Le réseau
de transport
d'électricité

Adaptation of the French Transmission Network to Climate Change

Summer school Energy, mathematics, and theoretical challenges
30 September 2024 – Class 2

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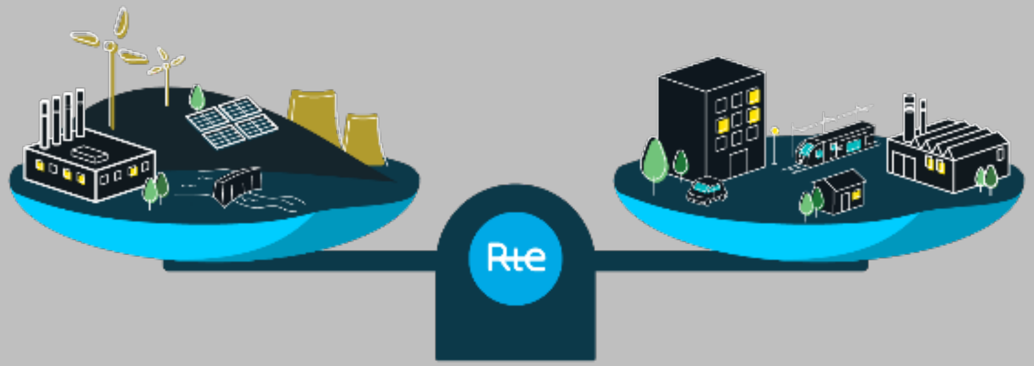
Thanks to Catherine Lelong, Bénédicte Jourdier, Erik Pharabod (RTE) and Alberto Troccoli (ICS/C3S)

Weather and climate impact the transmission power network

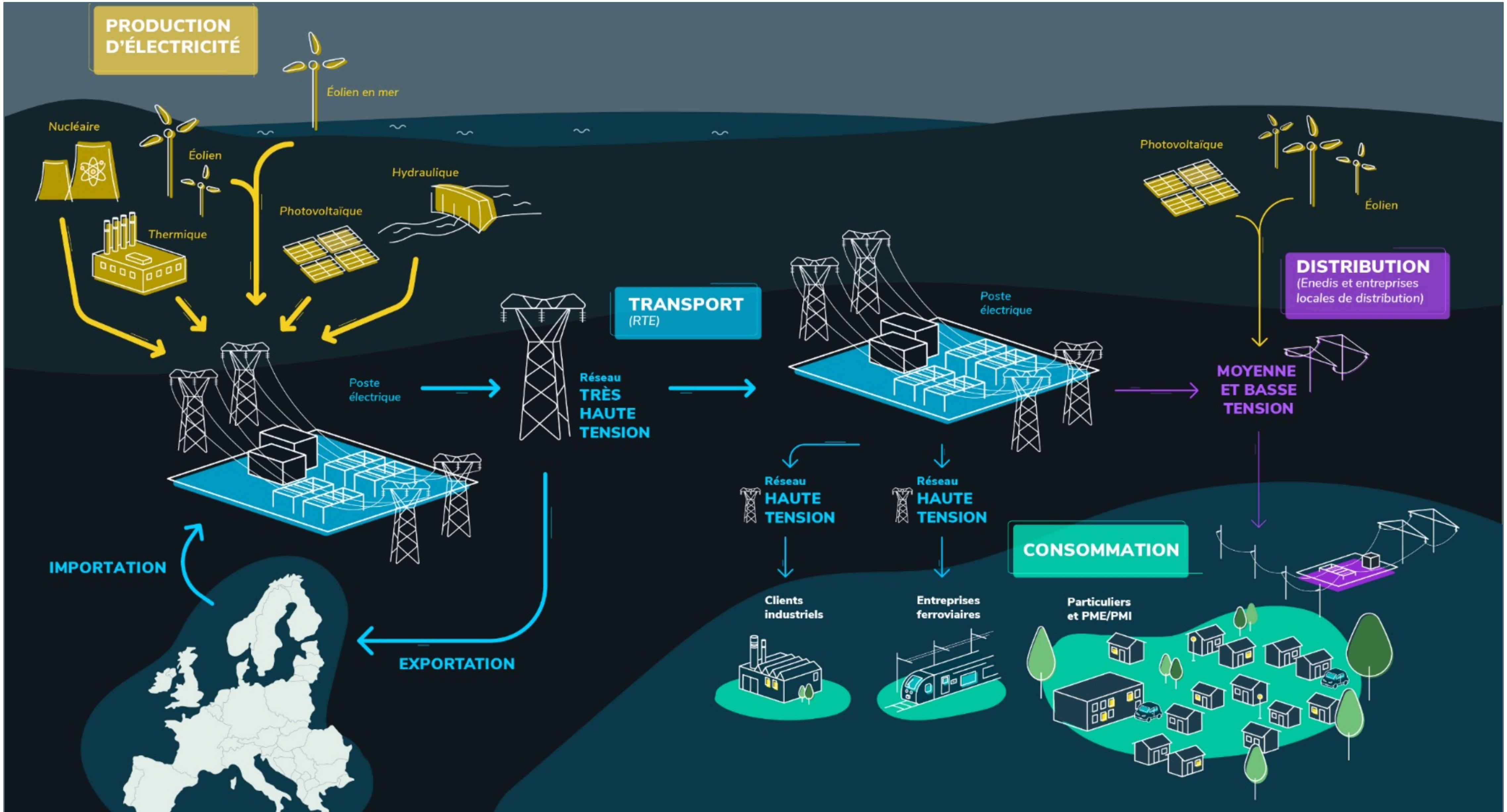
Supply/Demand Balance

Resource adequacy



Climate change and the rising share of renewables increase the dependence of power systems to climate variability and climate change

Each actor of the power system is responsible of its own adaptation



1. Resource adequacy

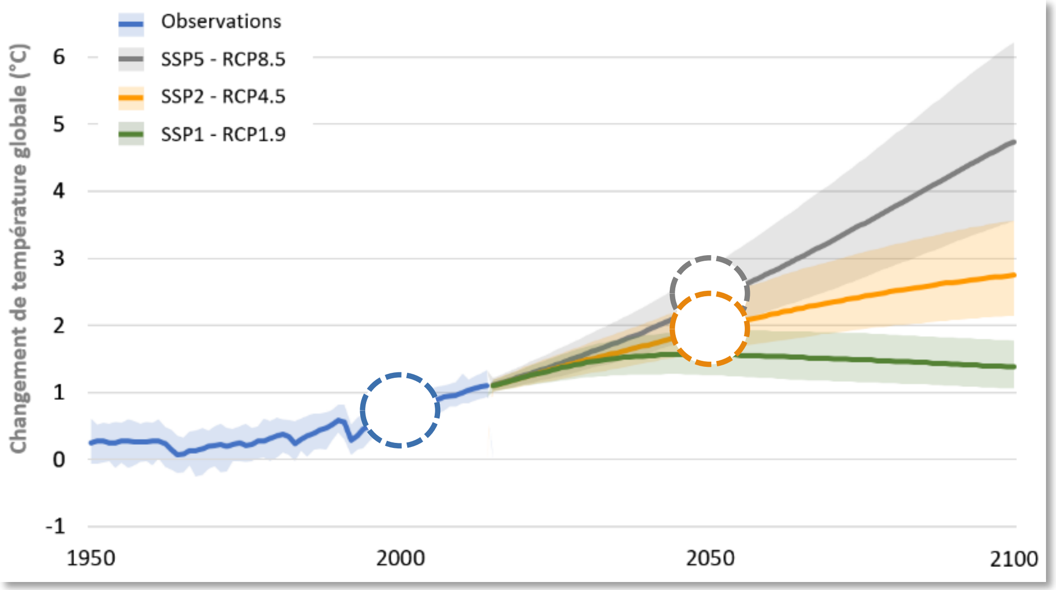
2. Resilience and adaptation of infrastructures

3. Climate change and workers

4. Current activities

Climate modeling at RTE, current approach

- Dedicated climate simulations provided by Météo-France, based on ARPEGE Climat v5 (CMIP5)
- So-called « constant climate simulations »
- Representing **3 different climates** :
  - **Climate 2000s**
  - **Climate 2050s – RCP 4.5**
  - **Climate 2050s – RCP 8.5**



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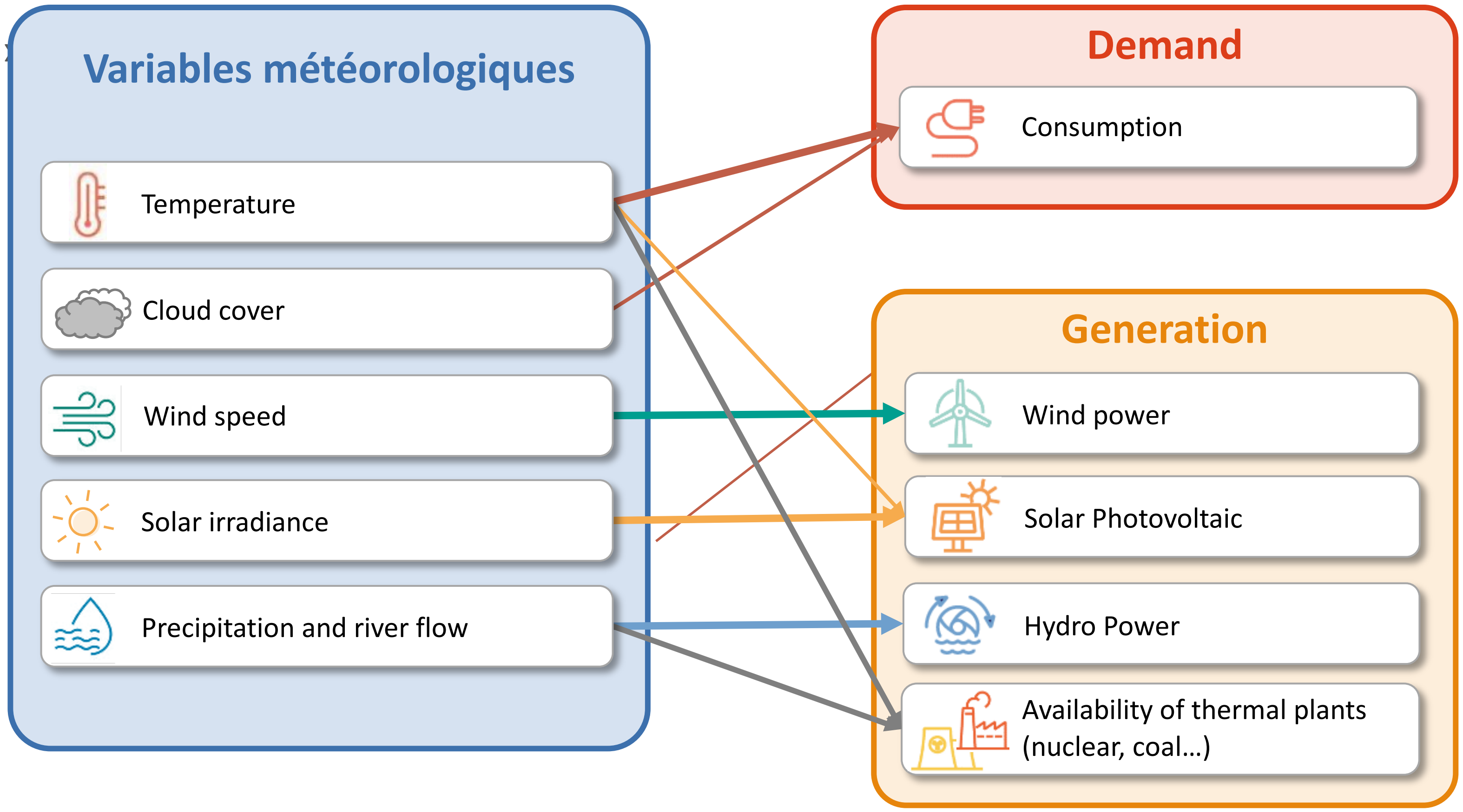
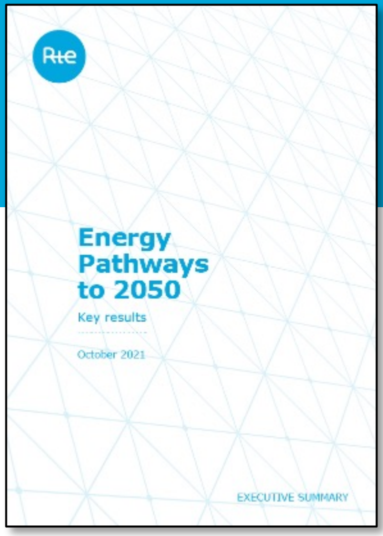
  - **Climate 2050s – RCP 8.5**

For each simulation set

- 200 fictives years (fictives) with 1-hourly timestep
- All over Europe
- All variables necessary for power systems simulations



Long-term adequacy studies



Demand and electric uses

Evolutions : equipment rate, efficiency, new uses, economic activity…

Climate Reference

Meteorological time series
temperature, wind, solar irradiance, cloud cover, precipitations/river flow

200 years
1-hourly timestep
European domain

Demand modeling

- Demand power curves

Generation modeling

- Wind / Solar
- Hydro
- Availability of thermal plants

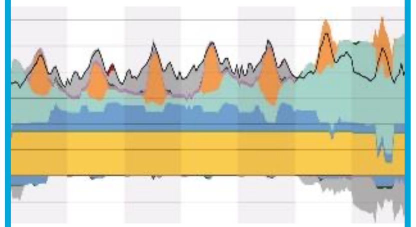
Production means and flexibilities

Assumption on installations : capacities (GW), localisation, technologies

Simulation of offer/demand balance

Economic Optimisation
Of the generation program, storage and other flexibilities

1000 ans 1-houry timestep
200 climate years
x 5 outage scenarios



antaressimulator

Results

- Energy balance
- Imports/exports
- Security of supplyt
- Generation costs
- CO_2 emissions
- …

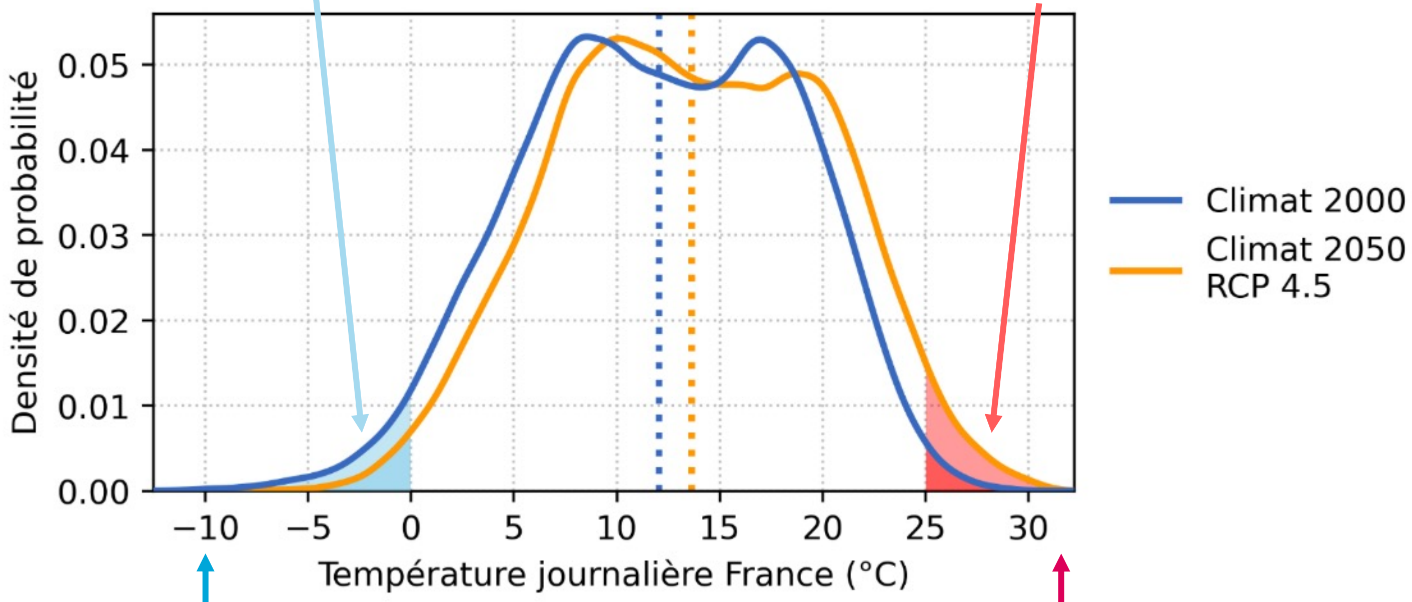
Climate Impacts | Temperature ➝ Electricity Consumption

