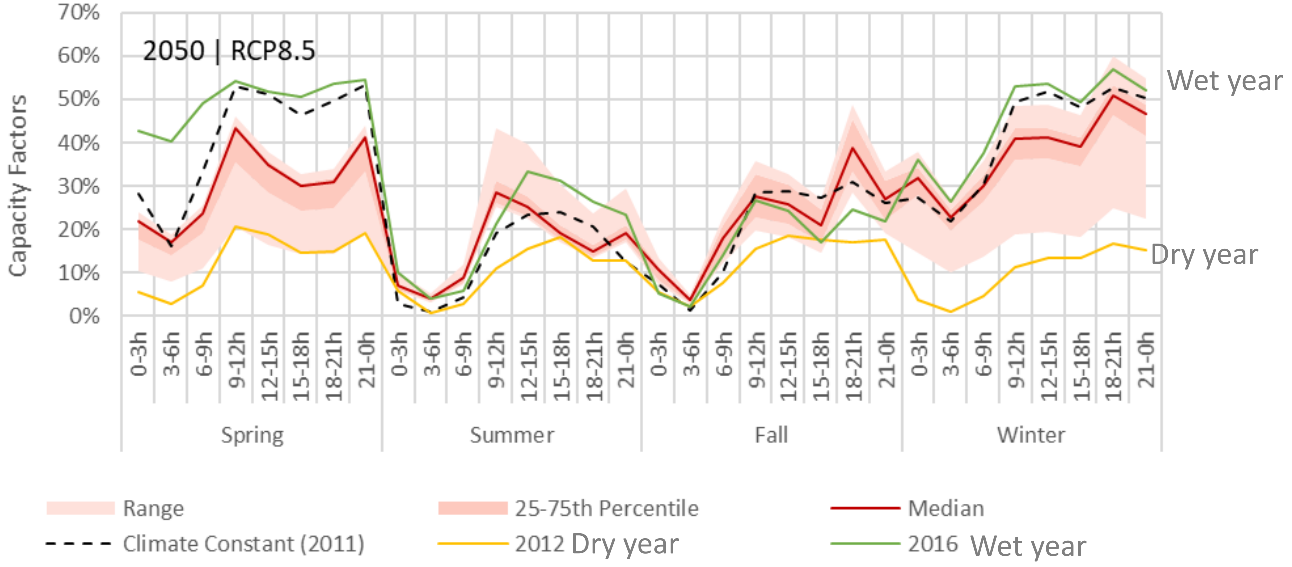
Onshore Wind

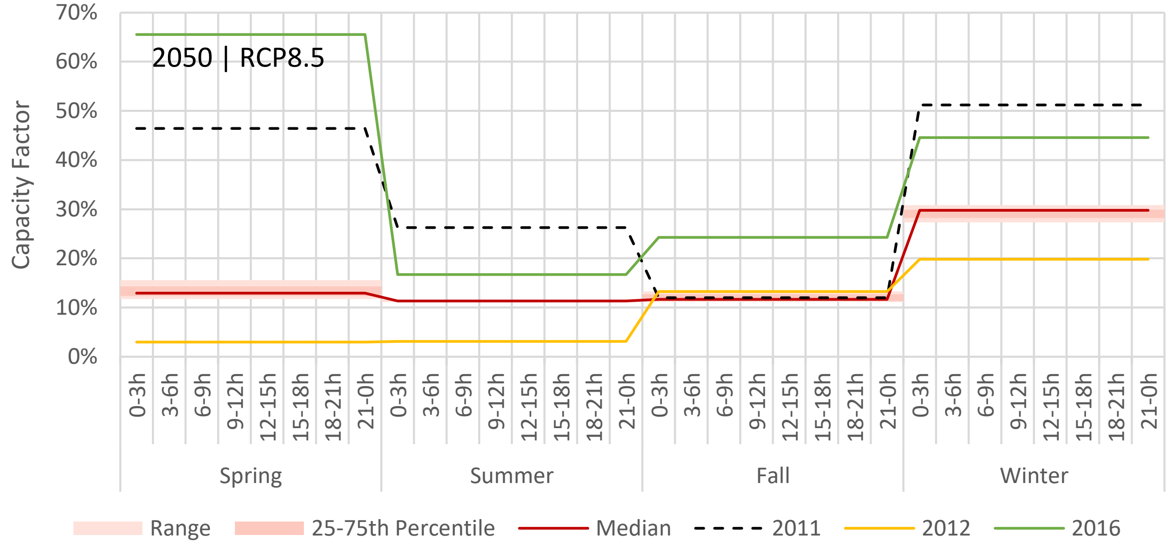


Future variation in hydropowe potential generation (capacity factors)

