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Joint Research Centre

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Impacts of the geography of intermittent renewables on global long-term scenarios

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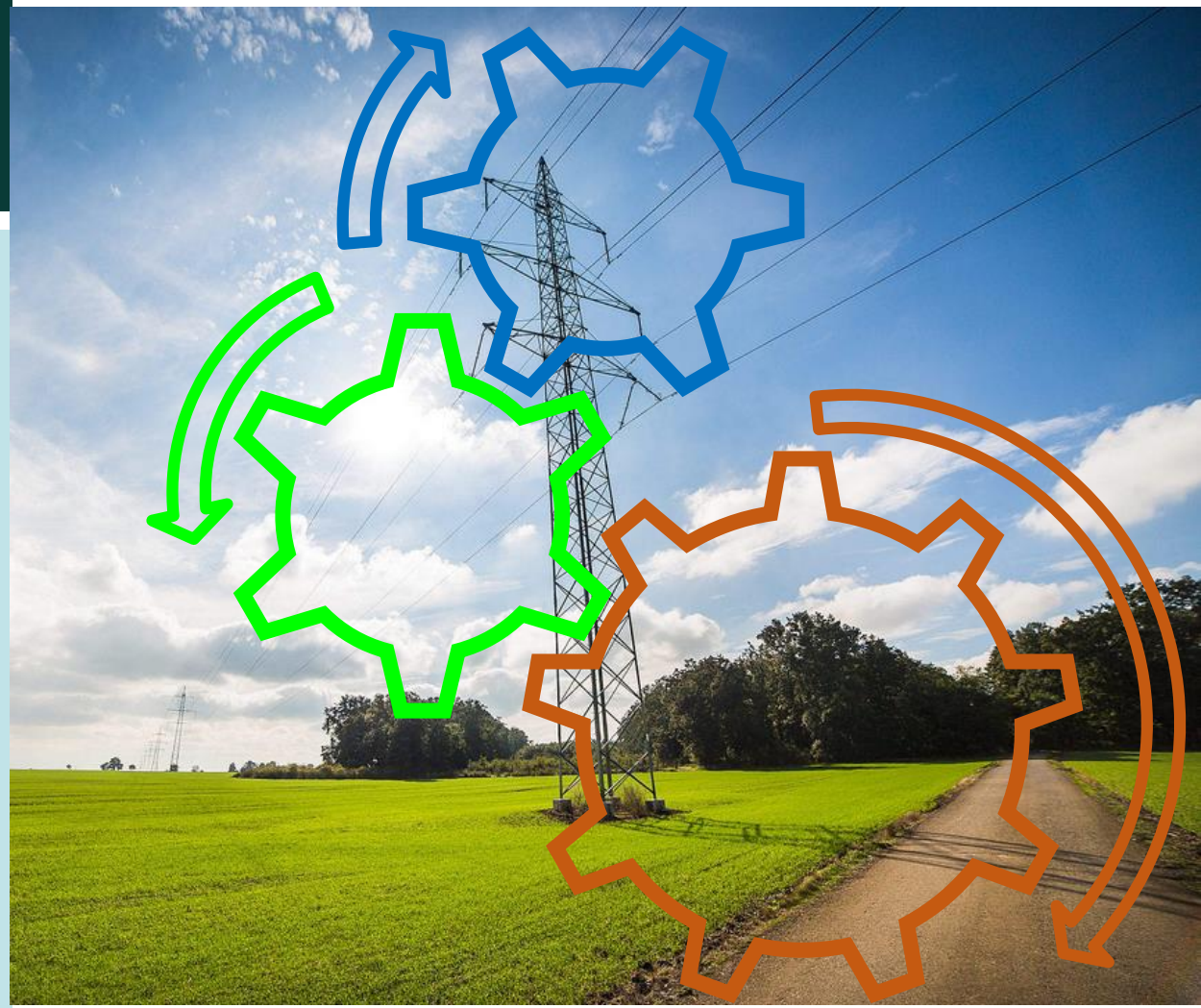
IRENA workshop, Bonn, 12/12/2019

European Commission

Agenda

- The POLES model
- Data
- Some results

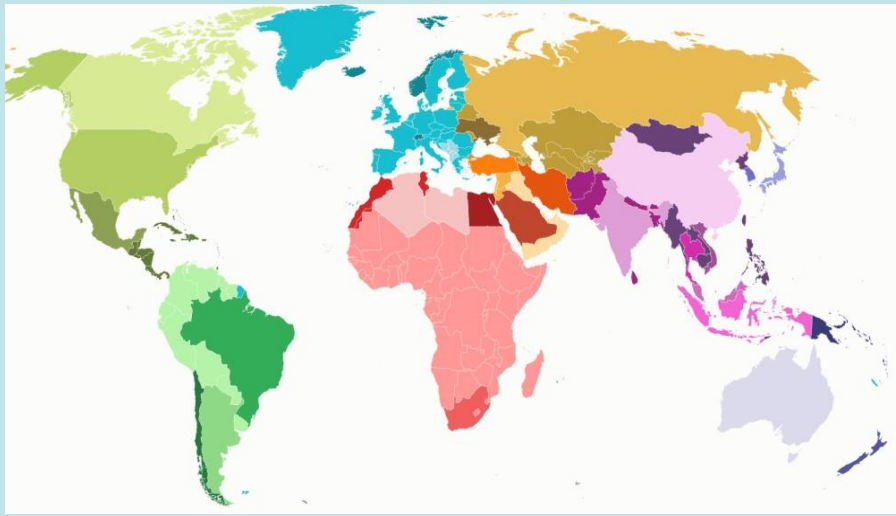


The POLES-JRC model

Prospective **O**utlook on **L**ong-term **E**nergy **S**ystems

https://ec.europa.eu/jrc/en/poles

- Simulating the evolution of the world energy System
- Yearly time step until 2050/2100
- 66 regional entities covering the world:
  - EU28
  - 26 non-EU countries: detailed OECD, G20, emerging Asia
  - 12 non-EU regions
  - Oil, gas and coal production: 80+ countries
- Full energy system
- Full GHGs coverage (linkage with specialist tools for non-energy)



Resources & production → **Trade** → **Transformation** → **Consumption** → **GHGs & other externalities**

POLES for EU policies

Issues addressed:

- **Energy** policies, markets, technologies (e.g. oil markets …)
- **Climate** policies (how to reach 2ºC and 1.5ºC, context for DG CLIMA, outreach to China, India…)
- **Integrated resource assessment** of climate mitigation policies (air quality, climate impacts…)