Evolution of **temperature** (average over France) :

2,5 x less very cod days (T < 0°C)

+1,6°C on average ➝

4,3 x more very hot days (T > 25°C)



Less cold extrêmes … but still possible

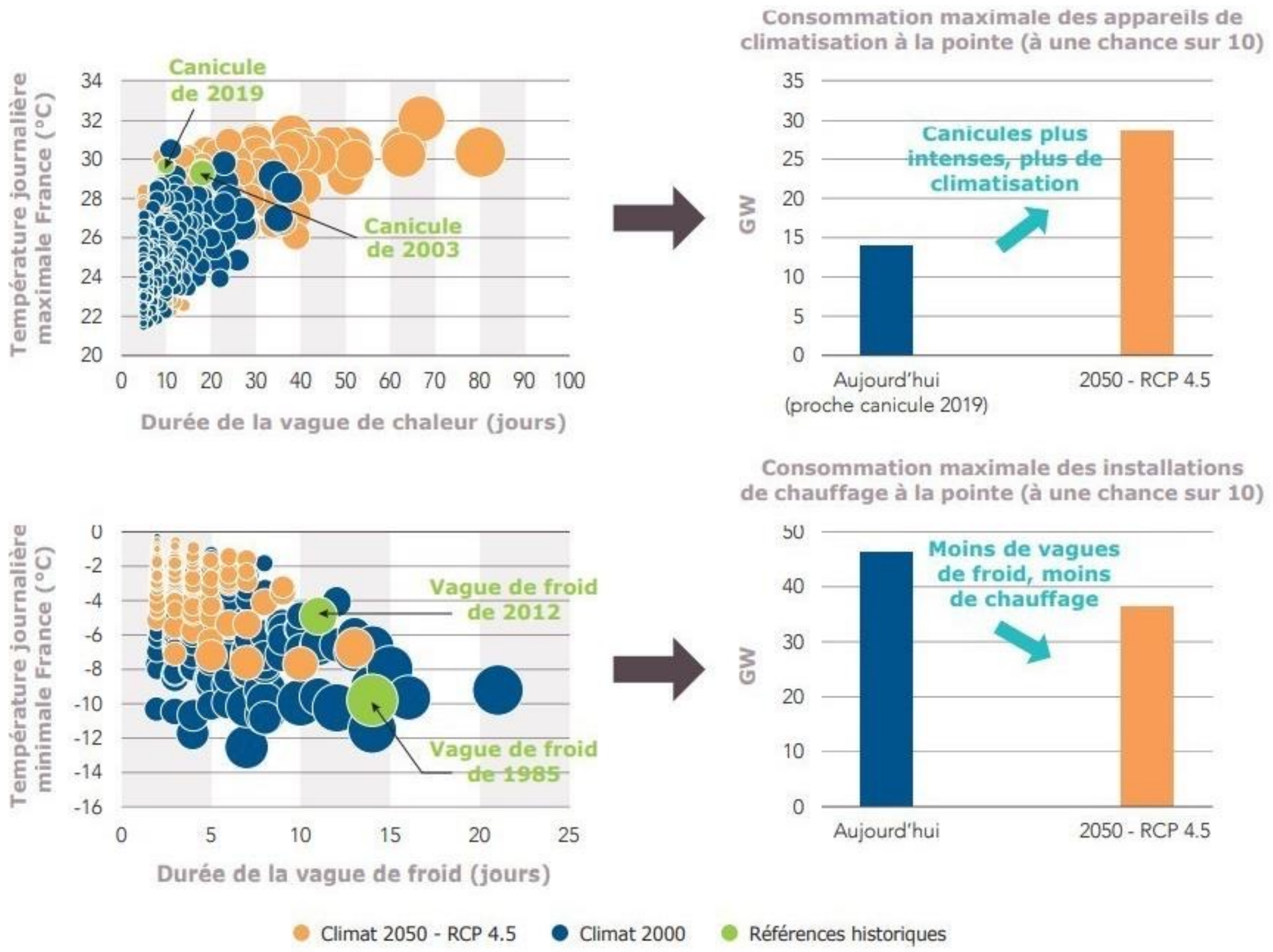
New hot extremes

- Impacts on **consumption**:
  - less heating
  - more cooling
- Reinforced by structural evolution:
  - More energy efficiency for heating equipments
  - More cooling devices
- Peak consumption:
  - Less important in winter
  - 2 x more important in summer

Impacts on demand

Summer Heat waves

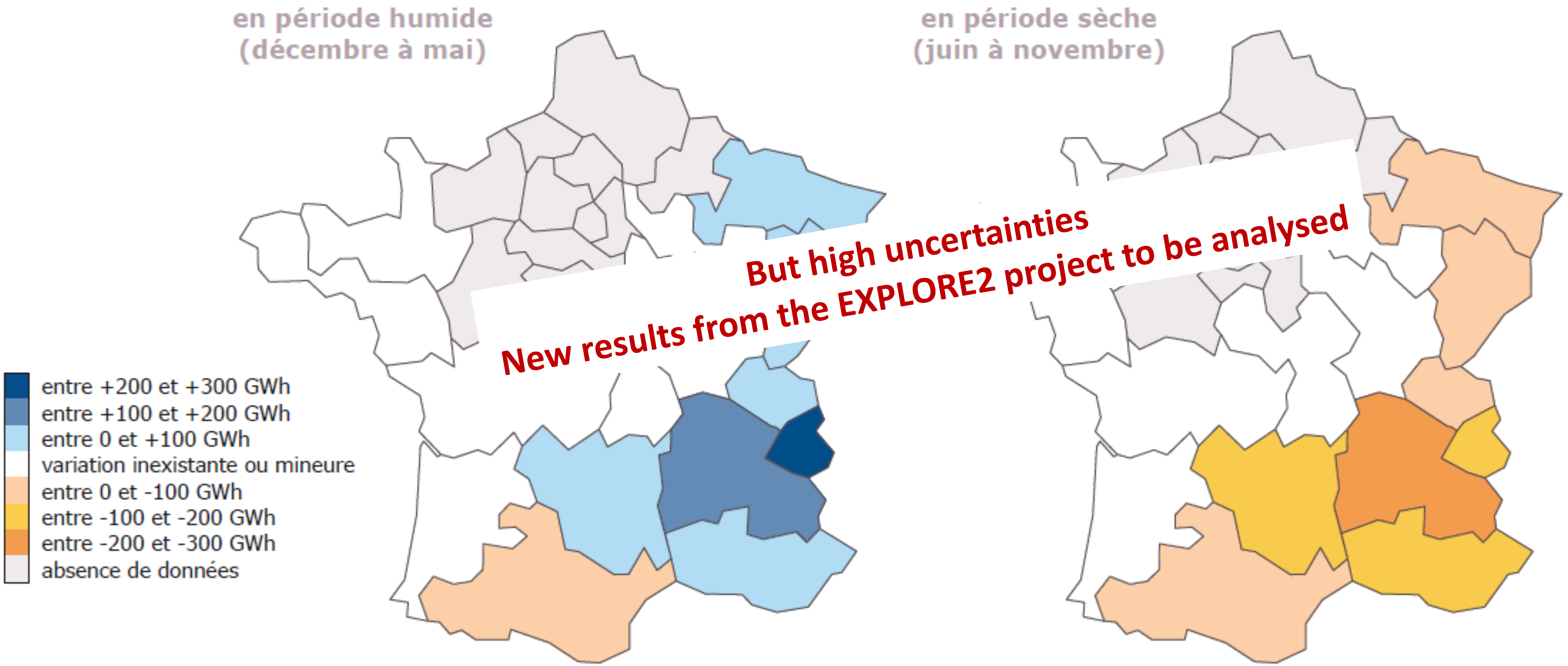
Winter Cold waves



Increase in cooling needs

Decrease in eating needs

Climate Impacts | Precipitations & river flow → hydropower generation



Extended winter: production increase

Summer/autumn : production decrease

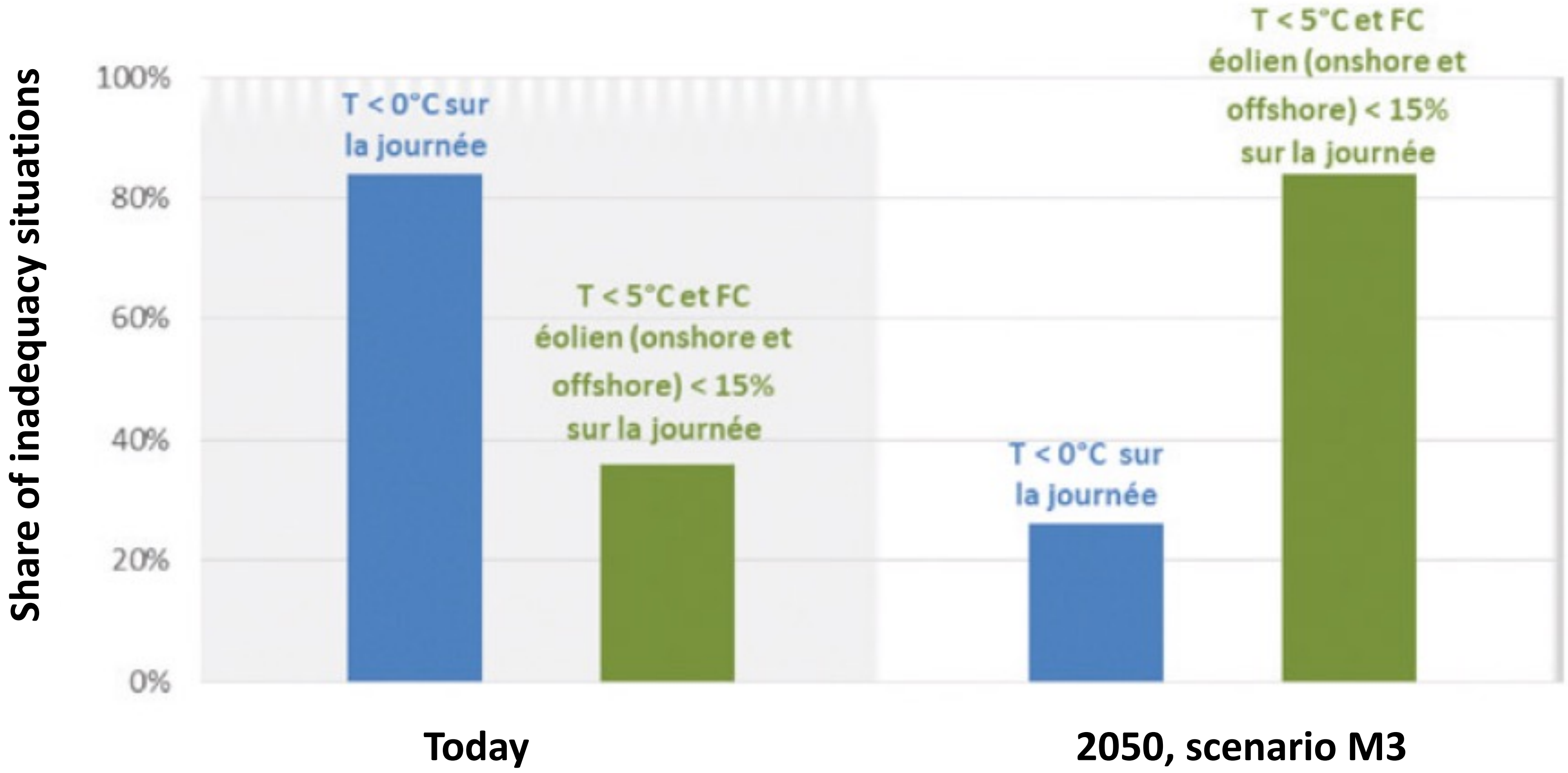
A moderate impact of climate change on wind and solar generation

Marginal change of the wind generation capacity factor, but an increase thanks to offshore wind farms development

No detected change in the solar capacity factor, but might be impacted by the nature of the new installed generation (rooftop, industrial, large ground plants with or without tracker, and PV panels technology)

The power system of the future will have a to deal wi the different risks compared to today (see next slide)

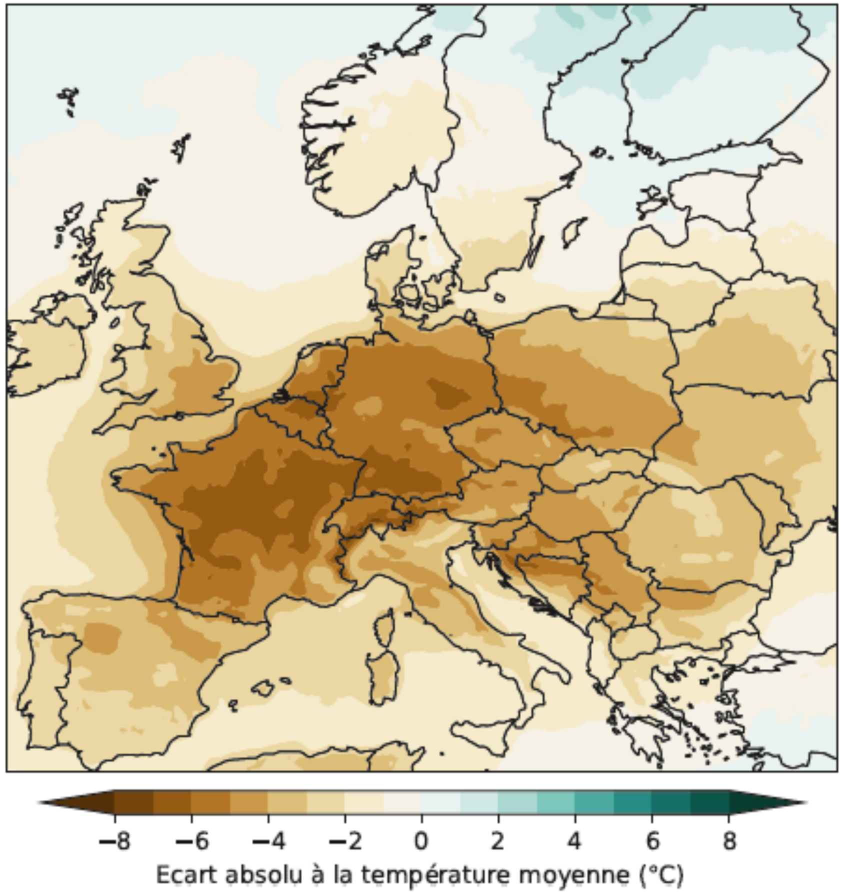
The nature of risks and their timing in the year will change



