DESTINATION EARTH

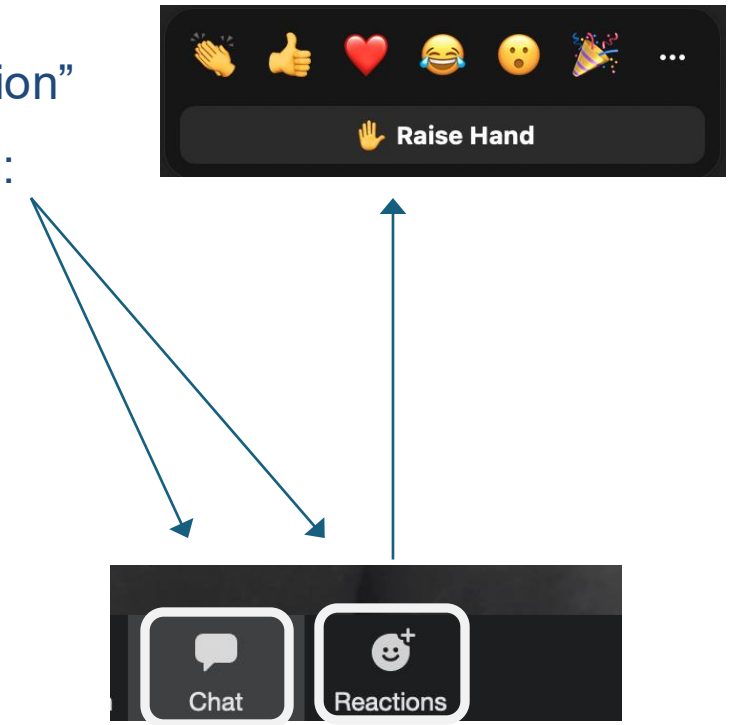
USE CASE ENERGY SYSTEM WEBINAR: MODELLING FOR CLIMATE RESILIENCE AND ADAPTATION

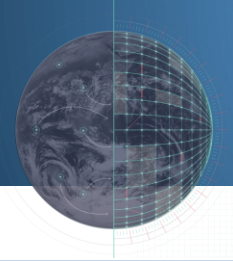
07 November 2024

Renewables Grid Initiative DLR AARHUS UNIVERSITY Funded by the European Union Destination Earth implemented by ECMWF esa EUMETSAT

HOUSEKEEPING

- This webinar is recorded and will appear on the RGI website and YouTube channel
- Camera on, microphone off
- Rename yourself to “Name, Organisation”
- If you have a question do the following:





Time	Agenda
11:00	Introduction: RGI, DLR Andrzej Ceglarz (RGI), Bruno Schyska (DLR)
11:05	DestinE: The bigger picture Jörn Hoffmann (ECMWF), Jakub Dąbrowski (DG-CNECT)
11:15	Use Case Energy Systems: Introduction, key results & users' engagement Bruno Schyska (DLR), Andrzej Ceglarz (RGI)
11:40	Use Case Energy Systems: Users' perspective Andreas Zucker (DG-ENER), Laurent Dubus (RTE)
11:50	Open discussion
12:25	Closing remarks Bruno Schyska (DLR), Andrzej Ceglarz (RGI)

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

- Space Administration
- Research institution
- Project Management Agency

- Aeronautics
- Space research and technology
- Transport
- Energy
- Security (cross-sectoral)
- Digitalisation (cross-sectoral)

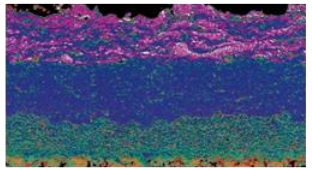
DLR Institute of Networked Energy Systems

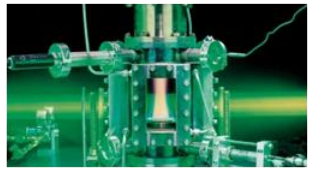
Energy Systems Analysis

Energy System Technologies

Solar Energy

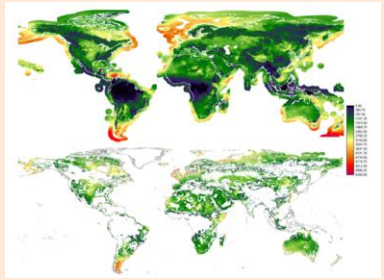
Wind Energy

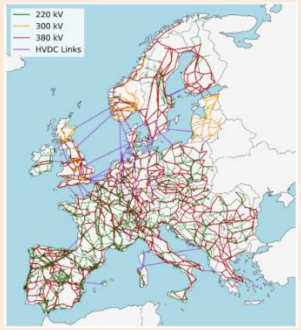

Energy Storage


Energy Converters

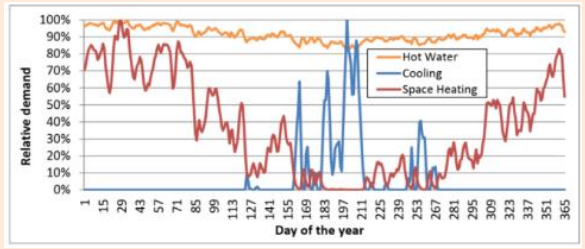
DLR: RESEARCH FIELDS

Improvement of the data basis for energy systems modelling

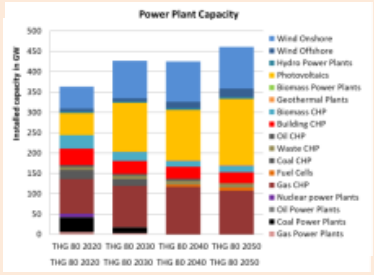


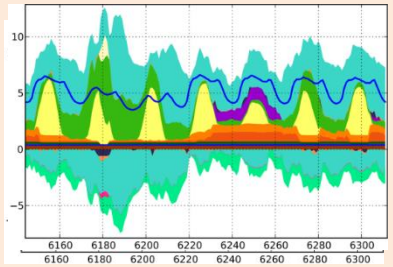


- Energy infrastructure data
- Renewable energy potentials
- Energy demand and its flexibility

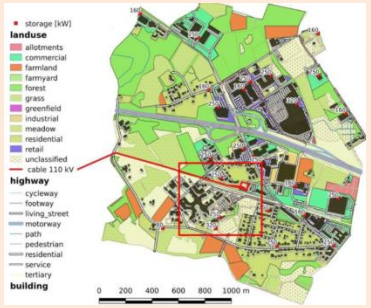


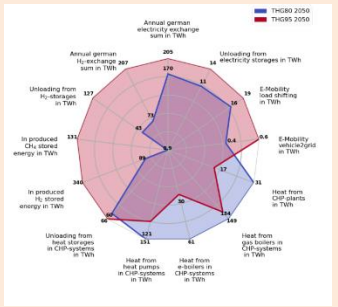
Investigation of energy system transformation pathways



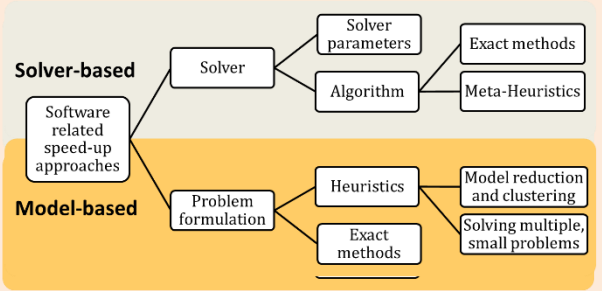


- Modelling national/continental systems
- Storage, transmission, sector coupling
- Resilience and security of supply
- Urban energy systems

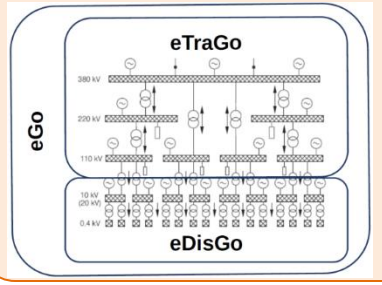


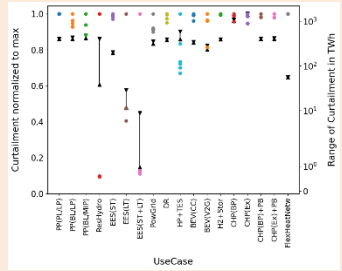


Enhancement of methodological competence



- Reduction of model solution times
- Strengthening robustness (models/data)
- Model coupling and comparison
- Remote sensing and machine learning
- Data management (metadata, ontology)





ABOUT RENEWABLES GRID INITIATIVE

RGI is a unique **collaboration of NGOs and TSOs** from across Europe engaging in an 'energy transition ecosystem-of-actors'. We foster knowledge exchange, discussions on the grid infrastructure needs, and the implementation of best practices within **three dimensions**:

GRIDS & ENERGY SYSTEMS

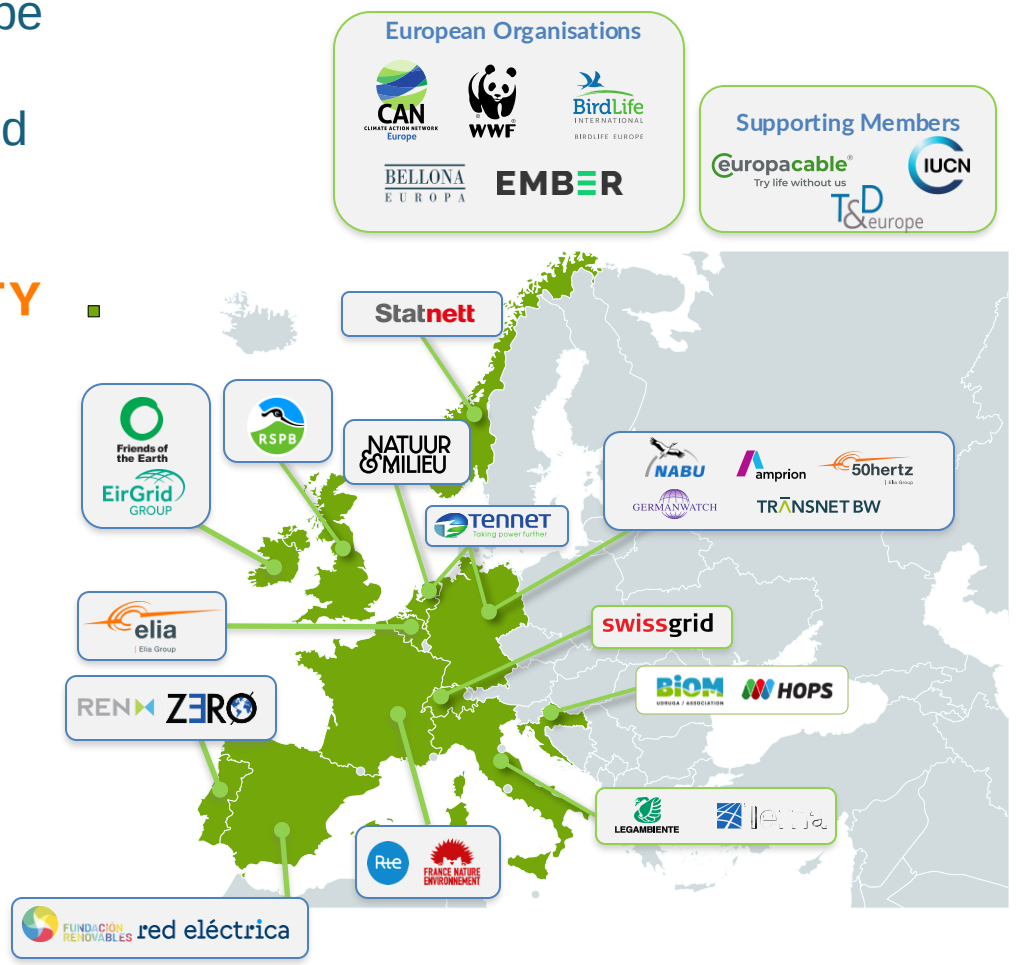
We enable discussions on **how to model, plan and implement** decarbonised and optimised clean energy systems, including different voices in the process.

ENERGY & NATURE

We ensure energy systems both onshore and offshore are developed in **coherence with nature and biodiversity**, promoting mitigation, enhancement and restoration measures.

ENERGY & SOCIETY

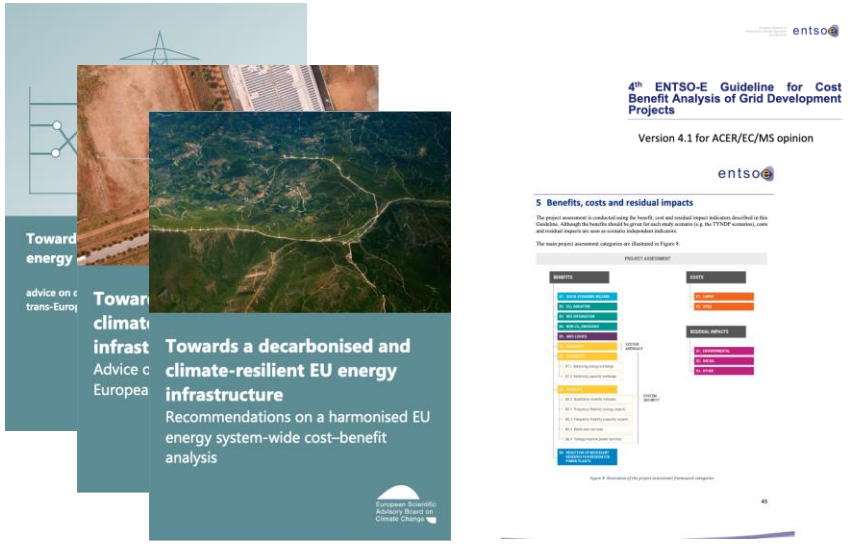
We **include and engage citizens, civil society and policy makers** on strategies towards full decarbonisation, improving capacity and knowledge on the role of grids within for the energy transition.



