Forecasting for an Integrated Energy System

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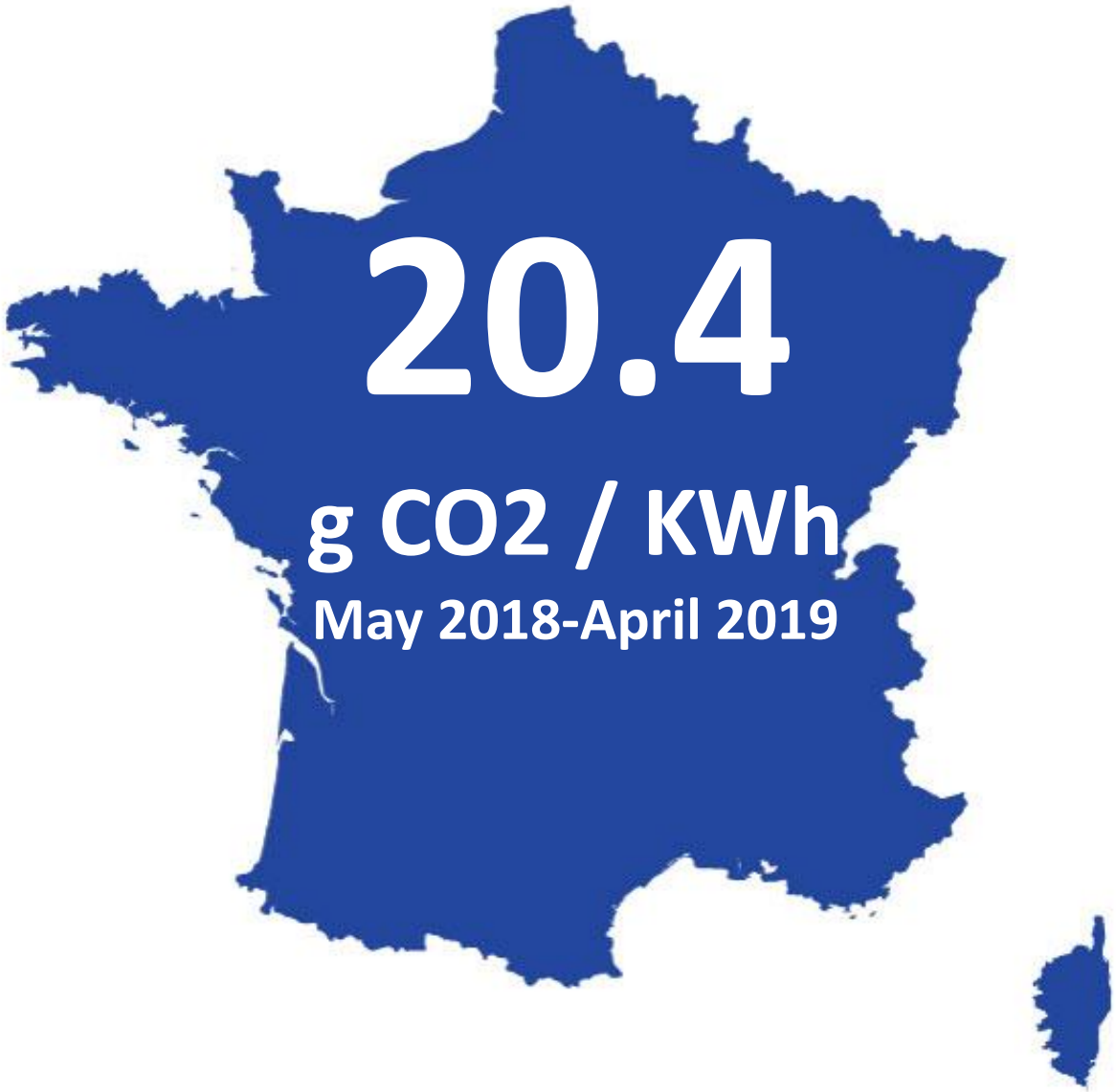
With contributions from Stéphanie Dubost, Christophe Chaussin, Bénédicte Jourdier, Thierry Jouhannique, Bruno Charbonnier, Paul Le-Guen, Sylvie Parey, Paul-Antoine Michelangeli and many others