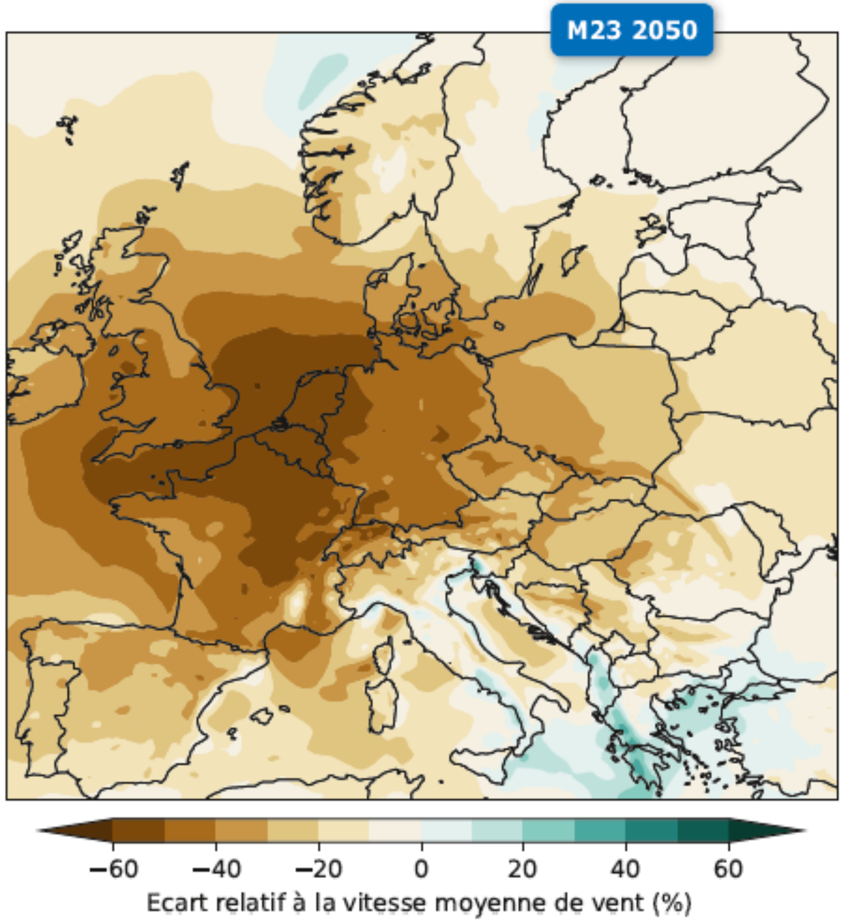
Risk = extreme cold
January/February

Tomorrow = moderate cold + wind drought
November to March

Typical temperature and wind speed anomaly during inadequacy events



Temperature anomaly composite

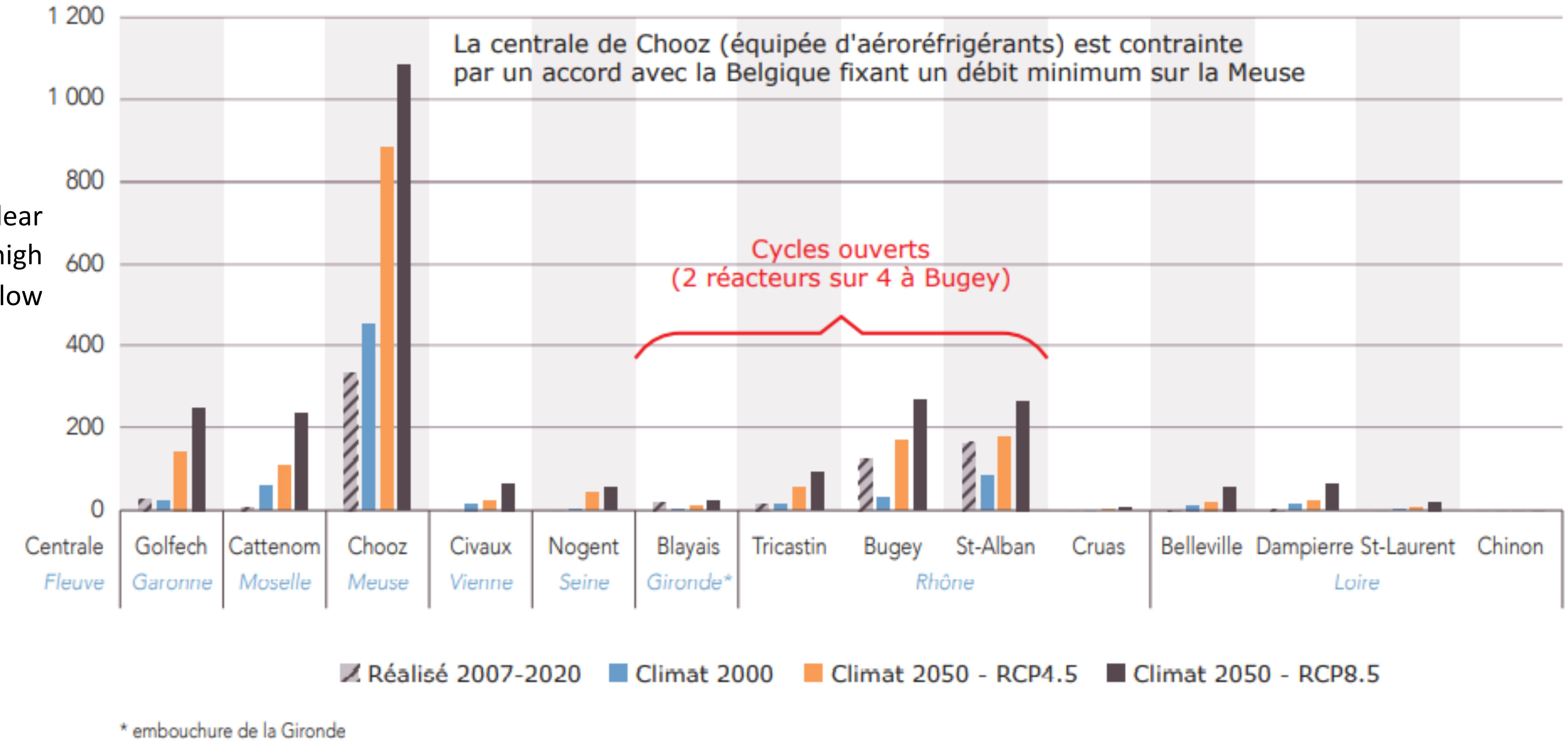


Relative wind speed anomaly composite

Anomaly = inadequacy days vs all winter days

Summer: Potential decrease in nuclear plants availability

Annual decrease in nuclear generation (GWh) due to high river temperature and/or low river flow



Summary

The « energy pathways to 2050» study considered:

- The weather variability
- Climate scenarios with 2 RCPs
- The electric mix including in particular more wind and solar installed capacity

Some uncertainties remain, including

- Hydro power :
  - evolution of precipitation and river flow
  - Water uses potential conflicts
- Infrastructures : network management under very high temperatures

Key fundings from the study:

16 By 2050: it will be possible for France to develop a power system adapted to carbon neutrality while keeping costs under control

17 By 2030: developing renewable energy sources as quickly as possible and extending the lifetime of existing nuclear reactors in order to maximise low-carbon generation, will increase the chances of reaching the "-55% net" target set in the new European package

18 Whatever the scenario considered, action cannot be delayed

Where are there maths here in?

Power/demand supply balance and resource adequacy study ➔ large optimization problems:

- Physical system
- Economical viability assessment for best investments decisions
- …

Adaptation of climate information to the sector’s specific needs ➔ many post processing step

- Temporal interpolation
- Spatial interpolation
- Models’ bias adjustment
- Models’ validation and evaluation …

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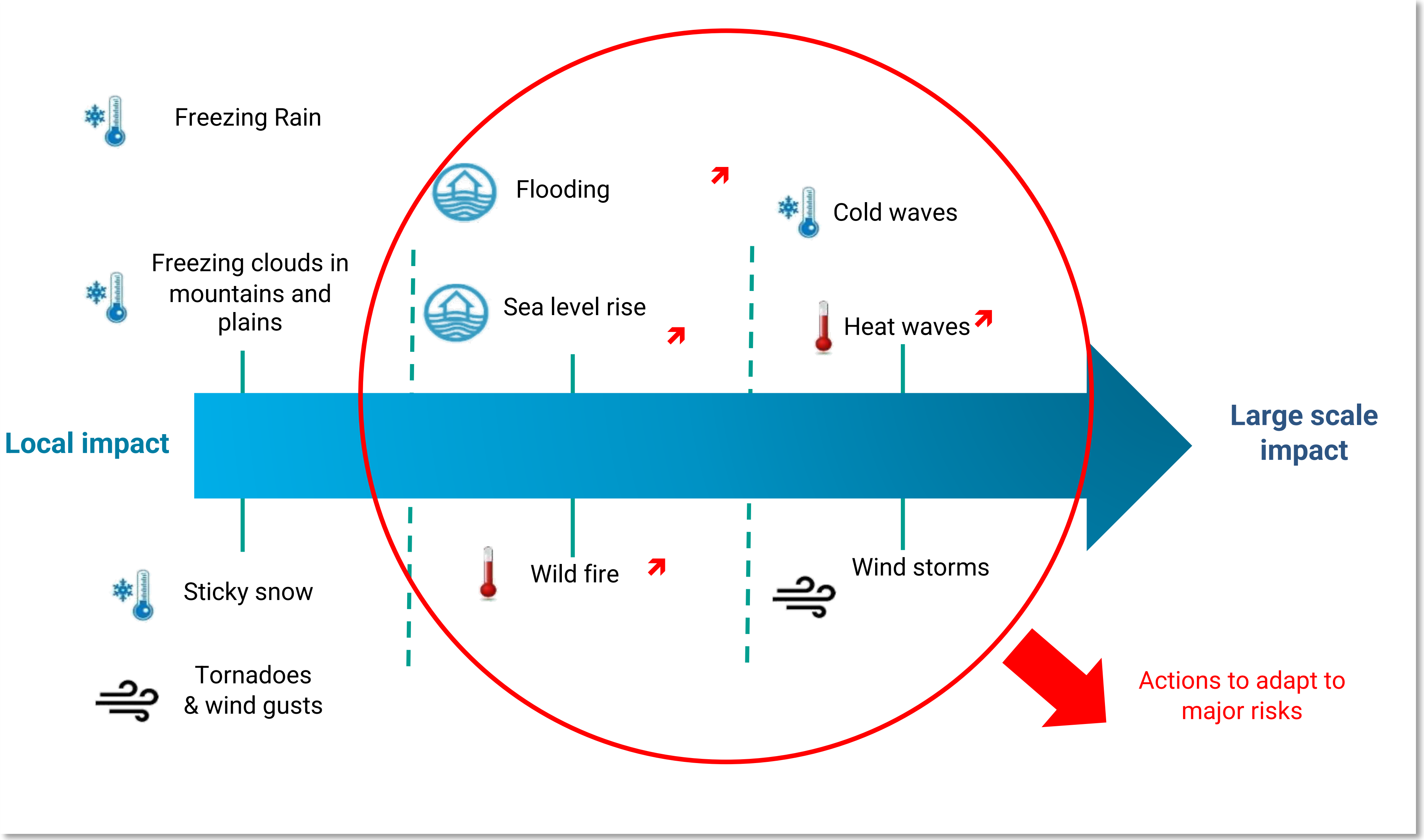
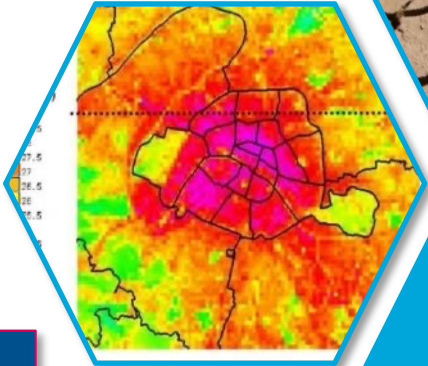
Mapping of risks and priorisation of activities