WHY CLIMATE RESILIENCE AND ADAPTATION

Credits: **Terna** (2023) and **REN** (2023)

Sources: CAN Europe (2024), "**Paris Pact Payoff: Speeding up the green transition for socio-economic co-benefits**"
&
WWF (2024), "**Climate adaptation and resilience in Europe: Principles for action**"



Sources: **ESABCC** (2022, 2023, 2024) and **ENTSO-E** (2024)

DESTINE: THE BIGGER PICTURE

Jörn Hoffmann

Applications and Innovation Partnerships Team Leader

ECMWF

Jakub Dąbrowski

Policy Officer, C1– High Performance Computing and Applications, Destination Earth sector

DG-CNECT

DESTINATION EARTH:
- the bigger picture

A NOVEL INFORMATION SYSTEM FOR A RESILIENT SOCIETY

Jörn Hoffmann, ECMWF

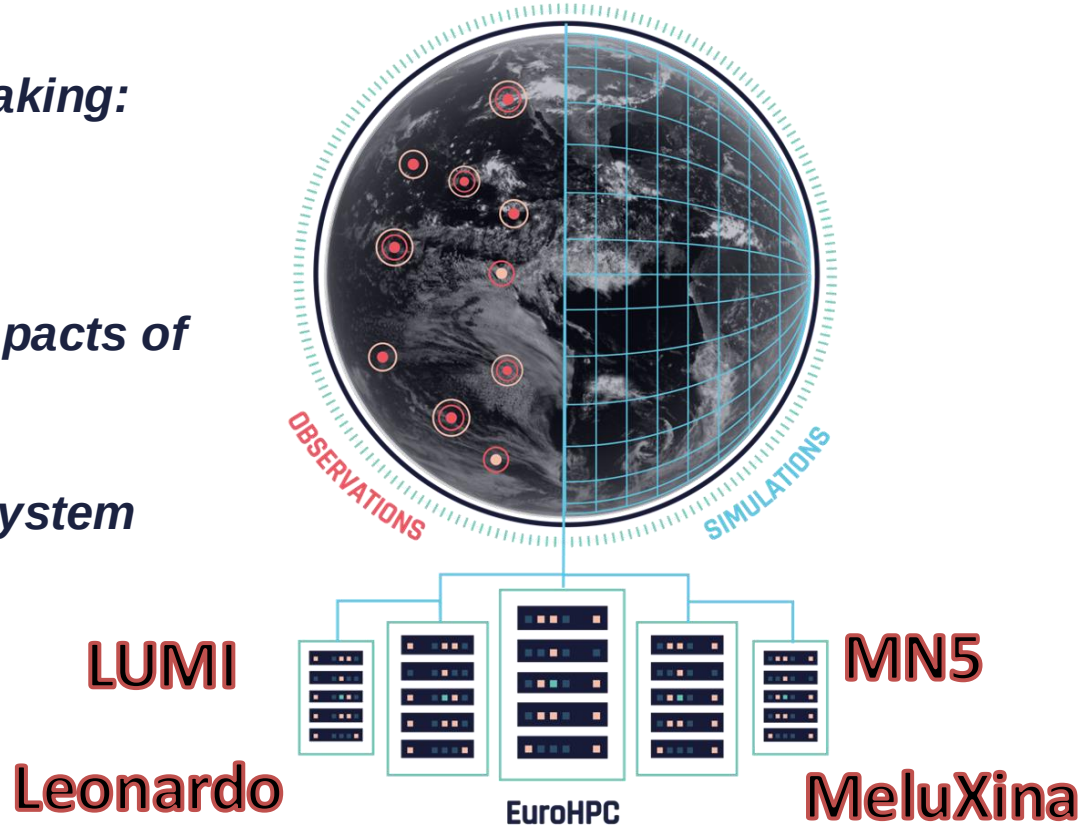
DestinE Use Case Energy Systems Webinar
November 7, 2024

Funded by the European Union
Destination Earth implemented by ECMWF esa EUMETSAT

DESTINE: A DIGITAL REPLICA OF OUR PLANET TO RESPOND AND ADAPT TO CLIMATE CHANGE AND EXTREME EVENTS

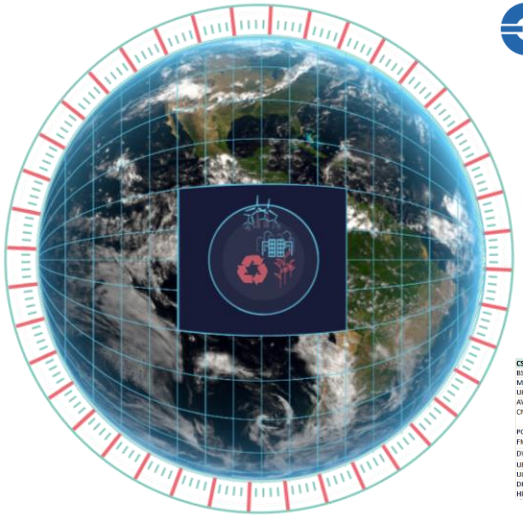
DestinE, in strategic partnership with EuroHPC Joint Undertaking:

- ***Establishes bespoke cutting-edge simulation capabilities***
- ***Provides Earth-system information at scales where the impacts of extreme events and climate change are felt***
- ***Fosters an innovative and thriving AI-enabled digital ecosystem***



FIRST HIGH PRIORITY DIGITAL TWINS SUPPORT THE GREEN DEAL

Climate change adaptation

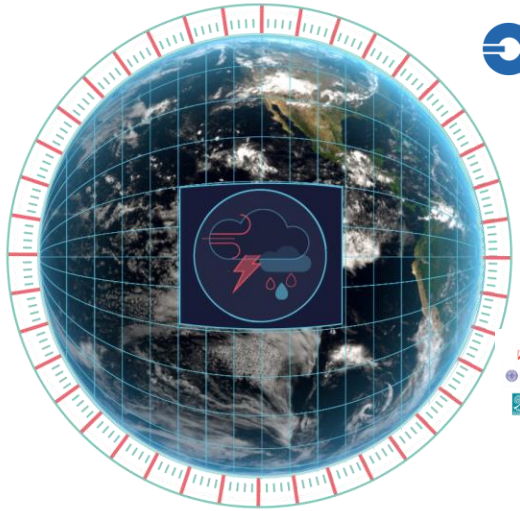


CSC	CSC – IT Center for Science
BSC	Barcelona Supercomputing Center/Centro Nacional de Supercomputación
MPI - M	Max Planck Institute for Meteorology
UH	University of Helsinki
AWI	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
CNR-ISAC	Consiglio Nazionale delle Ricerche, Instituto di Scienze dell'Atmosfera e del Clima
POLITO	Politecnico di Torino
FMI	Finnish Meteorological Institute
DWD	National Meteorological Service of Germany
UFZ	Helmholtz Centre for Environmental Research
UCLouvain	Université catholique de Louvain
DKRZ	German Climate Computing Centre
HPE	Hewlett Packard Enterprise

To support policymaking for adaption

Multi-decadal timescales

Weather-induced extremes



For rapid response to extreme events

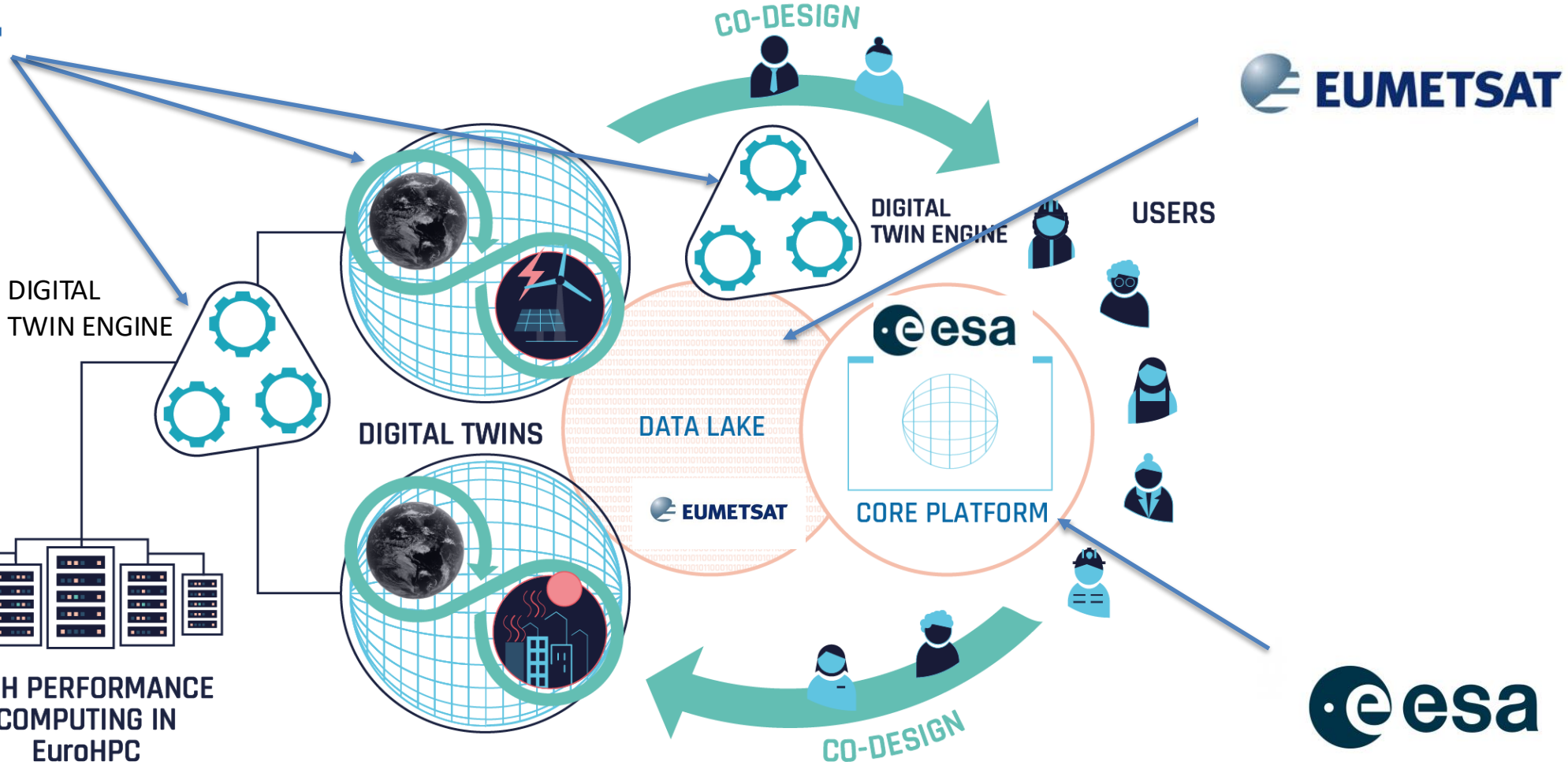
For a few days ahead

DESTINE: A NOVEL INFORMATION SYSTEM

ECMWF

+

90 entities in more than 20 countries



DESTINE'S DEVELOPMENT PHASES

2022 — 2024 — **June 2024** — June 2026 — 2030

Procuring and building the key components and interfaces demonstration at scale

System integration and testing with selected users

Opening to users the core service platform, the data lake, digital twin engine and digital twins

Evolutions and ramp-up operations, consolidation, maintenance and evolution of the DestinE system