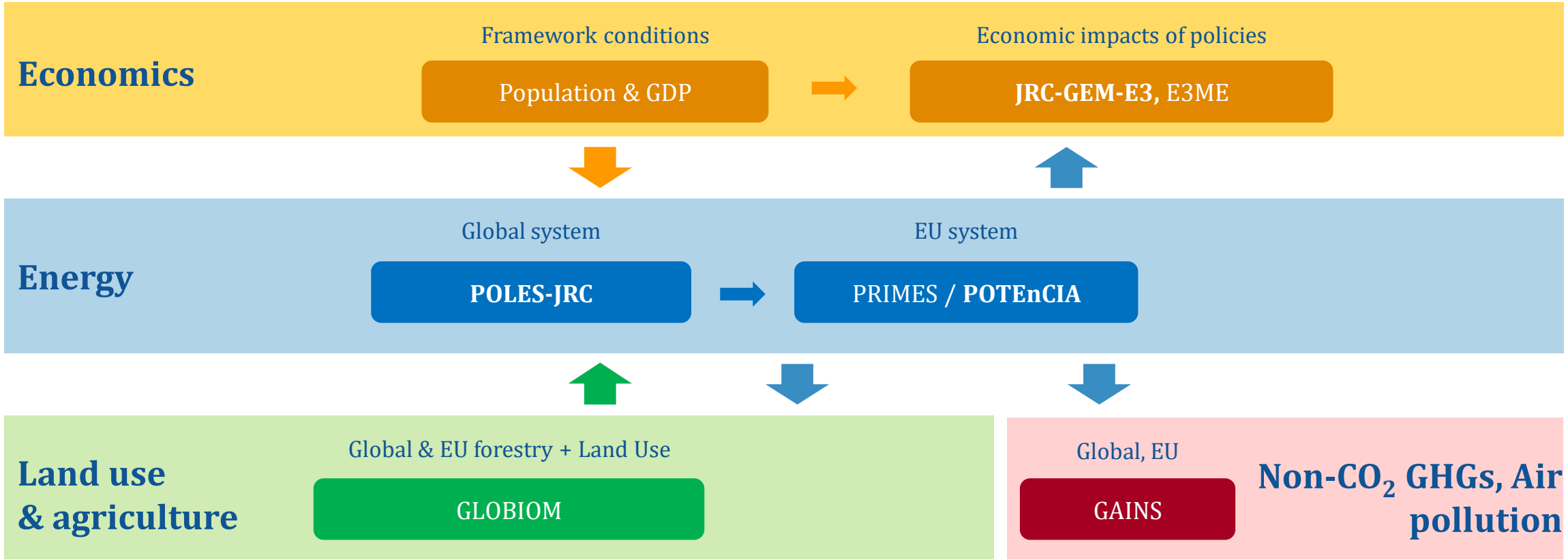
Used in:

- 2011 Low-Carbon Roadmap
- 2015 Paris Agreement COP21
- 2018 EC Long-Term Strategy
  https://ec.europa.eu/clima/policies/strategies/2050_en

Annual JRC Science for Policy Report:

- **G**lobal **E**nergy and **C**limate **O**utlooks (GECO)
- Report & data visualisation: http://europa.ec.eu/jrc/geco

EU modelling used for energy & climate policy: Combining global and domestic approaches