Miranda – Douro Hydropower

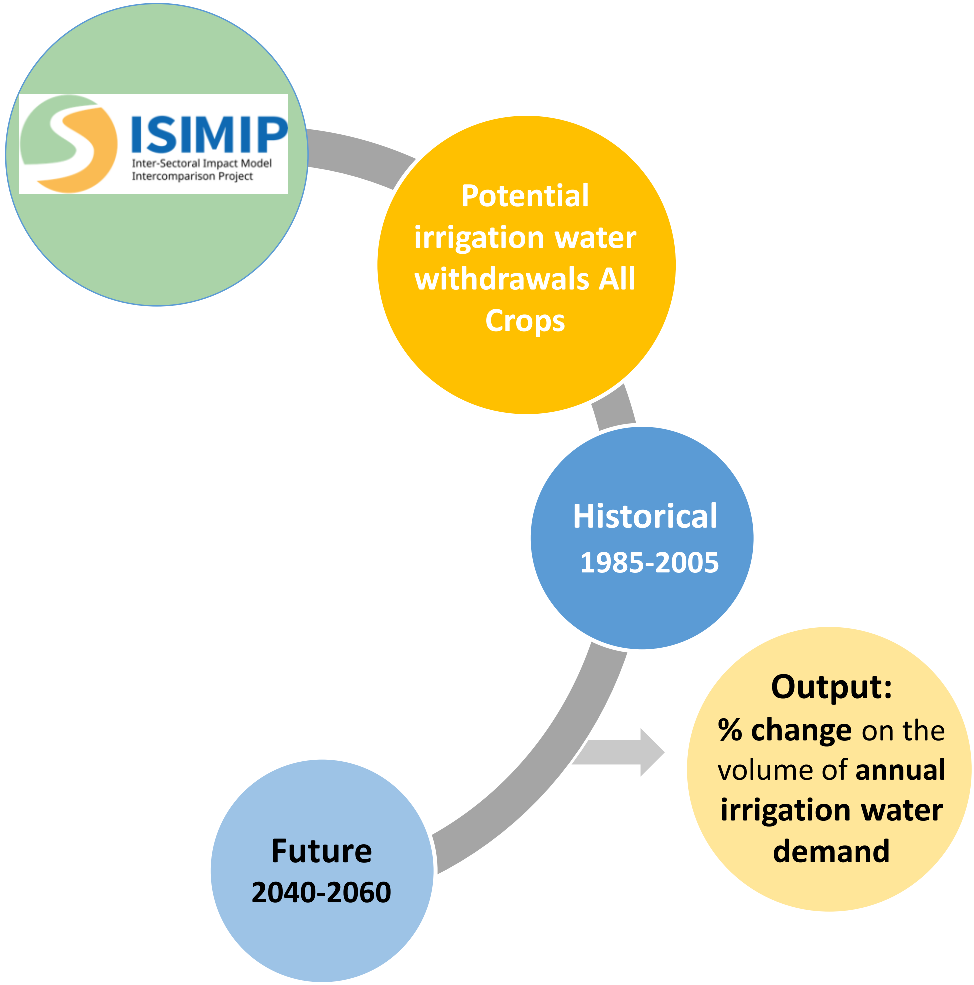
Without water competition

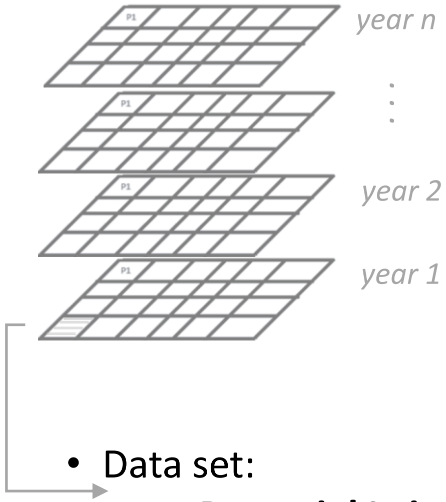


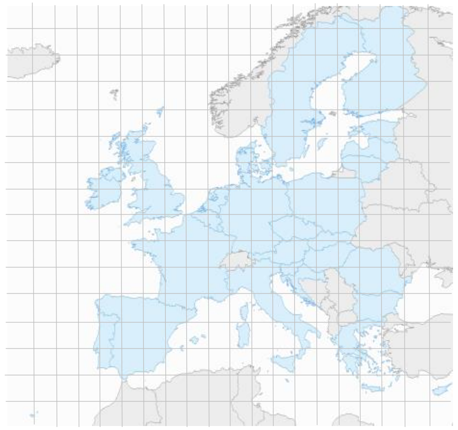


Non-Douro Dams (Centre and South of Portugal)

Methods – future water demands for irrigation







- Data set:
  - **Potential Irrigation Water Withdrawals (pirrww):** $km^3 \cdot month^{-1}$ (unlimited water supply)
  - **Historical (avg 1985-2005) & Future (avg 2040-2060)**
  - Grid resolution: 0.5° x 0.5° (~55 Km)

- **Future climate** scenarios:
  - **Land use scenario** fixed at **2005**
  - **RCP8.5**
  - **CO_2 concentration fixed** at 2005 levels and with **increasing CO_2 levels**
  - **Climate forcing** model: gfdl-esm2m (with bias correction)
  - **Impact model**: CLM45

Methods – impact of irrigation in hydropower capacity factors

Current seasonal water volumes abstracted for irrigation

- Review available water management plans
- Douro and Tagus watersheds, in Spain and Portugal
- Obtained current water abstracted for irrigation in hm^3

Current irrigation translated into % of current total river runoff

- hm^3 current irrigation **/** current total runoff of Douro and Tagus = % of total current river runoff used for irrigation