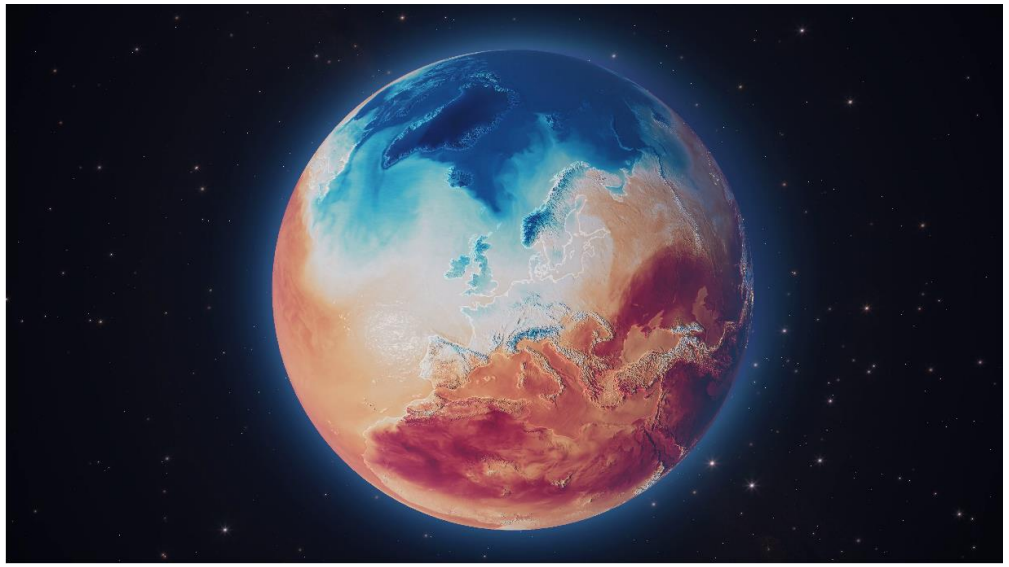
Transition to long-term operations

2023

EuroHPC access

Data access for users

CLIMATE DT: 1ST OPERATIONAL CAPABILITY FOR CLIMATE PROJECTIONS



3 global climate models at ~5km

IFS-NEMO
IFS-FESOM
ICON

CSC
next GEMS

Monitoring & evaluation framework

AQUA

Common format & data governance

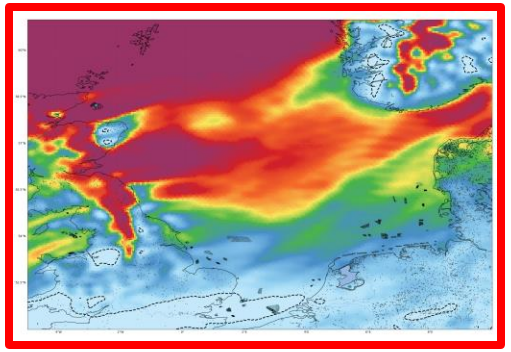
GSV

Computing statistics

One-pass algorithm

Impact-sector models

e.g Tailored information for wind energy



ECMWF

EXTREMES DT : A MAGNIFYING GLASS ON EXTREME WEATHER EVENTS

Global and **daily** simulations of extreme weather
4 days ahead at **4.4km**

On-Demand regional simulations
2 days ahead at **750m** to **500m**

Impact-sector models:
user-relevant information for societal impacts

IFS-NEMO

Arome
Harmonie-Arome
Alaro

ECMWF

METEO FRANCE
À VOS CÔTÉS, DANS UN CLIMAT QUI CHANGE

CO-DESIGN APPROACH VIA USE CASES

C r

https://destine.ecmwf.int/destine-uses/

USE CASE ENERGY SYSTEMS: INTRODUCTION AND KEY RESULTS

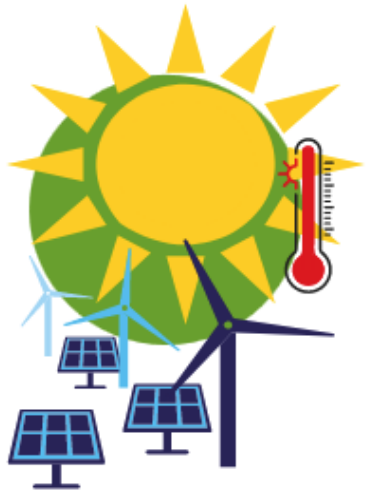
TOOLS AND DATA FOR IMPROVED ENERGY SYSTEMS MODELING WITH DESTINATION EARTH

Bruno Schyska

Project Leader, Institute of Networked Energy Systems

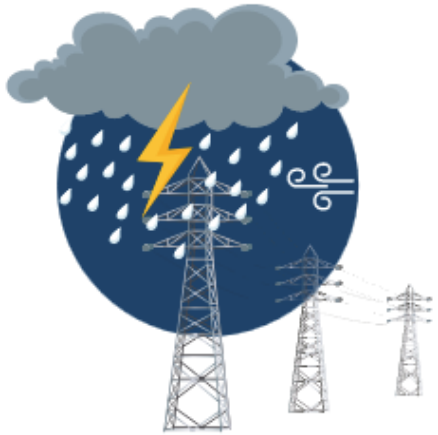
DLR

CLIMATE IMPACTS ON ENERGY SYSTEMS



GENERATION

Efficiency and potential of generation assets can be affected.



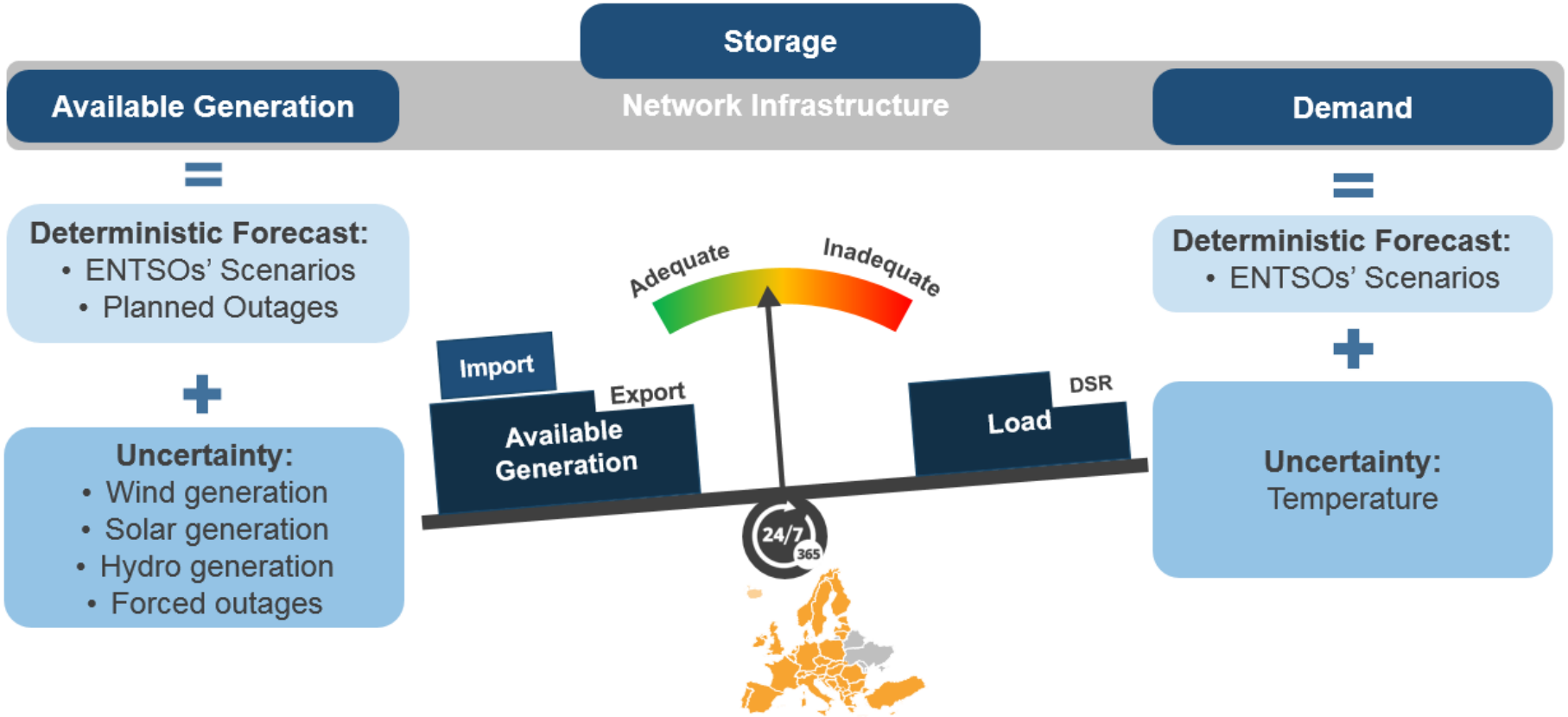
INFRASTRUCTURE

Transmission and distribution electricity grids can be disrupted.

DEMAND

Heating and cooling demands are directly affected by extreme temperatures.

ENTSO-E European Resource Adequacy Assessment (ERAA)



OBJECTIVES OF THE USE CASE ENERGY SYSTEMS

BRIDGING INFORMATION GAP

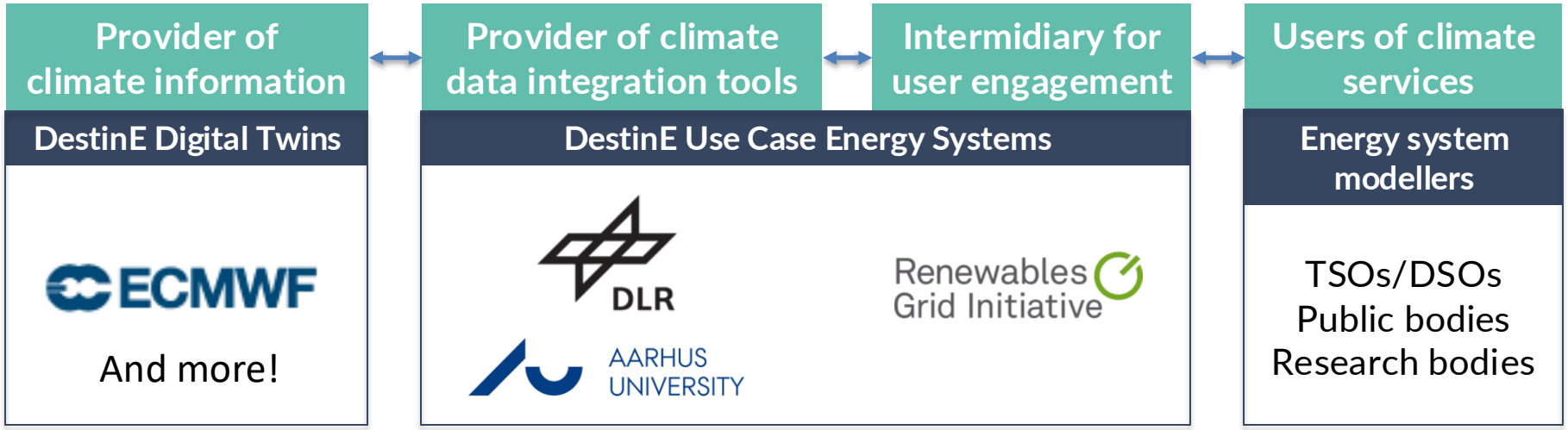
- Introducing **climate and weather data** into **power/energy system modelling**
- Providing more accurate **energy system planning**
- Contributing to the **co-design** of the **DestinE Climate DT**

SUPPORT USERS' COMMUNITY

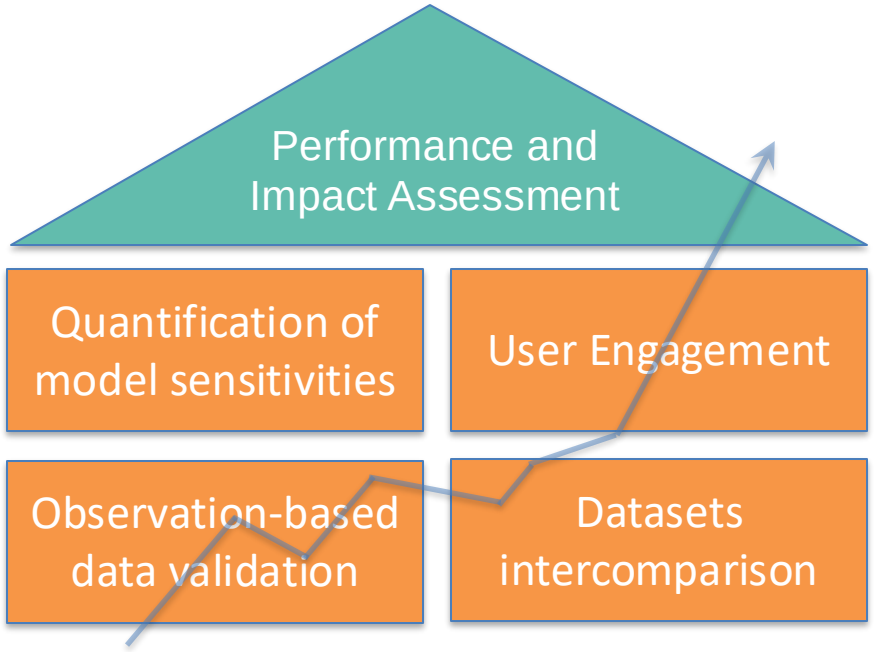
- Providing tools and methods for integration of **climate information** in **energy system models**
- Offering **guidance** and **expert knowledge**
- Contributing to **more informed decision-making process**

USE CASE ACTORS

CO-PRODUCING CLIMATE INFORMATION



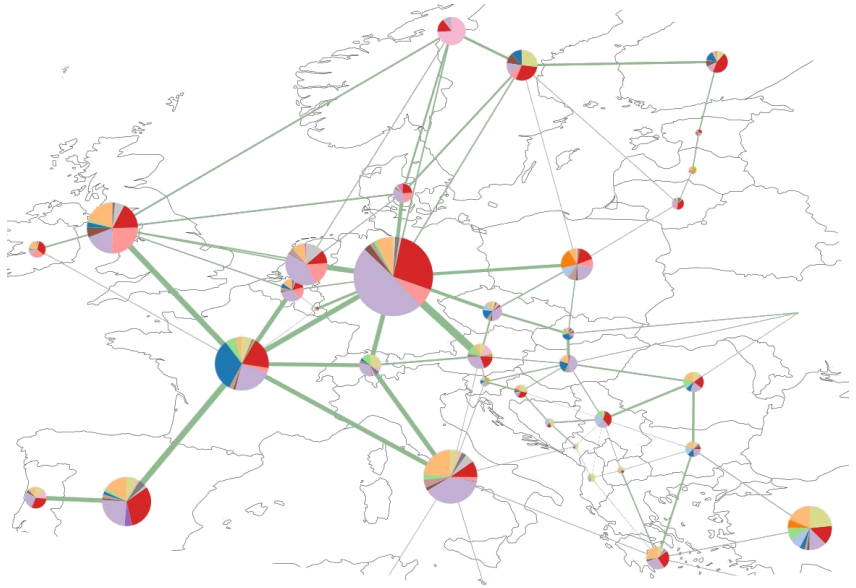
MOTIVATION



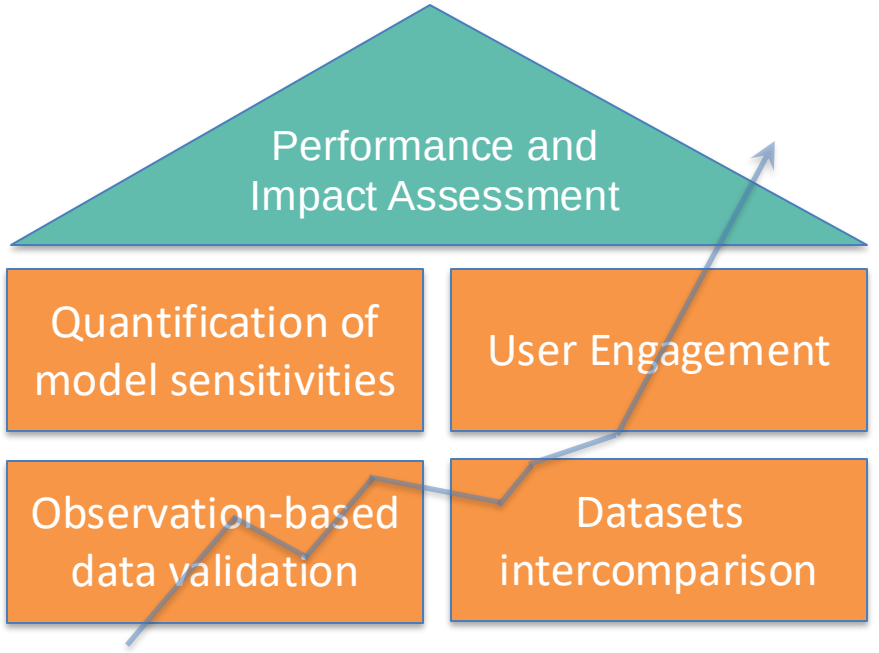
What a difference DestinE makes for energy systems modeling