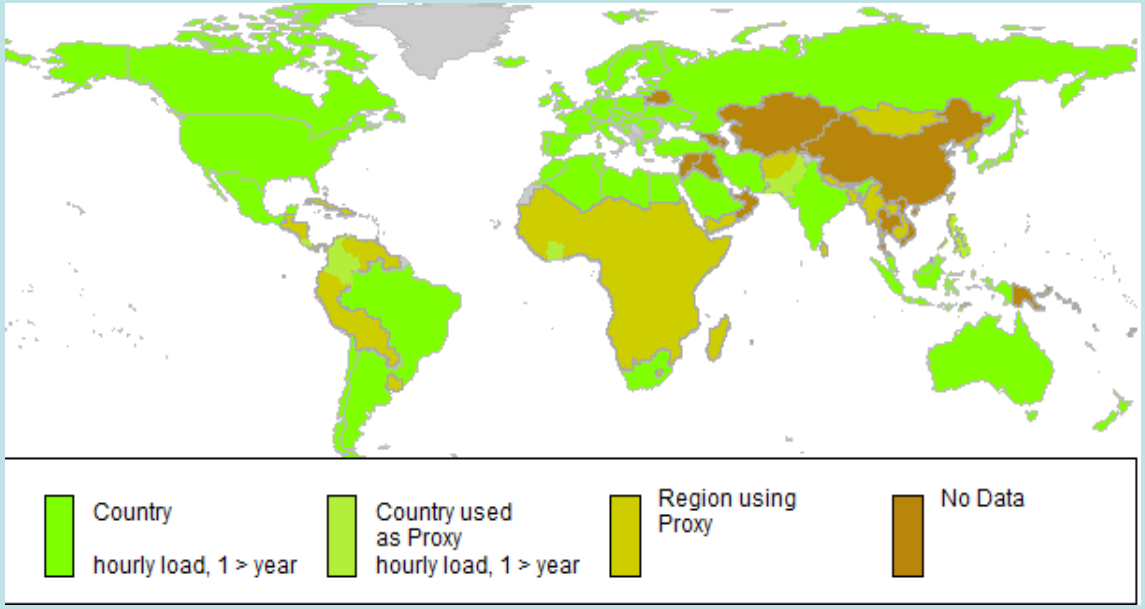


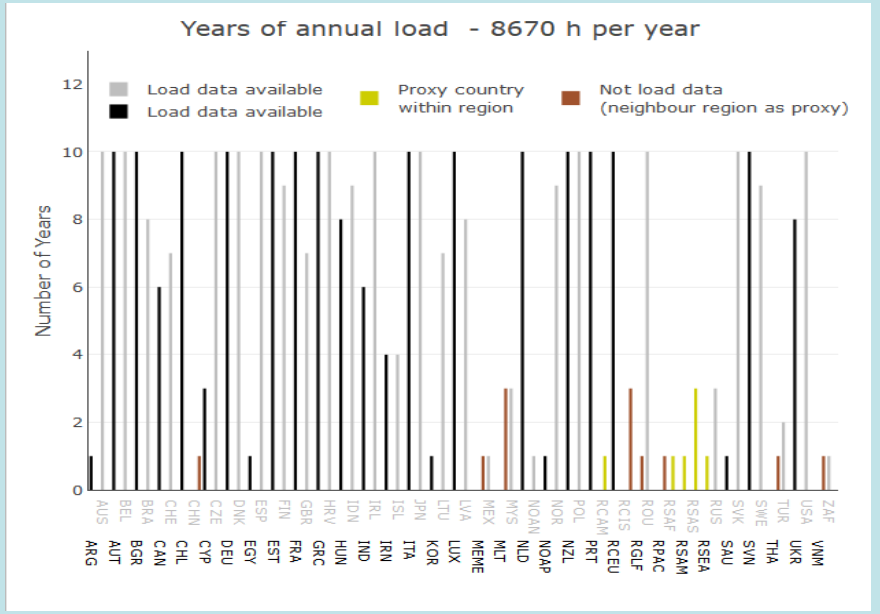
Agenda

- The POLES model
- Data
- POLES results

Input electricity load (hourly) data

Compiled from multiple sources





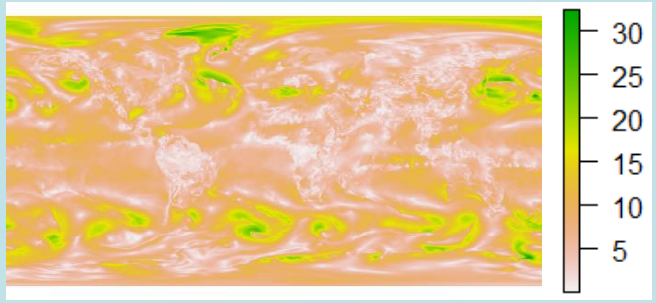
- 56 countries with ≥1 year

→ Data treatment

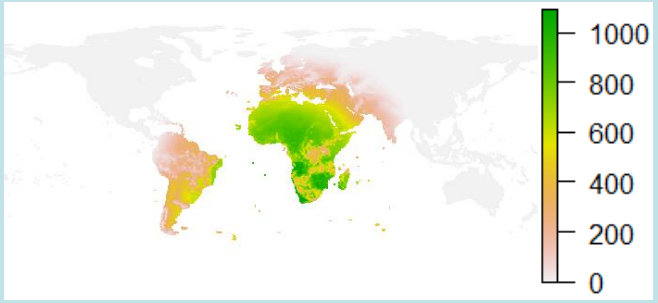
(Time zones,
Aggregate grid zones,
Outliers, interpolate missing data,
De-trend)

Input meteorological data

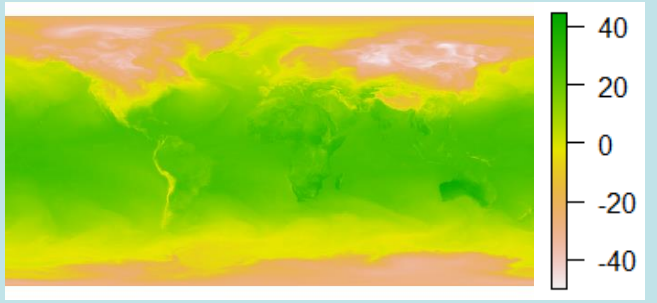
- Hourly resolution
- Wind (m/s)



Solar (W/m^2)



Temperature (°C)



- Satellite data from MERRA-2 (NASA)
  Modern-**E**ra **R**etrospective analysis for **R**esearch and **A**pplications
- 2003 to 2018
- Spatial resolution: 0.625°×0.5°

Data treatment
resource → production:
- Technical characteristics
- **Geographical weighting**

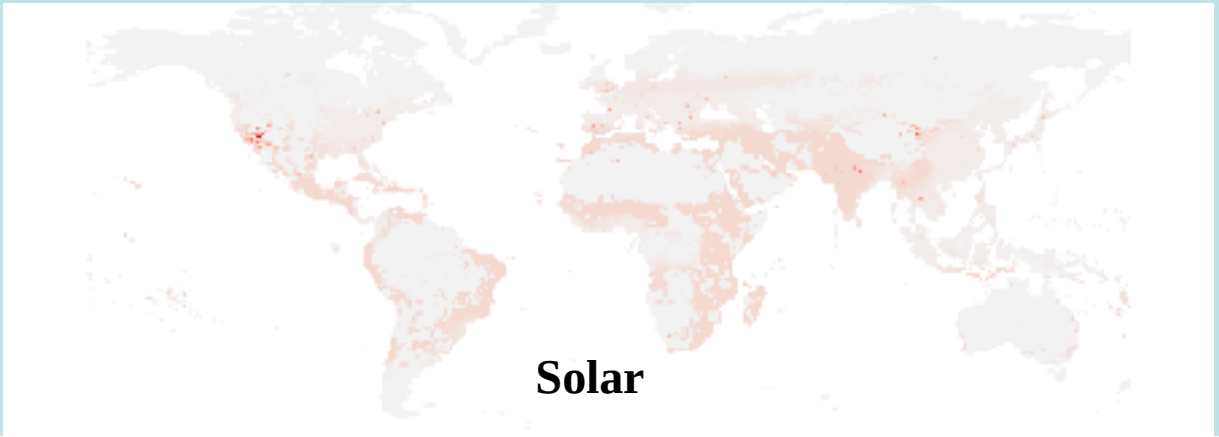
Spatial distribution of VRE capacities: Base case

- **Current Capacities:**
  - Wind: *The Wind Power* database
  - Solar: *World Electric Power Plant* database from Platts

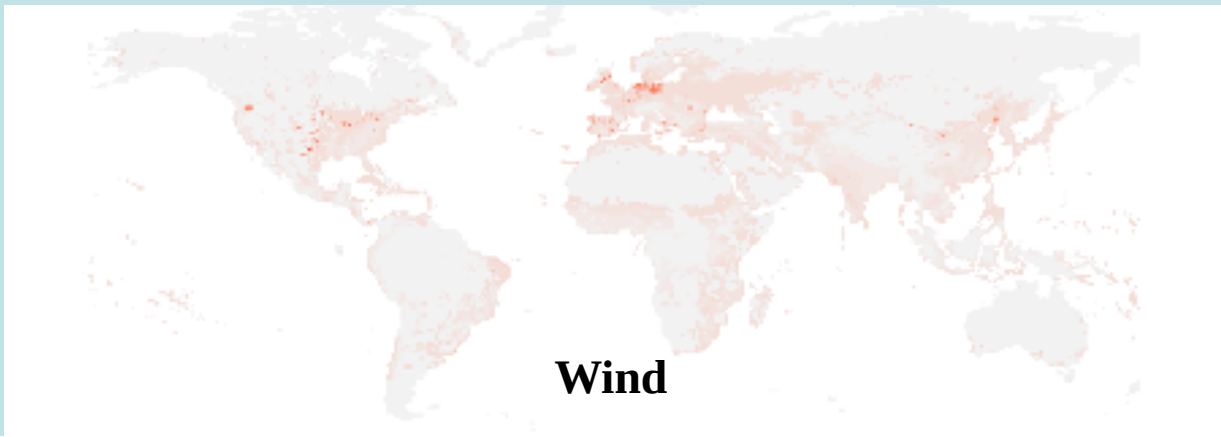
+ **Resource potential**: link between current capacities and meteorological mean

+ **Proxy for grid availability**: Population density between 10 and 10,000 persons/km^2