- for both an average and a dry hydrological year

2050 RCP8.5 irrigation water needs

- additional % water needed for irrigation **+** current irrigation water volumes for Douro and Tagus = 2050 irrigation water needs in hm^3
- 2050 irrigation water needs in hm^3 **/** total river runoff = % runoff for irrigation by 2050
- average and a dry year

% relative difference from current and future share of total river run-off for agriculture considered as a proxy value of less water available for hydropower generation and directly applied to the "historic" capacity factors

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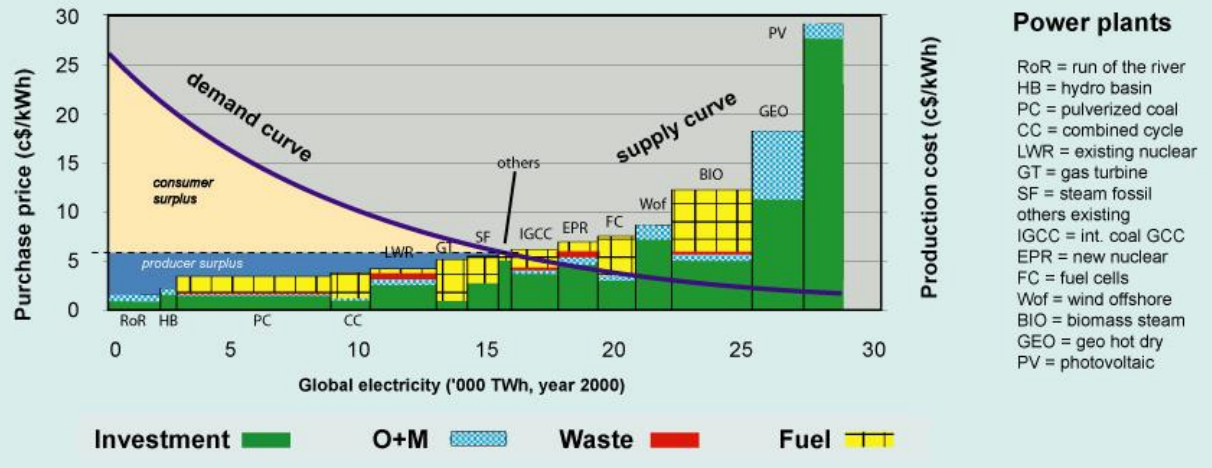
Methods – TIMES energy optimisation model

TIMES

- > **Linear Optimization Model** | Minimization of total system costs over the modelling horizon
- > Decisions based on costs (technologies and resources) and policy constraints without investment limits and perfect foresight – **Outcomes translate the best cost-effective solutions**
- > **Markets are not modelled** – costs and not prices



Typical representation of an energy commodity in MARKAL - TIMES.
The algorithm maximises the global surplus over thousands such markets.

