QTEM DATA CHALLENGE

SPRING 2025

Summary

1

Who is ENGIE?

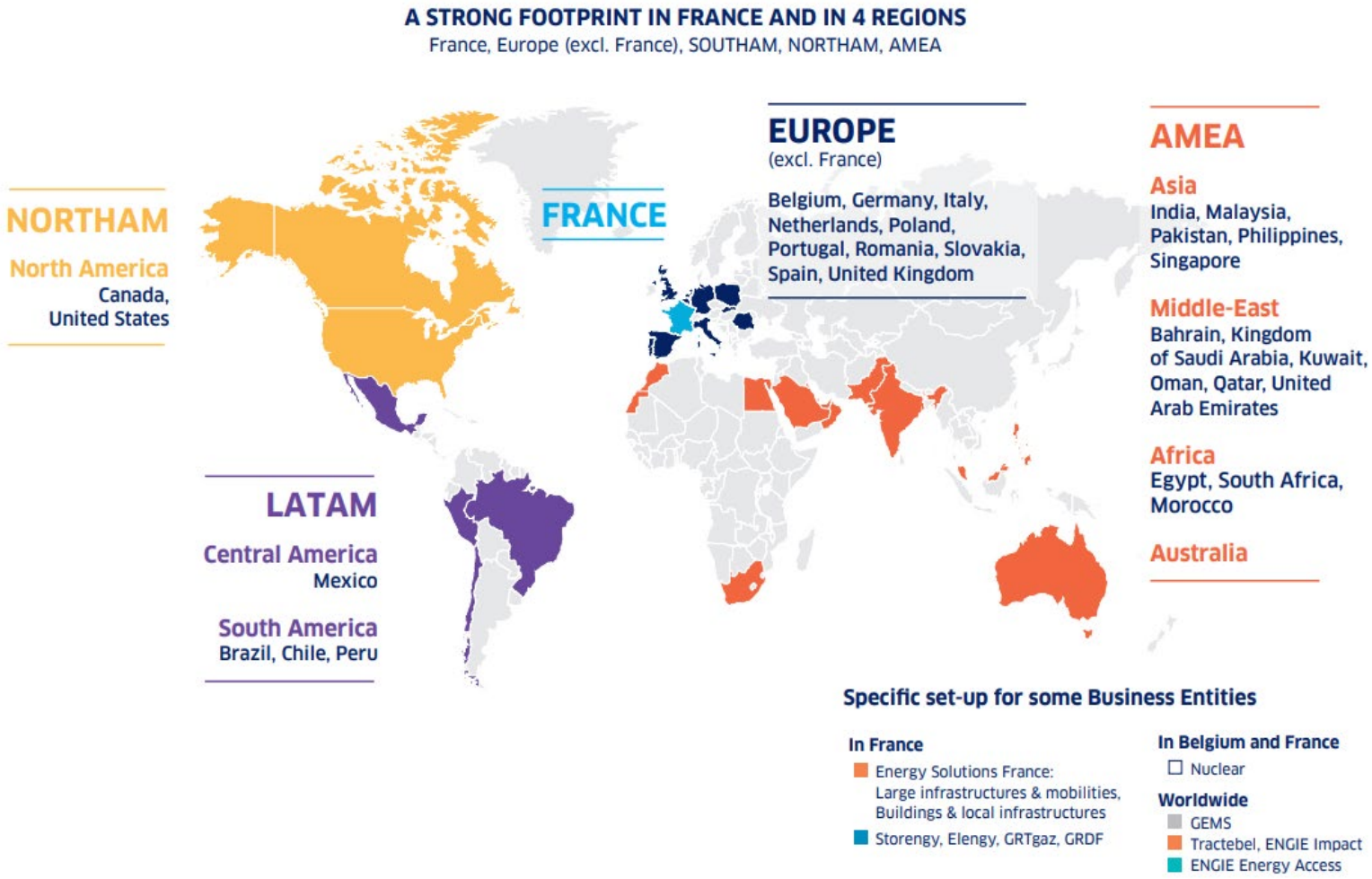
A Global Energy Player

“ENGIE’s purpose (“raison d’être”) is to act to accelerate the transition towards a carbon-neutral economy, through reduced energy consumption and more environmentally-friendly solutions.”

A Global Footprint with Operations in 31 Countries

In 2023:

- ✓ **97,300** employees
- ✓ **€82.6 billion** revenue
- ✓ EBIT of **€9.5bn**
- ✓ **3.9GW** installed renewables capacity added
- ✓ **€8.1 billion** growth Capex
- ✓ **10.8 TWh of annual biomethane production capacity** connected to ENGIE's networks in France
- ✓ Further progress on coal exit, with the announcement of the **disconnection of 2 units in Chile** in 2025 and the conversion of a third unit



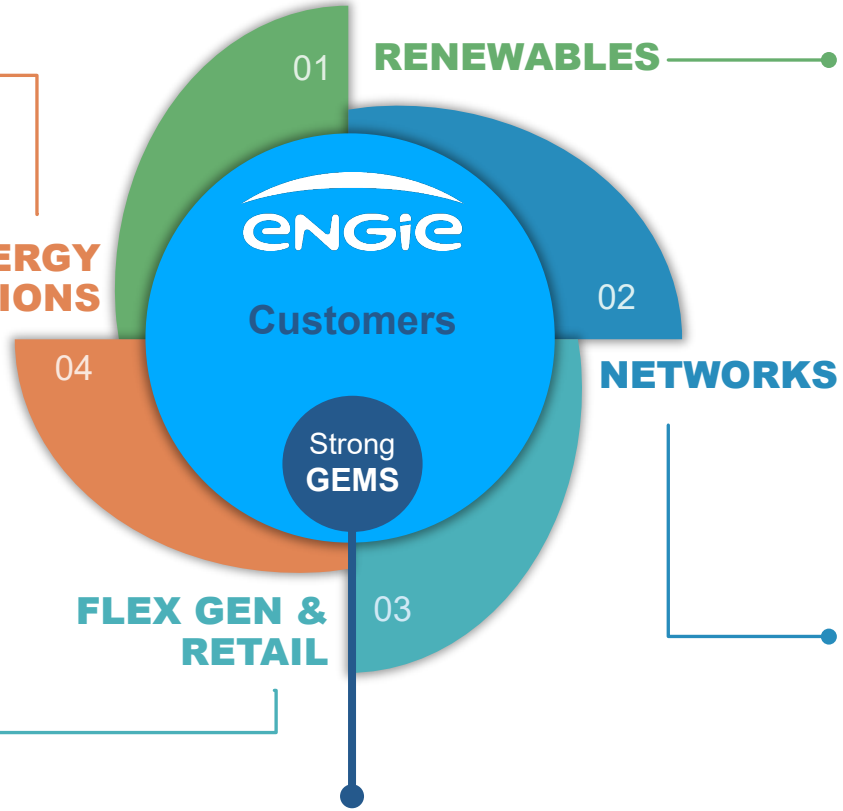
An Integrated Model to Leverage our Competitive Advantages

Distributed infrastructures to decarbonize our customers

Local energy networks | On-site energy production | Energy performance and management

Growing renewables capacity

Onshore Wind | Offshore Wind | Solar PV | Hydro



Bringing more flexibility to the system

Pumped Storage | CCGT | Storage

Leveraging existing infrastructures to support growth

Networks | Biomethane, Hydrogen

ENERGY MANAGEMENT EXPERTISE

- Commercializing renewables
- Optimizing our fleet and monetizing its flexibility

Our 4 Business Units at a Glance

RENEWABLES

- **Challenge:**
  - Ensure a Sustainable Energy Transition
- **Goal**:
  - Target of 80 GW of renewable capacities by 2030 vs 42.4GW as of June 2023
- **Activities**:
  - Hydropower
  - Onshore / offshore Wind
  - Solar (photovoltaic)
  - Battery storage (co-located BESS)

NETWORKS

- **Challenge**:
  - Decarbonize energy
  - Ensure a financially accessible energy transition
  - Guarantee the flexibility and security of the energy system
- **Activities**:
  - Renewable gas production
  - Transport and storage natural and renewable gas
  - Gas distribution
  - Management of liquefied natural gas
  - Electricity transmission