Impacts of climate change on infrastructures

The **RESILIENCE** project

Droughts



Heat waves

Flooding

Sea-level rise

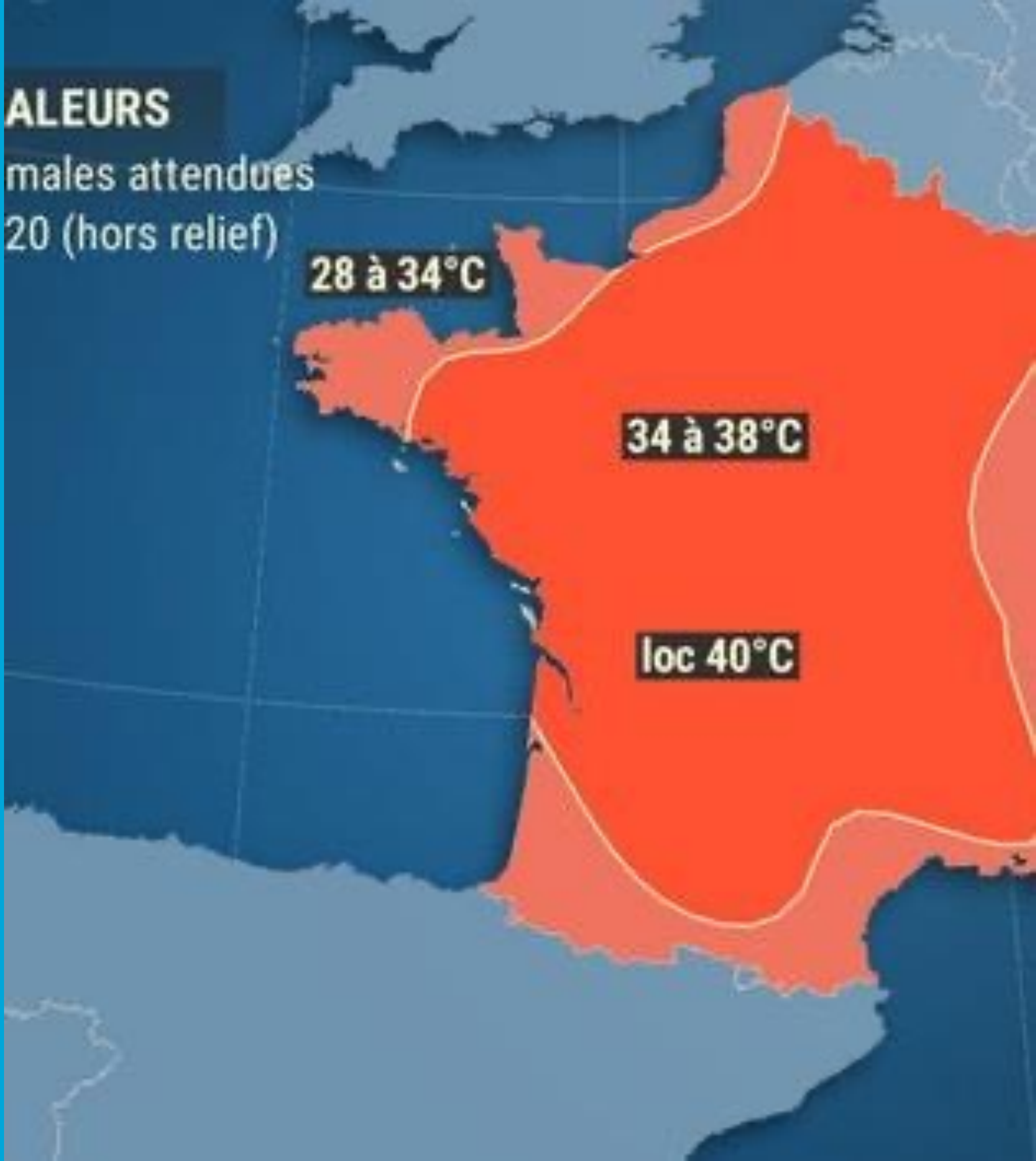
1

Adaptation to heat

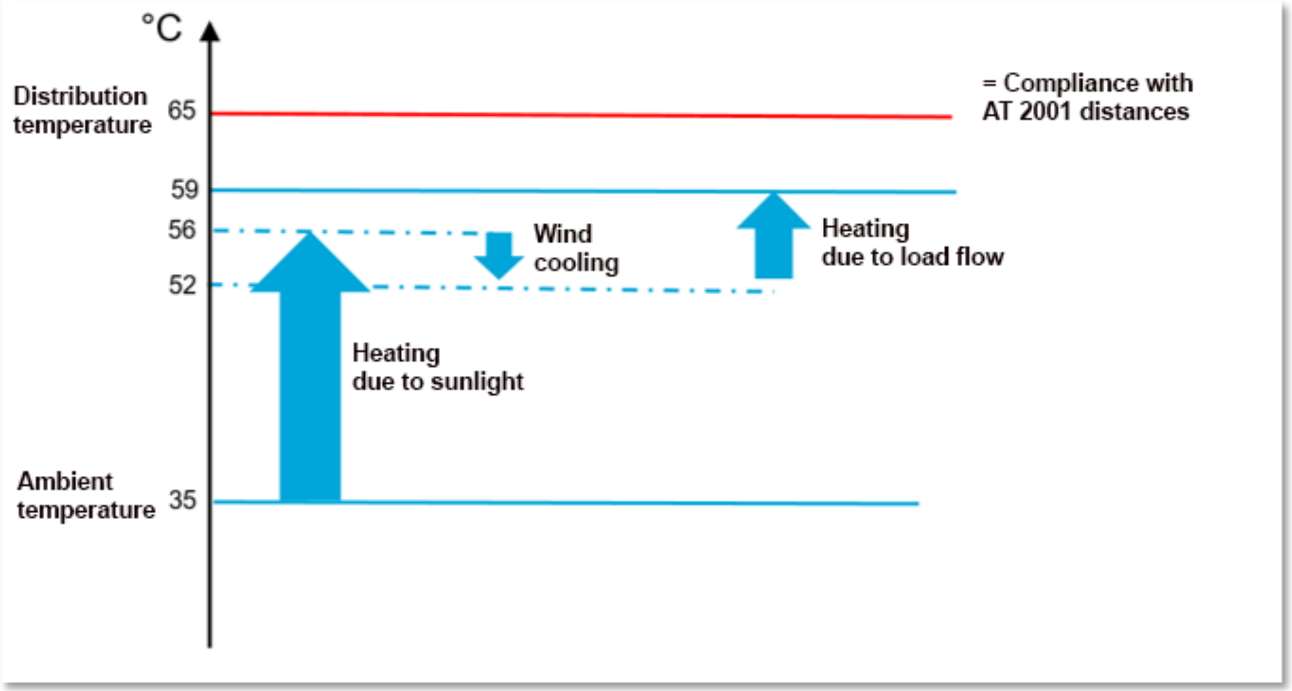
Increase in mean temperature

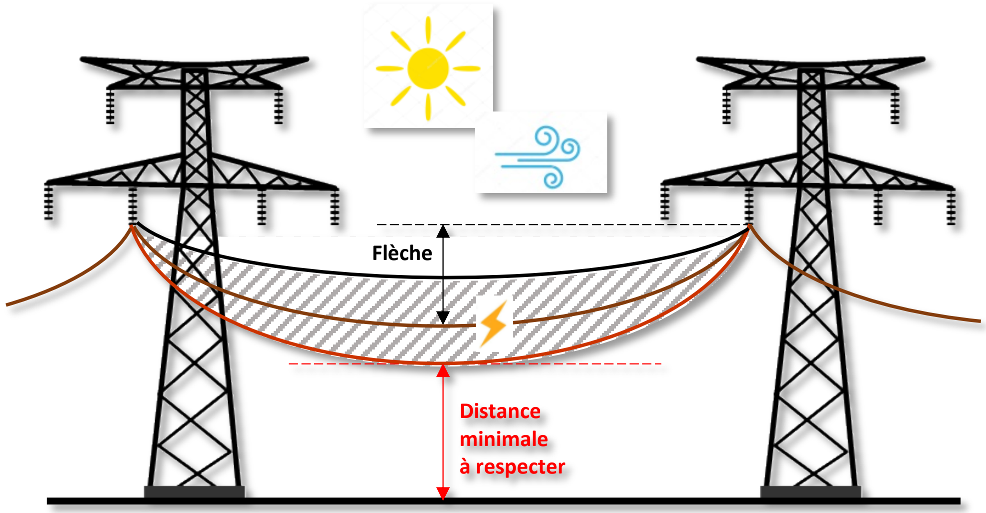
Heat waves

Droughts



The main problem with very hot weather is the operating temperature and load flow capacity of overhead power lines





Above a certain ambient temperature, a cable heats up and expands under the effect of the sun and the current flowing through it (load flow). It is cooled by the wind.

There is a risk that distances will be compromised if the load flow on the line is high AND if the weather is unfavourable (high ambient temperature, low wind, strong sun).

Historically, some older structures were designed for a maximum temperature of 45 °C.

Integrate the warming already observed in today's climate: RTE continues to treat overhead lines affected by the hot weather

Hot weather plan

- The plan concerns some 1,200 identified power lines, for which the operating temperature is around 45 °C and which, with their historical load flows, do not respect the required distances in the event of very hot weather.
- On these 1,200 power lines: application of a reduction in load flow capacity in summer when the ambient temperature around the line exceeds 35 °C, between June and August.

Overhead line resorption at 45 °C

- Around ten priority power line are subject to customer constraints (on both production and consumption sites): studies are in progress to increase operating temperatures or to analyse the need with the customer.
- The rest of the stock is treated in the course of refurbishing these structures, with an increase in the operating temperature at the end of structure's life.

Changes to requirements for new and refurbished power lines: first decision in **2019**

- In 2019, decision to rebuild with a minimum operating temperature of 65 °C (identical rebuild previously).
- Investigation of a further increase in minimum temperature as part of the Resilience project.

In December 2022, RTE decided to raise the operating temperature for new or refurbished structures to 85°C in anticipation of the future climate

Following the work of the Résilience project, which showed that the temperature of 65 °C was not sufficient for temperatures in the 2050-2100 timeframe, RTE decided to increase the minimum operating temperature for new or refurbished structures from January 2023, for all projects on which design work has not yet been initiated, or when appropriate if they are in progress.

Nature of the structure		Specified operating temperature until 2022	New specified operating temperature on 1/1/23
New or rebuilt structures	400 kV	90 °C	90 °C
	225 kV	75 °C to 80 °C	85°C
	90/63 kV	65 °C	85°C
Refurbished structures		Minimum 65 °C	80 °C to 85°C unless an exemption is granted to lower the temperature to 75 °C

Part of this increase in temperature (10 °C) will be allocated to climate change, not for additional load flow capacity. A benchmark has shown that the other TSOs are in the same process of raising requirements.

2 Adaptation to wild fires

Fires are already becoming a concern throughout the south of France

Limiting impacts in today's climate

- Legal obligations to clear undergrowth
- Starting in 2019, construction of a database of overhead power lines that have suffered a fire to monitor possible failures (melted grease) or premature ageing of conductors over the long term.
- Network operation: extension of the relationship with fire-fighting services, which has long existed especially in south-east (Mediterranean coast and Riviera) and south-west of France (forest of Landes on the Atlantic coast).

Anticipating the risks of ignition in a future climate

- Are there any high-risk materials? First stage of capitalising on data based on specific cause analysis feedback.
- If any exist, the aim is to cross-reference materials that could pose a problem with a map of fire risk in a future climate derived from the Copernicus database (studies are in progress).

3 Adaptation to flooding

Coastal flooding and coastline erosion

Run-off and mud flows

River overflow

At present, the risk of flooding is taken into account in town planning regulations, which are based on historical flood data

RTE protects itself against historic floods

- Design of new substations based on the PPRI (Flood Risk Prevention Plan) is a regulatory obligation.
- Case-by-case analysis of substations/pylons built before the existence of the PPRI: for example, securing the Trans-en-Provence* substation against overflowing, Paris substations**, securing the Boutre-Tavel axis, etc.
- Preventive organisation for existing sites located in at-risk areas, in conjunction with flood prevention services (flood warning maps, local information bulletins)

Technical solutions exist

- For existing substations (watertight doors, water barriers)
- For new substations: upgraded sensitive parts (instrumentation and control) or the entire substation
- For pylons: relocating pylons and rebuilding foundations



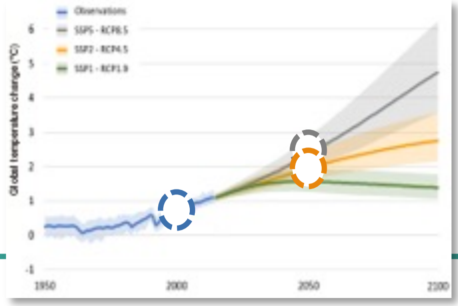
*** Paris Javel substation*

** Trans-en-Provence*


The french Central Reinsurance Fund (CRF, or CCR in french) has calculated the flood risk exposure of all RTE substations and pylons

Use of different parameters for different hazards

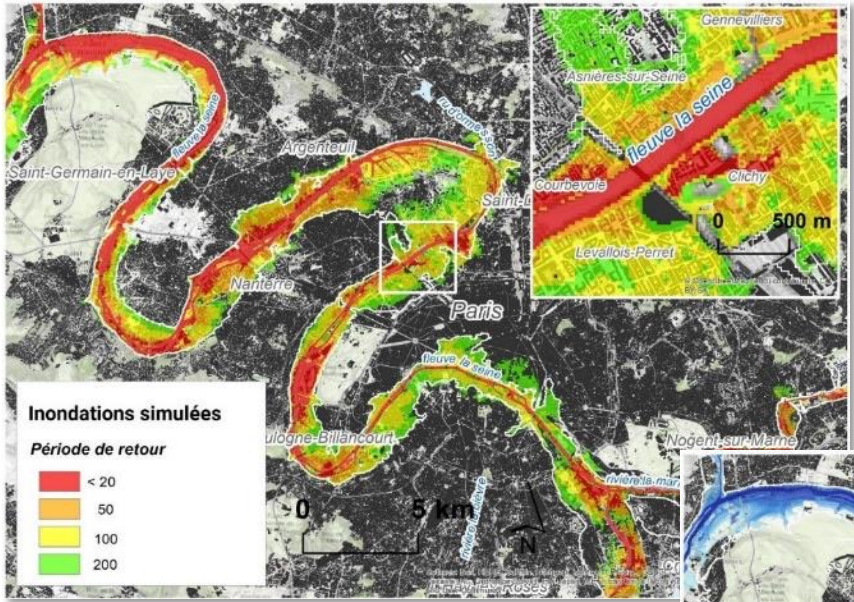
		Water height		*Flow*		*Flooded area*		*Soil erosion*	
Overflow		✓	✓	✓	✓	-	✓	✓	-
Run-off		-	-	✓	✓	-	✓	✓	-
Coastal flooding		✓	✓	-	-	-	✓	✓	-

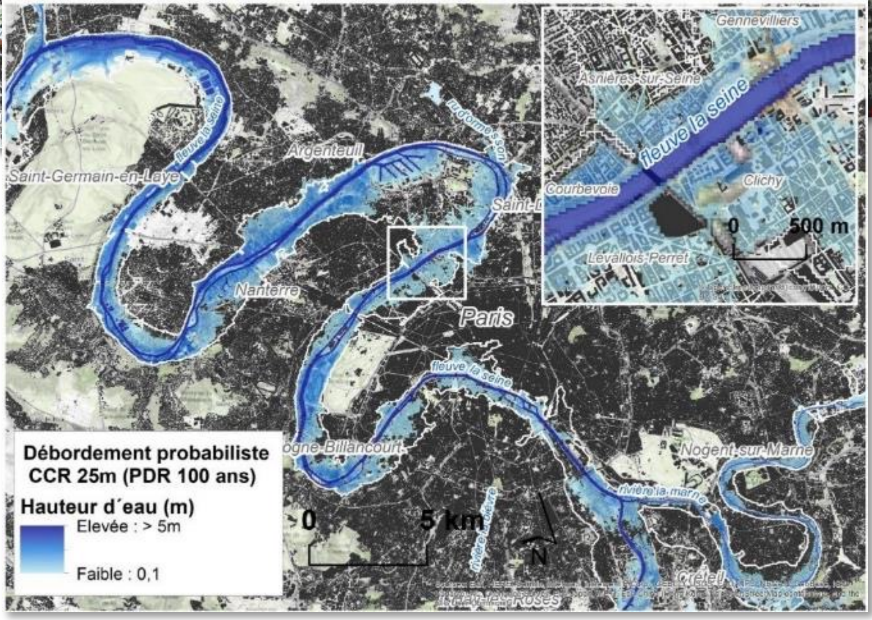


- 3 climate 2050 scenarios: current climate, RCP4.5 and RCP8.5
- 3 risks analysed, with cross-contact
- 4 return periods: 20, 50, 100 and 200 years
- 7 exposure classes defined by hazard, consistent between climate scenarios, ranging from "no exposure" to "major exposure"
- Resolution at 25 m
- Validation using RTE history and CATNAT decrees

Risk mapping at 25 m resolution

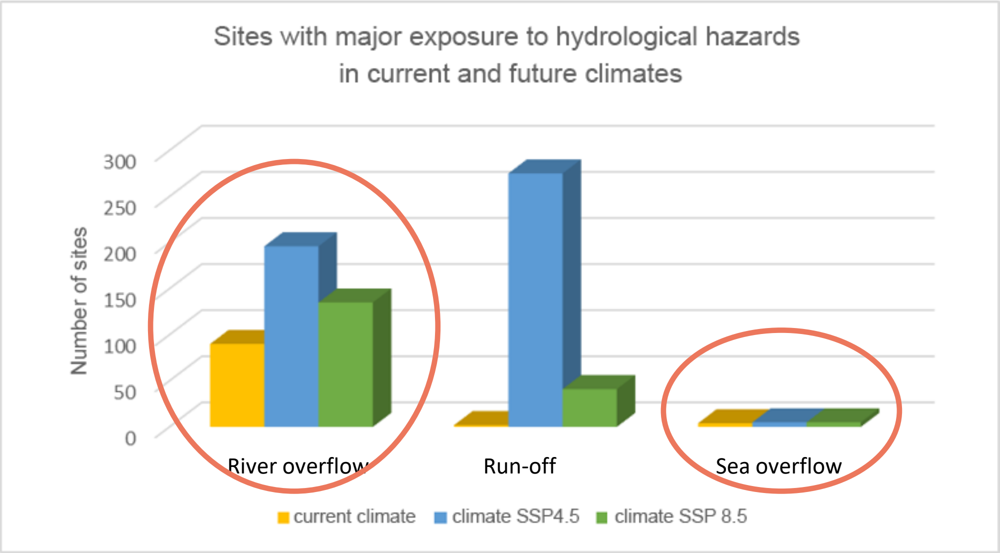
Example: Seine river in Ile de France



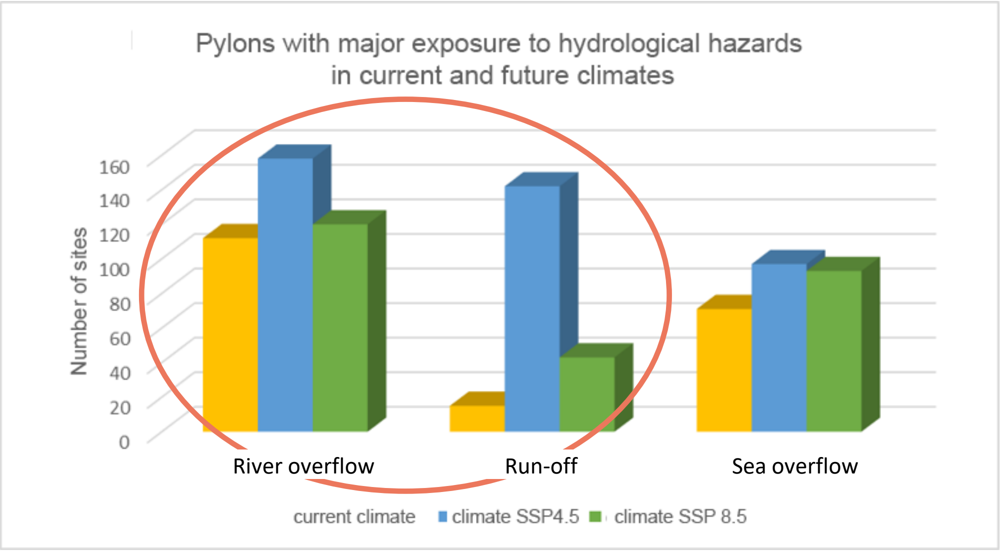


In view of the volume of structures with major exposure in the climate 2050 scenario, it is imperative to prioritise security measures on the structures that are most sensitive for the electricity system

Sites with major exposure (out of over 2700 sites)



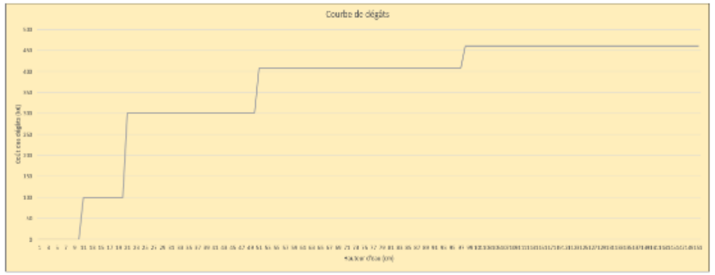
Pylons with major exposure (out of over 260,000 pylons)



The CRF study will answer a number of questions:

- Will the safety measures in place for certain substations already subject to flooding be sufficient in the face of climate change?
- How to prioritise the safety work required on existing structures?
- How will future structures be built?