Fonte: ETSAP

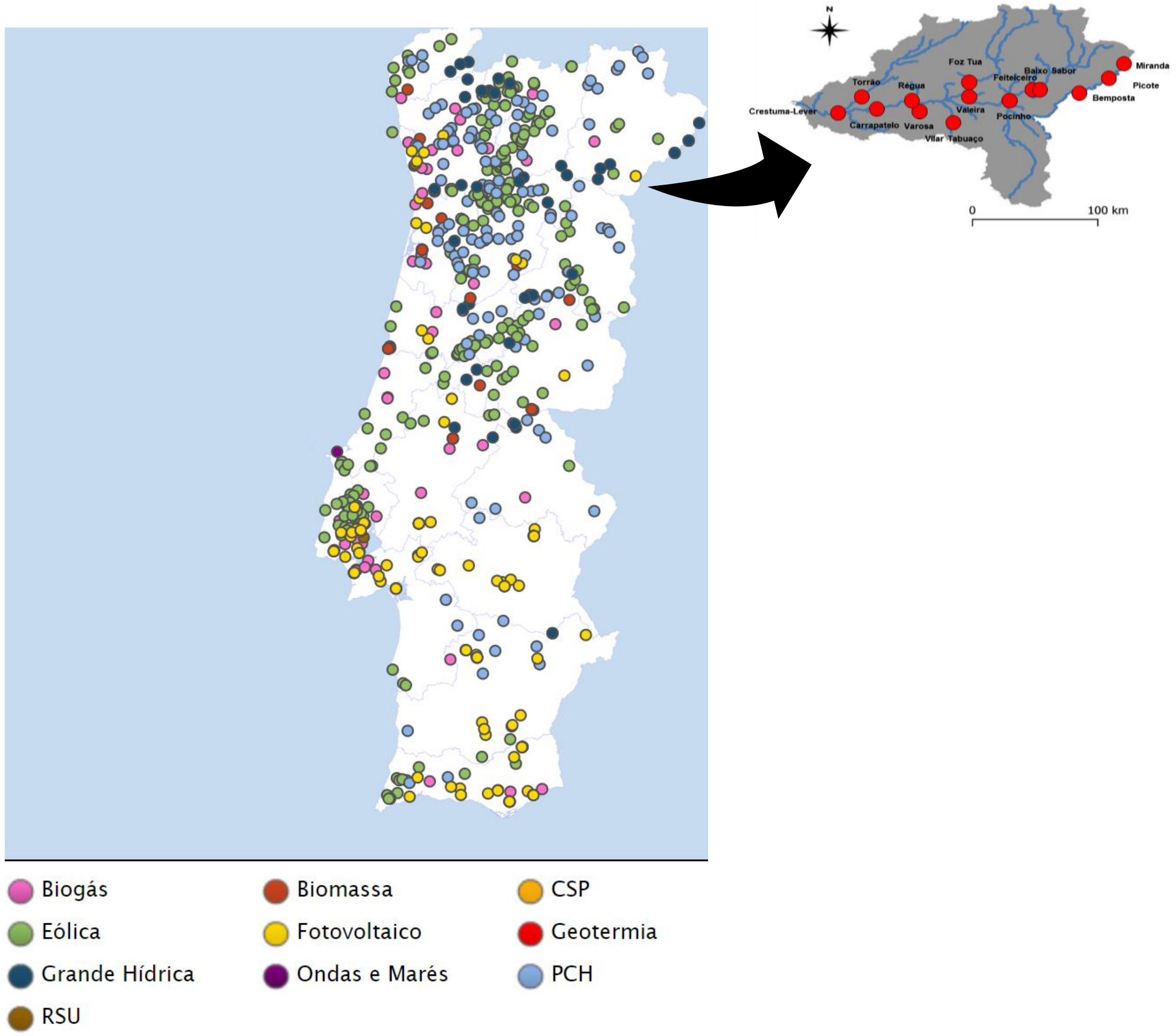
eTIMES_PT model

Time resolution

- \> **64 time slices per year**: 4 seasons | week day/weekend |8 day periods of 3h > Seasonal, intra-day and weekly dynamics
- \> Runs every **5 years between 2016 and 2050**, or yearly for seasonal forecast (2016 to 2025)