Distribution of capacities in base case



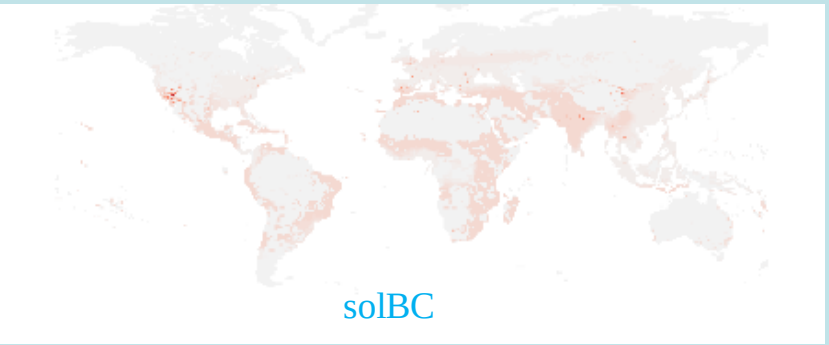
Solar



Wind

Spatial distribution: 4 variations of solar capacities

Base case solar capacities distribution

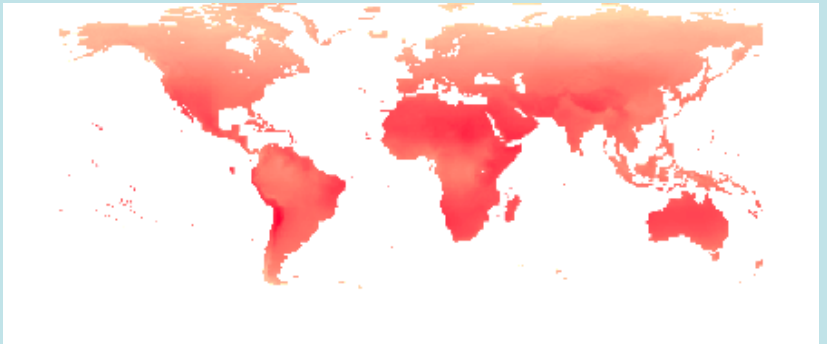


solBC

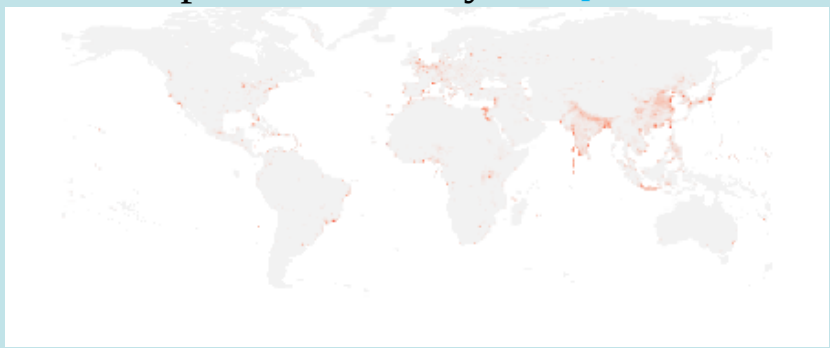
Variants of solar capacities distribution

- Current capacities solCapCur

- Mean irradiance sol10YIrrad



- Population density solPopD



- Equally distributed by area solArea

Spatial distribution: 4 variations of wind capacities

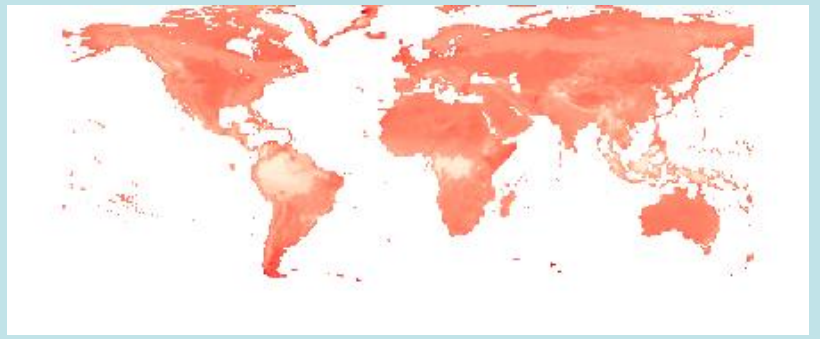
Base case wind capacities distribution

winBC

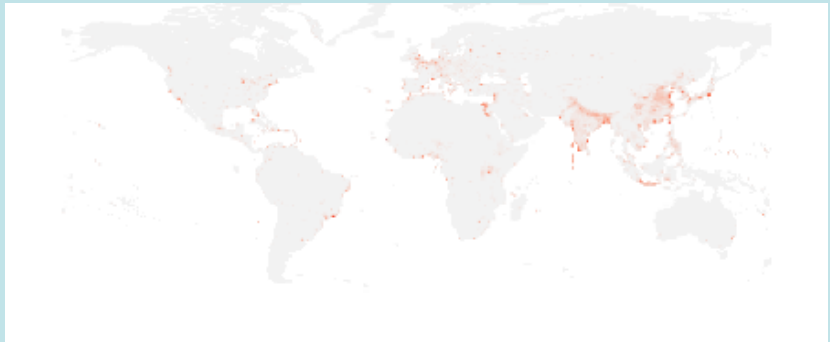
Variants of wind capacities distribution

- Current wind capacities winCapCur

- Mean wind speed win10YWsp



- Population density winPopD



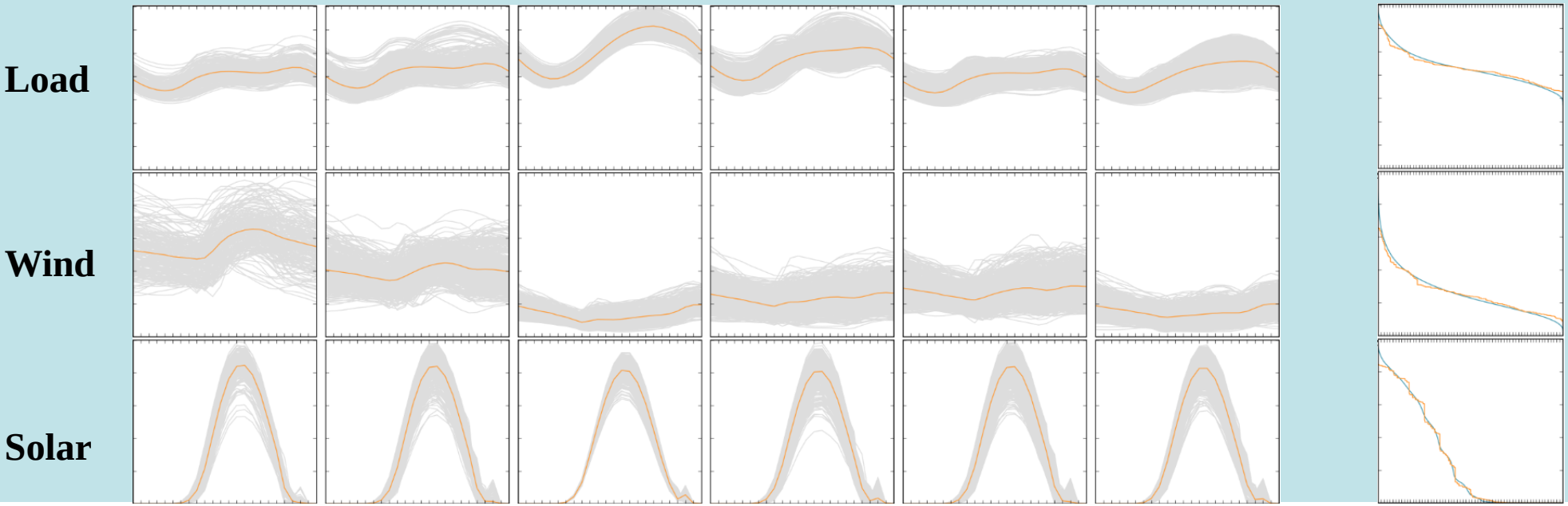
- Equally distributed by area winArea

Data treatment for POLES: selection of days

- Clustering based on simultaneous wind, solar and demand
- **Profiles are impacted by the geographical weightings**