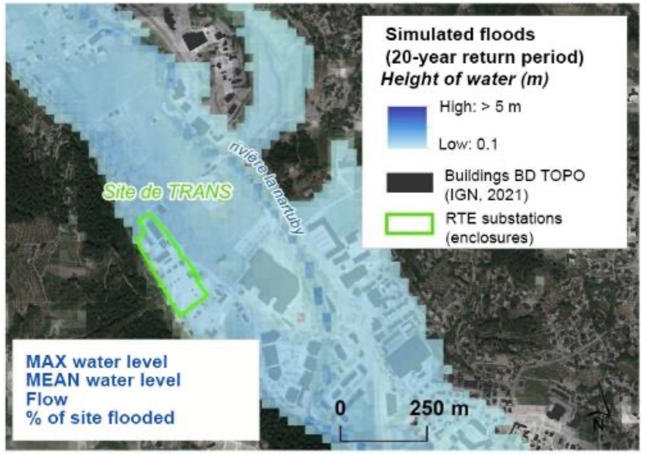
RTE's objective is to prioritise the most appropriate structures to secure or monitor for the local authority, on the basis of a multi-criteria assessment



Consequences by structure in terms of repair costs

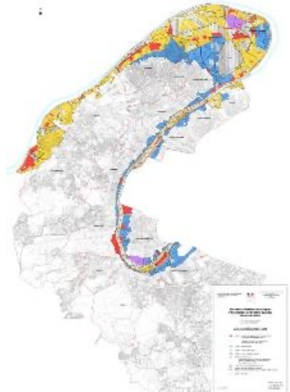
X

modelling results: frequency and intensity (heights, flow) of flooding by structure



Proposed scenarios for securing substations and pylons for the 2024 Ten-Year Network Development Plan

RTE's objective is to build new structures outside flood-prone areas by 2050, or with sufficient safety measures in place from the design stage



Flood Risk Prevention Plan

AND

Hazard by return period calculated by CRF (integrated into RTE's GIS)

Select sites outside flood zones, even in a future climate

OR

Water level/flow for a given return period

Specifications for substation design and pylon foundations in flood-prone areas in a future climate

AND

Catalogue of substation protection solutions

The Ten-Year Network Development Plan will enable RTE to present a comprehensive strategy for adapting to climate change

The adaptation strategy will be costed and will focus on building resilience:

- Refurbished overhead power lines to handle heat waves
- Overhead power lines for fire prevention
- Priority substations with regard to flooding
- Pylons on riverbeds to protect against flooding, for structures most at risk

Some questions of interest for RTE "work in progress" concerning resilience to climate change

- Feedback of TSO exposed to warmer climates (especially in Maghreb) ?
  - Impact of expansion and retraction of soil rich in clay
  - Impact of dust and sand wind on overhead electric infrastructure

- What are specific design principles under warmer climates ?
  - for overhead lines and substations
  - for underground cables

- Feedback of TSOs exposed to large wild fires ? Impact on network development strategy ?

- Flooding : how to study run-off impacts on infrastructure ?

Where are there maths here in?

Adaptation of climate information to the sector's specific needs (AGAIN!) ➔ many post processing step

- Temporal interpolation
- Spatial interpolation
- Models' bias adjustment
- Models' validation and evaluation …

Evaluation of extremes and high impact events:

- Return periods / Return levels
- Different thresholds depending on decision processes
- Multivariate aspects
- Fiability studies and assets replacement strategies
- All of this in non-stationary conditions (climate change)

1. Resource adequacy

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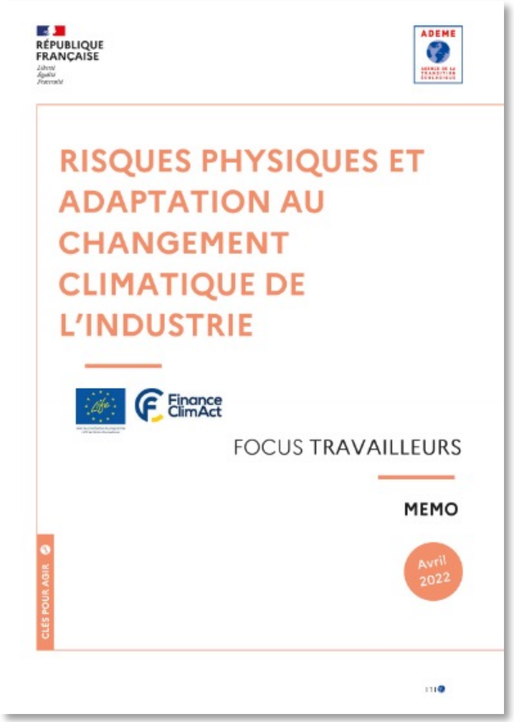
Climate change and workers' health

ANSES 2018 report

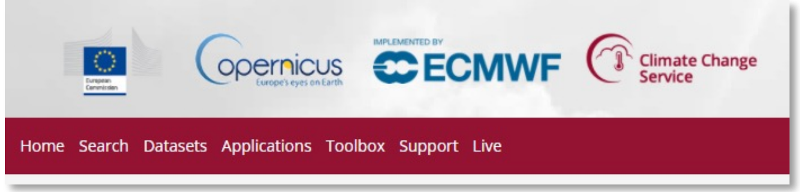
ADEME 2022 report

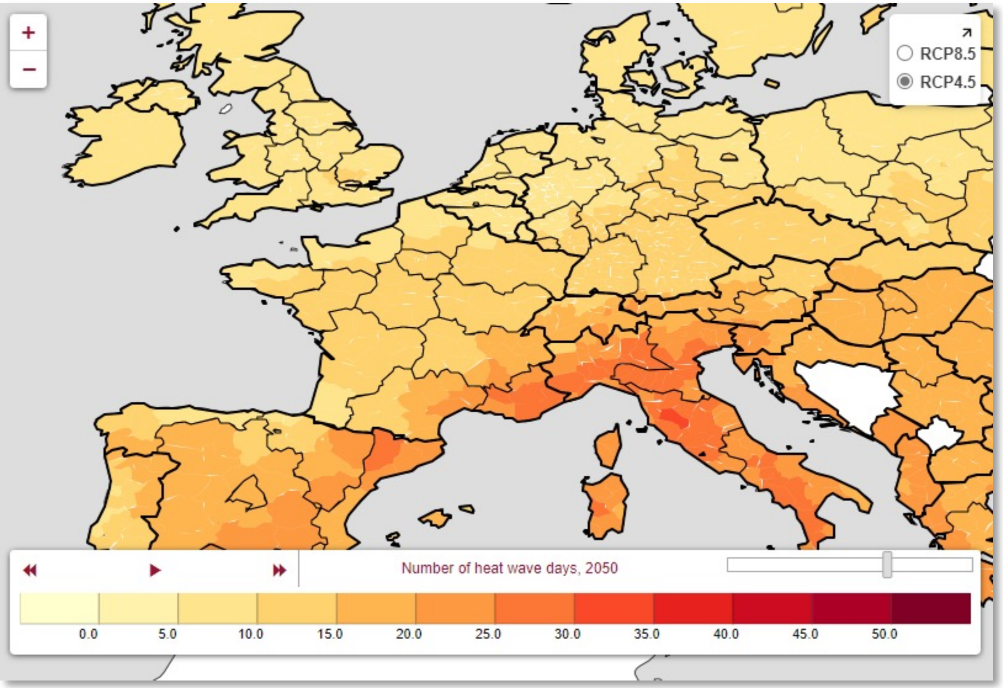
CESE 2023 report

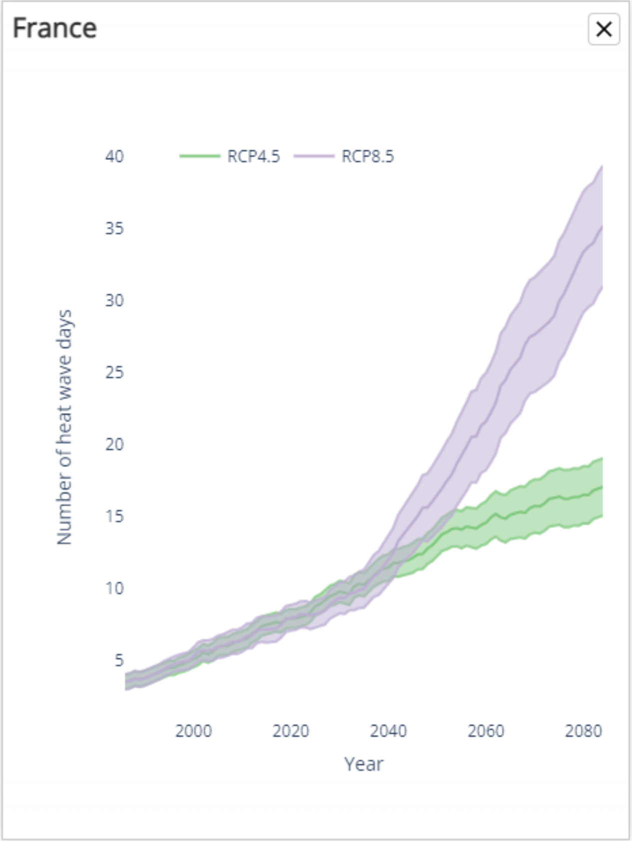
Main risks:
- Increase in temperature;
- Evolution of biological and chmical environment
- Change in frequency and intensity of some hazards



Climate change and workers’ health







This application is an exploratory tool for the [Heat waves and cold spells in Europe derived from climate projections] dataset. This dataset provides 30 year rolling means of the number of heat wave days based on bias adjusted output from the EURO-CORDEX ensemble of climate models.
A heat wave is a prolonged period of high temperature, relative to the region. A number of qualifying definitions of heat waves are used in the climate and health communities. This application presents two European-wide definitions: the ***Climatological EURO-CORDEX*** *and* ***Euroheat project*** *, and one set of* ***National definitions*** *which are available for a limited number of European countries.*

Climate change threatens work productivity

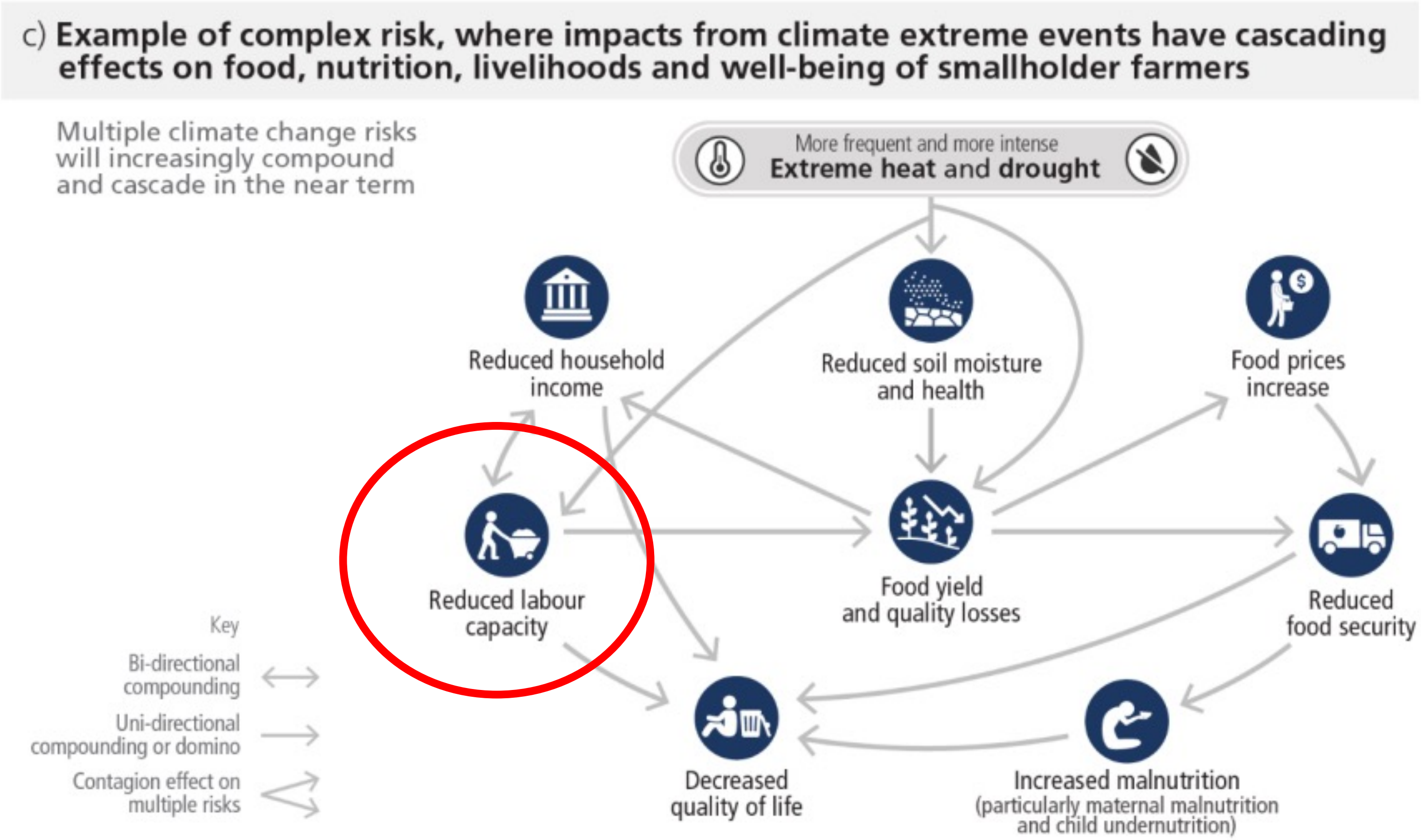
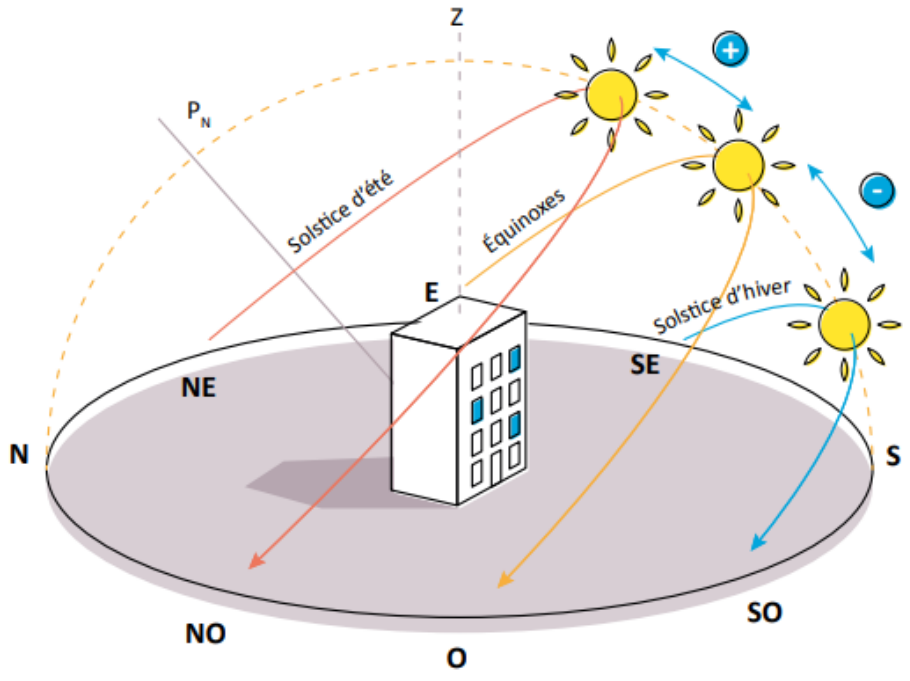