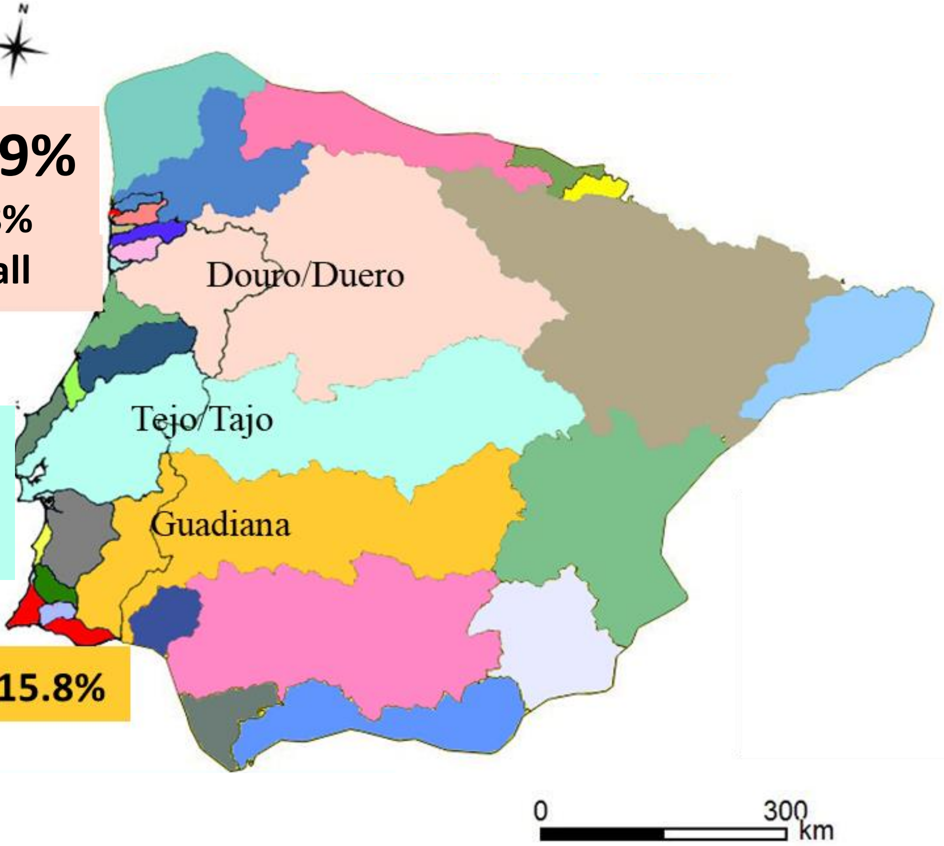
Spatial resolution

- \> Douro Dams individually represented
- \> Onshore Wind and PV (roof and utility) at municipality level
- \> RES potentials at NUTs4 level (municipality)



Amorim, F., Simoes, S.G., Siggini, G., Assoumou, E. (2020) **Integrating Climate Variability in energy system models**. Energy (206) https://doi.org/10.1016/j.energy.2020.118089

Results – water demand for irrigation in 2050



Douro +11/19%
+84% spring | +8% summer | 16% fall

Tejo +11/19%
+45% spring | +2% summer | 65% fall

Guadiana + 12-15.8%

Additional annual water irrigation per region and watershed compared with historical values

Portugal: +3.5/+ 9.7%
Spain: +26.7/+29.6%

Variation of 2050 river runoff due to climate change

Hydrological conditions	Watershed	% change from current runoff
Dry	Douro	- 30%
	Tejo (non-Douro)	- 38/42%
Average	Douro	– 25/28%
	Tejo (non-Douro)	-29%

Guerreiro, Selma B, Birkinshaw, S., Kilsby, C., Fowler, H.J., Lewis, E., 2017. Dry getting drier – The future of transnational river basins in Iberia. J. Hydrol. Reg. Stud. 12, 238–252. https://doi.org/https://doi.org/10.1016/j.ejrh.2017.05.009
Guerreiro, Selma B., Kilsby, C., Fowler, H.J., 2017. Assessing the threat of future megadrought in Iberia. Int. J. Climatol. 37, 5024–5034. https://doi.org/10.1002/joc.5140

Results – change in hydropower CF by 2050

Variation of hydropower CAPACITY FACTORS considering additional water needs for irrigation (compared to 2050 with climate change but no water competition)

