Climate Change

C3S Energy Webinar
Global Wind and Solar Power Energy Indicators

3 July 2024

“The global solar photovoltaic energy indicator”

Dr Rodrigo Amaro e Silva (ARMINES, ULisbon)
Dr Yves-Marie Saint-Drenan (ARMINES)

PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
IMPLEMENTED BY ECMWF

Goals for this session:

- 🎯 Context on the indicator and environmental factors
- 🎯 Modelling workflow
- 🎯 Undergoing improvements
- 🎯 Expectations for the future

Giving context to the indicator

Capacity Factor:
expected mean power per unit of installed capacity for a given time period

- W/Wp, or any equivalent (e.g., kW/kWp, MW/MWp, etc.)
- Adapts to end-user scenario, since:

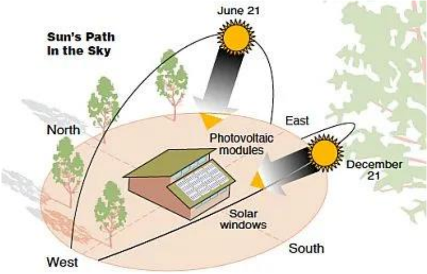
$$PV_{generation} = \text{Capacity Factor} \times \text{Installed Capacity}$$

We calculate this for three streams: historical (1950-present)
seasonal forecasts (6 months ahead)
projections (2015-2100)

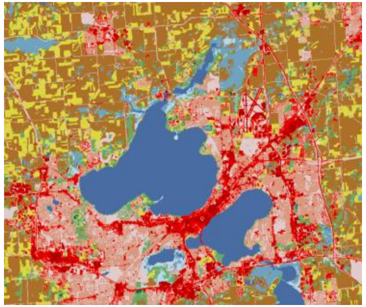
Giving context to the environmental factors

Different levels of dependency towards three main factors

Weather



Angle of incidence



Land use

Current version of PV indicator

Modeling – workflow

Physics-based approach based on CLIMIX model*

Weather data → Modelled regional PV generation time series

↑ PV conversion model chain

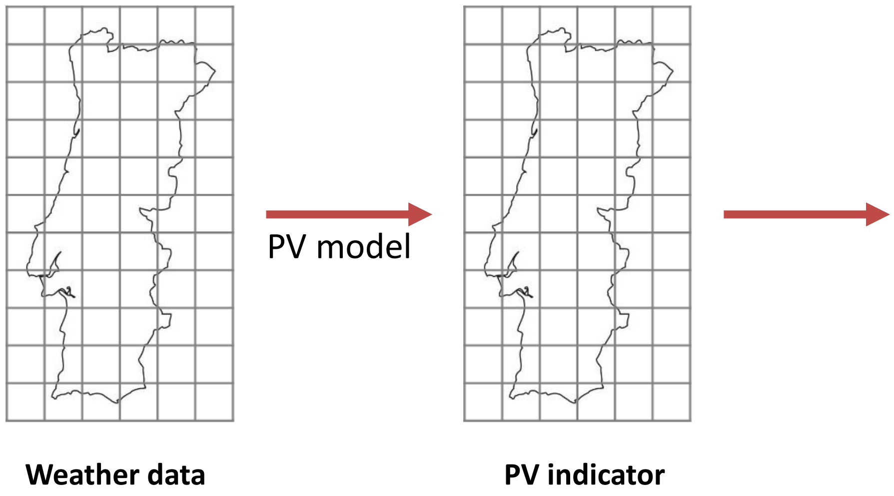
Simple model as a first approach to handle considerable amount of data