FLEX GEN & RETAIL

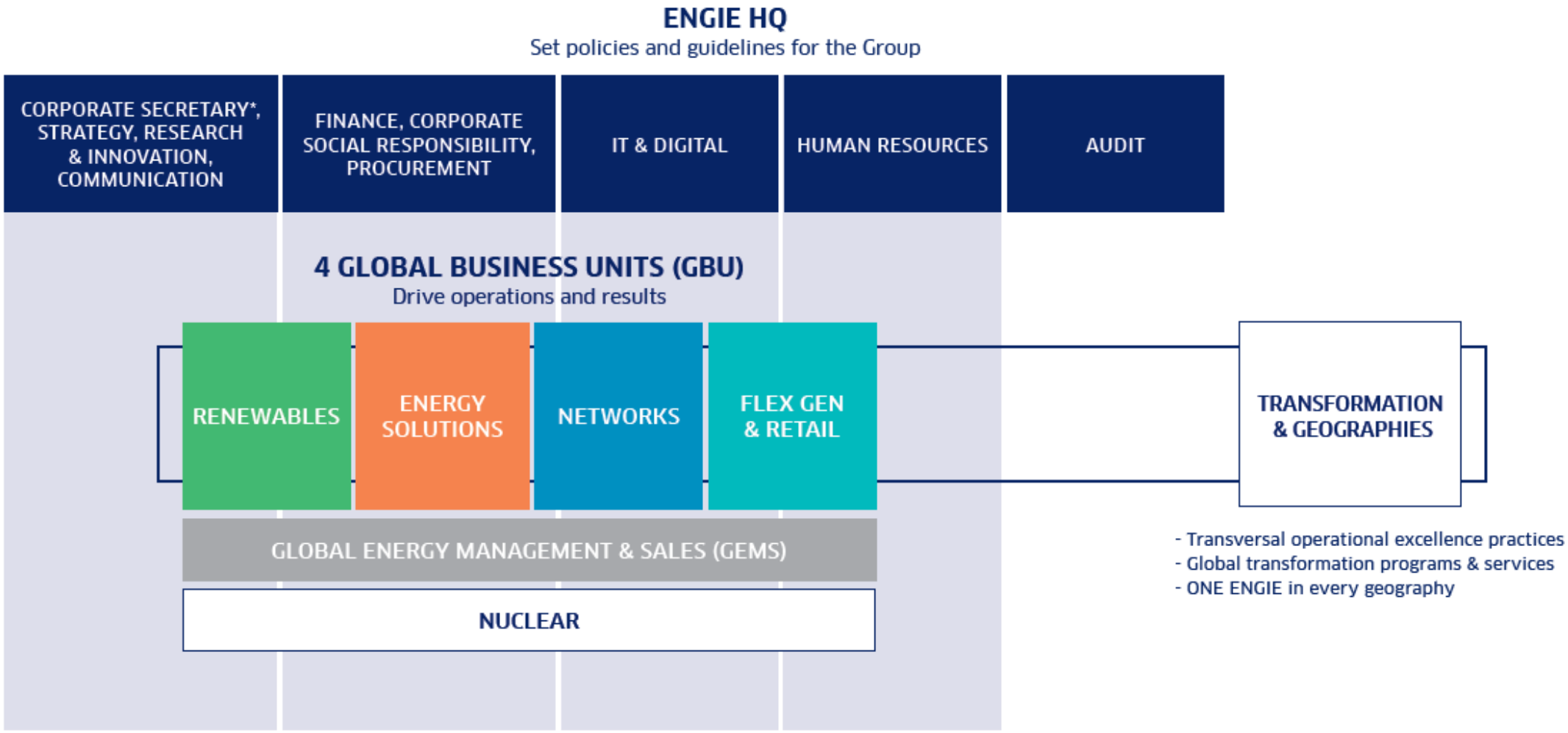
- **Challenge:**
  - Provide flexible, reliable and affordable low-carbon energies to the systems and solutions to decarbonize our clients
- **Activities**:
  - Asset management
  - Asset maintenance solutions (O&M)
  - Energy services
  - Project management
  - Power production from gas and renewable hydrogen
  - Power storage from batteries and hydro
  - Water desalination

ENERGY SOLUTIONS

- **Challenge**:
  - Decarbonizing our client's infrastructure
  - Reduce their energy consumption and costs
  - Reduce their CO2 emissions
- **Activities**:
  - District heating and cooling
  - Energy grid
  - On-site solar and storage
  - Public lighting
  - Sustainable mobility
  - Energy performance services and decarbonation advisory
- **Clients**: Municipalities, Industries, Properties