ESIG Meteorology & Market Design for Grid Services Workshop

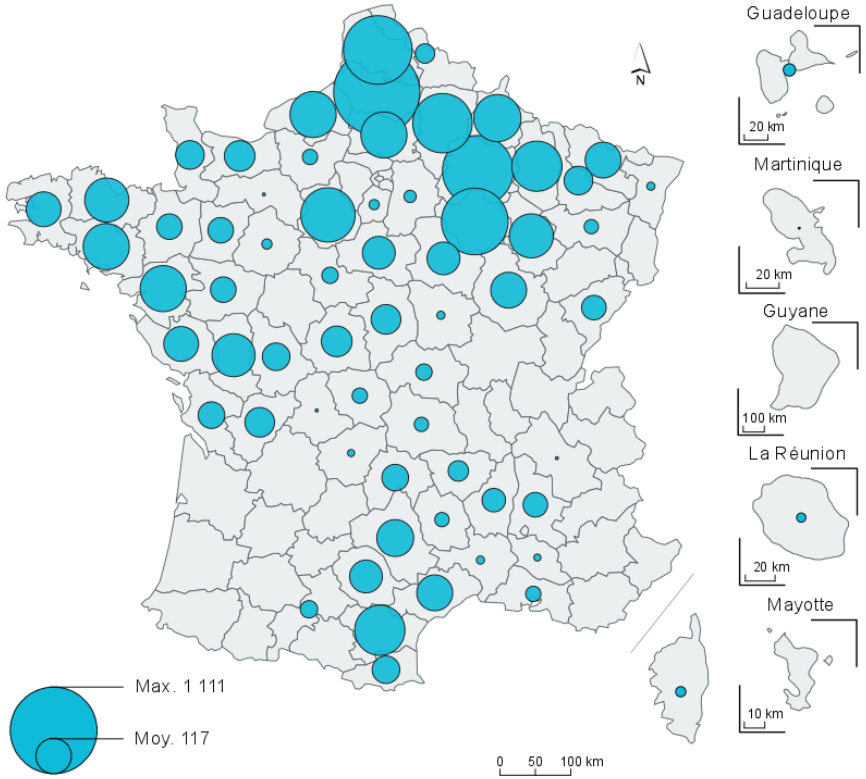
6 June 2019, Denver, CO

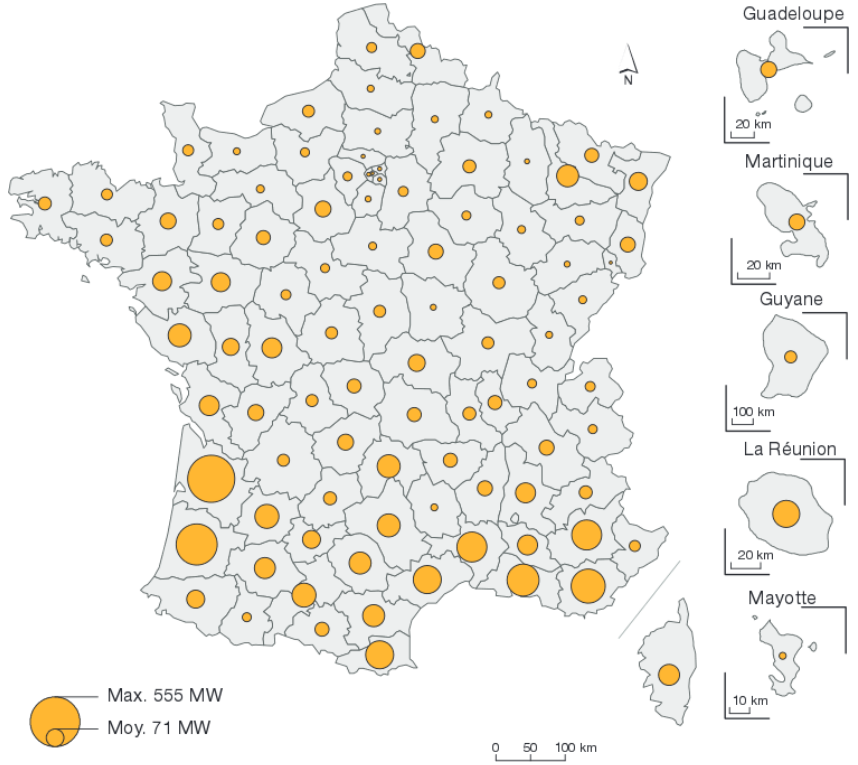
20.4


20.4
g CO2 / KWh
May 2018-April 2019

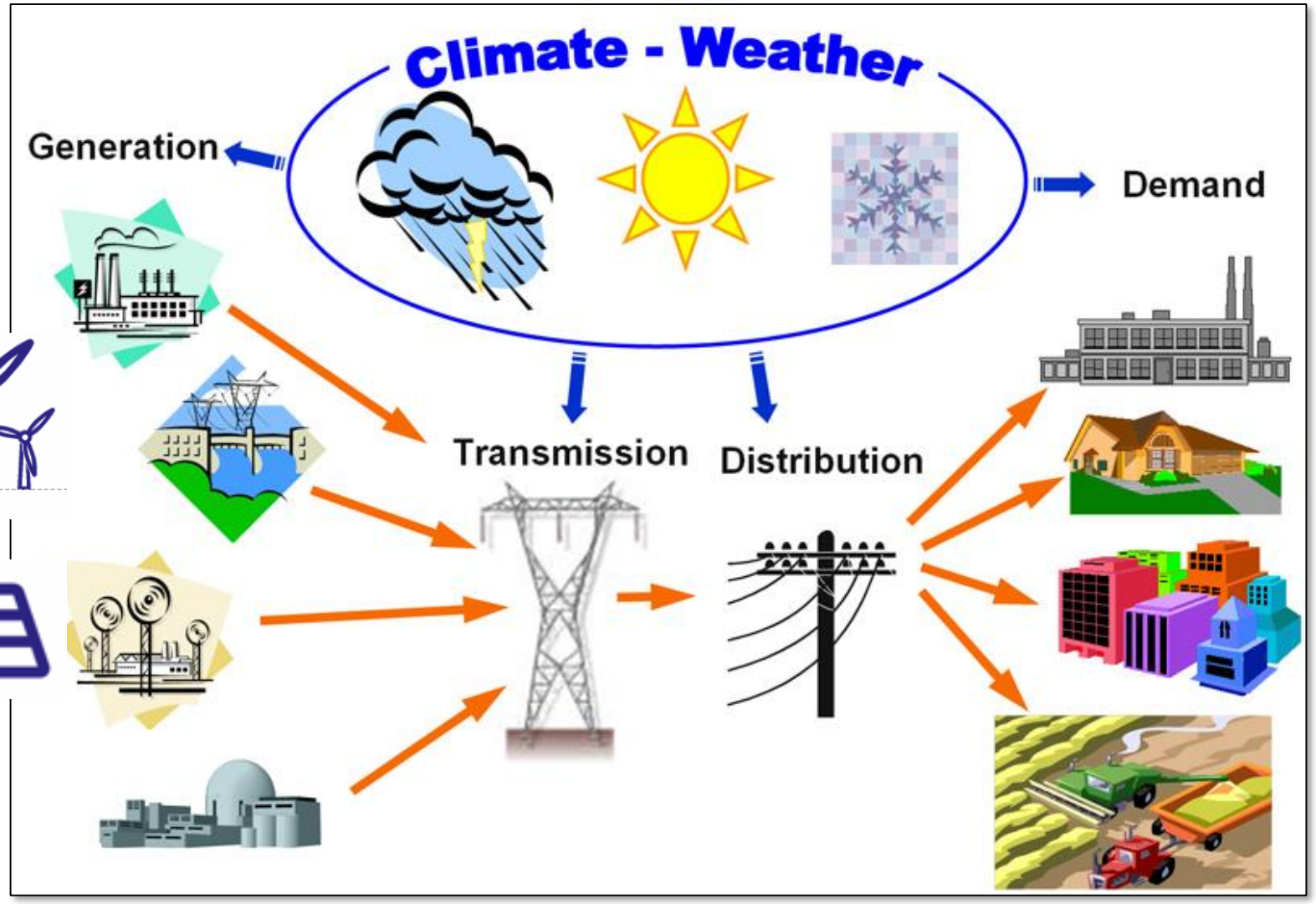

90%
of electricity CO2 free *
* Direct emissions, excluding the life cycle analysis of generating plant and fuel.

- End of 2018, the total installed capacity was:
  - **Wind power: 15.1 GW** (Objective 2023: 27 GW, incl. 2.4 Offshore)
  - **Solar power: 8.5 GW** (Objective 2023: 20.6 GW, 30 GW in 2035)
  - **Nuclear: 63,3 GW**
  - **Hydro: 22,8 GW**