- First stage of the service provides only monthly data

* Jerez et al., doi: 10.1016/j.rser.2014.09.041

Modeling – workflow

Physics-based approach based on CLIMIX model



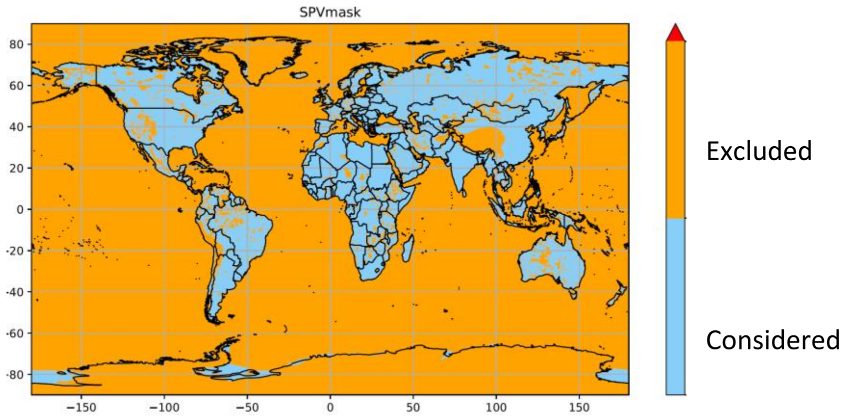
Spatial aggregation*:
- ADMIN0
- ADMIN1

* Depends on considered data stream

Modeling – exclusion layers

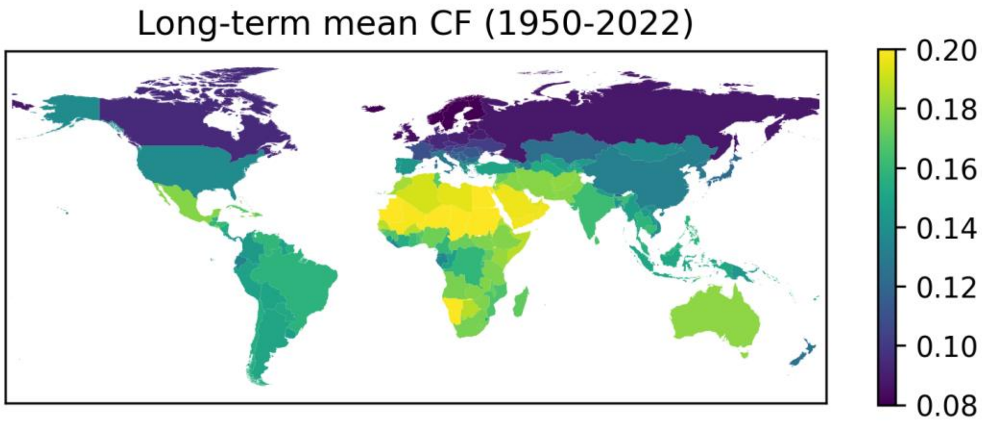
Not all grid cells are considered when modelling/aggregating:

- X Protected areas
- X Water bodies
- X High-slope
- X High elevation



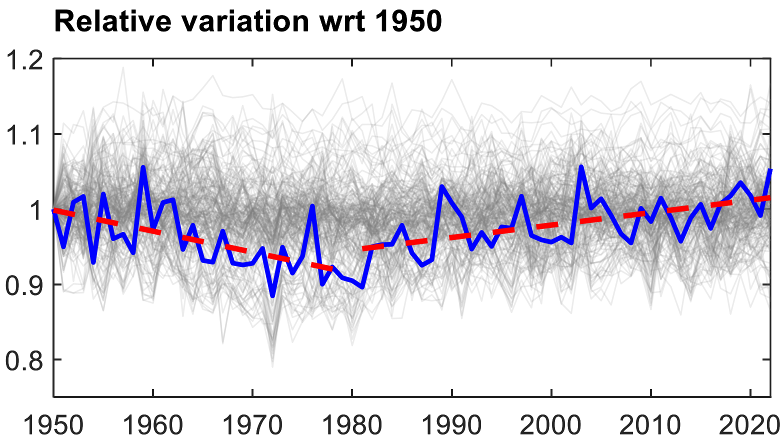
Outputs

Highlighting patterns in space



Outputs

Highlighting patterns in time (e.g., solar brightening and dimming*)



* “Global Dimming and Brightening”, IAC ETH Zurich

Providing hourly data

Undergoing improvements

General modeling

Provide hourly data, using a more detailed physics-based approach*

Weather data → Modelled regional PV generation time series

PV conversion model chain

Considers **PV module orientation**

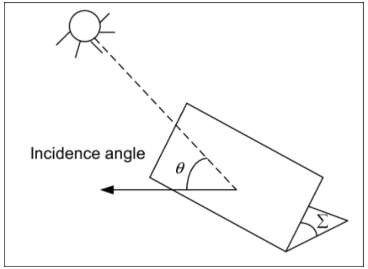
several loss factors (thermal, optical, module and inverter efficiency)

identical exclusion areas

* Saint-Drenan et al., doi: 10.5194/asr-15-51-2018

PV module orientation: an example of a technological factor

Impacts annual yield, but more importantly seasonality



New model considers location-specific distributions*

- Centered in 75% optimal tilt and South orientation
- Based on & expanded from real data from