A Simplified Organization Focused on Strategy Implementation

Activities Structured Around 4 Global Business Lines



* CORPORATE BODIES AND GROUP GOVERNANCE DEPARTMENT (DOSGG), LEGAL, PUBLIC AFFAIRS

2

Net Zero Carbon by 2045

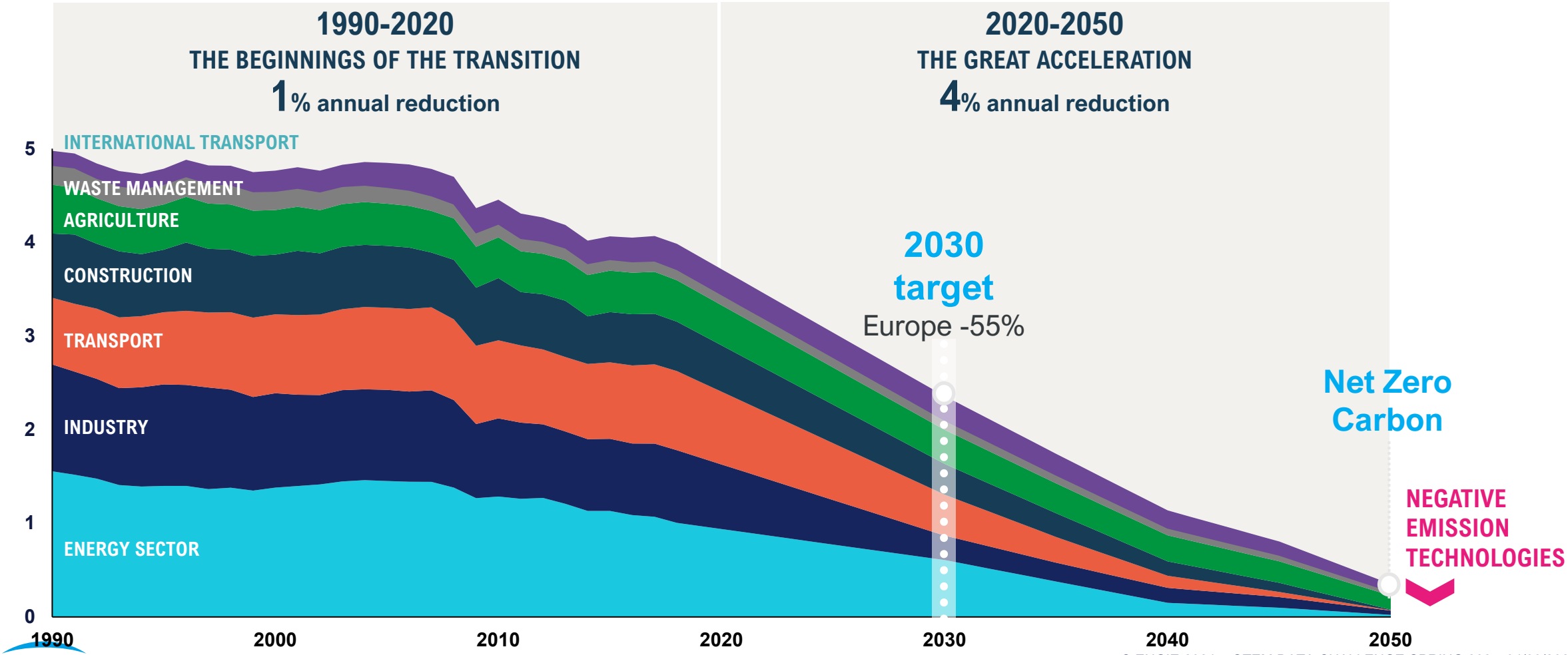
An Ambitious Commitment

European Decarbonization Goal

A Necessary Increase in Emissions Reduction Efforts

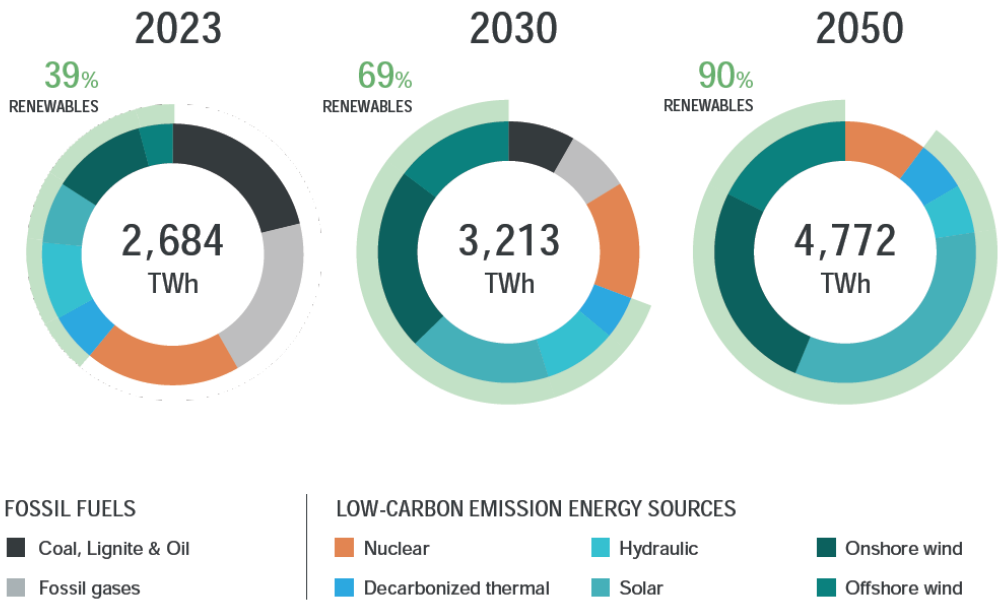
Greenhouse gas emissions

CO_2e, Gt / year

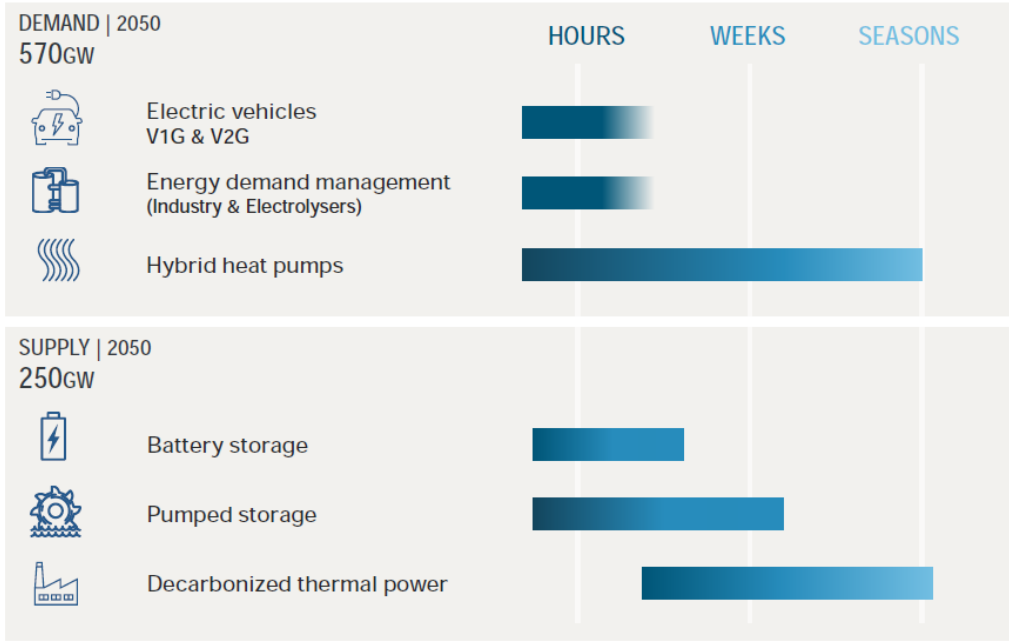


European Decarbonization with Renewables Will Require Massive Amounts of Flexibility in Power System

x6 in wind and solar generation by 2050



Flexibility is a necessary complement to intermittent



ENGIE Decarbonization Strategy

Net Zero Carbon by 2045…

ENGIE is **more aggressive** in its decarbonization strategy than the global Europe, and has set a goal of reaching **Net Zero Carbon by 2045** throughout its entire value chain (scope 1, 2 and 3) following a **Well-below 2°C trajectory** certified by the Science Based Target initiative (SBTi) in February 2023

ENGIE's decarbonization strategy within its value chain is based on three pillars:

Reduce - Avoid - Remove

Pillar A Reduce ENGIE's GHG emissions	**Pillar B** Avoid customers' GHG emissions through ENGIE's solutions	**Pillar C** Remove carbon from the atmosphere
First, reduce the direct and indirect GHG emissions resulting from ENGIE's activities by at least 90% compared to 2017	*Support customers' decarbonization so that they can reduce their GHG emissions*	*Then, increase carbon sinks to neutralize the last residual emissions that are the most difficult to abate*

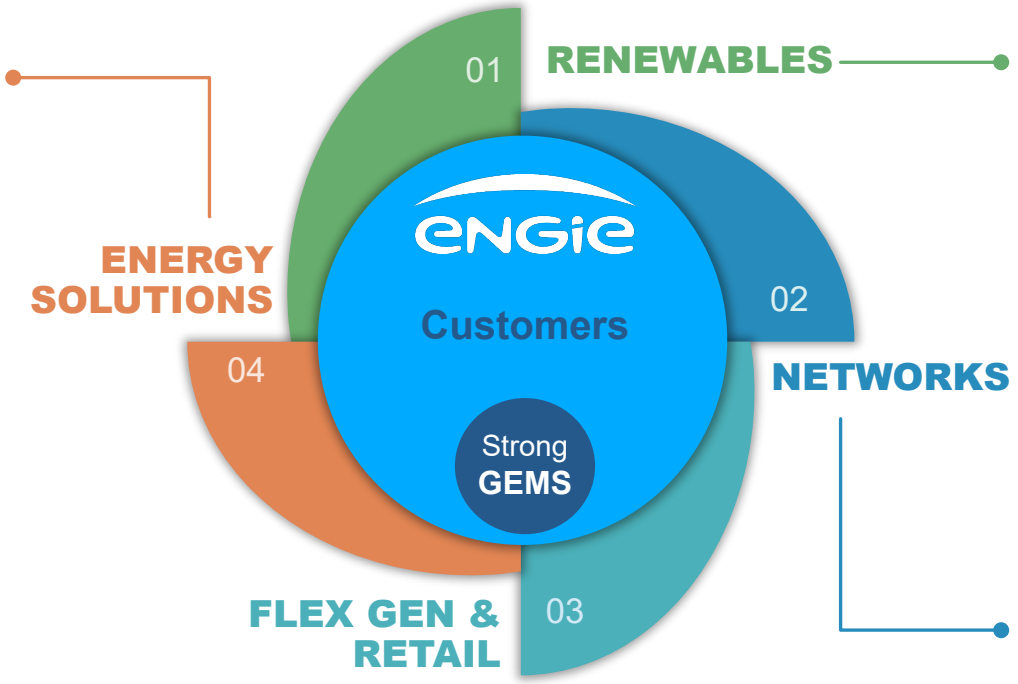
ENGIE Decarbonization Strategy

… With Strong Ambitions for 2030

+8 GW
of **distributed infrastructures** by 2025 (cf. 2020)

~4 GW
of **hydrogen** capacity by 2035

~10GW
of battery capacity by 2030



50 GW in 2025 › **80 GW** in 2030

~10 TWh
of **biomethane production** per year **in Europe** by 2030

Significant Progress in 2023 Confirming Climate Trajectory

Levers	2023	Objectives
Coal Exit	**2 %** of installed capacity, or ~**2 GW** **Brazil :** sale of a coal plant **Chile :** closure and conversion of **3 units** announced by 2025	**2025** in Europe **2027** in the rest of the world
Development of renewables	**41 %** of installed capacity, or **41,4 GW** **+ 3,9 GW** of additional capacity A portfolio of projects of **92 GW** in constant augmentation	**58 %** in the Group's mix in 2030 **80 GW** of installed capacity
Battery Energy Storage	**1,3 GW** of capacity in exploitation Acquisitions in the United States **3,6 GW** de projects secured Commissioning of the **Hazelwood** Battery Storage System	**10 GW** of battery storage systems in 2030
Greening Gas	**Production** **0,9 TWh** Acquisition in the UK commissioning of **9 units** in France **Networks in France** **10,8 TWh** connected capacities **+ 132** production units connected **Green Hydrogen** **24** ongoing projects	**Production** **10 TWh** in Europe in 2030 **Networks in France** **50 TWh** connected capacity in 2030 **Green Hydrogen** **4 GW** of electrolysers in 2035