Weather & Climate impacts



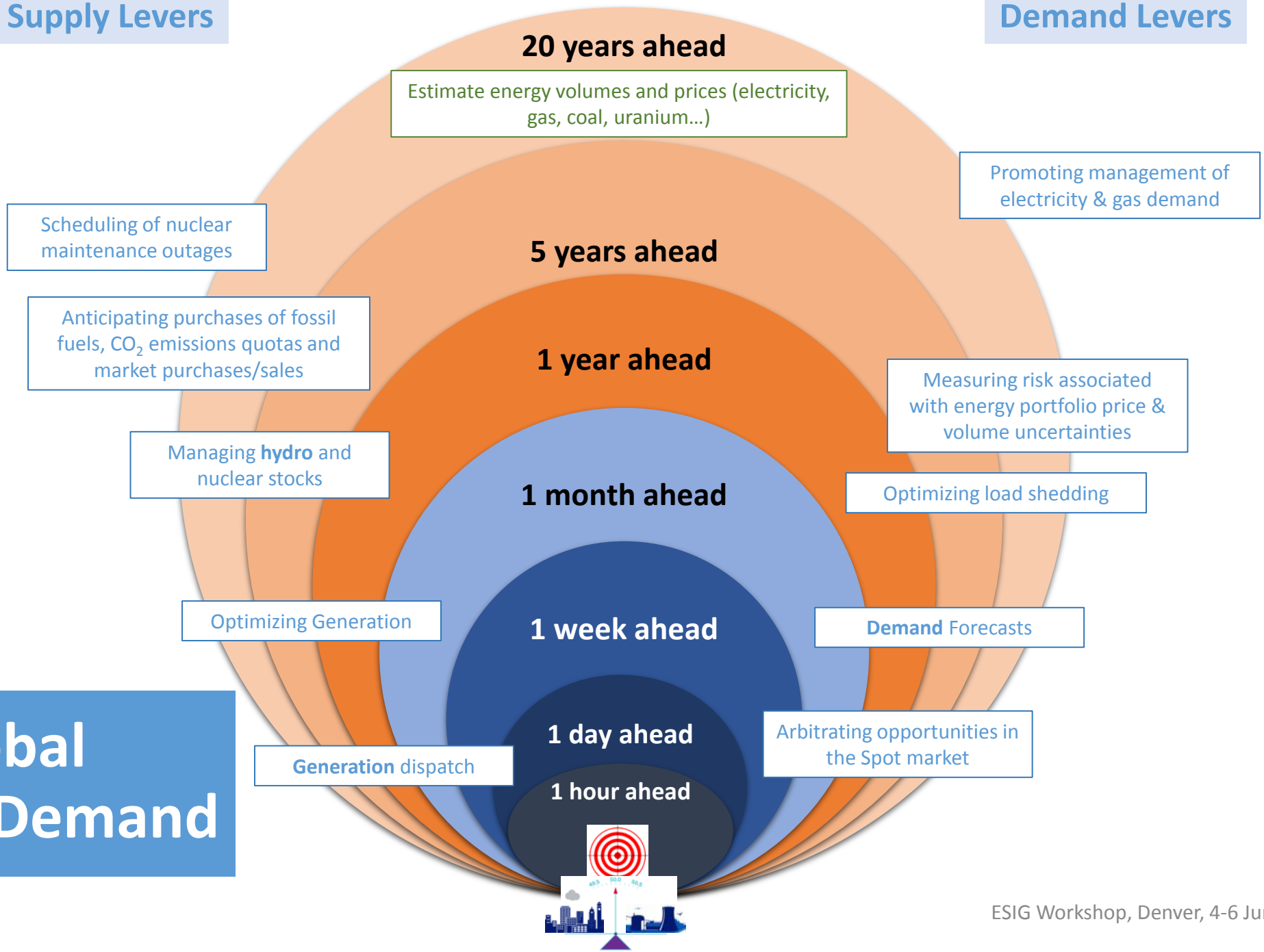
At all time scales!

Adapted from

Argonne NATIONAL LABORATORY

Center for Energy, Environmental, and Economic Systems Analysis (CEEESA)

Global Supply/Demand



Weather & Climate impact ALL production means (+ Demand)

Table 1
Potential climate impacts per asset class

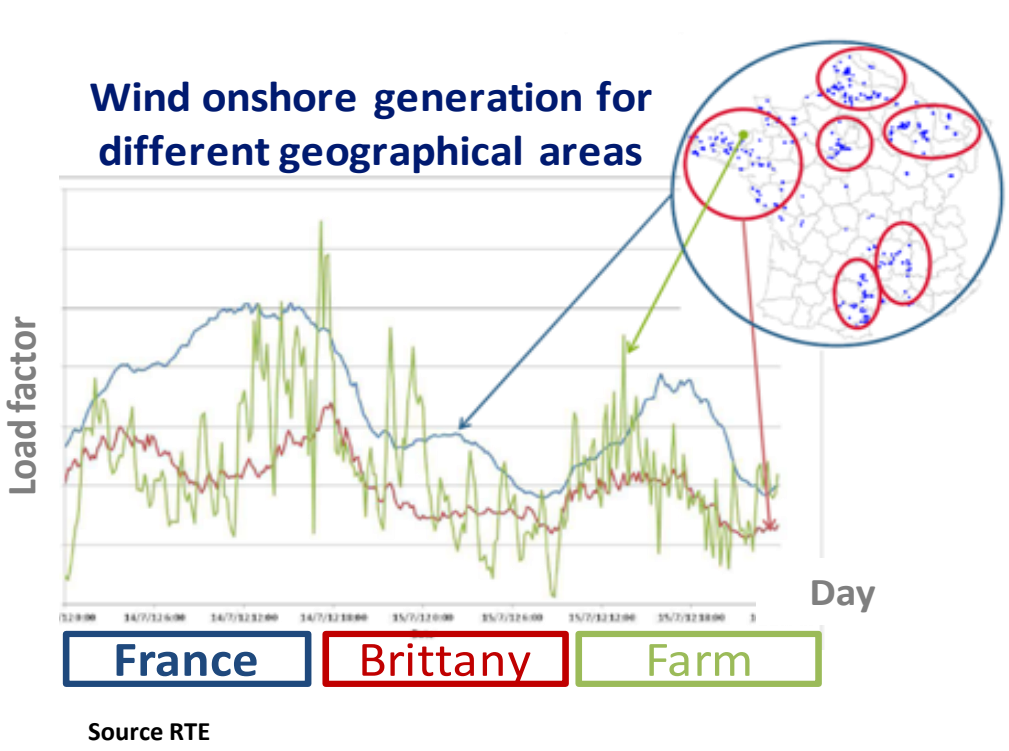
	Generation				T&D		Customers
	Thermal	Hydro	Wind/PV	Biomass	Lines	Stations	
Air temperature	●	●		●			●
Water temperature	●			●			
Water availability	●	●	●	●			
Wind speed			●		●		
Sea level	●	●	●	●	●	●	
Floods	●	●	●	●	●	●	
Heat waves	●		●			●	●
Drought	●	●		●			
Storms					●	●	
	Impacts						