(absolute quantities are determined in POLES scenarios)

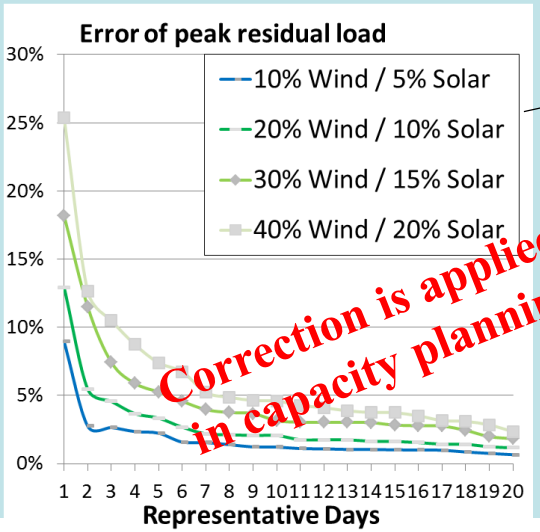
6 days (USA example):



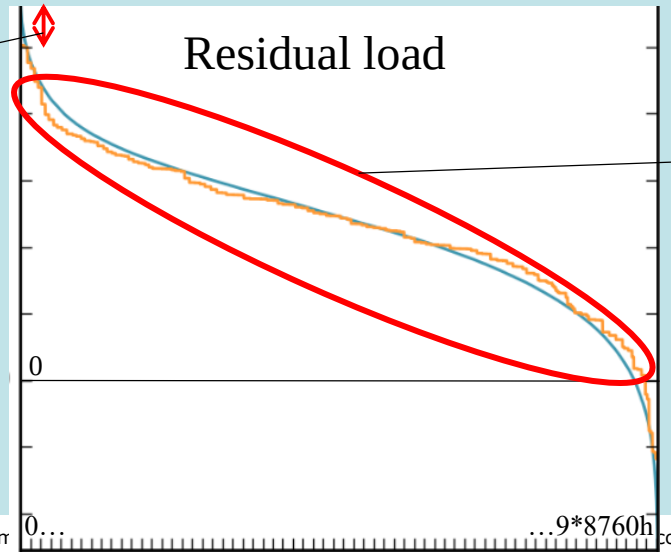
- P. Nahmmacher, E. Schmid, L. Hirth, and B. Knopf, "Carpe diem: A novel approach to select representative days for long-term power system models with high shares of renewable energy sources.," Jun. 2014.
- S. Collins *et al.*, 'Integrating short term variations of the power system into integrated energy system models: A methodological review', *Renewable and Sustainable Energy Reviews*, vol. 76, pp. 839–856, Sep. 2017.

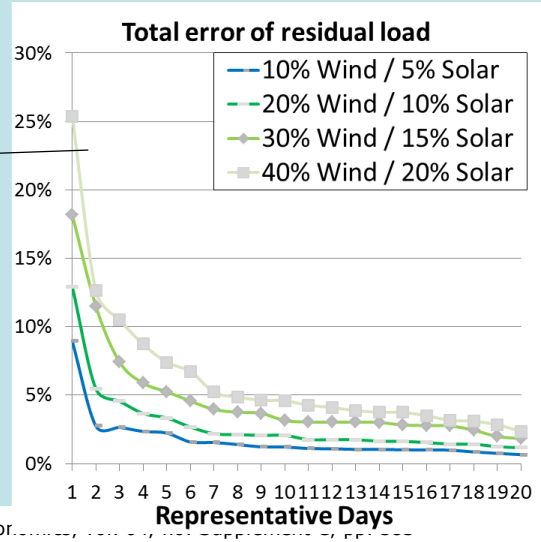
Quantification of the modelling errors induced

- Which criteria?
  - Having enough capacities
  - Good approximation of the expected load factors of future technologies