3

GMA Hydro Meteo

Benjamin Totel

GMA Hydro Meteo

RESTREINT | INTERNE | SECRET

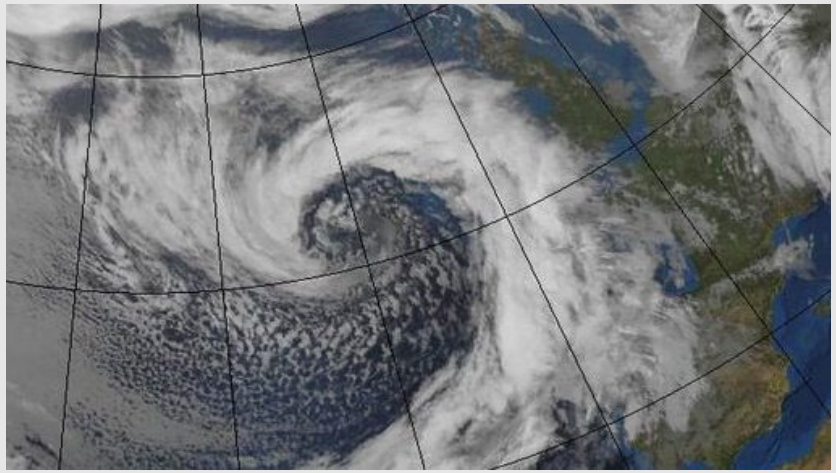
Agenda

1. **Introduction**
   - ✓ Weather risks for energy market
   - ✓ Weather related services in GEMS
2. **Operational tasks**
   - ✓ Daily briefings
   - ✓ Ad-hoc reports
3. **Projects**
   - ✓ Data Collection
   - ✓ Data visualization through dashboards
   - ✓ Model stack

1. Introduction

Weather risks for energy market

Temperature, wind, solar radiations and precipitations have more and more impacts on energy markets (demand and production) in the context of the energy transition.

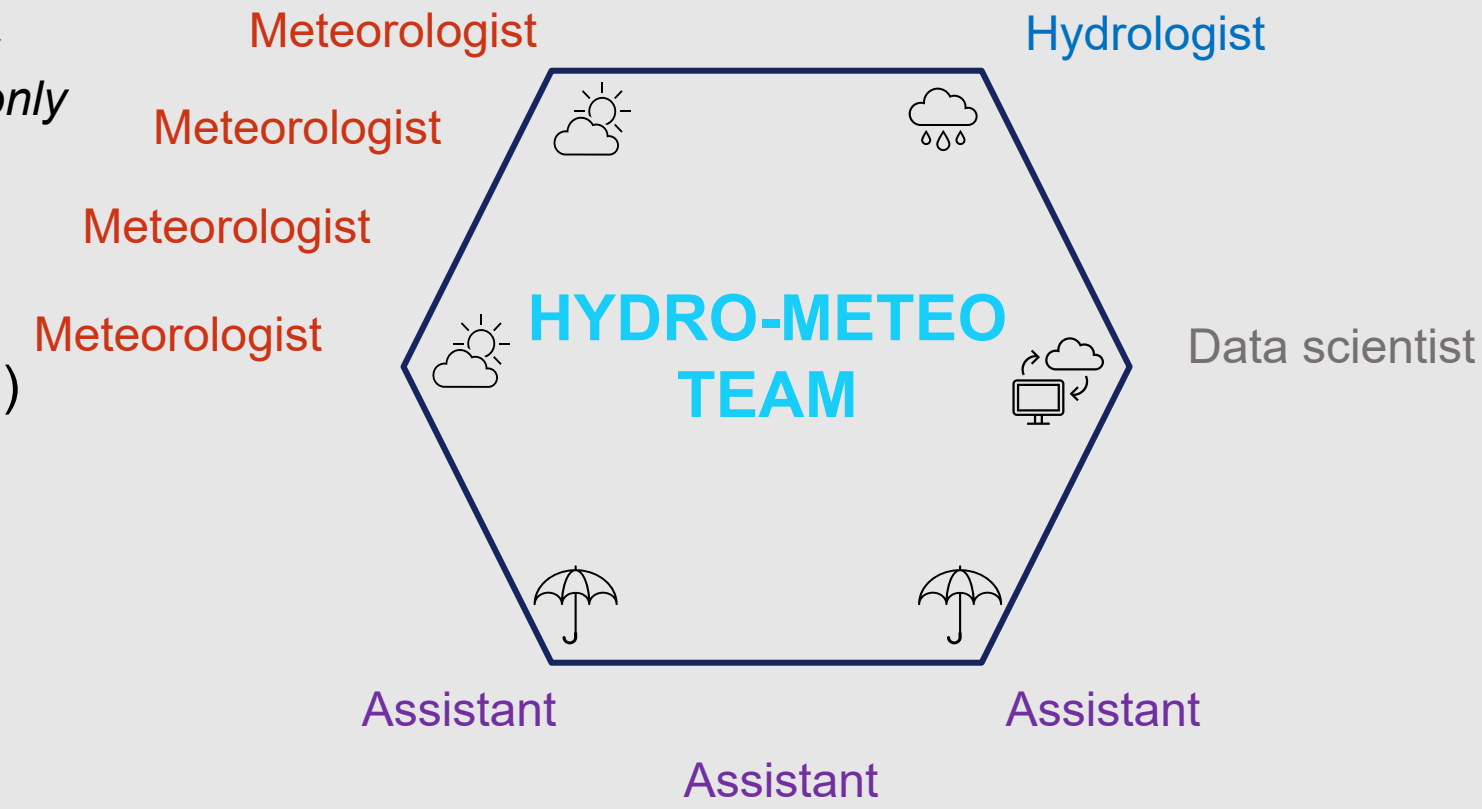


GEMS GMA Hydro Meteo

- **Hydro-meteo team**

A team of 9 within the EC Global Market Analysis *(only 1 Meteorologist in 2015)*

7 in Brussels (2 V.I.E)
1 in London in V&A (V.I.E)
1 in Houston



Weather and Hydro related services in GEMS

- ✓ Supporting traders, portfolio managers and analysts to anticipate weather related risks through reccurent forecasts for Europe, Asia and US based on Numerical Weather Prediction Systems (ECMWF, GFS, …).
- ✓ Data owner of weather and climate data (Meteomatics, Meteo-France, Speedwell, Meteoservices) on GEMS tools (Mercure, Singularity, CDH, Saturn).
- ✓ Developing a data and model driven approach (in house model built on external data feeds).
- ✓ Maintening and enhancing dashboards to share our analysis.