MOTIVATION

The Energy Systems Demonstrator



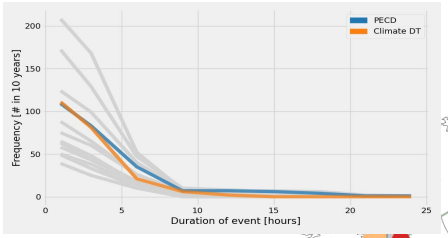
A representative user workflow implemented in on open-source power system modelling framework

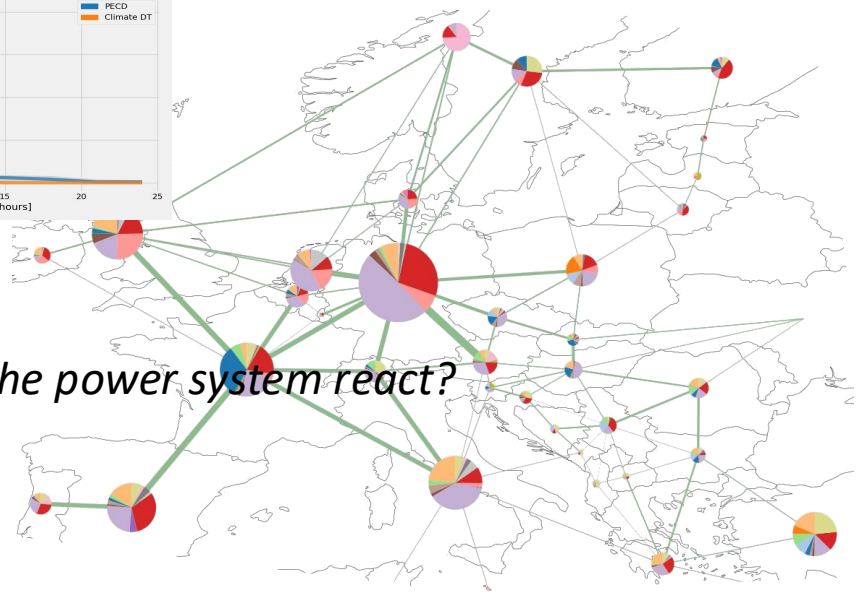


What a difference DestinE makes for energy systems modeling

MOTIVATION

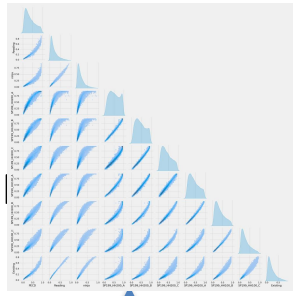
The Energy Systems Demonstrator



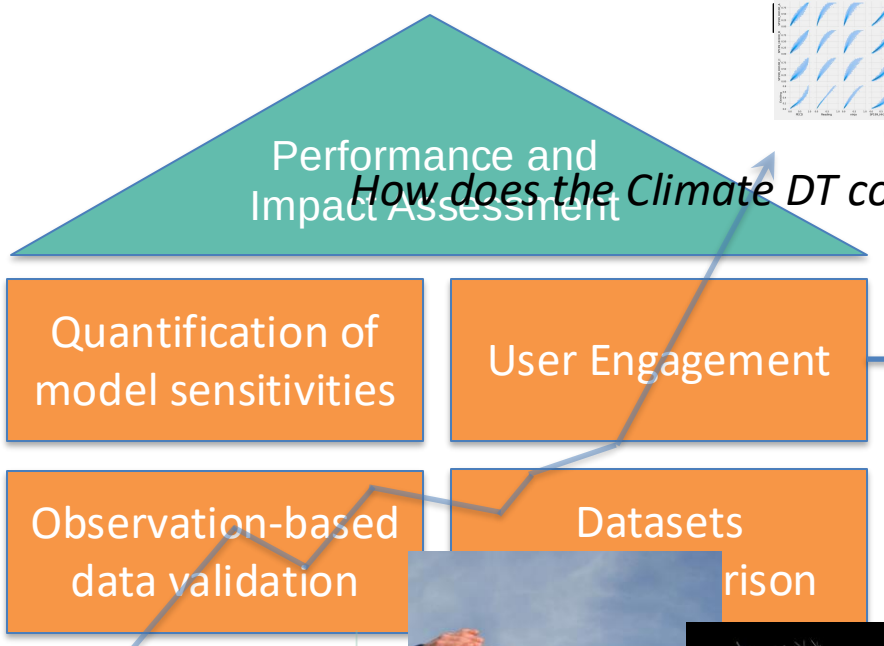


How does the power system react?

A representative user workflow implemented in on open-source power system modelling framework



How does the Climate DT compare?

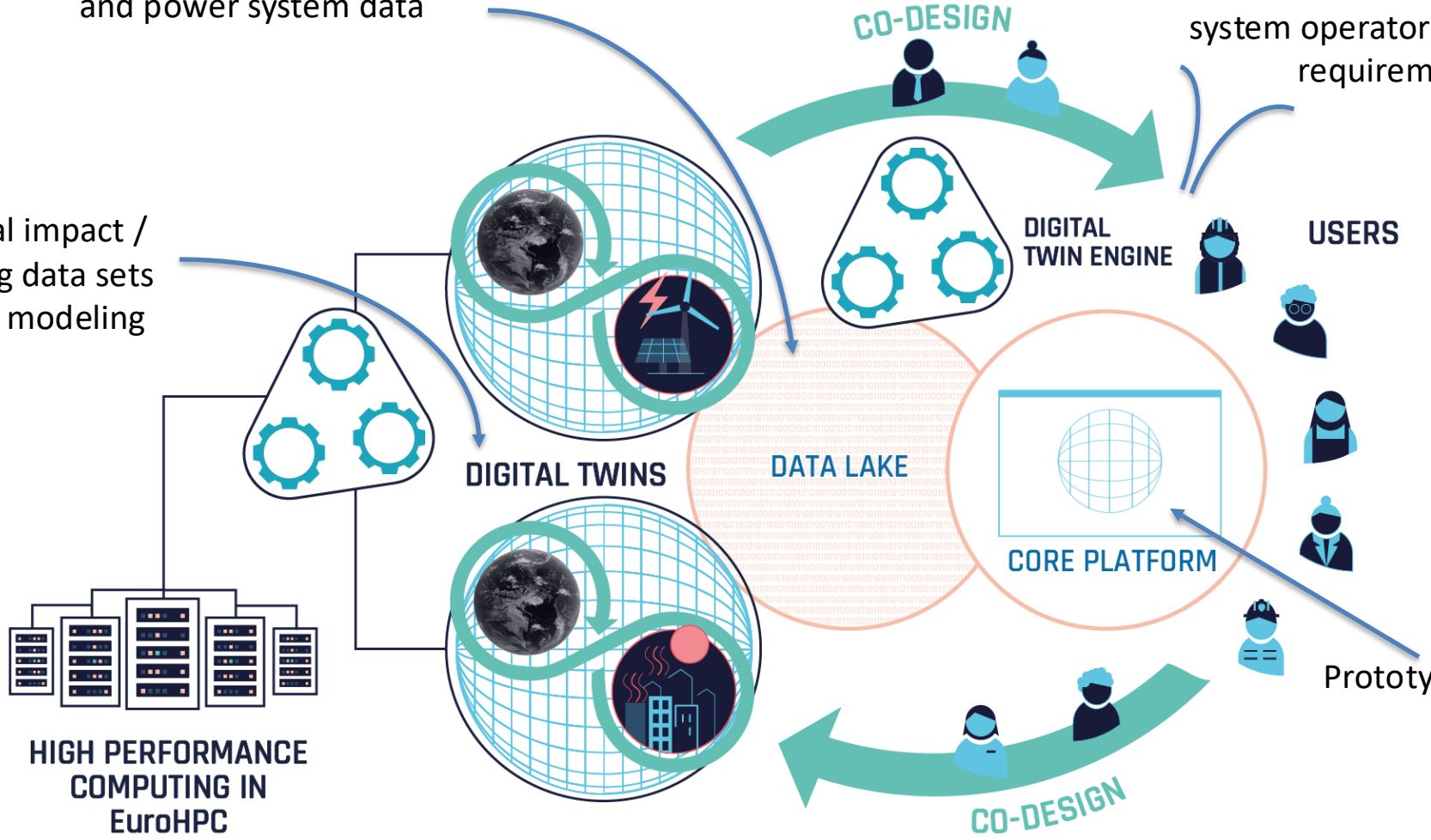


Quality of Climate DT data

CONTRIBUTING TO DESTINE

Enrich with renewable energy and power system data

Assess the potential impact / benefit over existing data sets for energy systems modeling



Intermediate / advocate for system operators needs and requirements

Prototyping a potential energy systems service

THE DATA

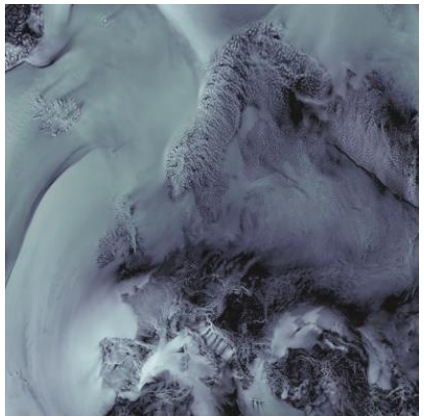
We combine:

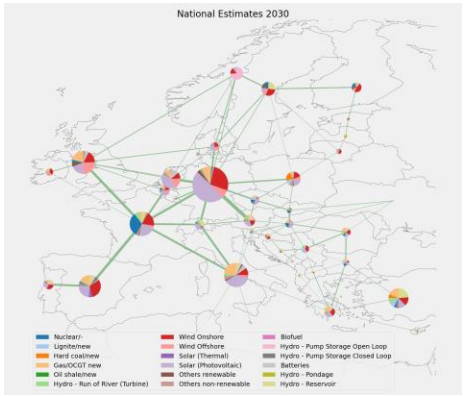
- Databases used by ENTSO-E for the annual *European Adequacy Assessment* (ERAA), namely the PECD and PEMMDB, with

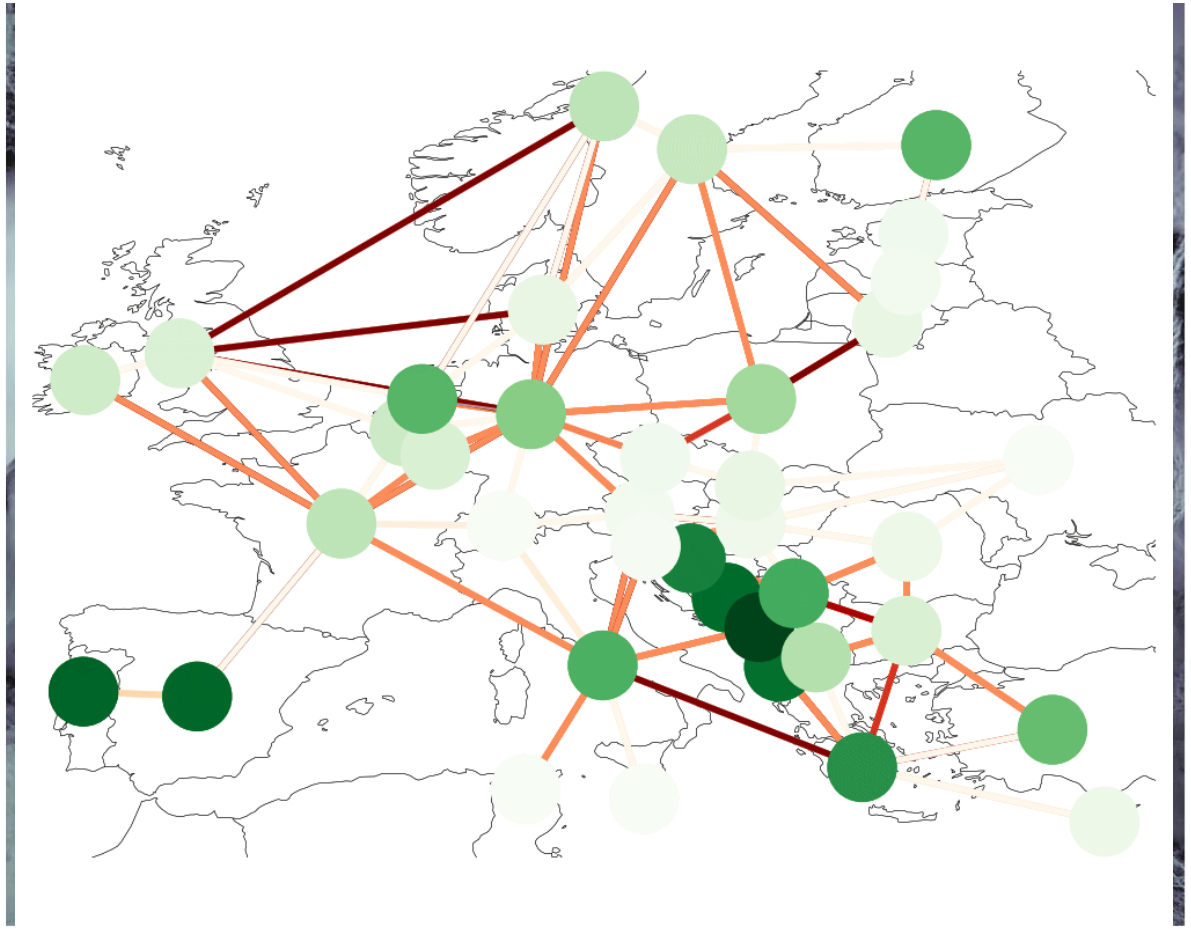
- Time series derived from DestinE's Climate DT,
- Alternative PECD scenarios[1] and
- Further openly available data sets (here: University Reading[2])