Average

Douro -17/-18%

Spring -59/-64% | Summer -61%/-69% | Fall -1%

-28/-33%

Spring -91/-92% | Summer -119/126% | -2%

Dry

Average

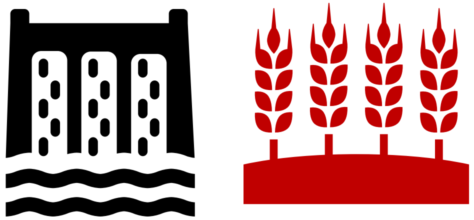
Tejo -17%

Spring -17/-16% | Summer -78%/-82% | Fall +1%

-77%

Spring -53/-132% | Summer -192/336% | Fall 0/-7%%

Dry



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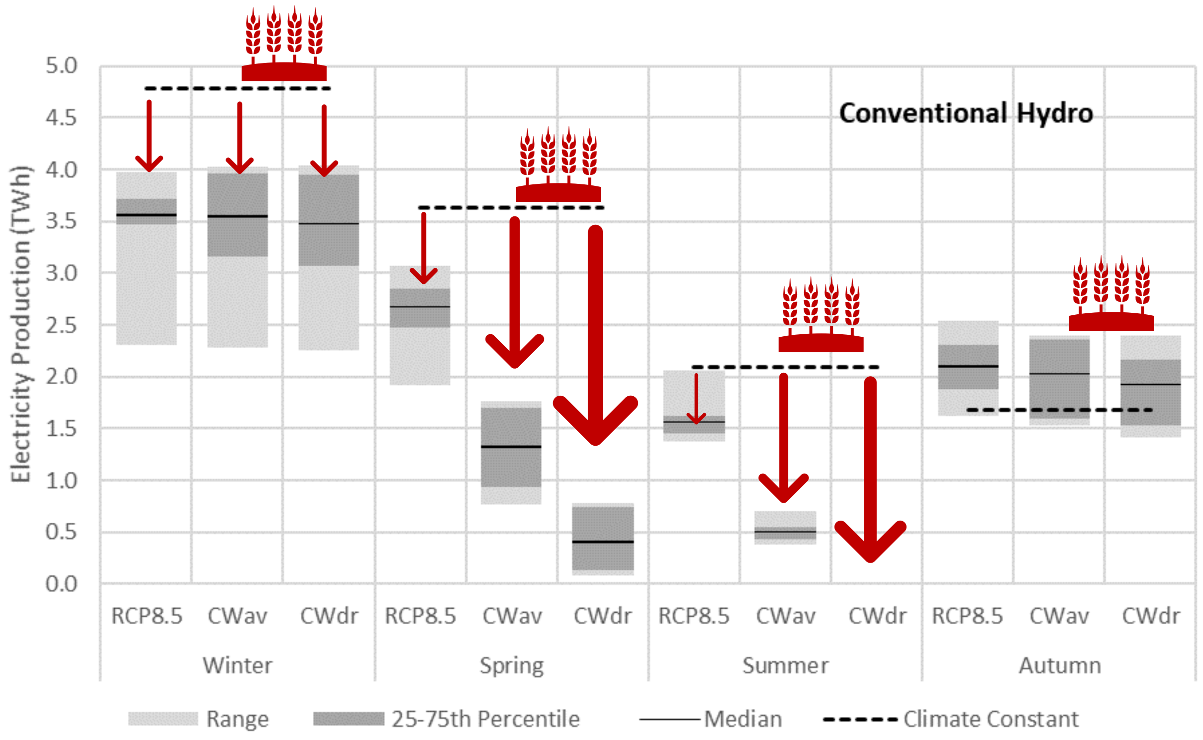
Results – hydropower generation in 2050



- No hydropower generation in summer for all projections
- Irrigation does not make a difference in winter
- Most significant differences in spring (almost no generation in all projections)

Bars show range of variation in results for 11 climate projections from different climate models for 2050