2. Operational tasks

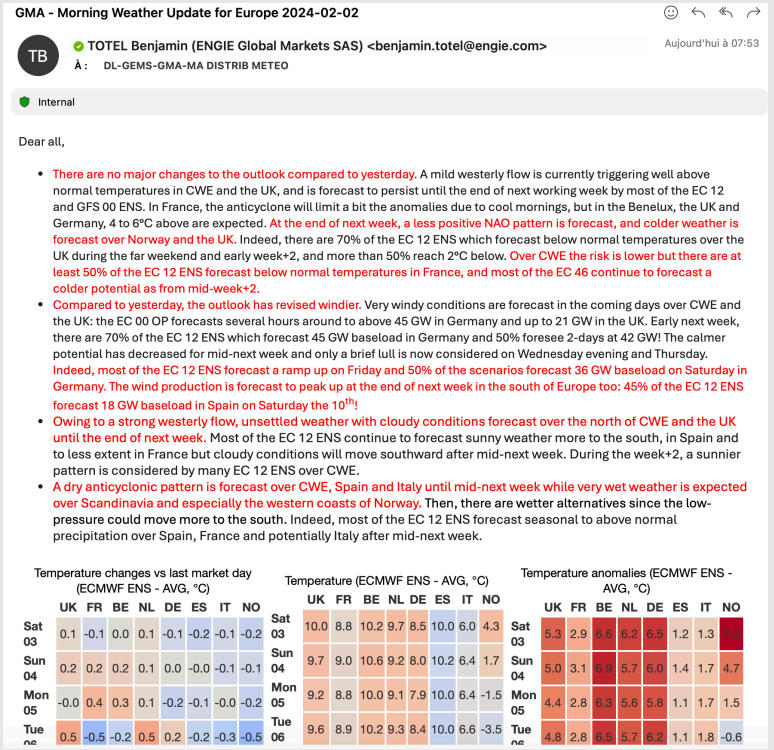
Daily briefings: email and/or video

- **Short-term, Mid-term and long-term:**

  ✓ Europe (CWE+SEE)
  ✓ NE Asia
  ✓ USA

- **Very short-term:** ***(day-ahead and intraday)***

  ✓ Belgium / Germany / Netherlands / France for wind and solar uncertainty management
  ✓ SHEM for hydro optimisation



GMA - Morning Weather Update for Europe 2024-02-02

TB TOTEL Benjamin (ENGIE Global Markets SAS) <benjamin.totel@engie.com> Aujourd'hui à 07:53
À : DL-GEMS-GMA-MA DISTRIB METEO

Internal

Dear all,

- There are no major changes to the outlook compared to yesterday. A mild westerly flow is currently triggering well above normal temperatures in CWE and the UK, and is forecast to persist until the end of next working week by most of the EC 12 and GFS 00 ENS. In France, the anticyclone will limit a bit the anomalies due to cool mornings, but in the Benelux, the UK and Germany, 4 to 6°C above are expected. At the end of next week, a less positive NAO pattern is forecast, and colder weather is forecast over Norway and the UK. Indeed, there are 70% of the EC 12 ENS which forecast below normal temperatures over the UK during the far weekend and early week+2, and more than 50% reach 2°C below. Over CWE the risk is lower but there are at least 50% of the EC 12 ENS forecast below normal temperatures in France, and most of the EC 46 continue to forecast a colder potential as from mid-week+2.
- Compared to yesterday, the outlook has revised windier. Very windy conditions are forecast in the coming days over CWE and the UK: the EC 00 OP forecasts several hours around to above 45 GW in Germany and up to 21 GW in the UK. Early next week, there are 70% of the EC 12 ENS which forecast 45 GW baseload in Germany and 50% foresee 2-days at 42 GW! The calmer potential has decreased for mid-next week and only a brief lull is now considered on Wednesday evening and Thursday. Indeed, most of the EC 12 ENS forecast a ramp up on Friday and 50% of the scenarios forecast 36 GW baseload on Saturday in Germany. The wind production is forecast to peak up at the end of next week in the south of Europe too: 45% of the EC 12 ENS forecast 18 GW baseload in Spain on Saturday the 10th!
- Owing to a strong westerly flow, unsettled weather with cloudy conditions forecast over the north of CWE and the UK until the end of next week. Most of the EC 12 ENS continue to forecast sunny weather more to the south, in Spain and to less extent in France but cloudy conditions will move southward after mid-next week. During the week+2, a sunnier pattern is considered by many EC 12 ENS over CWE.
- A dry anticyclonic pattern is forecast over CWE, Spain and Italy until mid-next week while very wet weather is expected over Scandinavia and especially the western coasts of Norway. Then, there are wetter alternatives since the low-pressure could move more to the south. Indeed, most of the EC 12 ENS forecast seasonal to above normal precipitation over Spain, France and potentially Italy after mid-next week.

Temperature changes vs last market day (ECMWF ENS - AVG, °C)

	UK	FR	BE	NL	DE	ES	IT	NO
Sat 03	0.1	-0.1	0.0	0.1	-0.1	-0.2	-0.1	-0.2
Sun 04	0.2	0.2	0.2	0.1	0.0	-0.0	-0.1	-0.1
Mon 05	-0.0	0.4	0.3	0.1	-0.2	-0.1	-0.0	-0.2
Tue 06	0.5	-0.5	-0.2	0.5	0.2	-0.2	-0.3	-0.5

Temperature (ECMWF ENS - AVG, °C)

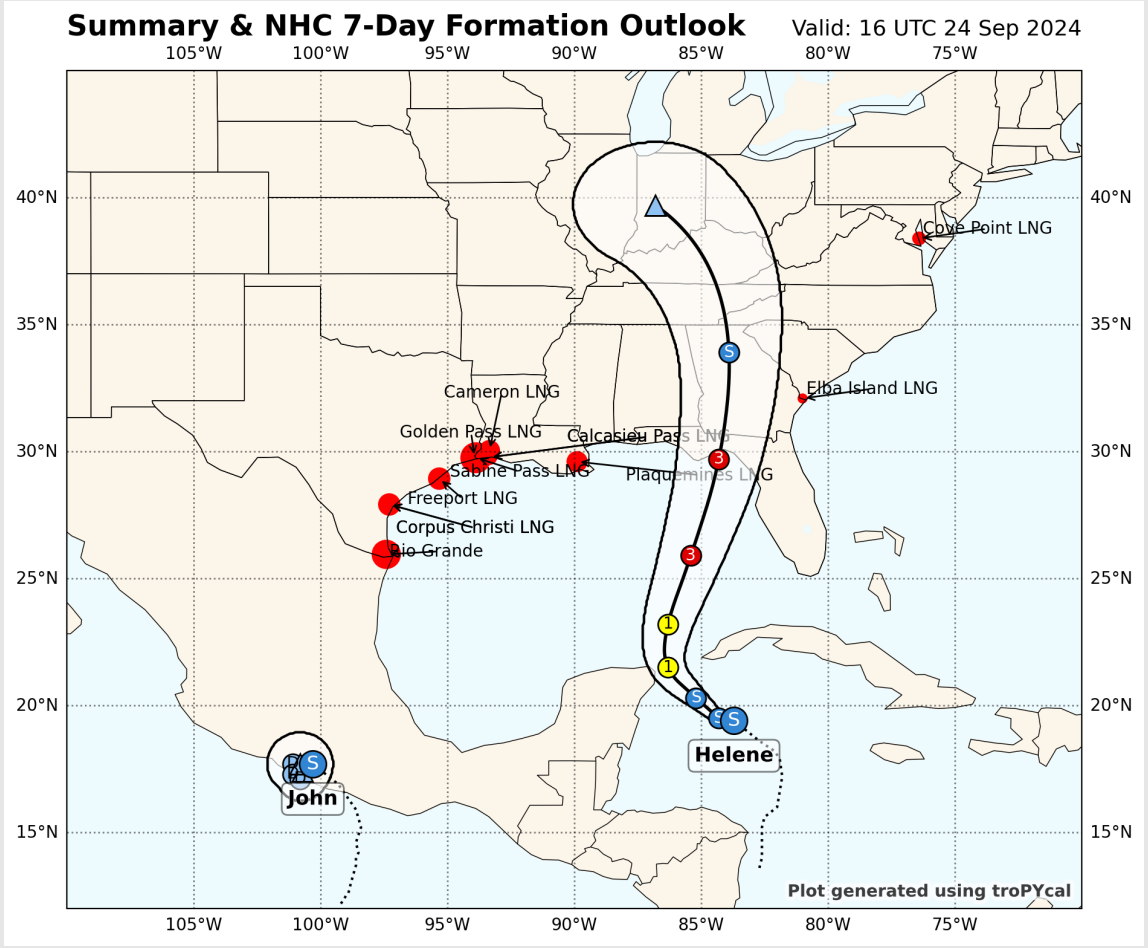
	UK	FR	BE	NL	DE	ES	IT	NO
Sat 03	10.0	8.8	10.2	9.7	8.5	10.0	6.0	4.3
Sun 04	9.7	9.0	10.6	9.2	8.0	10.2	6.4	1.7
Mon 05	9.2	8.8	10.0	9.1	7.9	10.0	6.4	-1.5
Tue 06	9.6	8.9	10.2	9.3	8.4	10.0	6.6	-3.5

Temperature anomalies (ECMWF ENS - AVG, °C)