1) Koivisto, Matti Juhani; Murcia Leon, Juan Pablo (2022). Pan-European wind and solar generation time series (PECD 2021 update). Technical University of Denmark. Collection. https://doi.org/10.11583/DTU.c.5939581.v3
2) Bloomfield, Hannah and Brayshaw, David (2021): ERA5 derived time series of European aggregated surface weather variables, wind power, and solar power capacity factors: hourly data from 1950-2020. University of Reading. Dataset. https://doi.org/10.17864/1947.000321

THE DEMONSTRATOR



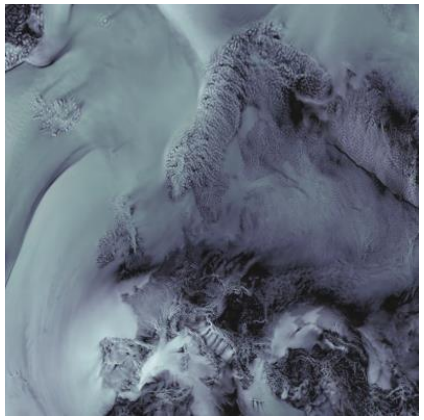


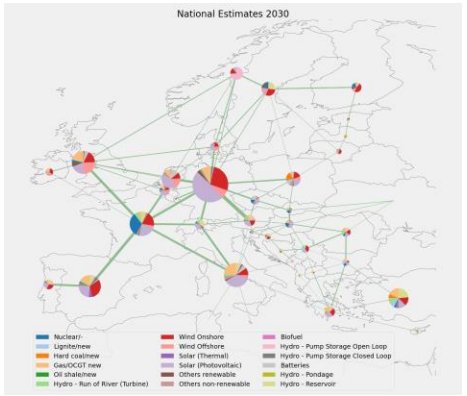


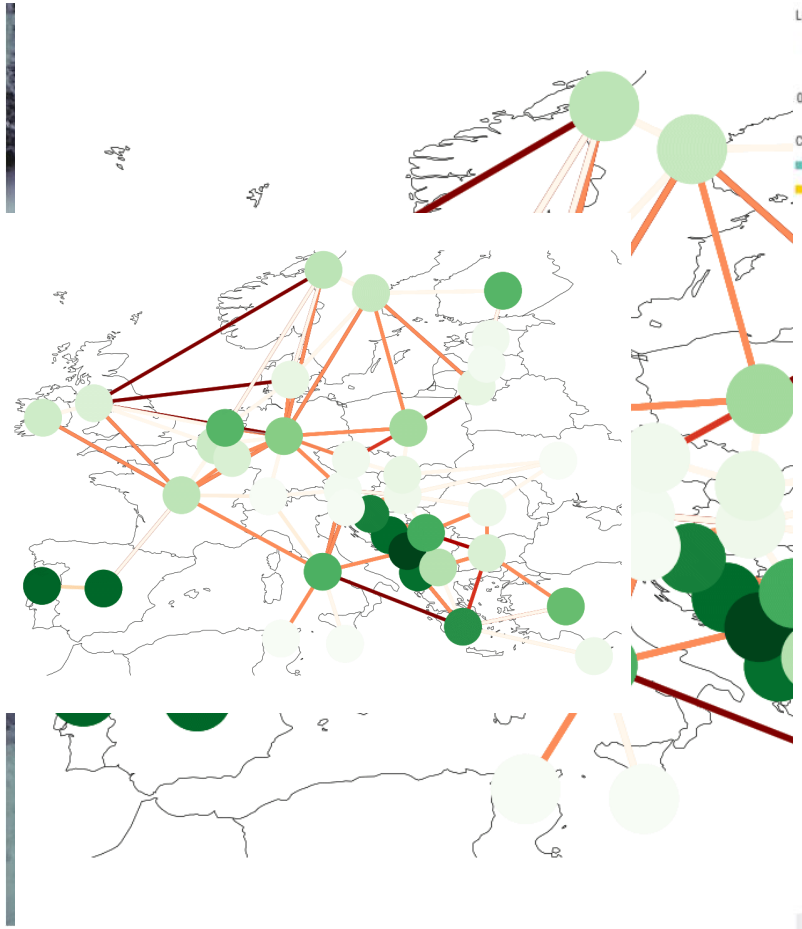
ERAA 2023 (Credit: ENTSO-E)

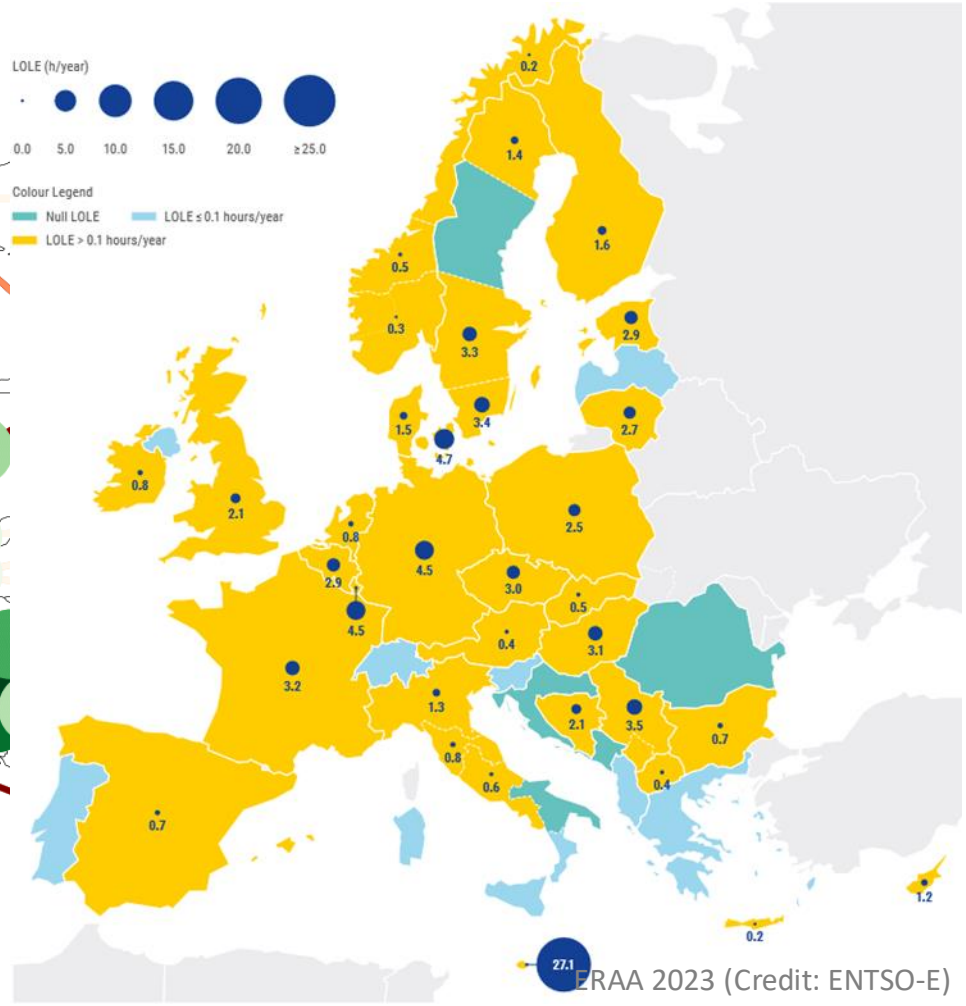
From information ⟶ through simulation ⟶ to impact

THE DEMONSTRATOR



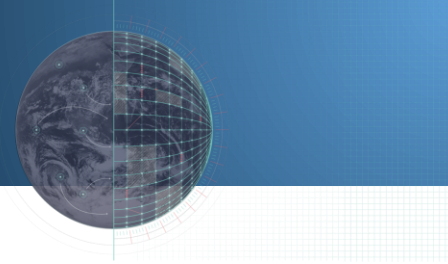






ERAA 2023 (Credit: ENTSO-E)

From information ⟶ through simulation ⟶ to impact



THE TOOLS

1. Demonstrator showcasing the use of meteorological information in a semi-operational power system modeling workflow following the lines of the European Resources Adequacy Assessment[1]

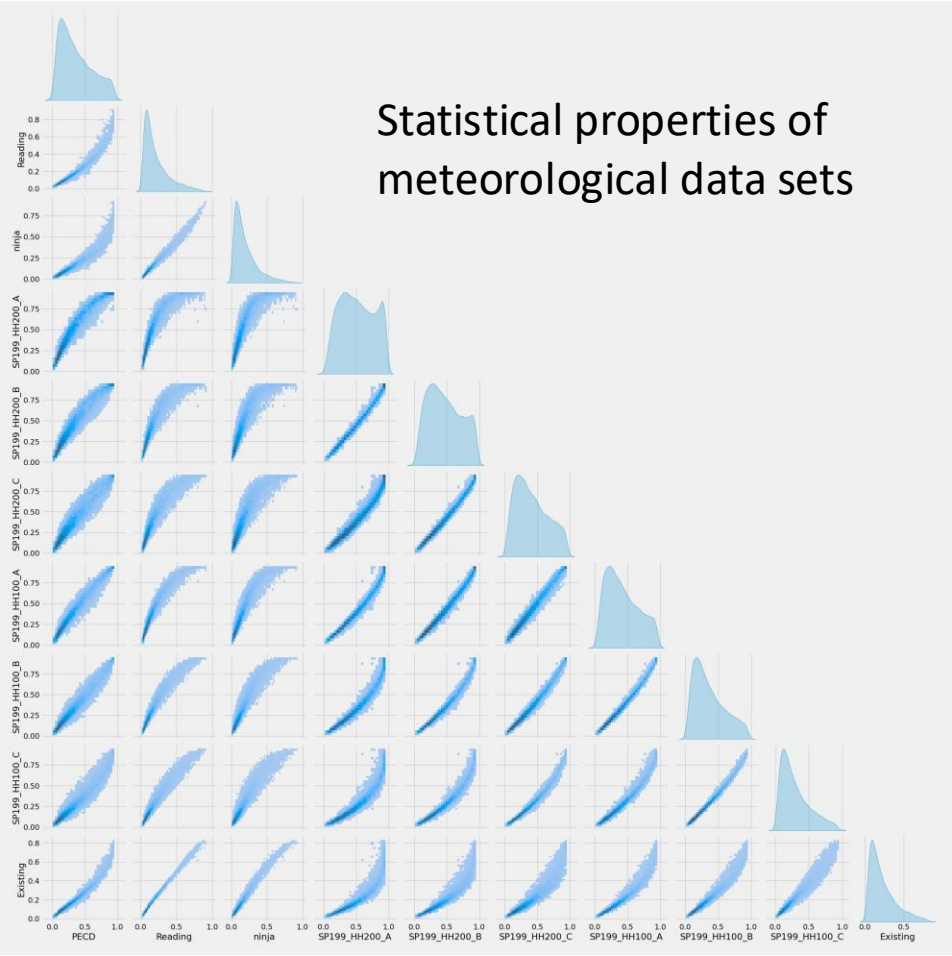
2. Standardized assessment of model sensitivities on meteorological parameters linking results of power system simulations to meteorological conditions

3. Validating Climate DT data with high-resolution observations

4. Machine learning to replace expensive and complex linear-optimal-power-flow (LOPF) calculations

[1] implementations are available open-source on GitHub: https://github.com/destination-earth/DestinE_ECMWF_EnSys

DATASETS INTERCOMPARISON



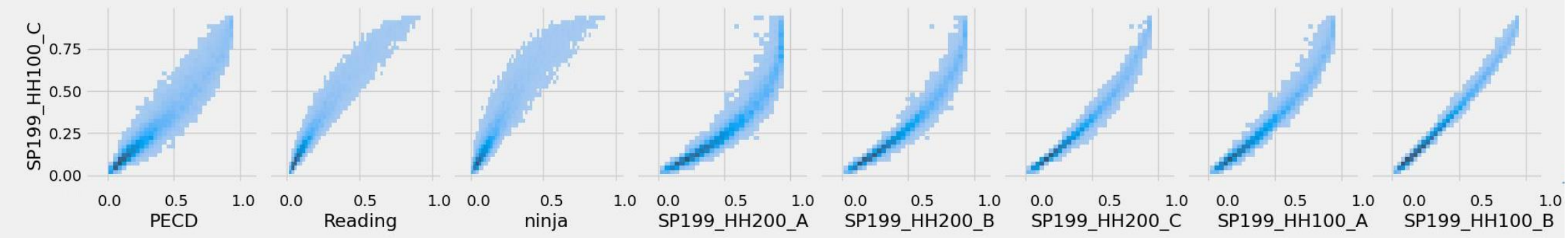
Meteorological data sets used for power system simulations differ in two major aspects:

1. The meteorological *basis* (reanalysis vs. climate models vs. observations)
2. The procedure to convert gridded meteorological information to standardized data sets for power systems modeling