Image generated in dezgo.com

*More info in annex section

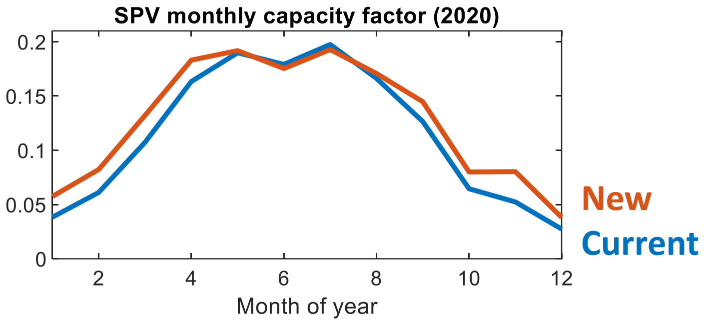
Outputs

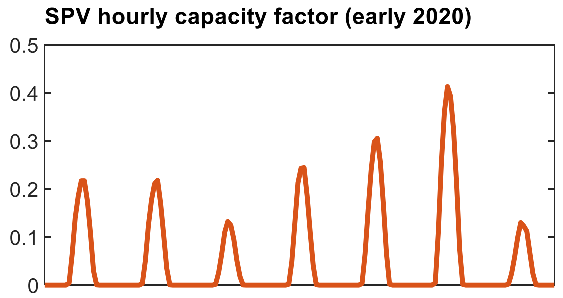
Better representation of the annual cycle:

- More detailed loss factors

Intra-day resolution:

- Daily cycle
- Shorter-term weather





Some computational aspects

Implies considerable number of calculations (in time and memory)

- Large spatial and temporal coverage
- Adding module orientation as 3rd dimension

Great need for optimizing our algorithm

- with ICS we were able to reduce computing time by >75%
- ongoing actions for further improvement

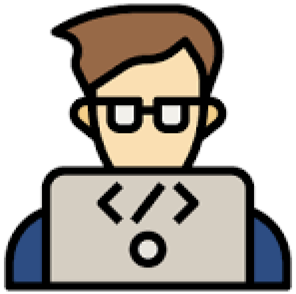


Figure credits: Flaticon.com

Targeting PV typologies

Undergoing improvements

Targeting PV typologies

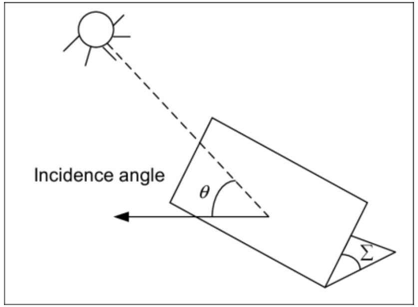
PV can be implemented in various contexts, such as

residential rooftops

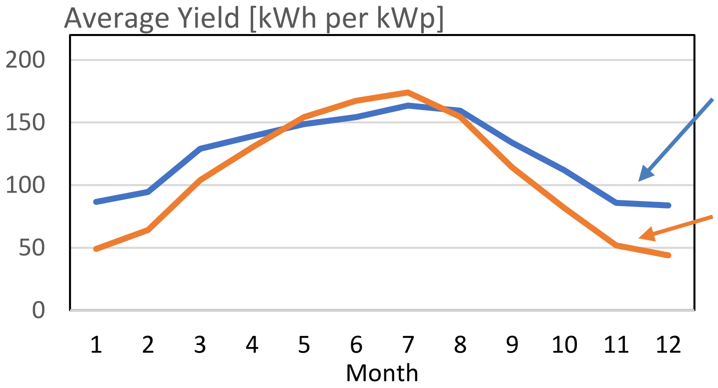
industrial rooftops

ground-based
(with and without tracking)

A matter of seasonality (and yield)



Growth of industrial self-consumption can change regional profile
(annual but also intra-day seasonality)