Source: Adapted from Asian Development Bank (2012).

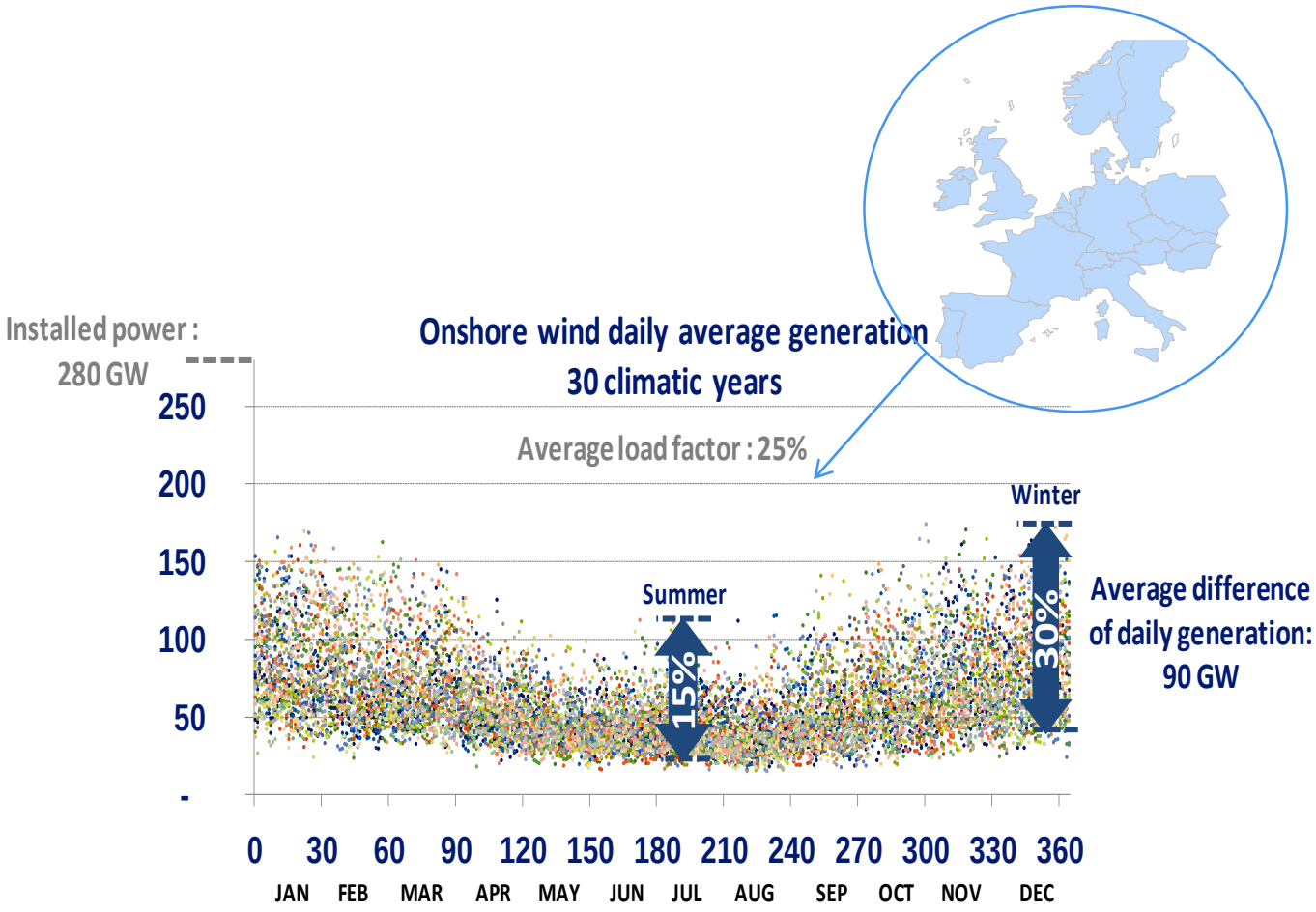
Source: WBCSD

Economic and technical assessment of a 60% RE EU system

GEOGRAPHICAL DIVERSITY DOES HELP, BUT THERE IS STILL SIGNIFICANT VARIABILITY AT EUROPEAN LEVEL



Source RTE

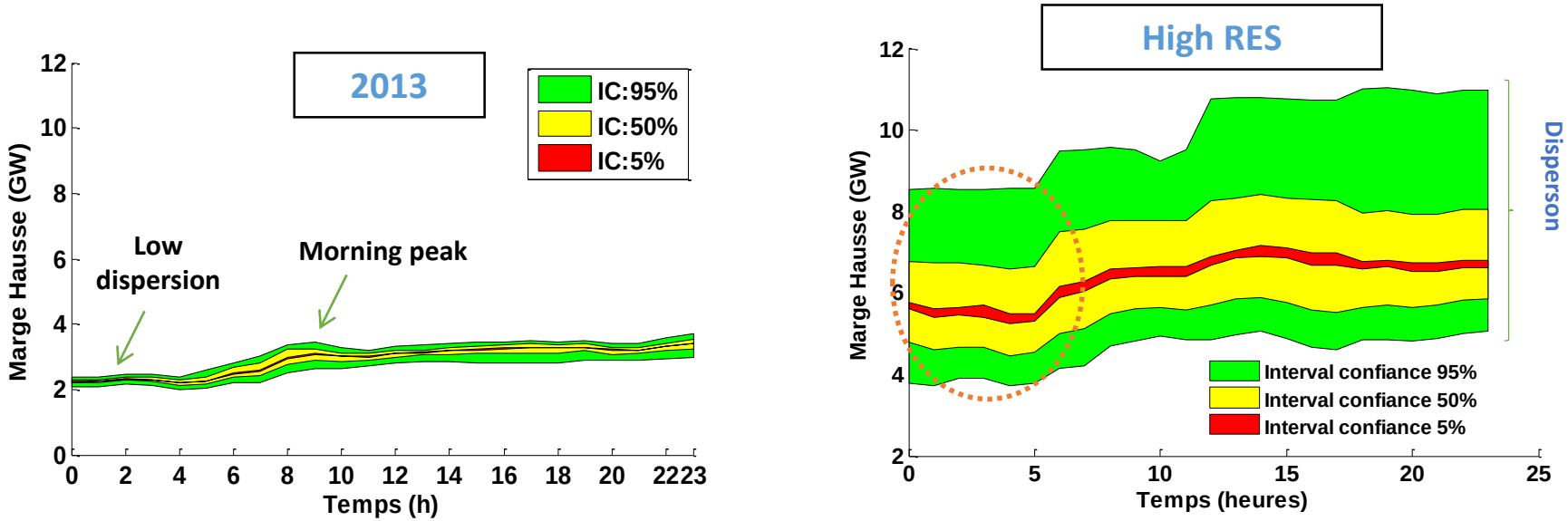


You can reduce the variability of wind and PV at local level but the correlation in weather regimes acts as a limit at continental level

Economic and technical assessment of a 60% RE EU system

FLEXIBILITY MARGINS NEED TO INCREASE DUE TO VARIABLE GENERATION (AND ASSOCIATED FORECAST ERRORS)