	UK	FR	BE	NL	DE	ES	IT	NO
Sat 03	5.3	2.9	6.6	6.2	6.5	1.2	1.3	7.0
Sun 04	5.0	3.1	6.9	5.7	6.0	1.4	1.7	4.7
Mon 05	4.4	2.8	6.3	5.6	5.8	1.1	1.7	1.5
Tue 06	4.8	2.8	6.5	5.7	6.2	1.1	1.8	-0.6

Ad-hoc reports / briefings

- Hydro reports
  - ✓ France
  - ✓ Rhine
  - ✓ Iberia
- Tropical storms
  - ✓ Atlantic
  - ✓ Pacific
  - ✓ Australia

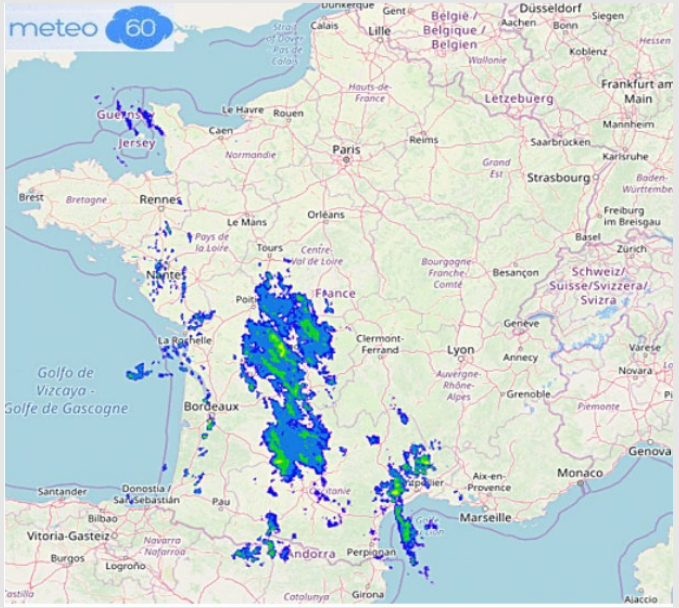


Hydro

SHEM:

- **Daily**
  - Weather briefings
- **Bi-Weekly**
  - Snowmelt
- **Monthly**
  - Monthly realised
  - Backtest: hydro models

- SHEM Dashboard
  - https://saturn-hydro.gem.myengie.com/shem_dashboard/



MOVHERA:

- **Twice per week**
  - Weather briefings

- Movhera Dashboard
  - https://saturn-hydro.gem.myengie.com/movhera_dashboard/

3. Projects

3.1 Data collection

Data collection, storage and transformation

- Numerous weather and climate DB are used within GEMS. GMA Hydro Meteo actively helps to **download** and **manage Terabytes** of data:

  - Raw meteo data from ECMWF (ERA5, IFS, ENS) = roughly **100 Tbytes** of data.
  - Processed meteo data from external providers (Meteo-France, Meteomatics. Meteoservices…). The main problematic with these datasets is the lack of homogeneity between them in the historical systems.
  - Webscrapping other open-source datasets using Saturn.

- Since **mid 2024**, there is an ongoing work to deploy a new information system for data collection and transformation to replace our historical systems (**Solaris**). We are deeply involved for the meteo data (historical and forecasts).

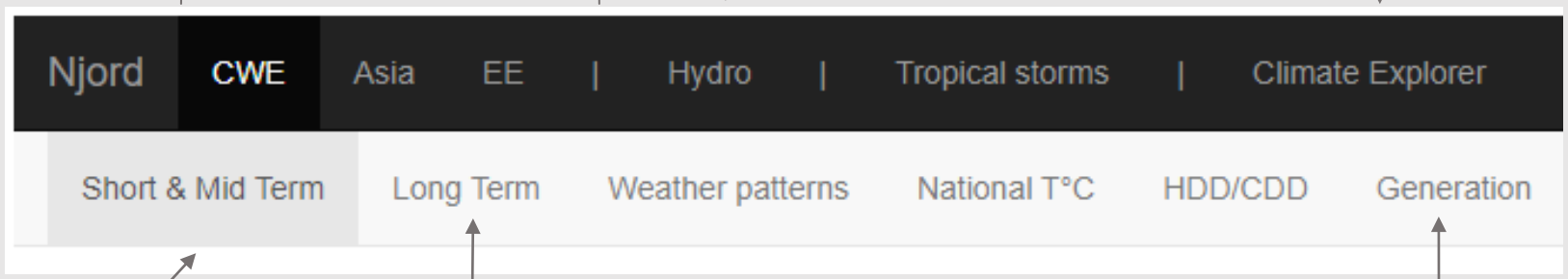
3.2 Data visualisation through dashboards