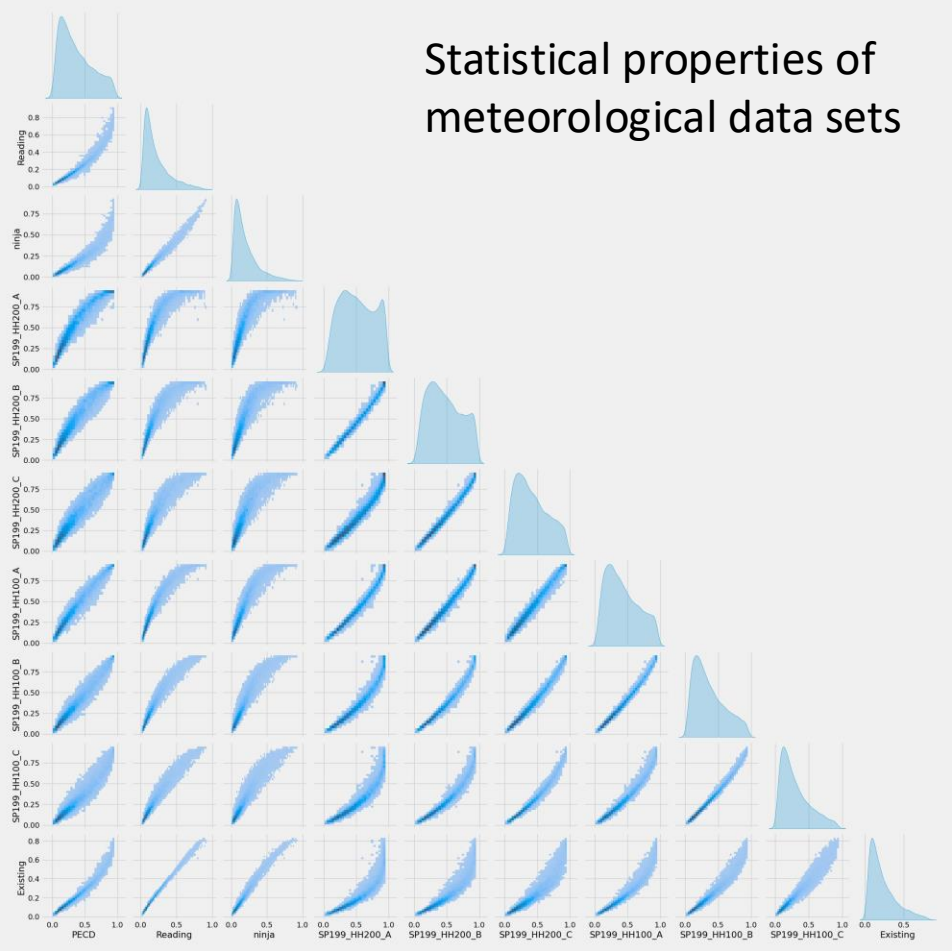
Hourly onshore wind power capacity factors in DE (1985-2015) from 10 different data sets / scenarios.

RESULTS

1. There are distinct differences between the meteorological scenarios.

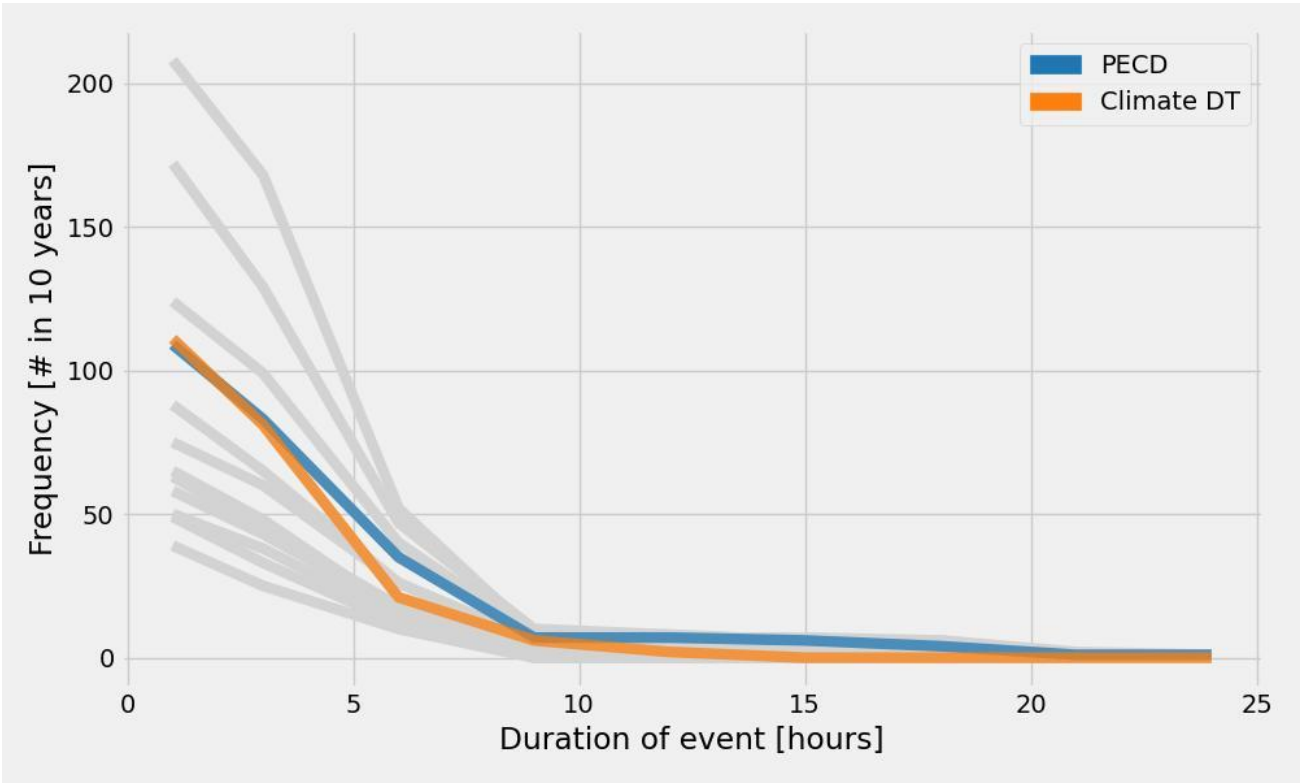


SENSITIVITY ANALYSIS



Statistical properties of meteorological data sets

⟺ Simulation results (here: Lossed-load-events)



SENSITIVITY ANALYSIS

Scenario / Indicator	Energy Not Served			Loss-of-Load Expectation		
	DE	BE	DK	DE	BE	DK
PECD	0.09	0.02	0.05	53.8	22.9	30.4
Minimum	0.02	0.0	0.0	15.1	6.3	2.3
Maximum	0.19	0.04	0.15	99.8	48.6	68.1
Climate DT	0.07 (4)	0.01 (2)	0.04 (3)	45.0 (5)	9.0 (1)	24.1 (4)

Adequacy Indicators* derived from running the DestinE Energy Systems Demonstrator with 13 different meteorological data sets.

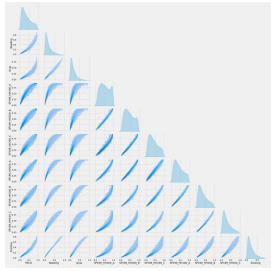
* Our Demonstrator is a simplified implementation of ERAA. Results must not be compared to the offical results published by ENTSO-E.

RESULTS

1. There are distinct differences between the meteorological scenarios.

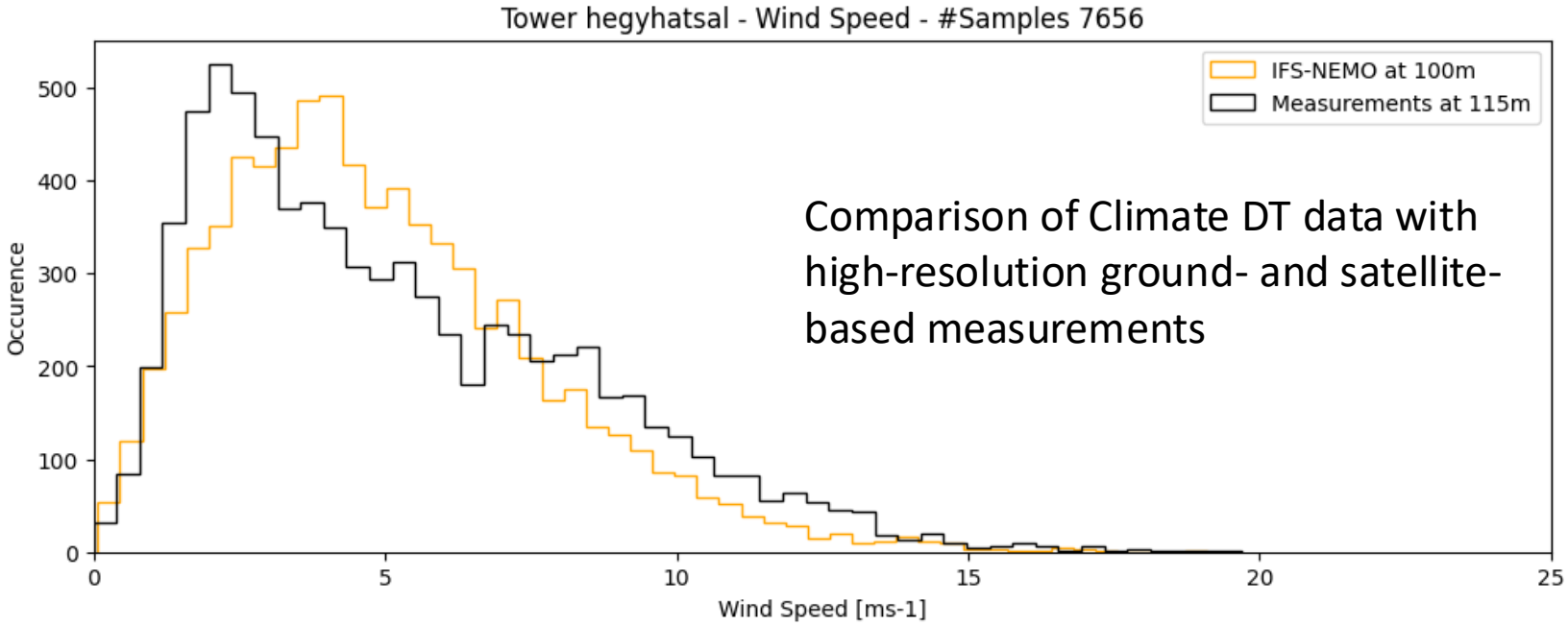
2. The power system reacts sensitive to statistical properties of the meteorological information used for the simulations.

QUALITY ASSESSING DESTINES CLIMATE DT

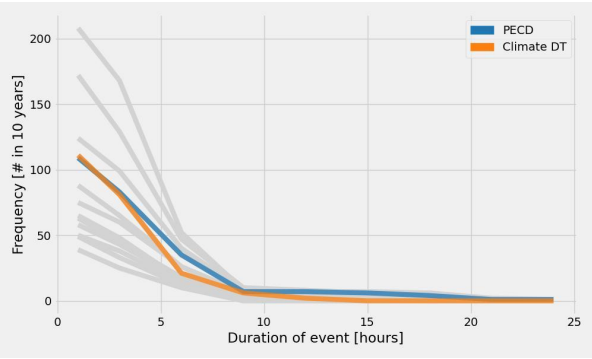


Statistical properties of meteorological data sets

Simulation results (here: Lossed-load-events)



Comparison of Climate DT data with high-resolution ground- and satellite-based measurements



OBSERVATION-BASED DATA VALIDATION

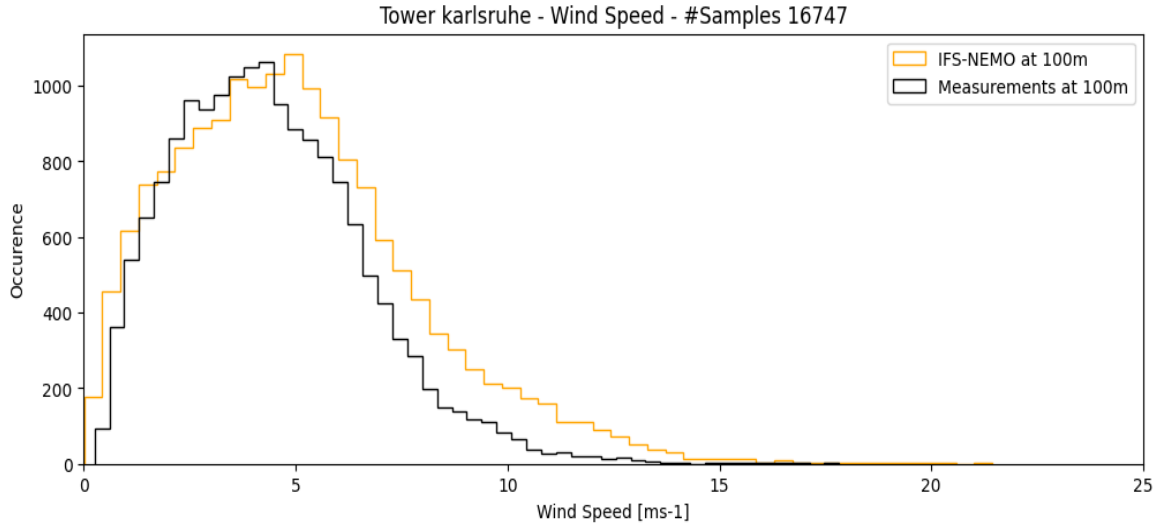
We have performed an observation-based validation of the DestinE ClimateDT data using