Also leads to variations in intra-day profiles

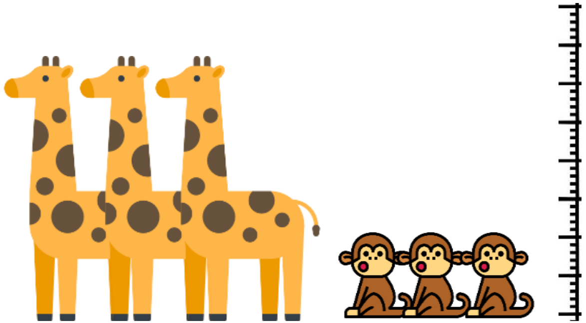
Urban rooftops: different as well

Rooftops in Lisbon

Targeting PV typologies

So, we want to move from a “one-model-fits-all” algorithm

- avoiding overly generic model parameters



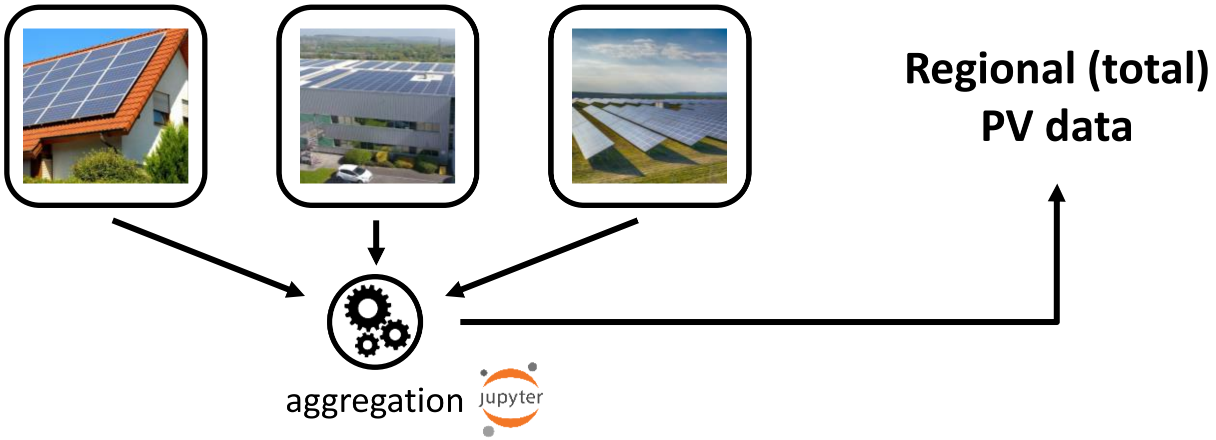
Same as an “animal mean height” would not represent any species individually

Targeting PV typologies

Differentiate segments

- Specific model assumptions (e.g., tilt/azimuth, performance)
- Spatial placement considering land use (e.g., urban vs non-urban)
- For large-scale PV: fixed vs single-axis tracking system

Redesigning PV model framework



Increasing accuracy but also modelling flexibility (consider tech. scenarios)

Conclusions

Conclusions

🛠️ Added value of C3S2 Energy contract

- **regional PV timeseries** for end-users to assess the **impact of climate change**
  - robust and interpretable
  - iterative product, **continuous improvement** mindset
- **contribute to science** through method and review papers (undergoing)
- Benefits from interactions with **ENTSO-E*** and **IEA PVPS Task 16**

+ From another contract

What's to come (shorter-term)

- SOON Monthly data to be made available in Copernicus platforms
- Already working towards hourly, more accurate modelling

- ⌛ Providing data for specific typologies (residential, industrial, utility-scale)

- ⌛ Allowing end-users to make similar calculations for their own PV installation

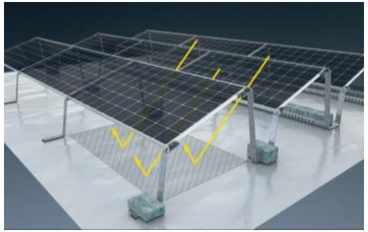
+ From another contract

What's maybe to come (longer-term)

- Consider additional typologies
- Validating & refining exclusion zones (e.g. per typology)

(floating PV)

(PV balcony)

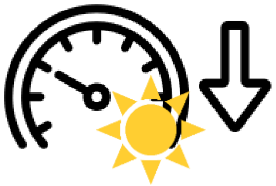


(bifa cial PV)

What's maybe to come (longer-term)

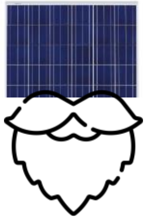
- Consider non-weather factors impacting PV output

Storage



Curtailment

Soiling



Aging

MINES PARIS | PSL

ARMINES

Thank you for your attention.

rodrigo.amaro_e_silva@minesparis.psl.eu
yves-marie.saint-drenan@minesparis.psl.eu