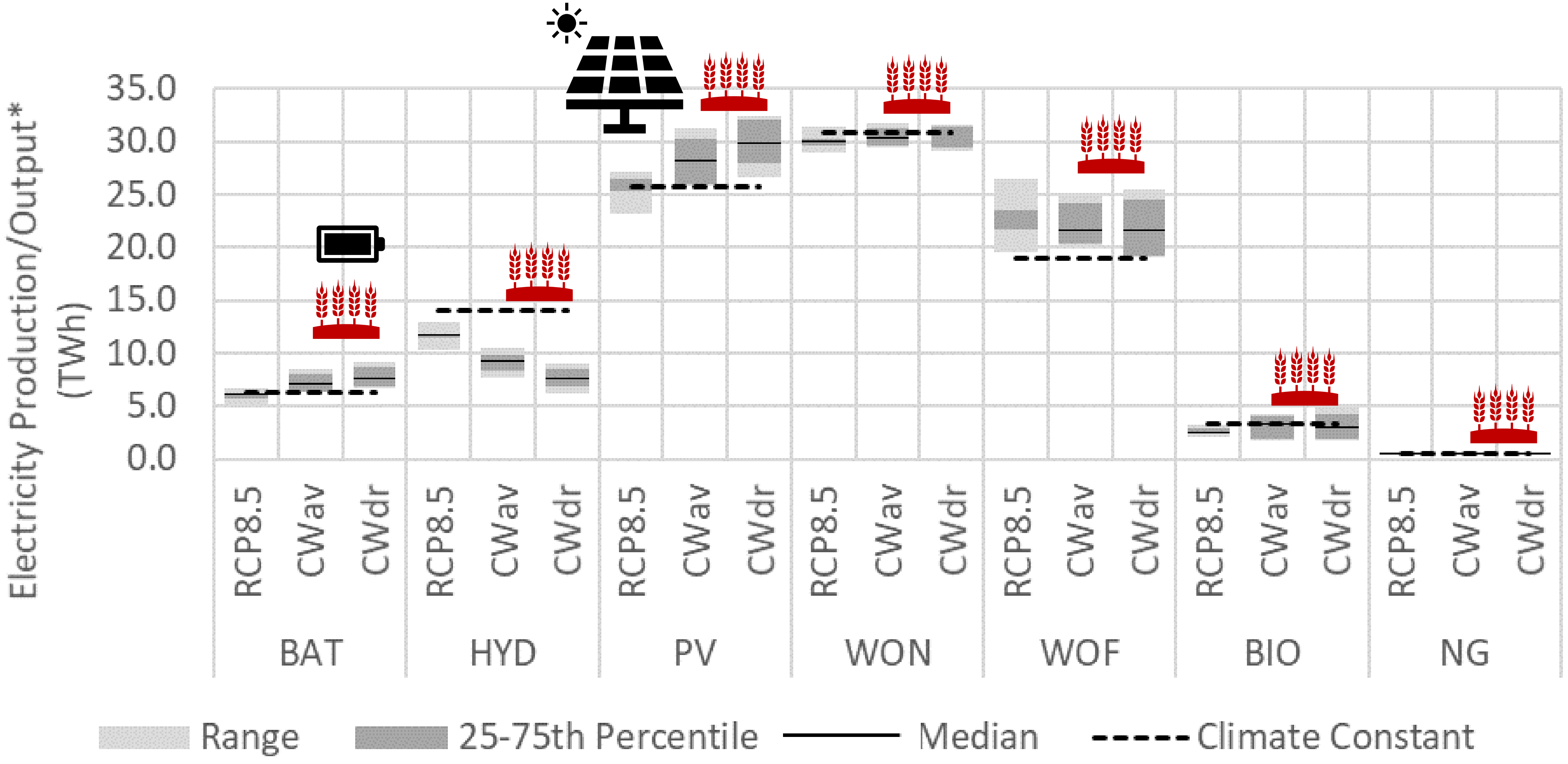
Climate constant assumes no climate change impacts

RCP8.5 – climate change impacts but no concurrent water uses

CWav – competing water uses on an average hydrological year

CWdr - competing water uses on a dry hydrological year

Results – overall power generation in 2050



* Electricity output refers to battery operation, since strictly speaking batteries do not generate electricity.