Figure 4.3: Every region faces more severe or frequent compound and/or cascading climate risks in the near term. Changes in risk result from changes in the degree of the hazard, the population exposed, and the degree of vulnerability of people, assets, or ecosystems. **Panel (a)** Coastal flooding events affect many of the highly populated regions of the world where large percentages of the population are exposed. The panel shows near-term projected increase of population exposed to 100-year flooding events depicted as the increase from the year 2020 to 2040 (due to sea level rise and

Source: IPCC, SYNTHESIS REPORT OF THE IPCC SIXTH ASSESSMENT REPORT (AR6)

RTE – Consideration of climate change for summer confort in buildings, and individual equipments



New regional headquaters in Marseille et Lille

- CC considered during conception (roof vegetalisation, sun visors…)

Refurbishment of existing buildings

- Guidance document for adaptation to temperature increase

Refurbishment of existing buildings

- Design of new individual equipment to reduce heat stress

1. Resource adequacy

2. Resilience and adaptation of infrastructures

3. Climate change and workers

BONUS

4. Current activities

Rte Le réseau de transport d'électricité

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PSL UNIVERSITÉ PARIS

THÈSE DE DOCTORAT
DE L'UNIVERSITÉ PSL

Préparée à l'École nationale supérieure des mines de Paris

Améliorer la fiabilité des algorithmes d'apprentissage profond en vue d'accroitre l'observabilité des installations photovoltaïques en toiture en France

Gabriel Kasmi

Thesis motivation

Image: RTE

Photovoltaic energy

Plants ($\geq 1\ MWp$)

Measurable : RTE has access to real time measurements of the production

Decentralized ($< 1\ MWp$)

- Small plants
- Distributed (aka rooftop PV)

Observable : RTE can reconstruct the PV production from *ex post* measurements

No measurement of the production (either real time or *ex post*)
No comprehensive and exhaustive registry (i.e. with sufficient information to accurately estimate the production)

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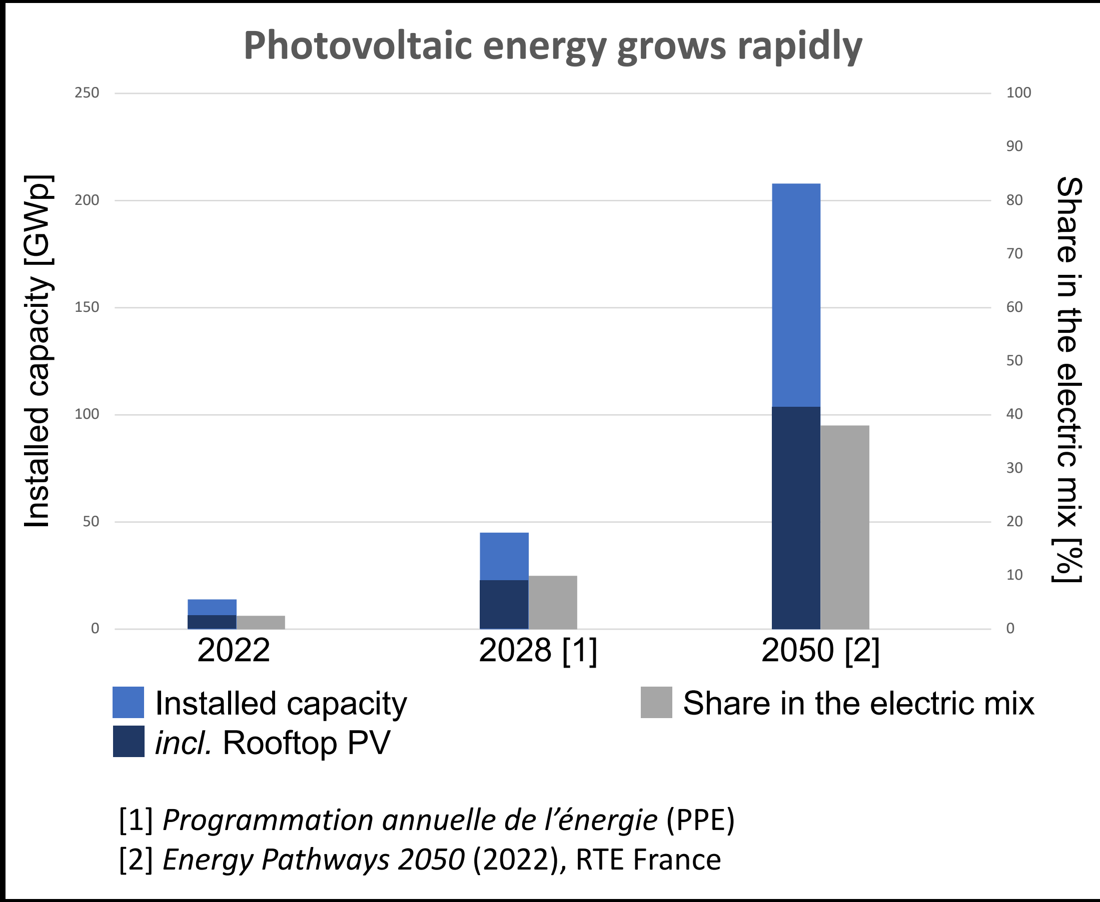
Thesis motivation



- We need to improve rooftop PV observability: be able to estimate the PV power production with good accuracy.

Thesis objectives

1. Characterize the rooftop PV fleet, i.e., construct a registry,

2. Use this registry to improve the estimation of the rooftop PV power production.

Remote sensing of PV installations

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- The lack of information regarding small-scale PV is not restricted to France. It is common in many countries.
- To bridge this « information gap » several works leveraged deep learning algorithms and orthoimagery.

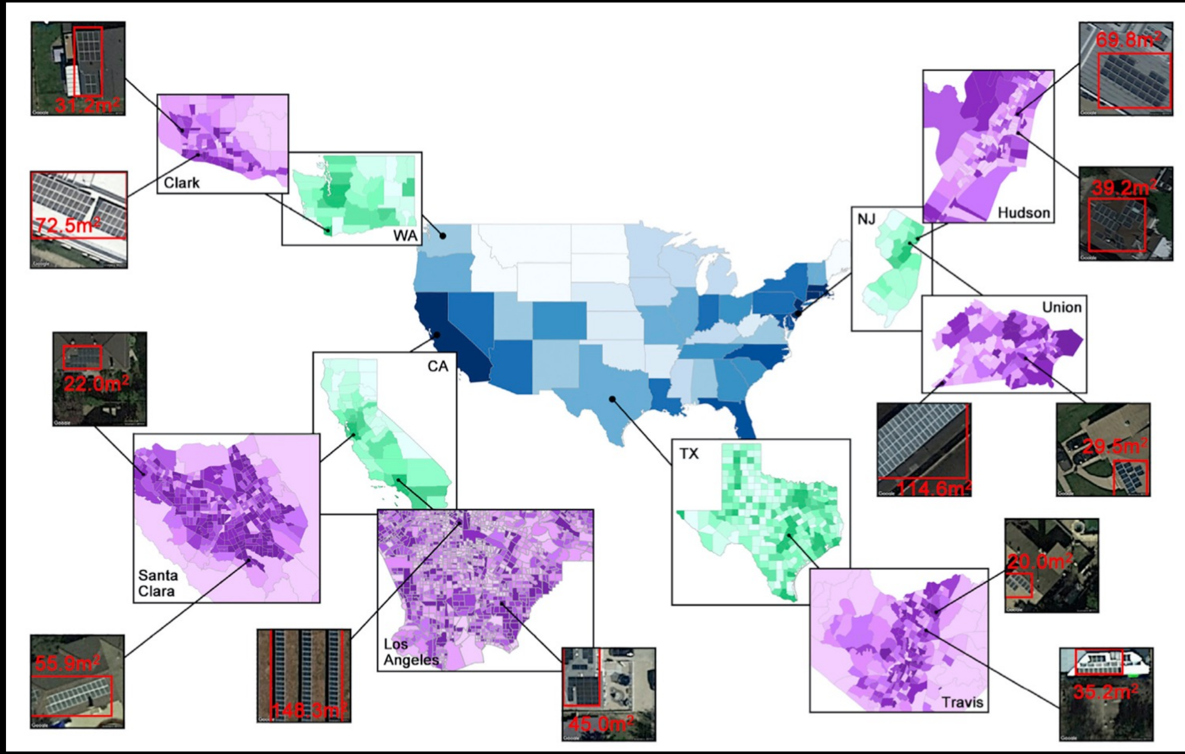

Image: DeepSolar database (Yu *et al.*, 2018)

Remote sensing of PV installations

- The
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  algorithms and
  orthoimagery.

Is deep learning-based remote sensing on orthoimagery a suitable method for constructing a nationwide registry of rooftop photovoltaic (PV) installations intended to improve the observability of PV power production in France?

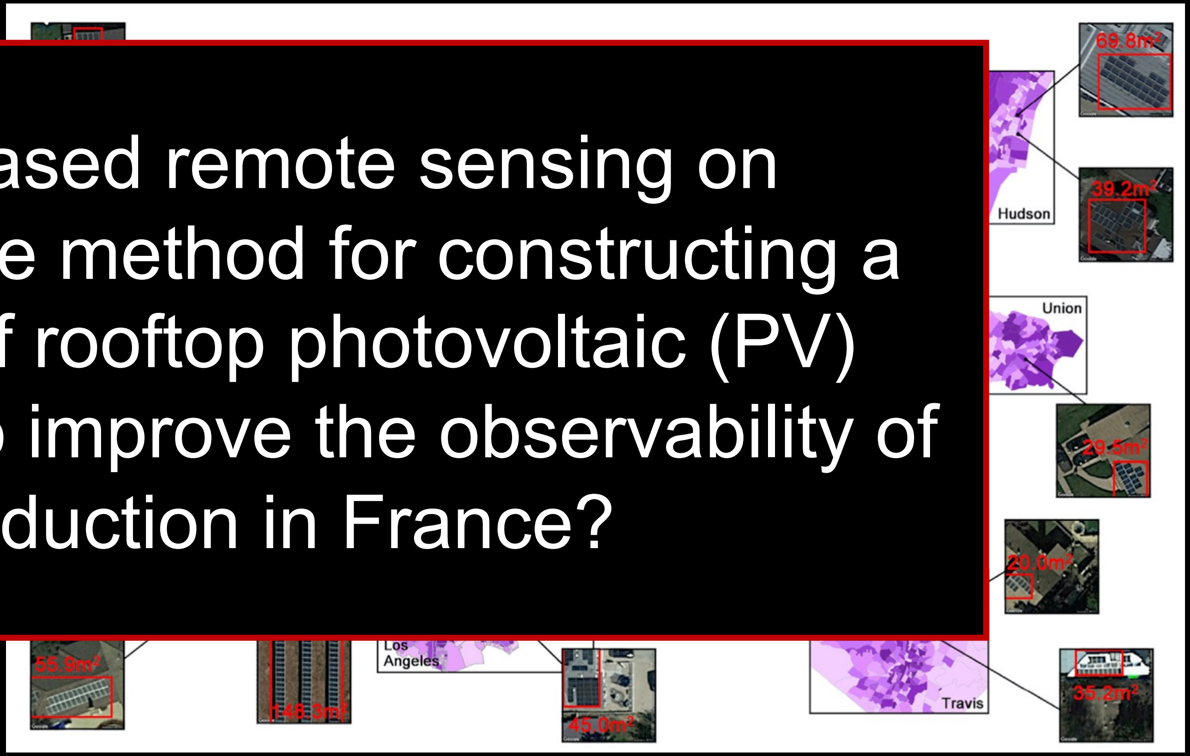
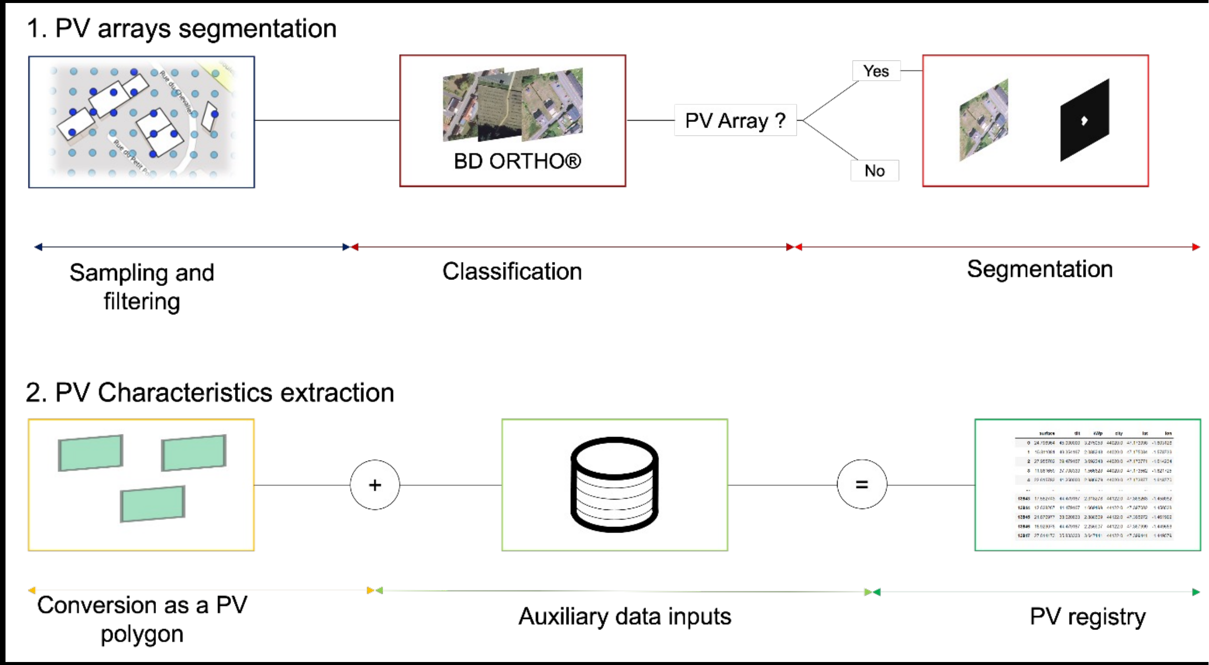
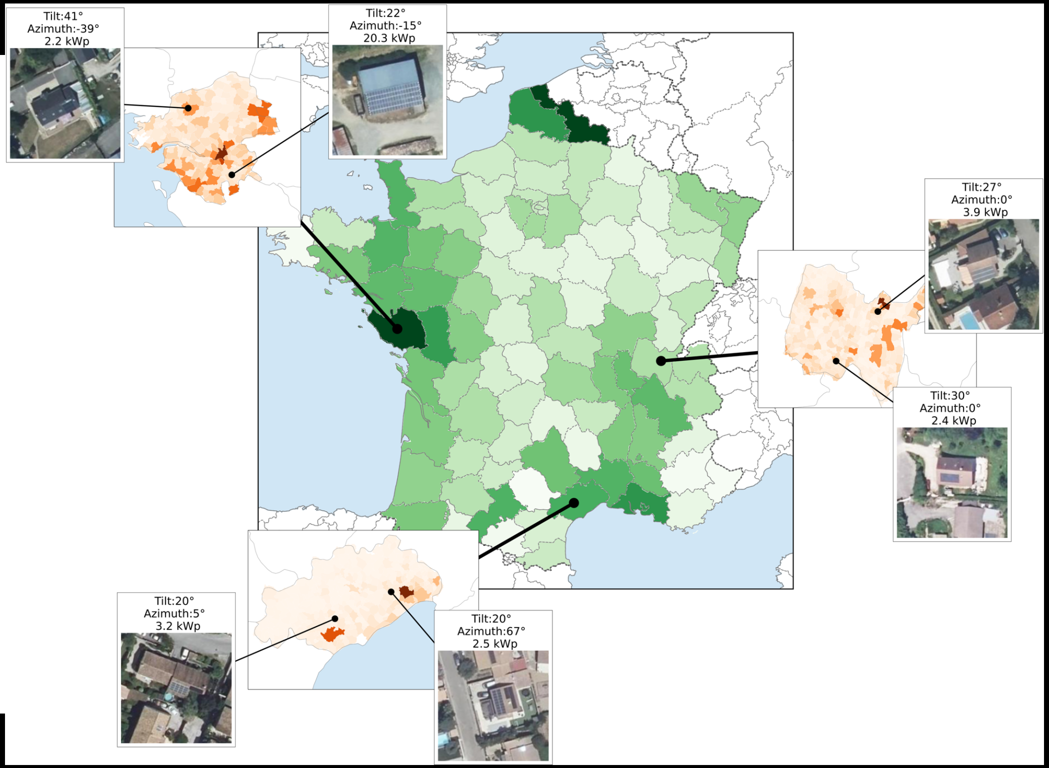