Njord weather portal: mid to long-term

Models in CDH -> Data in Saturn -> Display in Climate Explorer

Regions

Hydro reports



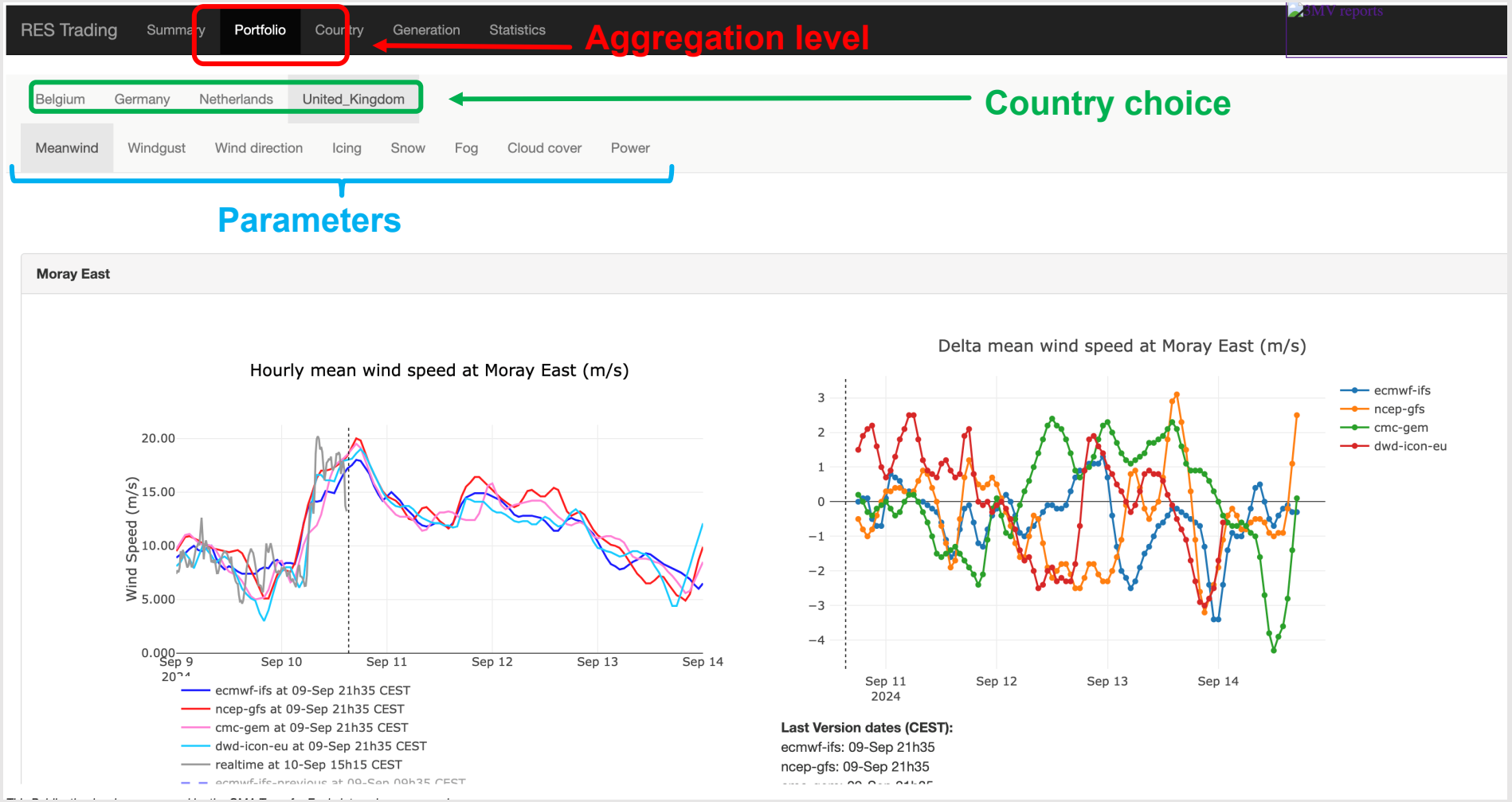
Daily updated forecast

Seasonal forecast

Power generation

https://gma.gem.myengie.com/gma_reports/report/njord/

RES: Short-term weather portal



https://gma.gem.myengie.com/gma_reports/report/res/

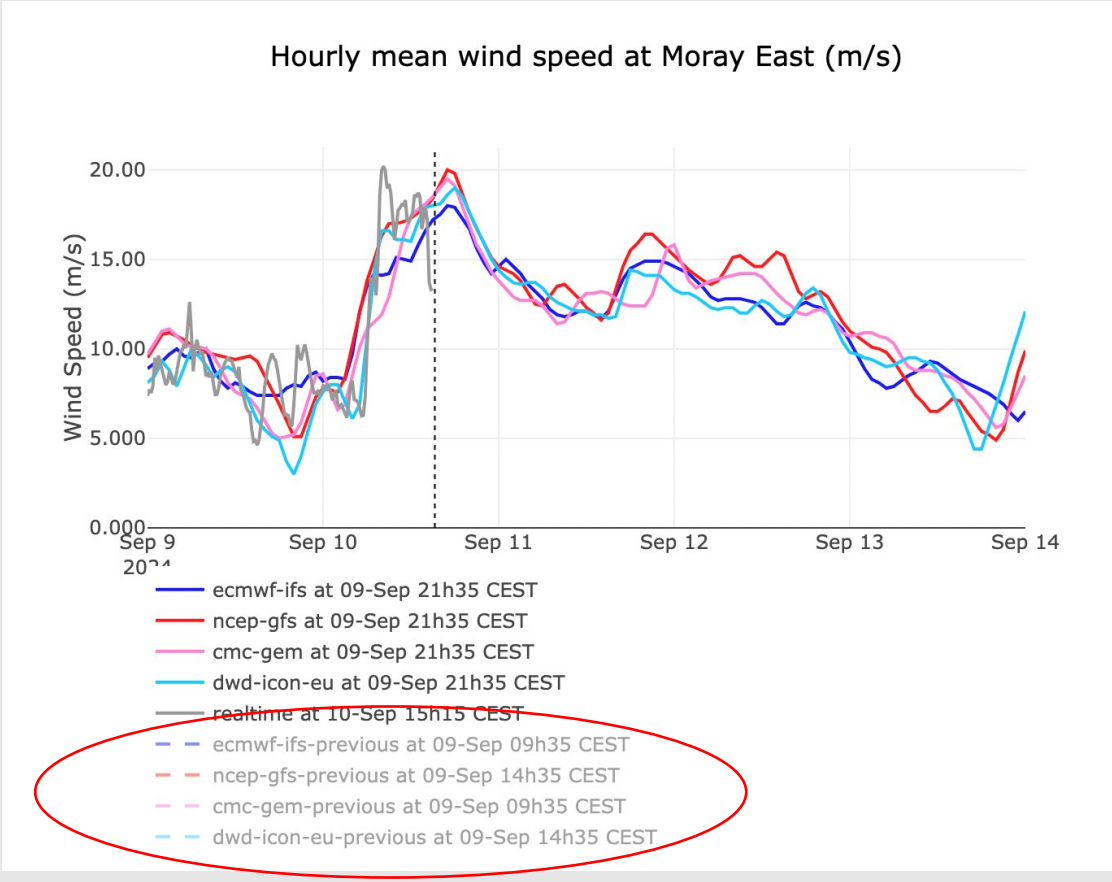
Short-term weather portal

Portfolio:

- **Weather parameters at asset level**:

✓ For wind generation:
- wind speed
- wind gusts
- wind direction
- icing risk

✓ For solar generation:
- snow (depth and snowfall probability)
- fog
- cloud cover (low and medium)



With view of the previous forecast

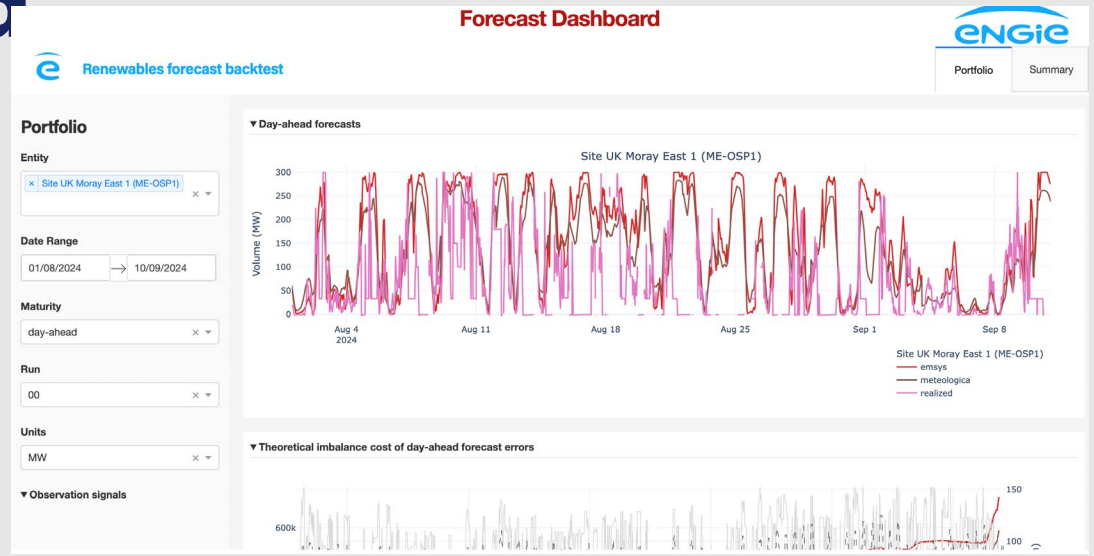
https://gma.gem.myengie.com/gma_reports/report/res/

Backtesting dashboard

- **Renewables forecast backtest**:

  - ✓ Day-ahead forecast
  - ✓ Theoretical imbalance cost of day-ahead forecast errors
  - ✓ Day-ahead forecast errors
  - ✓ Day-ahead residuals distribution
  - ✓ Day-ahead total errors

- **Summary of the forecast errors**:



Forecast errors

		180 min		day-ahead	
		emsys	meteologica	emsys	meteologica
2024-07-29	Site UK Creag_Riabhach	39.0%	54.0%	39.0%	56.5%
	Site UK Moray East 1 (ME-OSP1)	101.3%	85.0%	96.0%	103.0%
	Site UK Moray East 2 (ME-OSP2)	136.8%	87.5%	162.3%	98.2%
	Site UK Moray East 3 (ME-OSP3)	86.2%	80.7%	88.1%	82.1%
	Site UK Sandy_Knowe	99.1%	92.3%	107.4%	99.2%
2024-08-05	Site UK Creag_Riabhach	106.1%	114.1%	122.9%	118.5%
	Site UK Moray East 1 (ME-OSP1)	83.3%	92.7%	109.3%	93.0%
	Site UK Moray East 2 (ME-OSP2)	99.4%	115.5%	143.5%	120.0%
	Site UK Moray East 3 (ME-OSP3)	75.1%	73.9%	92.3%	76.6%
	Site UK Sandy_Knowe	69.2%	66.2%	76.9%	69.7%
2024-08-12	Site UK Creag_Riabhach	84.2%	84.3%	96.8%	90.6%
	Site UK Moray East 1 (ME-OSP1)	166.7%	208.7%	226.7%	196.3%
	Site UK Moray East 2 (ME-OSP2)	214.2%	265.7%	299.4%	248.8%
	Site UK Moray East 3 (ME-OSP3)	223.1%	284.9%	282.9%	262.5%
	Site UK Sandy_Knowe	51.2%	47.6%	57.0%	53.5%
2024-08-19	Site UK Creag_Riabhach	265.7%	254.2%	287.0%	267.5%
	Site UK Moray East 1 (ME-OSP1)	220.9%	314.6%	370.6%	320.0%
	Site UK Moray East 2 (ME-OSP2)	202.2%	268.8%	334.6%	278.2%
	Site UK Moray East 3 (ME-OSP3)	183.1%	298.7%	326.9%	301.0%
	Site UK Sandy_Knowe	186.5%	162.2%	174.0%	154.3%
2024-08-26	Site UK Creag_Riabhach	131.0%	116.9%	126.2%	121.2%
	Site UK Moray East 1 (ME-OSP1)	219.9%	302.3%	371.7%	272.8%
	Site UK Moray East 2 (ME-OSP2)	307.5%	423.1%	535.0%	387.1%
	Site UK Moray East 3 (ME-OSP3)	329.2%	533.4%	551.9%	502.2%
	Site UK Sandy_Knowe	101.9%	98.2%	110.4%	102.5%

https://gma.gem.myengie.com/gma_reports/report/res_forecast_dashboard/

3.3 Model stack

RES Modelling

Wind and Solar management needs complex models for:

1. **Historical modelling of the volume risk:** P50 and seasonality assessment using RESPY and ERA5 data, for the portfolio managed by GEMS, but also at country scale for long-term power prices forecasts.