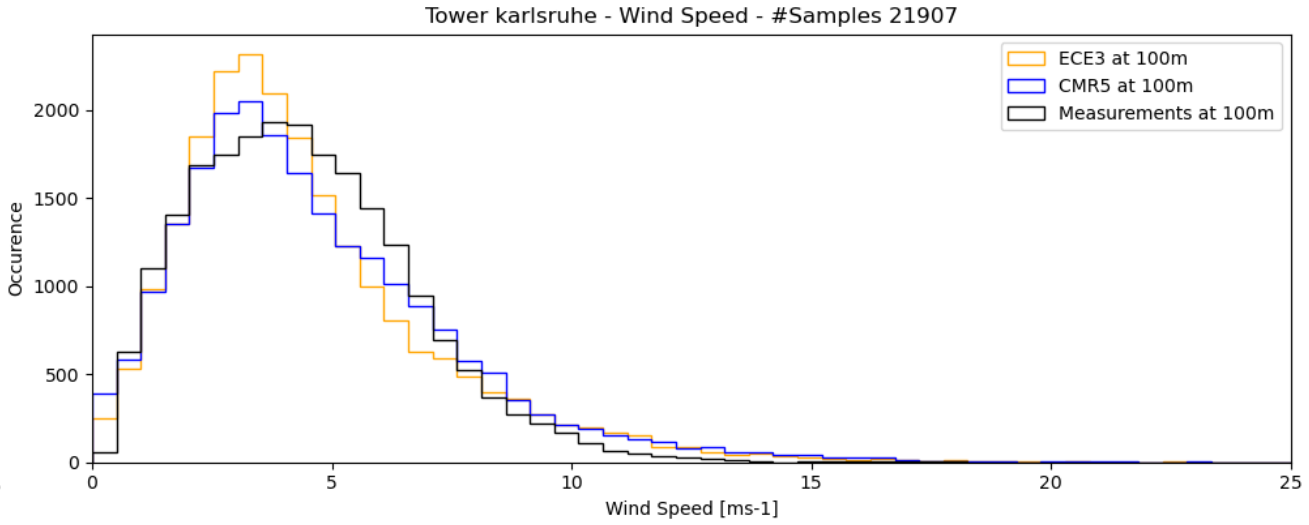
- DLR's unique cloud and radiation measurement network *eye2sky*
- Long-term measurement timeseries from the *Baseline Surface Radiation Network* (BSRN)
- Satellite-based solar irradiance products (*DLR-Solarleistungsprognose* SLP, *CAMS gridded data v4.5* CRS)
- Wind measurements from BSC's tall tower data archive[1]

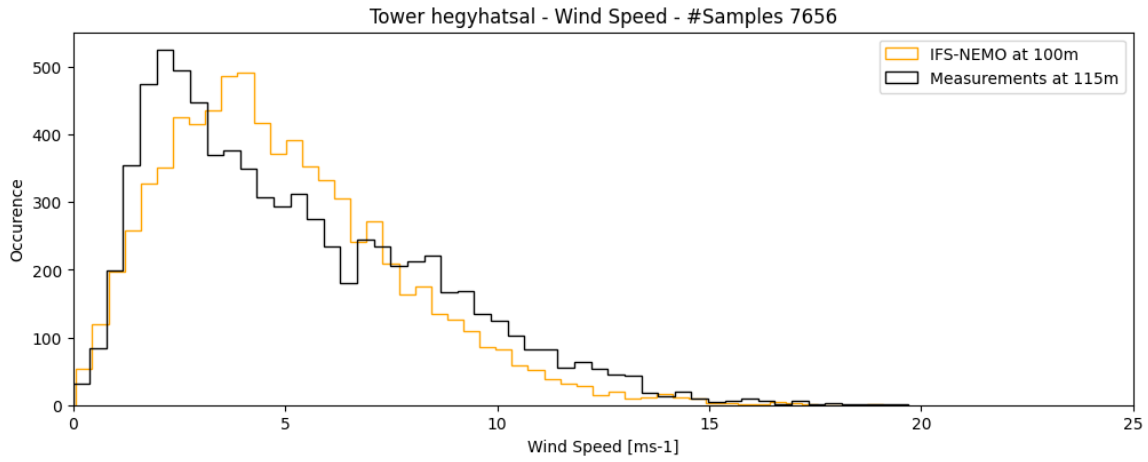
The validation focuses on statistical parameters (mean bias error, data distribution), variability metrics for temporal and spatial patterns with respect to data resolution and a comparison between climate models and observations.

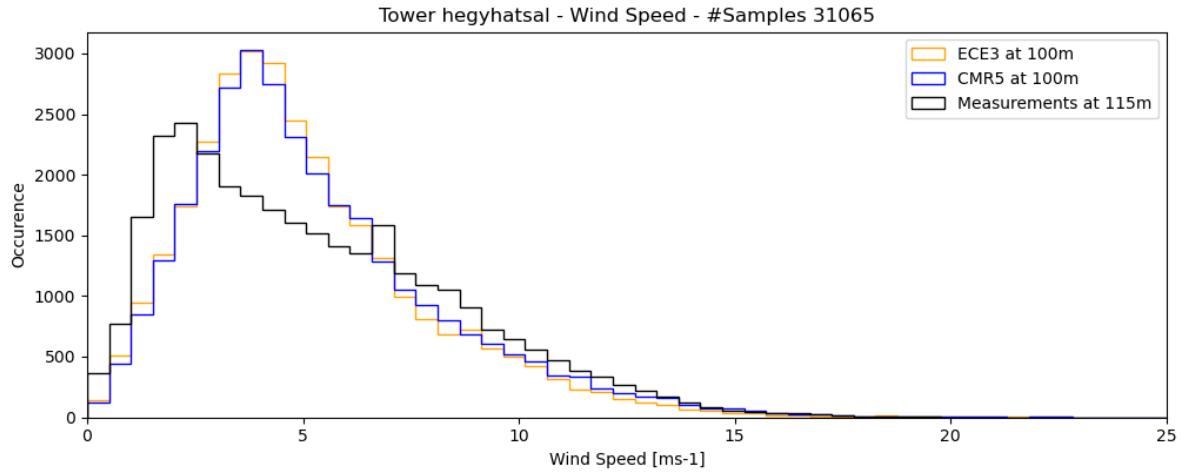
This work is ongoing, results are preliminary.

OBSERVATION-BASED DATA VALIDATION









RESULTS

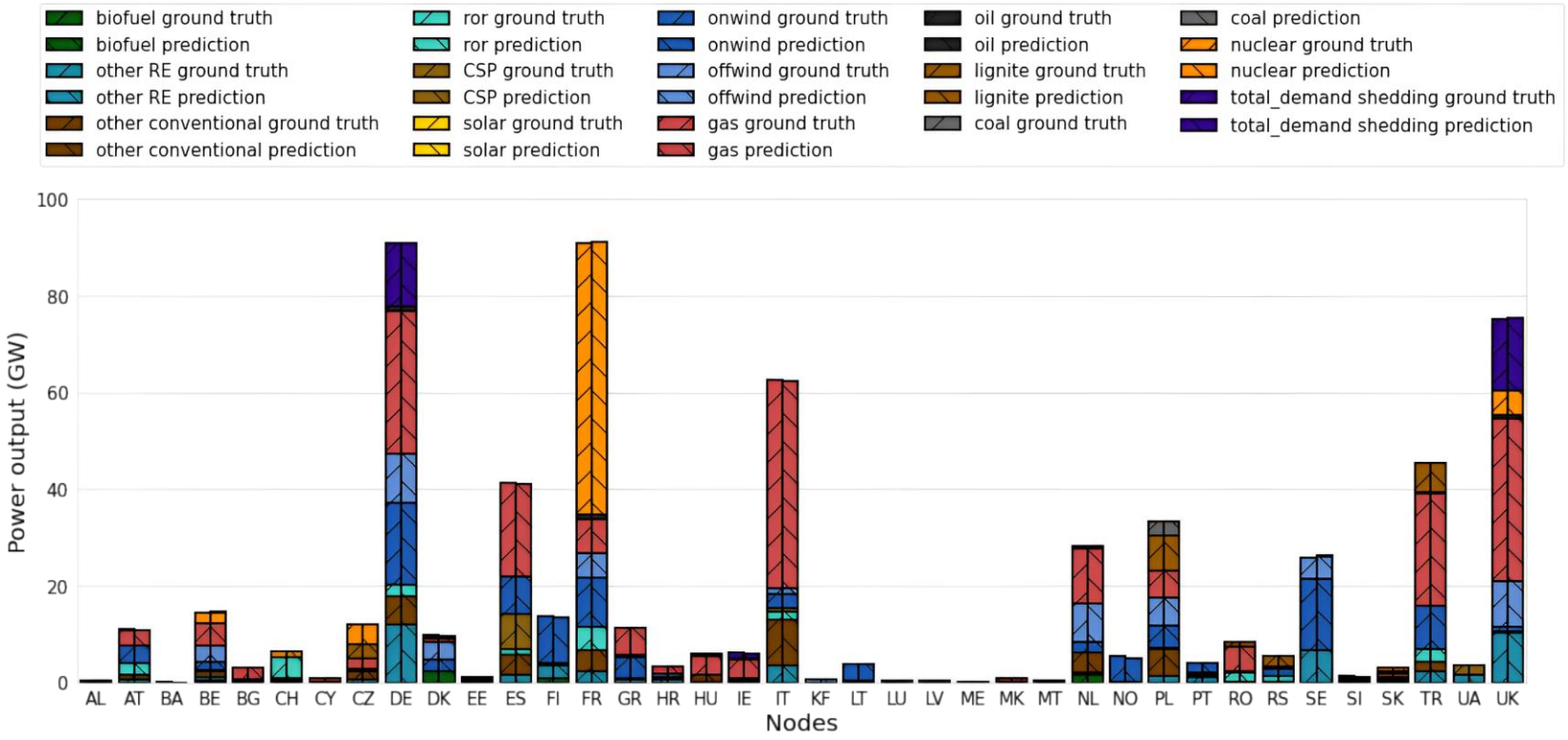
1. There are distinct differences between the meteorological scenarios.

2. The power system reacts sensitive to statistical properties of the meteorological information used for the simulations.

3. The Climate DT shows a comparable high accuracy with respect to the representation of spatial and temporal variability of energy-related variables.

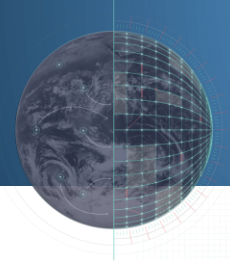
ML PROOF-OF-CONCEPT: RESULTS

- ML model is able to accurately predict the cost-optimal power dispatch in critical situations (occurrence of *lossed load*).
- No expensive optimization is required, computational cost are reduced.



CONCLUSIONS

1. DestinE provides high-quality, state-of-the-art data which should be considered as a data source for power systems simulations.



CONCLUSIONS

DestinE provides

- ✓5-10 km resolution
- ✓Global information with local granularity
- ✓Regular operational production

important

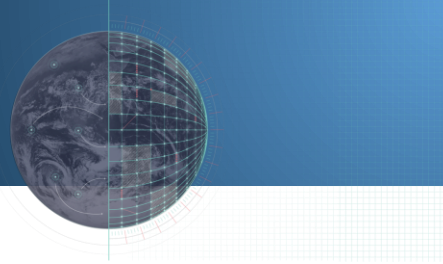
- ✓Bringing earth system models and impact sector models within the same workflow.

exciting

- ✓Platform for bringing together research + industry + policy to turn data and knowledge into action

Most important

[adopted from Irina Sandu]



USE CASE ENERGY SYSTEMS: USER ENGAGEMENT AND CO-DESIGN

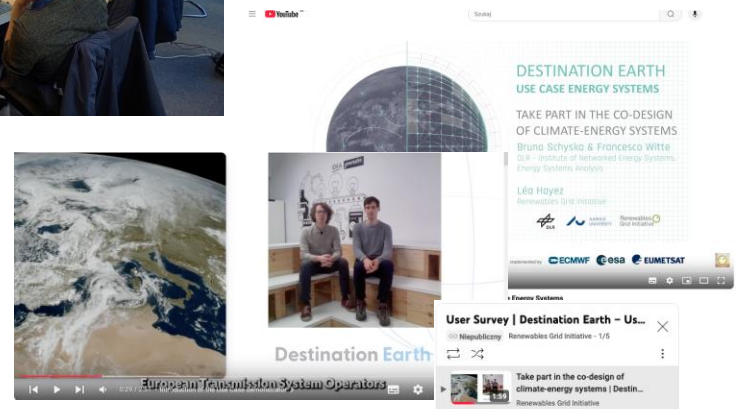
OBJECTIVES OF USER ENGAGEMENT

Target audience	Objectives
Grid operators – technical level (planning & operation)	_Raise awareness about climate adaptation in the context of grid planning _Ensure relevance of the demonstrator to users' practices _Understand users' needs to integrate climate information in their workflows _Collect feedback on modelling development
Grid operators – strategical level	_Raise awareness about climate adaptation in the context of grid planning _Ensure relevance of the demonstrator to users' practices _Disseminate DestinE objectives & status
The scientific community	_Disseminate DestinE objectives & status _Collect feedback on modelling development
Public bodies	_Raise awareness about climate adaptation in the context of grid planning _Disseminate DestinE objectives & status _Collect feedback on modelling development _Inform with required policy adjustments for enabling climate-proof energy systems

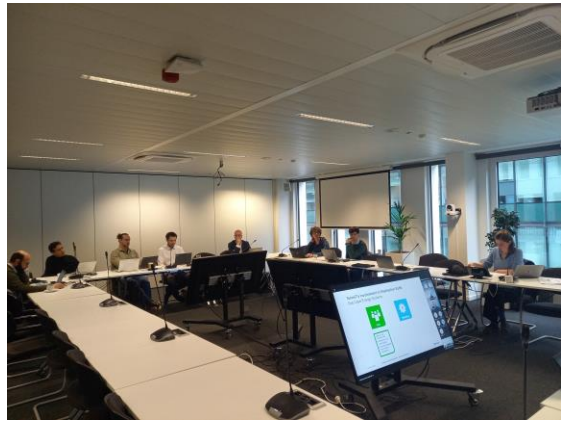
USER ENGAGEMENT
CO– PRODUCTION ACTIVITIES

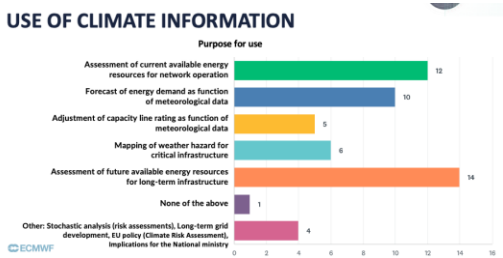
- 28.02.2023 – User Needs Workshop (Bonn), hybrid, 40 participants