Image: DeepSolar database (Yu *et al.*, 2018)

Main results (power systems)

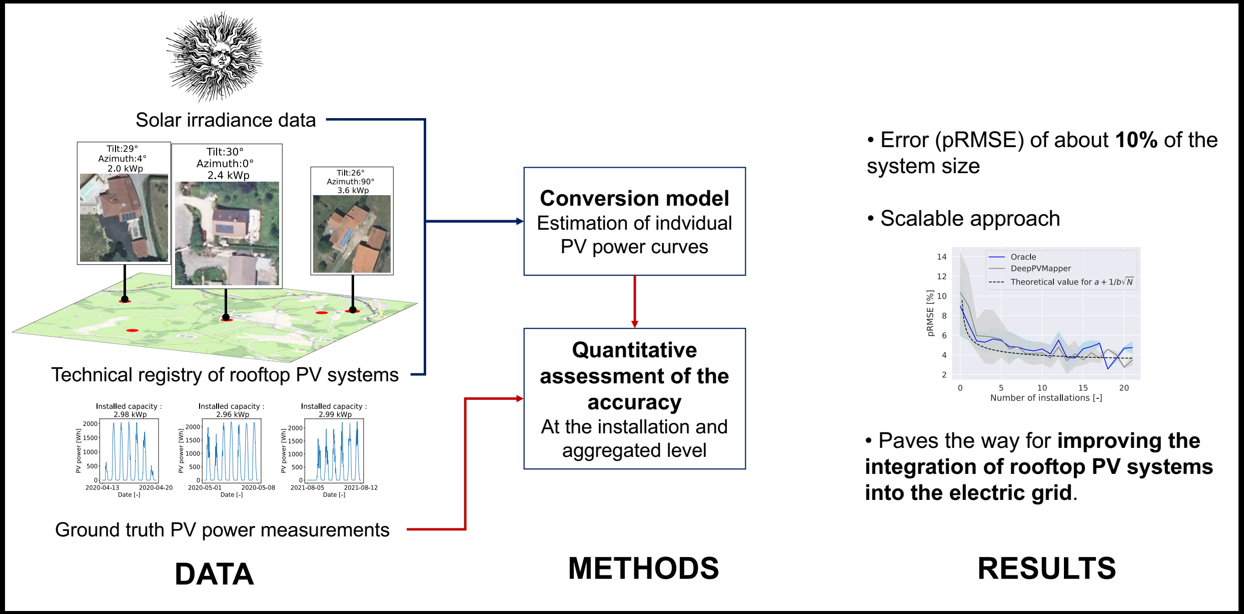
- An algorithm to map rooftop PV systems (DeepPVMapper, [1])





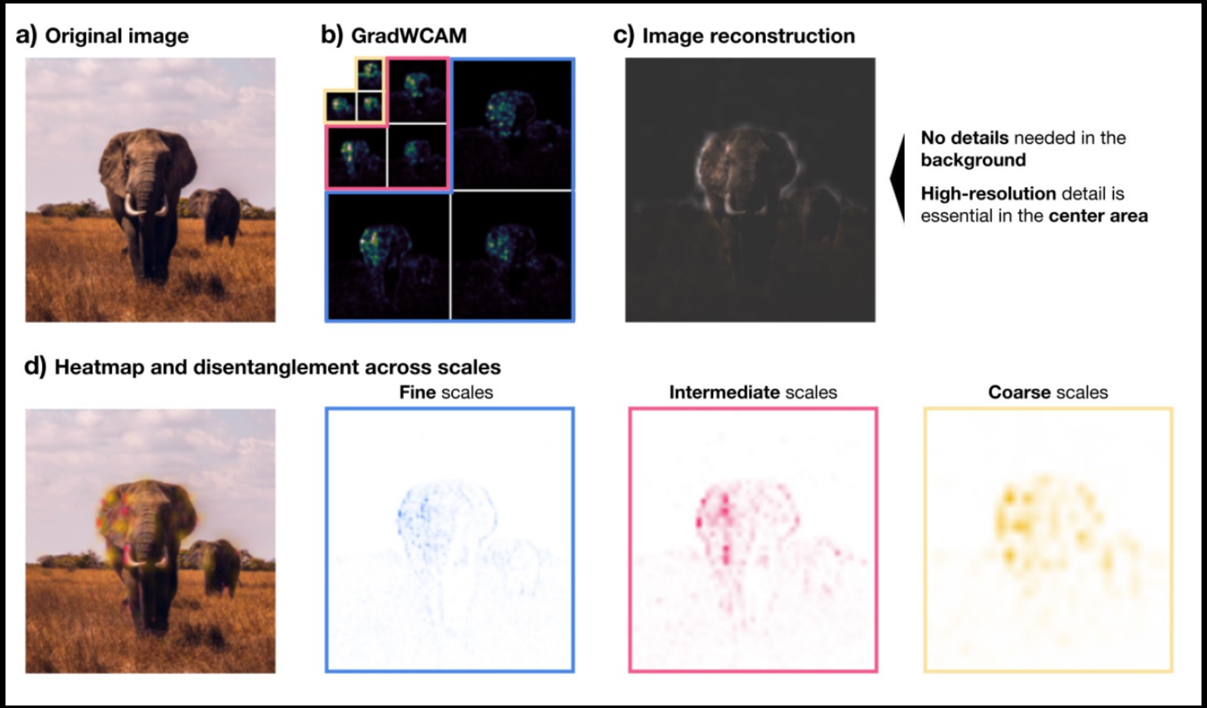
Main results (power systems)

- An assessment of the feasability of estimating the PV power production of individual PV systems using remote sensing and weather data [2]



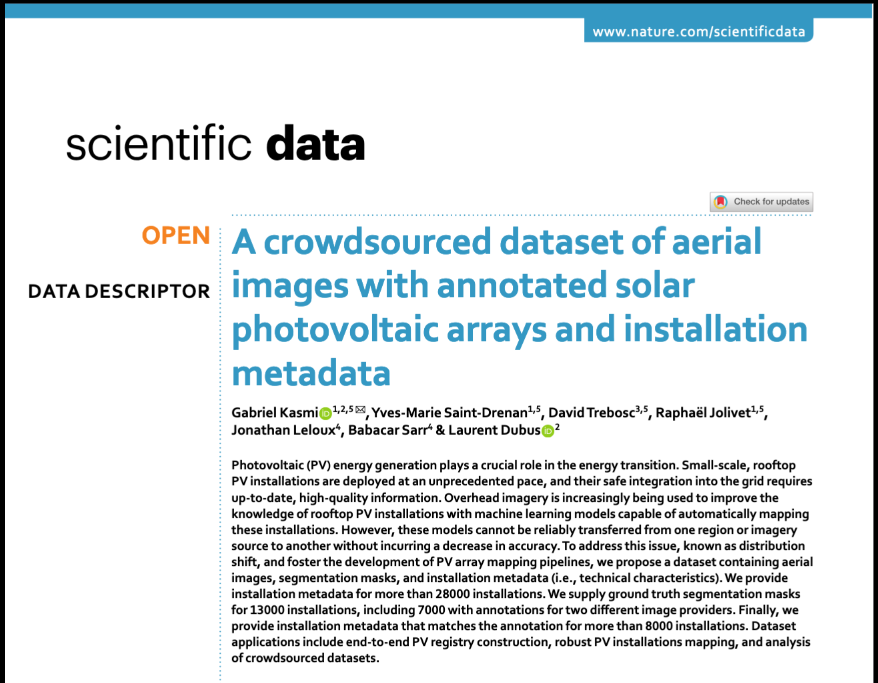
Main results (machine learning)

- A new « feature attribution » method [3]



Additional contributions

- A new training database, BDAPPV [4], a Python package for extracting characteristics of PV systems (PyPVRoof, [5])



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scientific **data**

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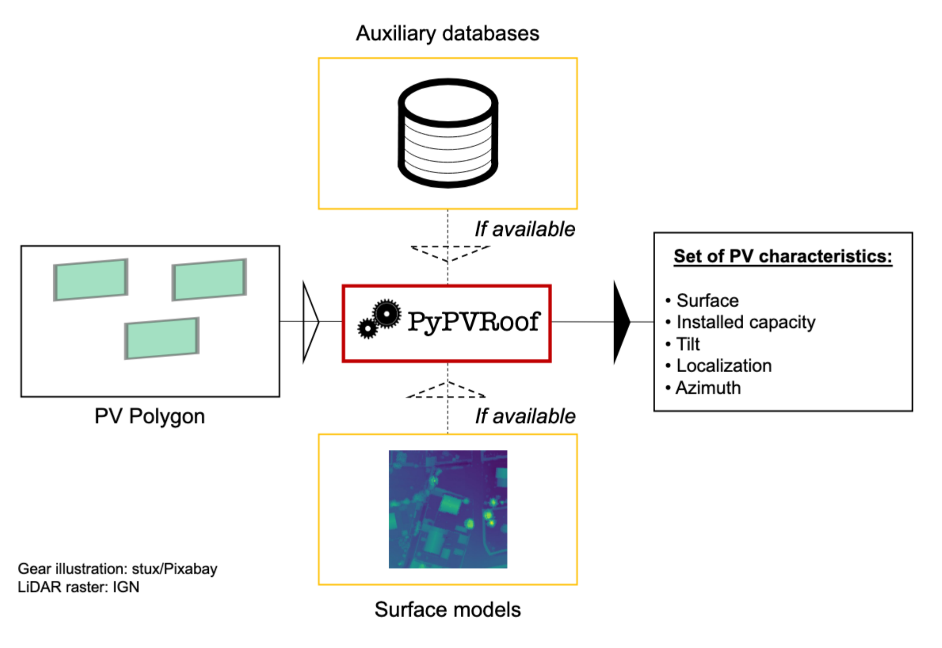
DATA DESCRIPTOR

A crowdsourced dataset of aerial images with annotated solar photovoltaic arrays and installation metadata

Gabriel Kasmi[1,2,5] ✉, Yves-Marie Saint-Drenan[1,5], David Trebosc[3,5], Raphaël Jolivet[1,5], Jonathan Leloux[4], Babacar Sarr[4] & Laurent Dubus[2]

Photovoltaic (PV) energy generation plays a crucial role in the energy transition. Small-scale, rooftop PV installations are deployed at an unprecedented pace, and their safe integration into the grid requires up-to-date, high-quality information. Overhead imagery is increasingly being used to improve the knowledge of rooftop PV installations with machine learning models capable of automatically mapping these installations. However, these models cannot be reliably transferred from one region or imagery source to another without incurring a decrease in accuracy. To address this issue, known as distribution shift, and foster the development of PV array mapping pipelines, we propose a dataset containing aerial images, segmentation masks, and installation metadata (i.e., technical characteristics). We provide installation metadata for more than 28000 installations. We supply ground truth segmentation masks for 13000 installations, including 7000 with annotations for two different image providers. Finally, we provide installation metadata that matches the annotation for more than 8000 installations. Dataset applications include end-to-end PV registry construction, robust PV installations mapping, and analysis of crowdsourced datasets.



Current perspectives

- Continue the development of DeepPVMapper
- Comparison of the proposed method for estimating the rooftop PV power production with RTE's current methods
- Extensions of the feature attribution method

Rte Le réseau de transport d'électricité

MINES PARIS | PSL

Images: Stable Diffusion

Google Scholar

Thank you for your attention!

Selected publications

[1] Kasmi, G., Dubus, L., Blanc, P., & Saint-Drenan, Y. M. (2022). Towards unsupervised assessment with open-source data of the accuracy of deep learning-based distributed PV mapping. In MACLEAN: MAChine Learning for EArth ObservatioN Workshop co-located with the European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML/PKDD 2022)

[2] Kasmi G, Touron A, Blanc P, Saint-Drenan Y-M, Fortin M, Dubus L. Remote-Sensing-Based Estimation of Rooftop Photovoltaic Power Production Using Physical Conversion Models and Weather Data. Energies. 2024; 17(17):4353. https://doi.org/10.3390/en17174353

[3] Kasmi, G., Dubus, L., Drenan, Y. M. S., & Blanc, P. (2023). Assessment of the Reliablity of a Model's Decision by Generalizing Attribution to the Wavelet Domain. In XAI in Action: Past, Present, and Future Applications workshop at NeurIPS 2023

[4] Kasmi, G., Saint-Drenan, Y. M., Trebosc, D., Jolivet, R., Leloux, J., Sarr, B., & Dubus, L. (2023). A crowdsourced dataset of aerial images with annotated solar photovoltaic arrays and installation metadata. Scientific Data, 10(1), 59.

[5] Trémenbert, Y., Kasmi, G., Dubus, L., Saint-Drenan, Y. M., & Blanc, P. (2023). PyPVRoof: a Python package for extracting the characteristics of rooftop PV installations using remote sensing data. arXiv preprint arXiv:2309.07143.