2. **Cleaning of historical observations:** our RES Outlier cleaner tool, allow us to clean historical datasets of observed wind and solar production (curtailments, maintenances…).

3. **Short-term renewable forecasts for our portfolio:** RESHAPE is a key project within GEMS in which GMA Meteo is a key contributor.

Temperature normal modelling

- **One of the key topic for GEMS but also for the group as a whole:**

1. GMA Hydro Meteo has developped warming methodologies and normals since several years. However, in 2023-2024, a strong collaboration with Gas Supply and BP Downstream has allowed us to make an important step forward.

2. We have been deeply involved in the evolution of the normal for the BP Downstream in France over the summer. Normals using ERA5 Meteomatics data were delivered for FR, BE, DE (all weather stations).

3. First tentatives to improve ERA5 dataset quality were **stopped** to focus on point 2 and technical tasks to improve our systems of information and the data quality problems (limitation of Saturn/Singularity/Mercure).

Future normal temperature stack

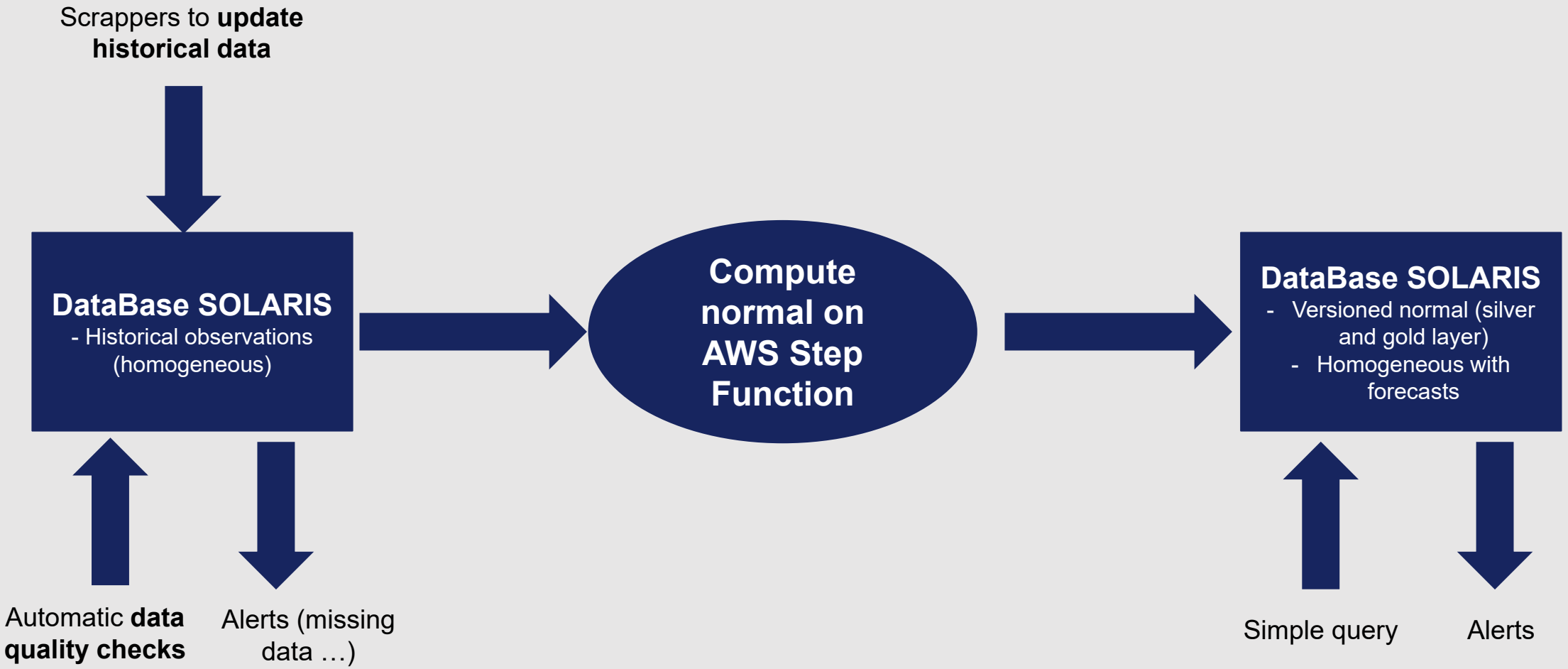
- **Ongoing tasks:**

  - Deployement of scrappers on the Common Data Hub for forecasts of Meteo-France, Meteomatics and Meteoservices in CDH DEV.
  - Historical datasets for Meteo-France (3 hourly), Meteomatics.
  - First technical stack to use our model in a AWS environment.

To be done

- Forecasts and Observed datasets (Meteo-France, Meteomatics and Meteoservices) in SOLARIS **(Q4 2024).**
- Technical stack to compute normal (station and index) on CDH PROD **(Q4 2024).**
- Add Speedwell and other Meteo datasets to SOLARIS **(Q4 2024).**
- Accompany GST and IS to connect OT to SOLARIS.

Technical Stack for Temperature normal



Future improvement for the normal

To be done

- ERA5 quality improvement for problematic weather stations.

  ✓ Linear models showed limited improvement and problematic behaviors. **To be confirmed**
  ✓ Investigate quantile models or kriging methodologies: we could start in Q4 2024 or early next year.

Normals??

engie.com

4

Business Case Presentation

Julie Payan

ENGIE's Data Challenge

General Outline

Part 1:

Based on past weather and production data (load factors of individual Solar and Wind sites / assets), is there an optimum in Engie's portfolio of assets? *i.e. assuming that all the sites have the same nominal capacity, what is the best combination of assets (assets being in or out of portfolio) under a dual optimization constraint : (i) maximize production and (ii) minimize variability.*

Part 2:

Same question but from a revenue perspective, using past weather, production and adding price data (prices captured by each of the individual productions assets). Assuming again same nominal capacity for each of the individual sites, what is the combination of assets that (i) maximizes total revenues while (ii) minimize volatility.

Part 3:

- What differences can we see between the production and revenue analysis (if any)?
- Would the conclusion of Part 2 be different if you were able to choose [0% - 100%] the weighting of energy that would be contracted from each asset?

OPTIONAL - Part 4:

As part of the data set, weather and production data are provided. They are not in adequation: often times, production is lower than what would theoretically have been possible owing to anomalies (curtailment, partial unavailability).

What would the conclusions of the exercises (Part 1 through 3) have been if production would have been aligned with what weather data (sun, temperature, wind) would have allowed?

ENGIE’s Data Challenge

Dataset

Hourly weather and production data in Belgium, Germany, and the Netherlands, over 5 years of:

- 71 Solar production sites
- 2 Offshore Wind production sites
- 97 Onshore Wind production sites

Quarter-hourly prices and liquidity data for the same countries, over 3 years

We also provided a data dictionary with a small explanation of the variables, and a file with coordinates and sites numbers, to locate them

How to Start

To get you starting on the right path, here are some tips:

- Try to identify in which countries the production sites are located
- Match the variables files with each site. Please be aware that the dataset is not homogeneous. There are probably missing data and outliers. It will be key to make sure to deal with those problems

- For simplification, take the assumption that power was sold at the Day Ahead price, and that Engie is paid the delta between the Day Ahead and Intraday market price

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Q&A

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