Profile of day-ahead upward operation margin required to cover a 1% risk level

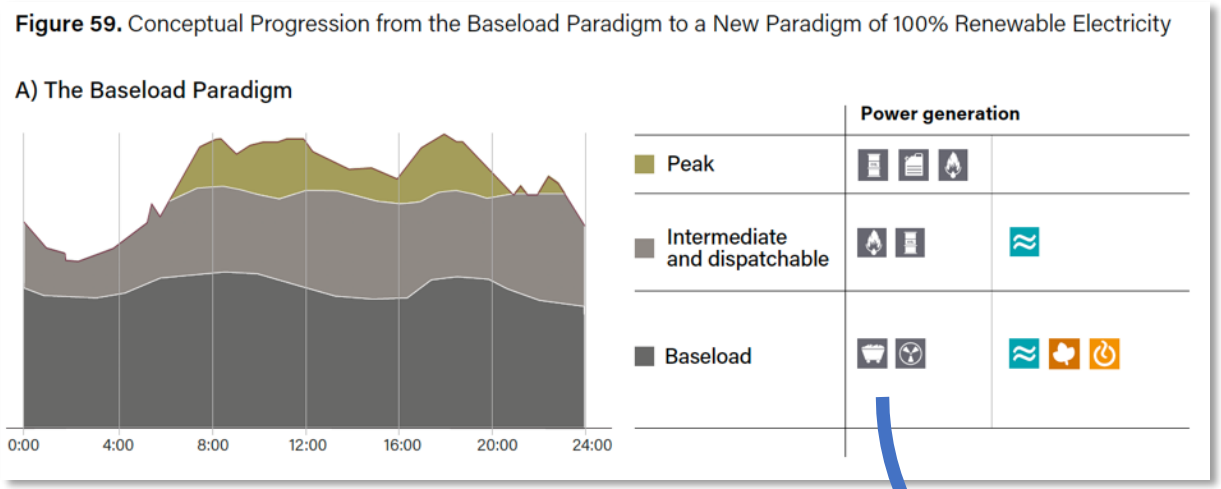


The operation margin profile changes and in the future critical periods are no longer driven by demand patterns => need for dynamic calculation of flexibility margins and reserve requirements

➔ **For large penetration of wind and PV generation:**

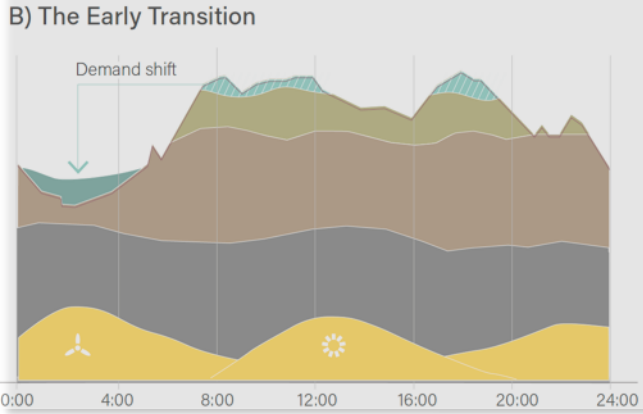
- **variability and uncertainty** have a significant impact
- **short term operation** needs to be considered at **planning stage**

New Energy paradigms are necessary

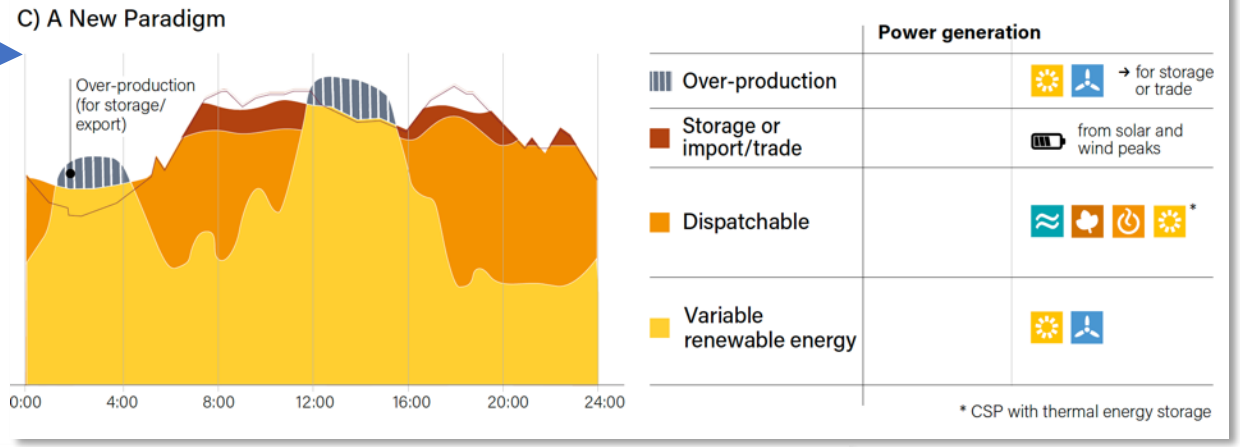


Improved Forecasts
&
New Forecasts
are necessary

In the early stages of progression to larger shares of variable renewable generation, power systems make some adjustments in their grid operations, develop forecasting systems for renewable energy production, and introduce improved control technology and operating procedures for efficient scheduling and dispatch.



In the late stages of progression towards fully renewable power systems, variable renewable power will be integrated through advanced resource forecasting, grid reinforcements and strengthened interconnections, improved information and control technologies for grid operations, widespread deployment of storage technologies, greater efficiency and scope of demand response, and coupling of electricity, heating and cooling, and transport sectors.