1. Resource adequacy

2. Resilience and adaptation of infrastructures

3. Climate change and workers

4. Current activities

Ongoing work: evolution of climate reference dataset

Initial situation

- RTE : Météo-France « constant climate » simulations, single model
- ENTSO-E until 2023 : 35 climate years from ERA5

Both approaches have pros and cons but recent development in climate services provide an opportunity towards convergence and some improvements

Target :

- State of the art data (CMIP6)
- Public & open access data
- Reduced cost
- Transparency

European Commission | Copernicus Europe's eyes on Earth ECMWF

C3S Lot 2 - Introduction

C3S2 412 Enhanced Operational Services for the Energy Sector
C3S Energy Lot 2 for short

Main objective: to provide support to ENTSO-E in the preparation of the **P**an **E**uropean **C**limate **D**atabase (**PECD**)

- Delivering climate and energy variables
- Building tools to aggregat data over user relevant areas
- Delivering energy models through toolbox applications

Conversion models from climate variables to energy indicators

SPV and CSP generation

Wind power generation (onshore and offshore)

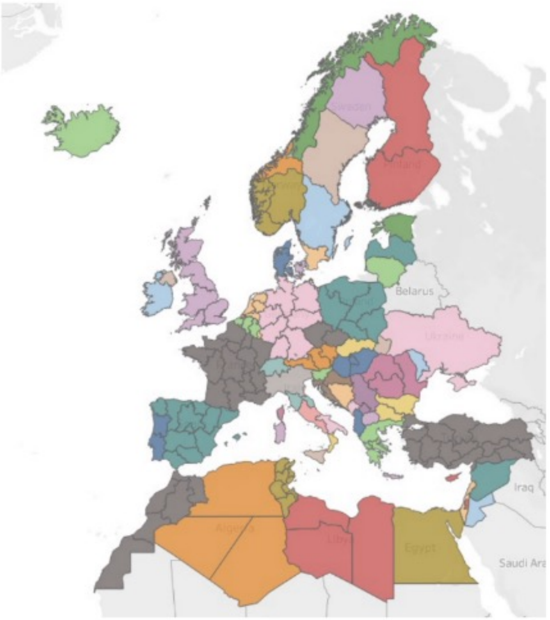
Hydro power (generation and inflow)

1950 **present**

Historical stream

Projection stream

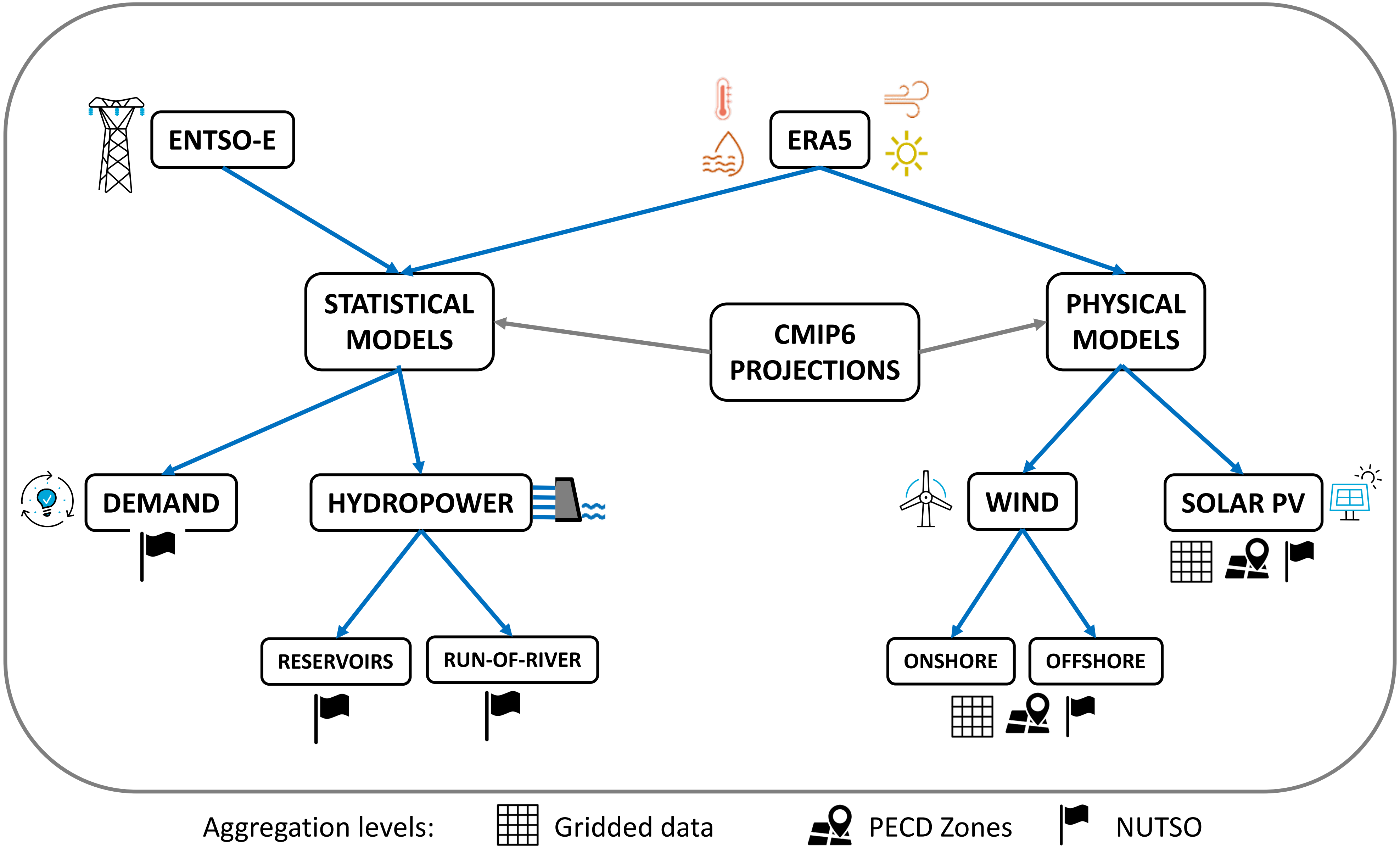
2006 **2100**



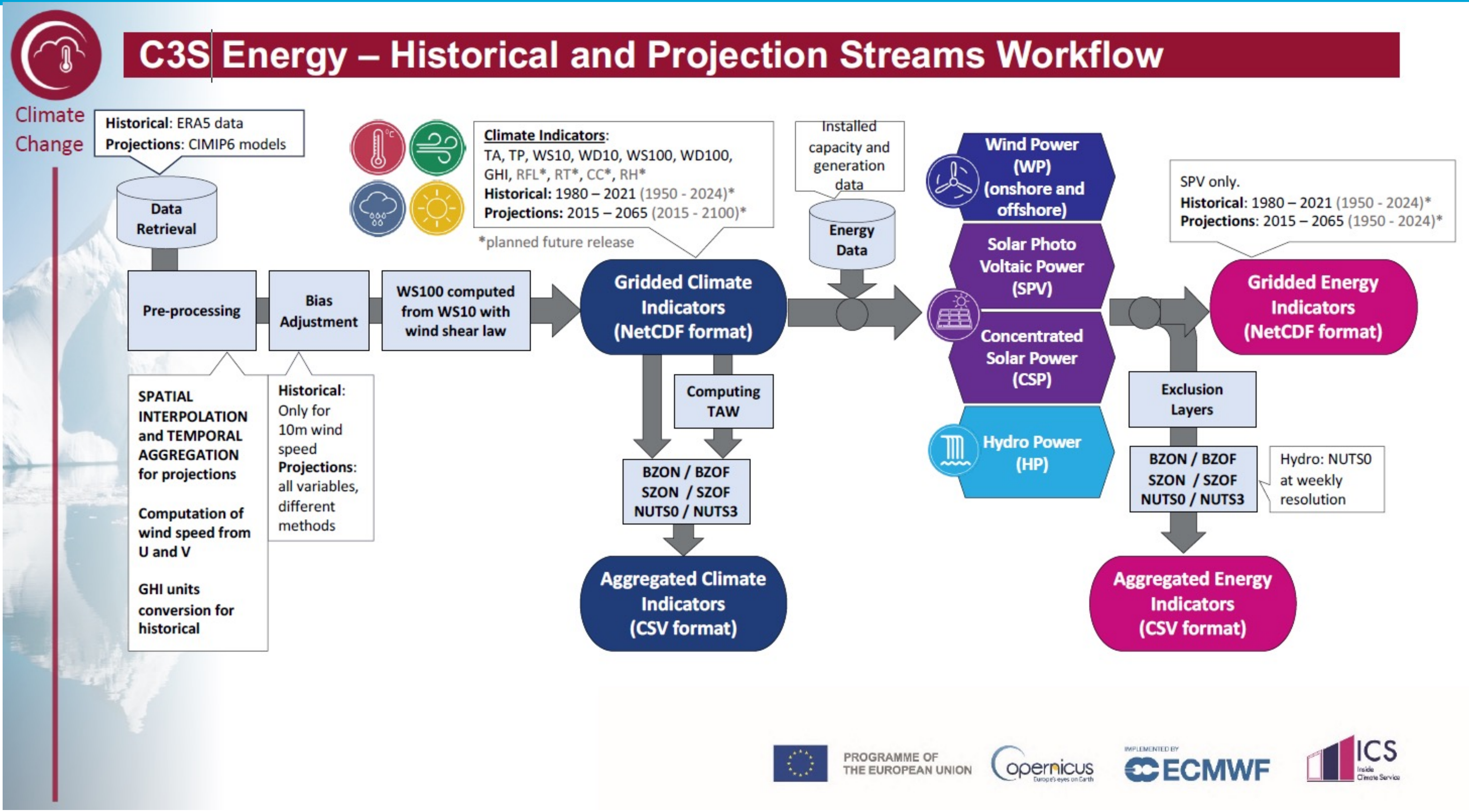
Current PECD zonal configuration

Work packages of the C3S Energy Lot 2 Service

Climate to energy conversion models



Resulting in a complex workflow



New PECD versions coming soon

ENTSO-E PECD

Climate data

PECD 4.1 (Sept. 2024)
Historical Stream: 1980-2021
Projections: continuous simulations 2015-2065
3 climate models (CMIP6)
1 scenario: SSP245

Climate variables:
- Temperature (includ. Population weighted temp)
- Wind speed at 10m and 100m
- Precipitations
- Global Horizontal Irradiance (no cloud cover)

On a **25km resolution grid + aggregated on PECD zones, bidding zones and country level**

Conversion models

Energy data

Onshore wind:
- Existing fleet (as of 12/2020)
- Future fleet : 3 hub heights * 3 specific power
  → 9 combinaisons of tech/load factor

Offshore wind:
- Existing fleet (as of 12/2020)
- Future fleet : 2 specific power / 150m hub height

PV : Single model for all techs, but pilot project to split residential/commercial/utility scale

Hydro : reservoirs, run-or-river, pondage and open-loop pumping

Data aggegated on PECD zones, bidding zones and country level

Future version

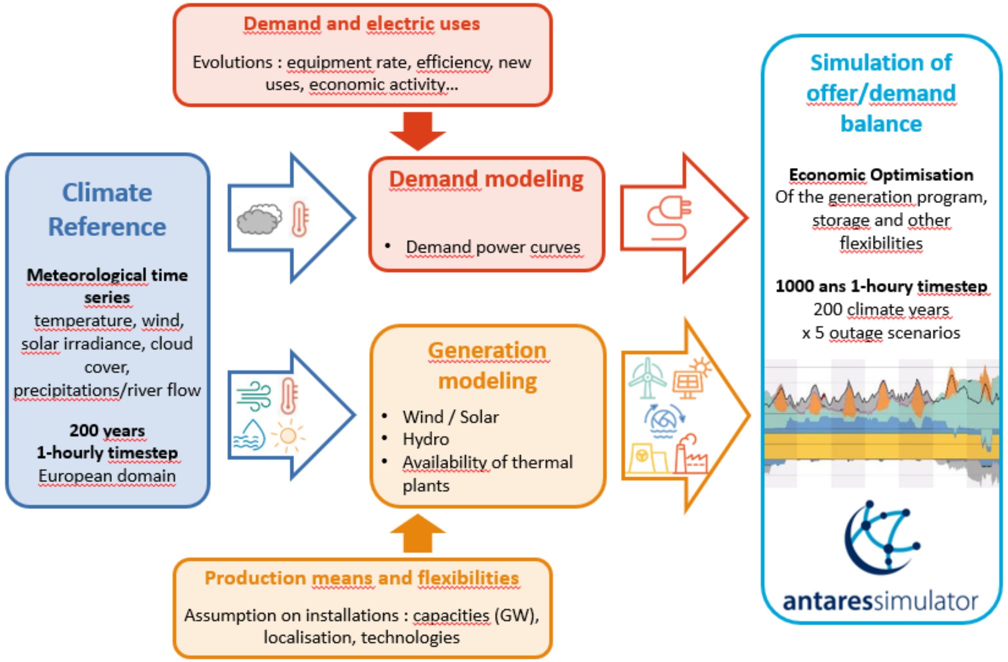
PECD 4.2 (December 2024)
Historical stream : 1980-2023
Projections : Continuous simulations **2015-2100**
6 climate models (CMIP6)
4 scenarios: **SSP126**, SSP245**, SSP370 and SSP585**

Public availability in the Copernicus Climate Data Store:
- ***PECD4.1: September 2024***
- ***PECD4.2: Q1/Q2 2025***

Summary

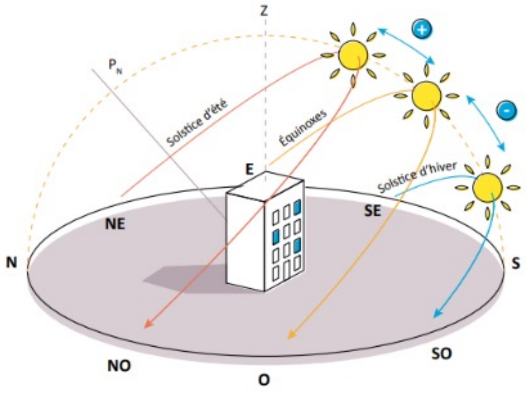
A short summary

Aequacy studies (BP, EP2050, seasonal outlooks)



Resilience of infrastructures

Poste 90kV de Lumbres (Nord) inondé le 6/11/2023



This was only about adaptation to climate change

Maths are everywhere in the energy sector:

- **Renewable energies potential estimation → mainly stats**
- **Short term forecasts (demand, renewables generation): Machine Learning, Deep learning…**
- **Estimation of real-time generation from unobserved generation means, in particular rooftop PV → DL + aerial images (see PhD by Gabriel Kasmi, Mines Paris PSL & RTE, 2024)**
- **Automatic inspection of assets like overhead lines, closed or remote power stations → image & sound processing with DL**
- **…**

Rte

We need our partners and network

Climate

ICS Inside Climate Service

Copernicus Europe's eyes on Earth

Climate Change Service

WEMC World Energy & Meteorology Council

BRINGING TOGETHER CLIMATE SCIENCE & ENERGY EXPERTISE

entsoe

MINES ParisTech

PSL

CCR

IPSL

FRANCE ENERGIES MARINES

METEO FRANCE

CERFACS

CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Some final messages

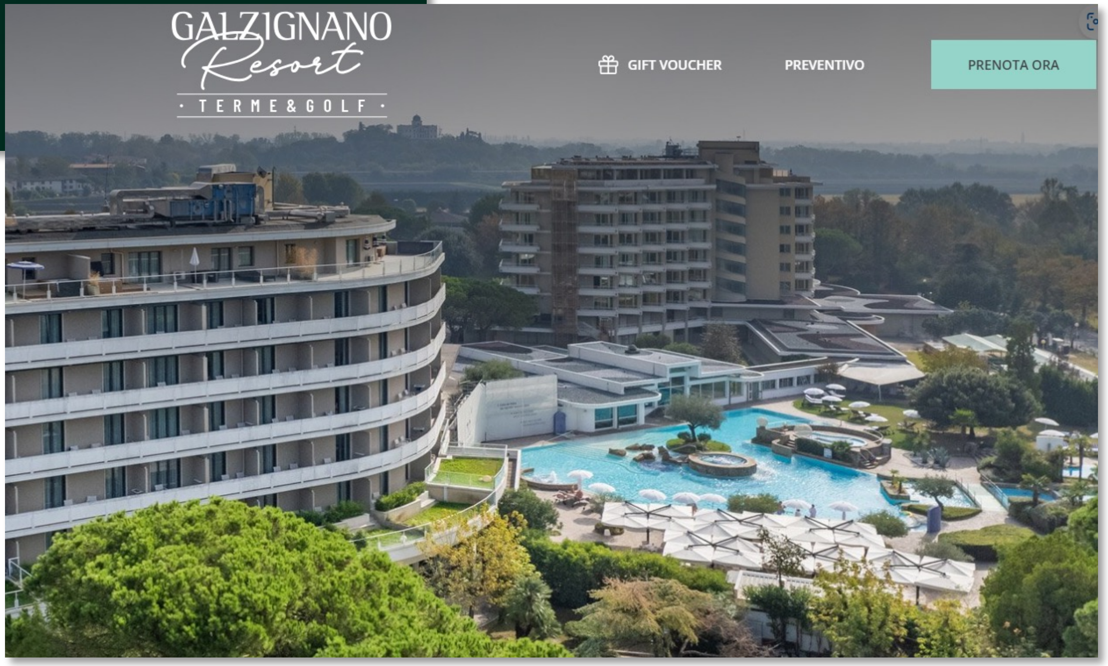
Climate change and the necessary transition towards low carbon societies increase the dependence of power systems to climate variability and climate change: impacts on the network itself infrastructures), on its operation, but also on the workers and their health

Energy planning requires authoritative weather and climate data

Climate services are a key component and collaboration between the climate community and the energy sector still needs to be reinforced, in a systemic and multi-disciplinary approach, including HR and social sciences

<u>And maths have a significant role to play</u>

If you want more on the Weather & Climate and Energy nexus



Le réseau
de transport
d'électricité

Thank you