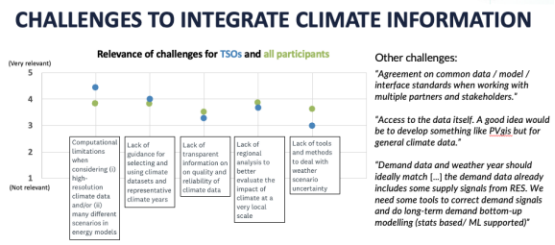
- January/February 2024 – online survey (+30 respondents)



- 6.02.2024 – User Perspectives Workshop (Brussels), hybrid, 30 participants

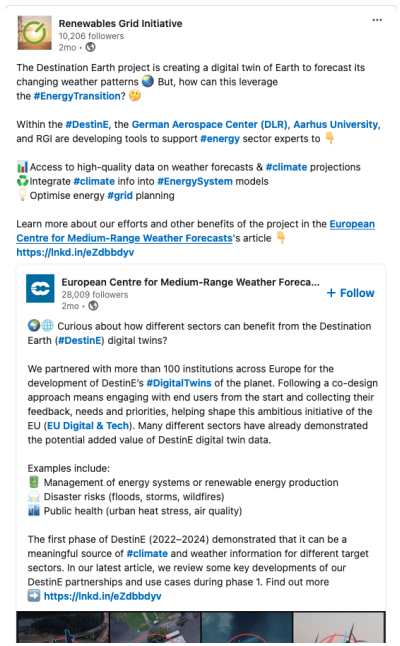


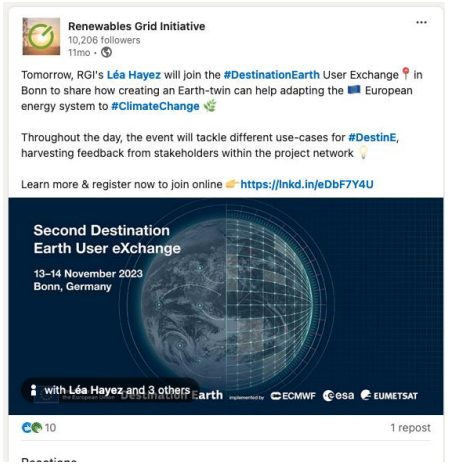




USER ENGAGEMENT

FACILITATING USER COMMUNITY



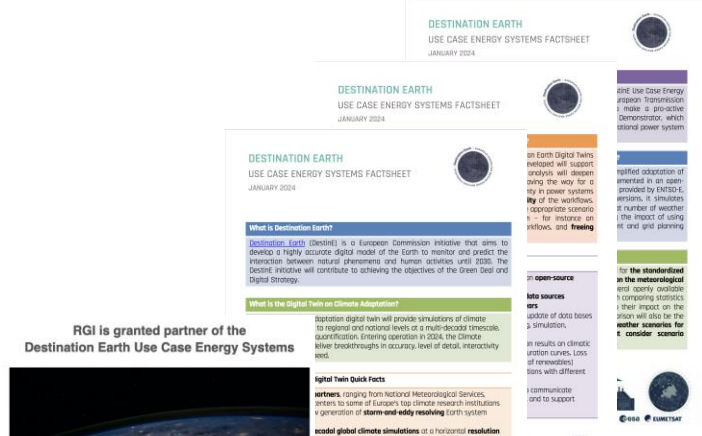


Attendance in dedicated events

DestinE Users Exchange Meeting 14/11/2023 (©ECMWF)

RGI's XR Conference 29/10/2024 (©RGI)

Publications



RGI is granted partner of the Destination Earth Use Case Energy Systems

Destination Earth (DestinE): Towards co-design of climate-energy models

On **28 February**, RGI organised a "User Needs" workshop on how **energy system modellers and operators** can enhance the use of climate information in their workflows. The hybrid workshop was attended by a group of 40 experts representing several user perspectives, including TSOs, DSOs, researchers in energy and climate modelling, and representatives of the European Commission.

This activity was developed within the Destination Earth (DestinE) *Use Case Energy Systems*, led by the European Centre for Medium-Range Weather Forecasts (ECMWF) and the German Aerospace Center (DLR). As a DestinE partner, RGI will co-design innovative methods and tools to improve the climate resilience of the energy system together with model users.

Read more about the project

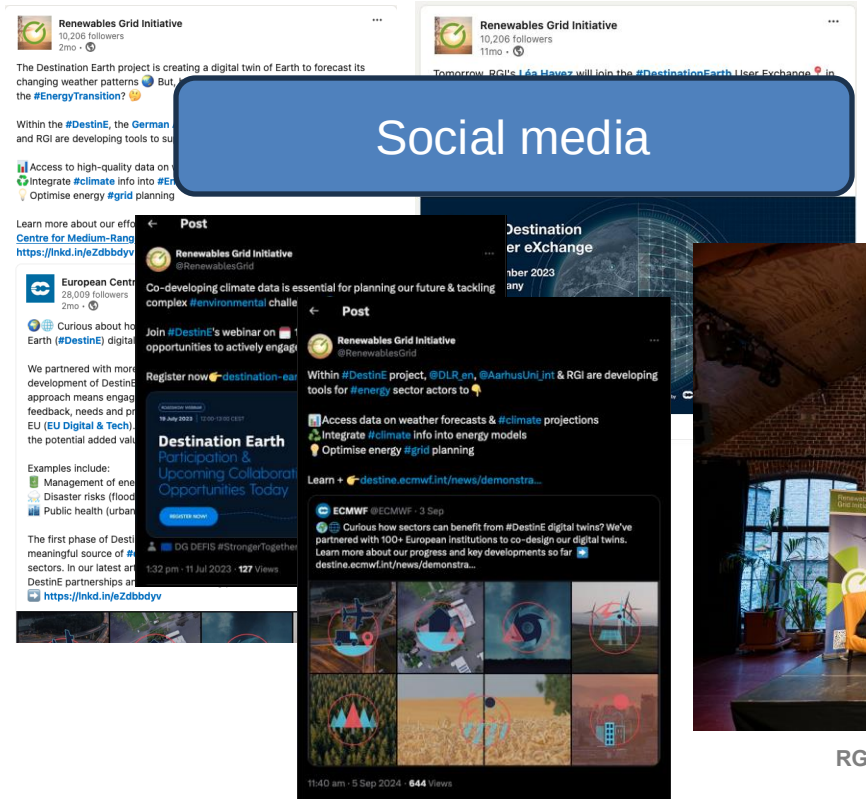
Contact Léa Hayez if you would like to participate in future exchanges

Newsletter items

USER ENGAGEMENT

FACILITATING USER COMMUNITY

Social media



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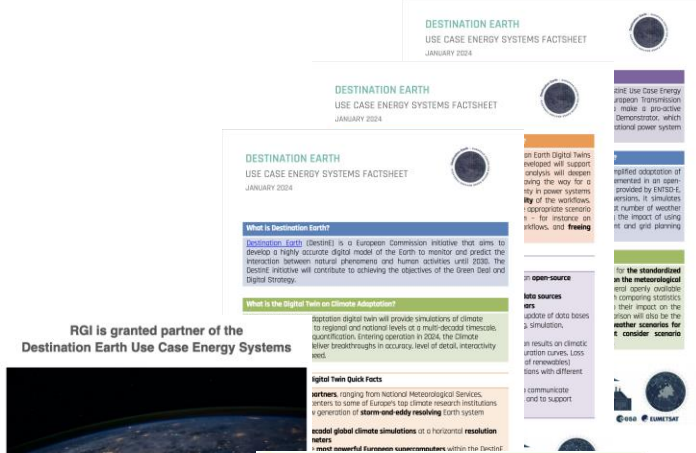

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Read more about the project

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15-16 October 2024

Event

Darmstadt, Germany

The third Destination Earth User eXchange aims to convene current and prospective users of DestinE and developers of the DestinE system. During various sessions the resources available to users will be demonstrated, highlighting how they can benefit. Goals include sharing information about the system's status and use, showcasing user interaction examples, identifying expectations and requirements for future adaptations, fostering dialogue between stakeholders and potential partners, attracting interested parties, and exploring ways to enhance interaction and engagement.

All information on the event is available here

Newsletter items

USE CASE ENERGY SYSTEMS: USERS' PERSPECTIVE

Andreas Zucker

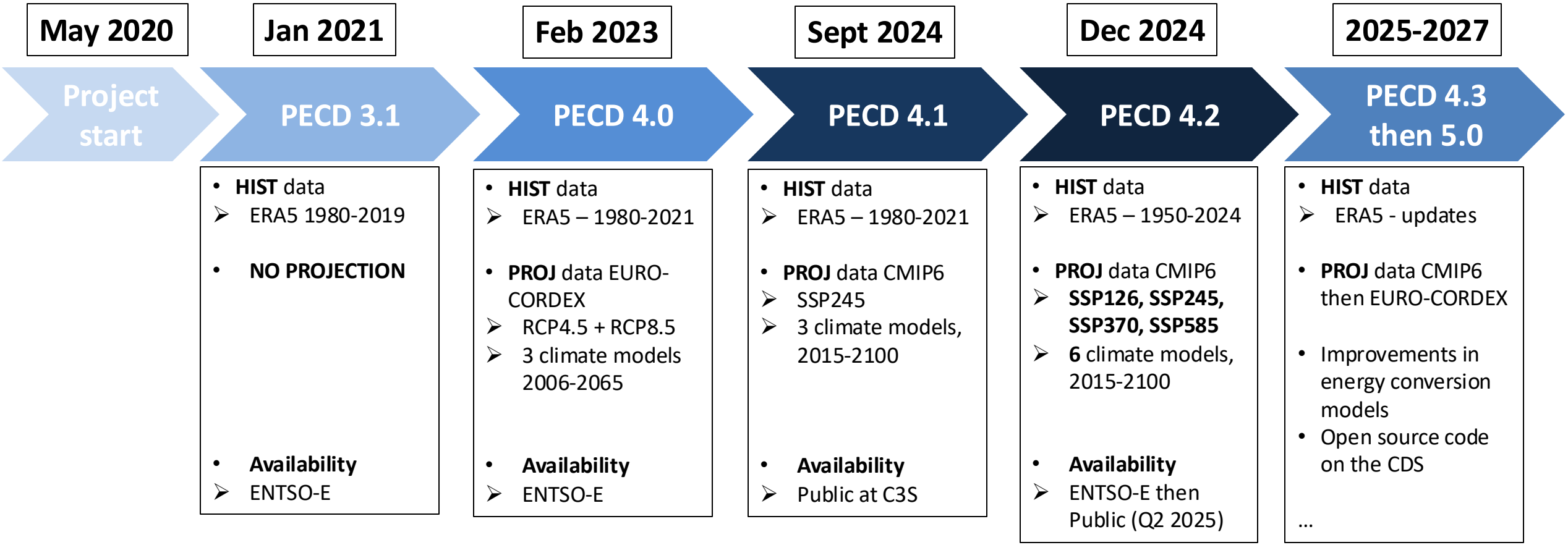
Policy Officer, Chief Economist Unit

DG-ENER

Laurent Dubus

Senior Scientist at Climate, Long-Term Power System Adequacy and Planning Group

RTE


May 2020
Project start
Jan 2021
PECD 3.1
• HIST data
➢ ERA5 1980-2019
• NO PROJECTION
• Availability
➢ ENTSO-E
Feb 2023
PECD 4.0
• HIST data
➢ ERA5 – 1980-2021
• PROJ data EURO-CORDEX
➢ RCP4.5 + RCP8.5
➢ 3 climate models 2006-2065
• Availability
➢ ENTSO-E
Sept 2024
PECD 4.1
• HIST data
➢ ERA5 – 1980-2021
• PROJ data CMIP6
➢ SSP245
➢ 3 climate models, 2015-2100
• Availability
➢ Public at C3S
Dec 2024
PECD 4.2
• HIST data
➢ ERA5 – 1950-2024
• PROJ data CMIP6
➢ SSP126, SSP245, SSP370, SSP585
➢ 6 climate models, 2015-2100
• Availability
➢ ENTSO-E then Public (Q2 2025)
2025-2027
PECD 4.3 then 5.0
• HIST data
➢ ERA5 - updates
• PROJ data CMIP6 then EURO-CORDEX
• Improvements in energy conversion models
• Open source code on the CDS
…

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

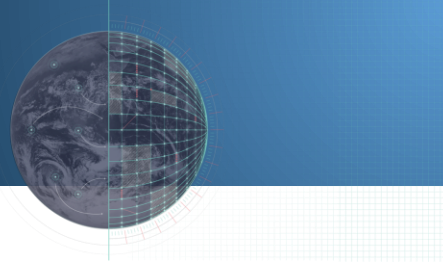
Future version Including significant improvement in wind power capacity factors

PECD 4.2 (December 2024)

Historical stream : 1980-2023

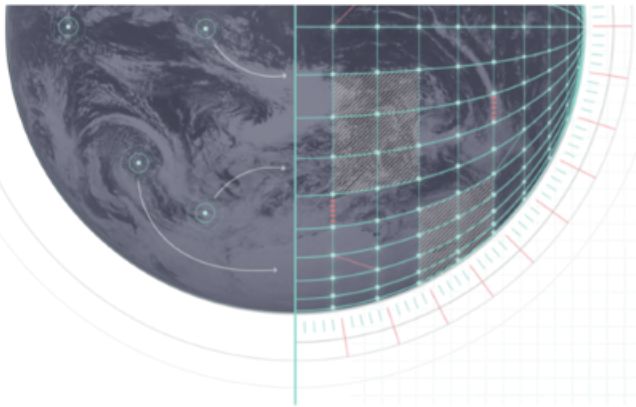
Projections : Continuous simulations **2015-2100**
6 climate models (CMIP6)
4 scenarios: **SSP126**, SSP245**, SSP370 and SSP585**

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



TIME FOR QUESTIONS!

THANK YOU!



DESTINATION EARTH – USE CASE

ENERGY SYSTEMS

DLR AARHUS UNIVERSITY Renewables Grid Initiative

Funded by the European Union Destination Earth implemented by ECMWF esa EUMETSAT