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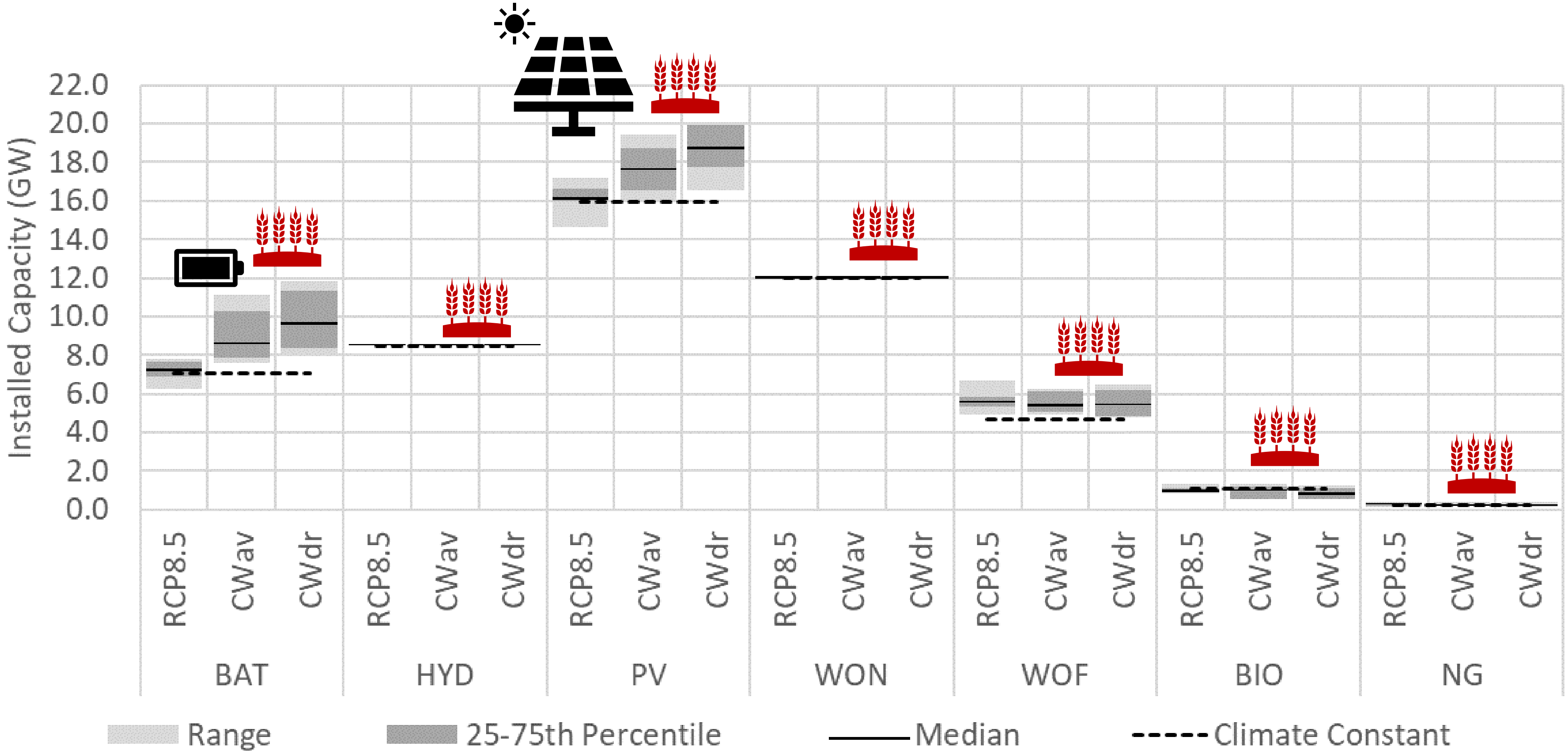
Results – installed capacity in 2050



More 2.6 to 3 GW of solar PV

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Final remarks

> Climate Change can lead to an **increase of water demand for irrigation** up to 19% in Douro and 12% in Tejo watersheds from 2005 levels – at seasonal level, the biggest impact is felt during **spring**

> Translated into a **reduction of capacity factors** of 9% and 10%, for hydropower plants located in Douro basin and in other water basins, respectively.

> By further considering **future water competition for irrigation**, hydropower electricity production is lowered in median terms by circa -27% compared to a climate constant scenario (circa 7% less than in RCP8.5 in median terms)

> **Solar PV** appears as the most cost-effective technology to compensate for hydropower decline, justified, among others, by its high-capacity factor, in **spring and summer** when comparing to other RES technologies

> Main **limitations** of this work – only RCP8.5; large uncertainty across different climate change models; ISIMIP results assumes land-use change maintained constant till 2050; substantial uncertainty on translation of irrigation increase into CF of hydropower (that does not reflect market strategies of power companies)

Muito obrigada!

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