Correction is applied in capacity planning



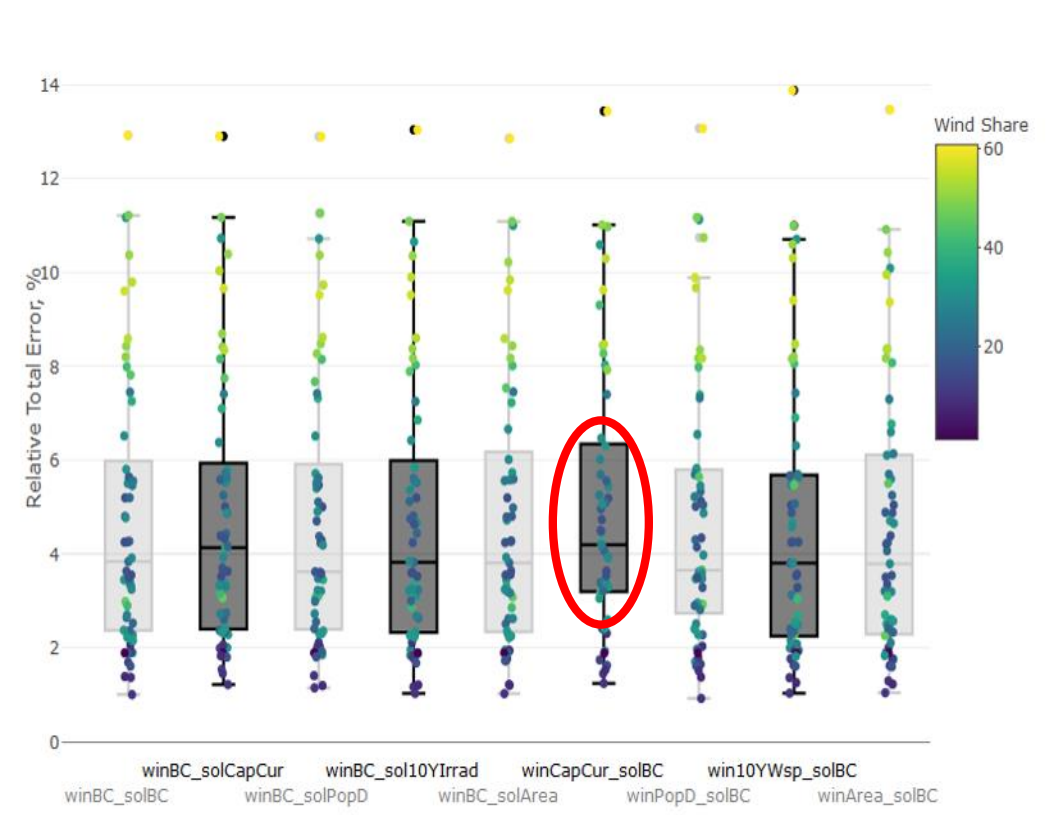


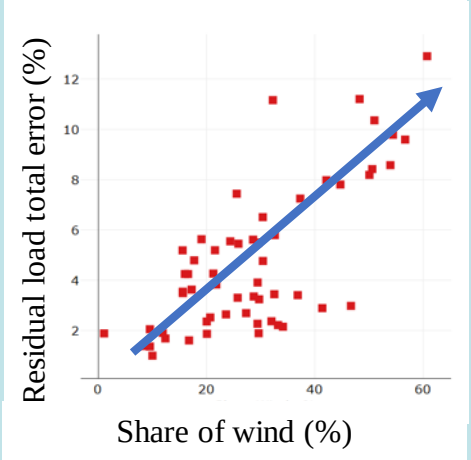
USA example

- R. C. Pietzcker et al., 'System integration of wind and solar power in integrated assessm… 599, May 2017.
- J. Després, "Modelling the long-term deployment of electricity storage in the global energy system," PhD thesis, Université Grenoble Alpes, 2015.
- J. Després, S. Mima, A. Kitous, P. Criqui, N. Hadjsaid, and I. Noirot, 'Storage as a flexibility option in power systems with high shares of variable renewable energy sources: a POLES-based analysis', Energy Economics, vol. 64, no. Supplement C, pp. 638–650, May 2017.
- L. Hirth, F. Ueckerdt, and O. Edenhofer, "Why Wind is Not Coal: On the Economics of Electricity," Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 2428788, Apr. 2014.
- K. Poncelet *et al.*, 'Selecting representative days for capturing the implications of integrating intermittent renewables in generation expansion planning problems', *IEEE Transactions on Power Systems*, vol. PP, no. 99, 2016.

Resulting errors

- Residual load total error:



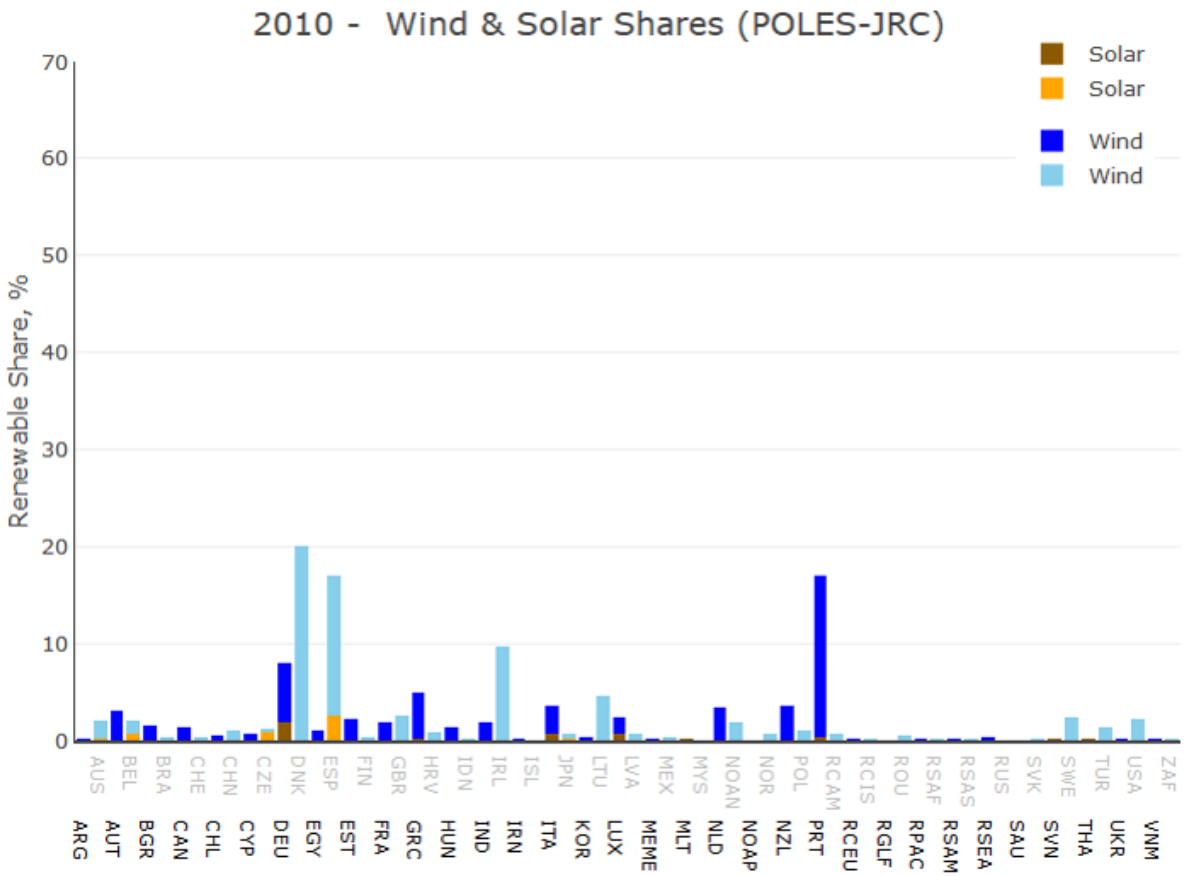


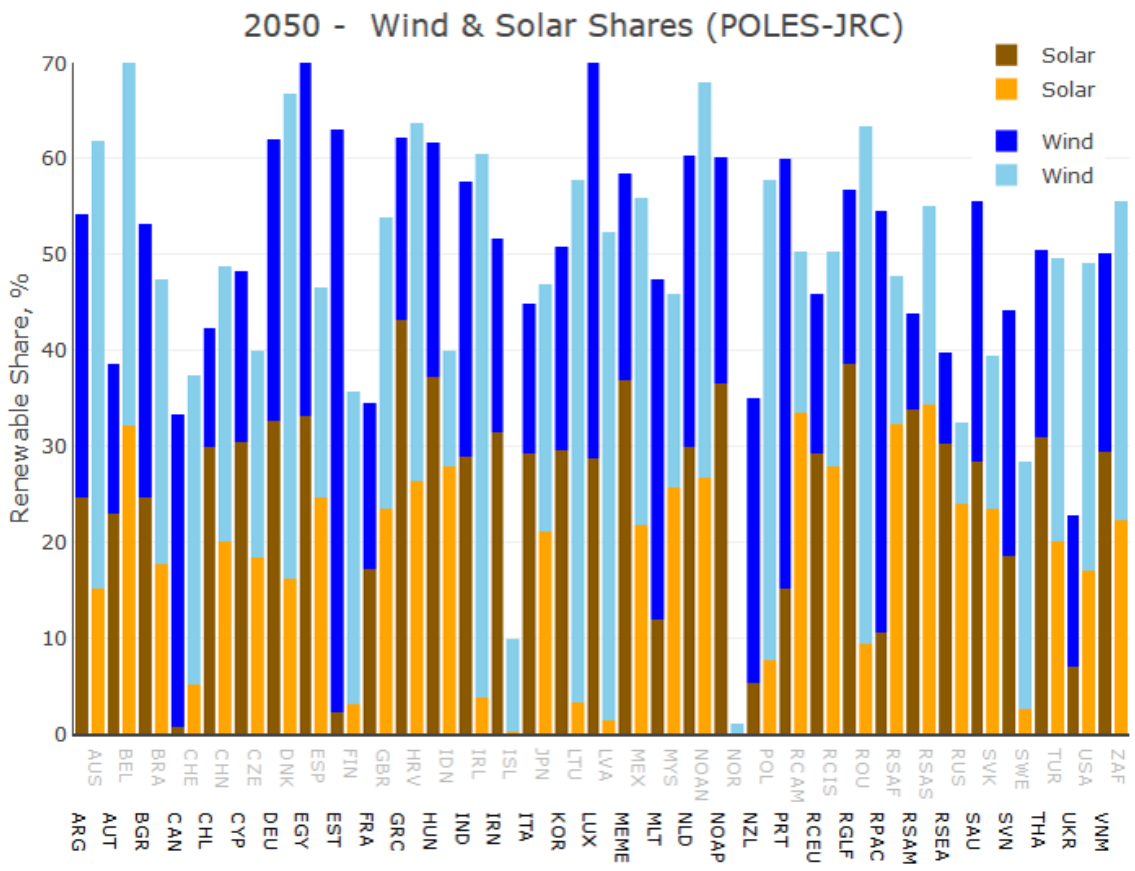
- Wind shares and surface influence more the errors than the geographical distribution chosen
- Current distribution of capacities is the most variable option, leading to higher errors of approximation

Agenda

- POLES model
- Data
- POLES results

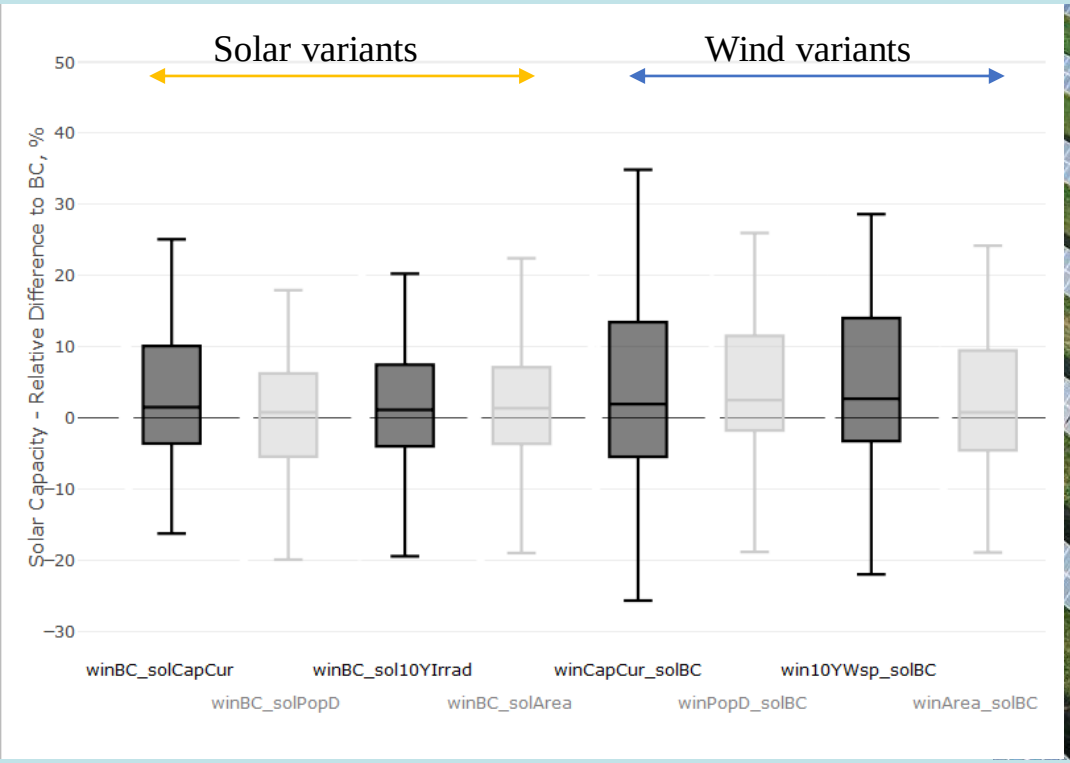
Model results: shares of VRE

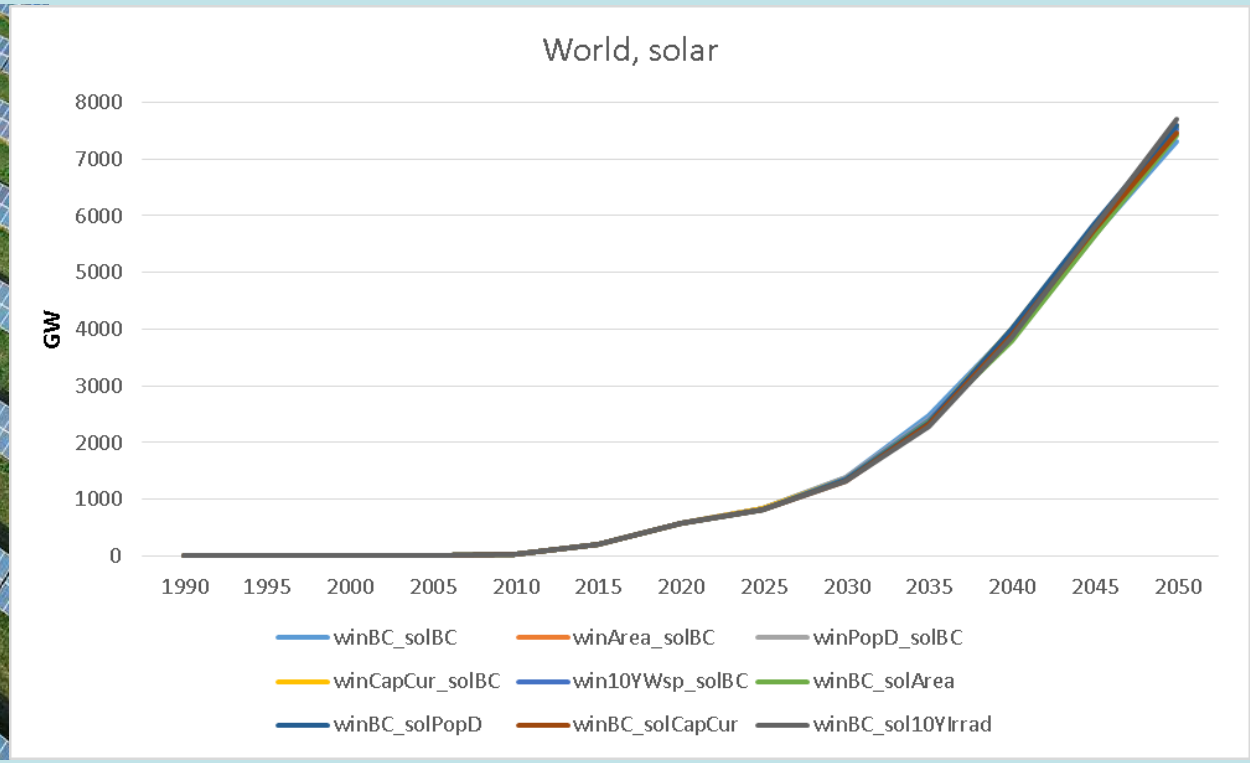




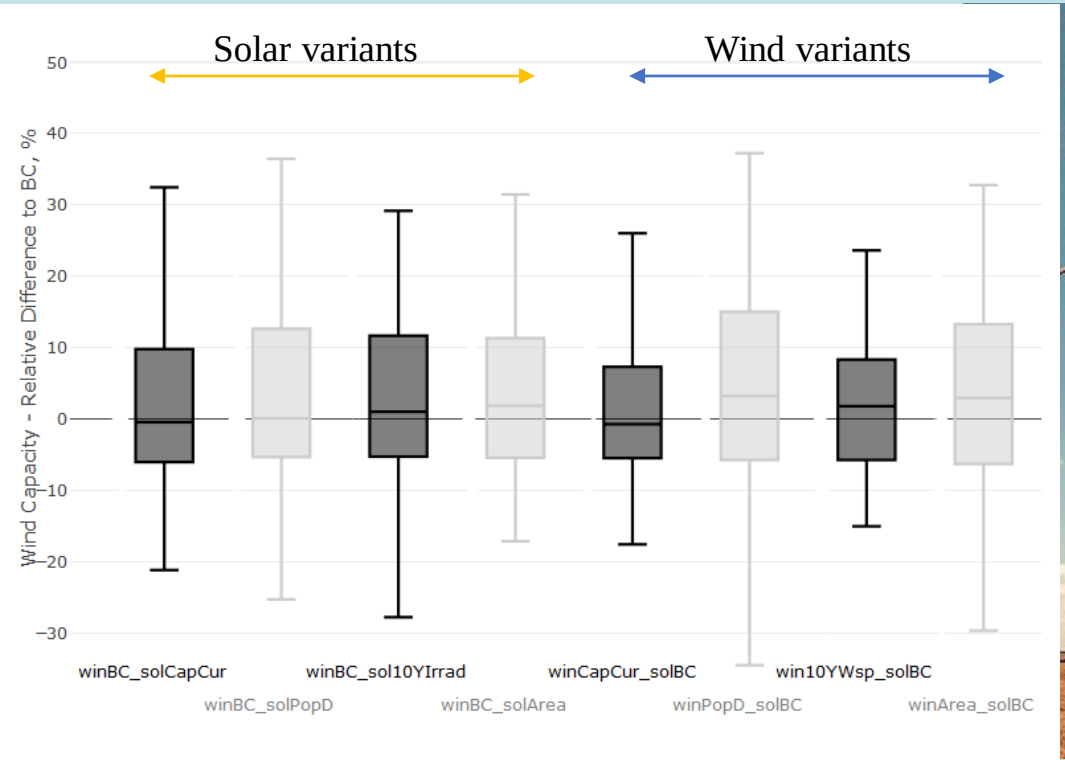
2 degree scenario (limited biomass) – GECO 2018

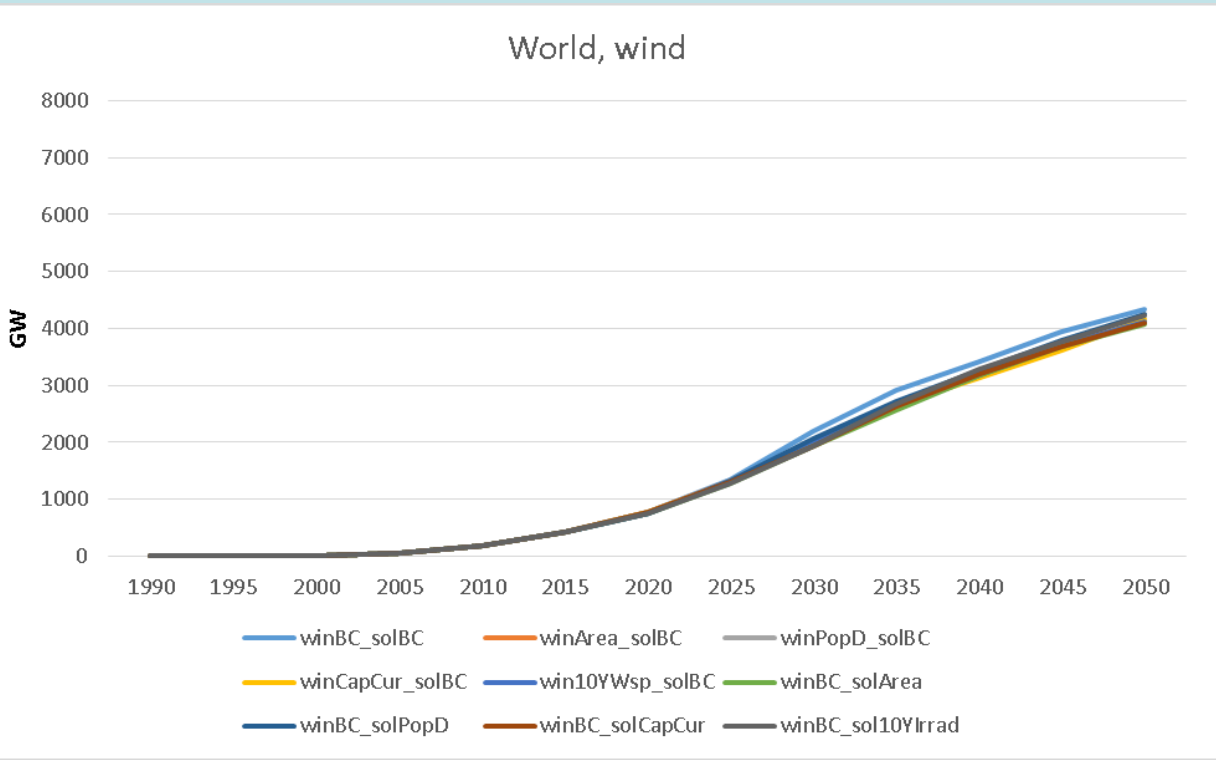
Model results (I): Solar capacities





Model results (II): wind capacities





Remaining challenges

- Clustering methods → importance to peak of residual demand
  - Only clustering? Preclustering for Peak day + clustering?
  - Could reveal some capacity adequacy issues in the operation

- **Grid operation (imports/exports) and planning?**
  - Only partially addressed (lack of spatial-temporal detail)

Thank you

Questions and remarks are welcome!

You can find me at Andreas.schmitz@ec.europa.eu

Andreas Schmitz (data collection and treatment)
Jacques Després (data treatment and modelling)

with special thanks to Alban Kitous (modelling)

European Commission