Coal-fired · Oil-fired · Diesel generator · Nuclear · Natural gas-fired · Hydro-power · Bio-power · Solar PV and CSP · Geothermal power · Wind power

Source: REN21

EDF and subsidiaries: Many space & time scales

	EDF France	EDF Purchase Obligations	EDF Agregio	ENEDIS DSO	EDF Overseas	EDF Renewables
Spatial scale(s)	France	France	France (subset of Wind & Solar farms)	France + Local	Territory (Islands + French Guiana)	Individual Farms
Main Variables	**Load, Hydro, Wind, Solar, Thermal**	**Wind, Solar**	**Wind, Solar**	**Load, Wind, Solar**	**Load, Hydro, Wind, Solar**	**Wind, Solar**
Time scale(s)	RT to ~5-10 years	Day-Ahead + Intra-Day	Day-Ahead + Intra-Day	Day-Ahead + Intra-Day + up to 1-3 years	RT to Day-Ahead	Intra-Day Day ahead...
Target	Supply/demand Balance	Market	Market	Distribution System Management	Distribution System Management	Monitoring, performance, market operations
Available data	Public (regional + national)	Individual farms (not in RT)	Individual farms (not in RT)	Wind power: 10' measurements at every farm (not RT) Solar power: 10' measurements for <50 % (in capacity) (not RT)	RT aggregated data	Individual farms

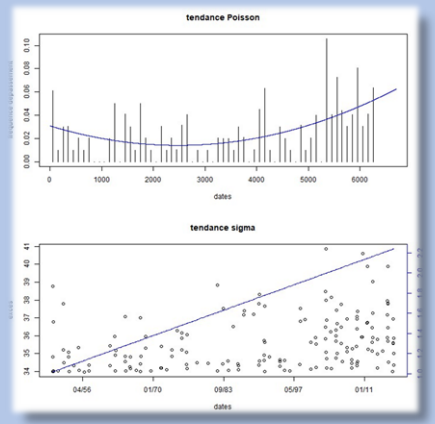
Weather, Climate and Renewables Forecasting Group activities

Renewables Forecasts (Solar PV & Wind +input data for hydrological modelling)

Long-range forecasts (monthly to seasonal), Climate Change impacts & Climate Services

Implemented by ECMWF as part of The Copernicus Programme
Climate Change Service

Natural Hazards & Extremes



Internal & external expertise weather/climate/energy

Training

Other renewables

Users' support

Data (meteorology, energy)

Scientific Watch

Monthly & Seasonal outlooks

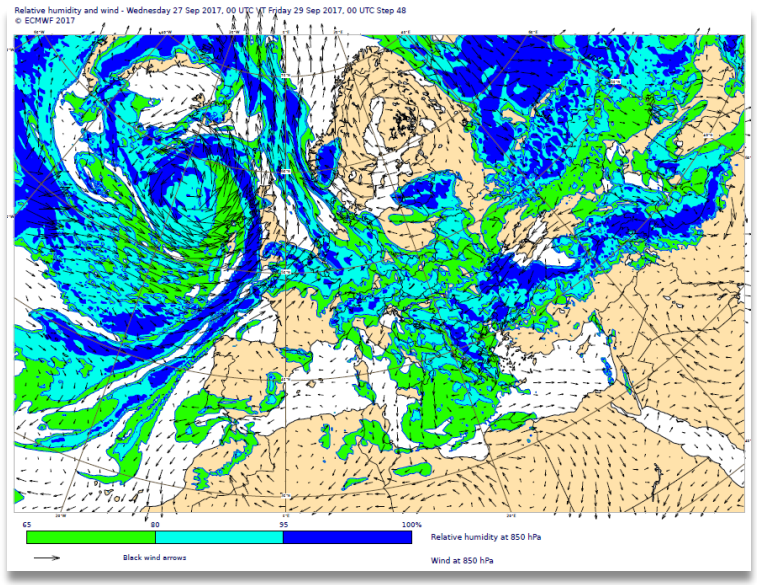
A (quick) focus on solar forecasts...

Renewables Forecasts

Medium term : D+4 to D+14

Weather forecasts

Climatology



Mainly ECMWF & Météo-France

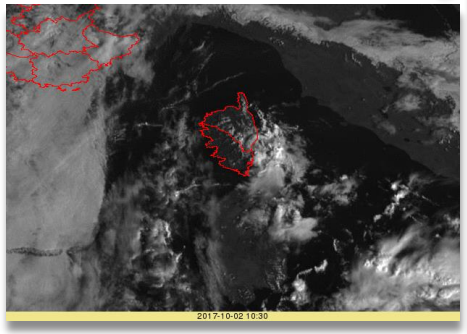
Short term : ID to D+3

Weather forecasts

Nowcasting: H to H+6

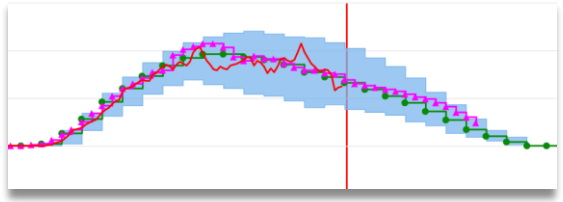
Real time generation data

PV : satellites Images / Ground cameras

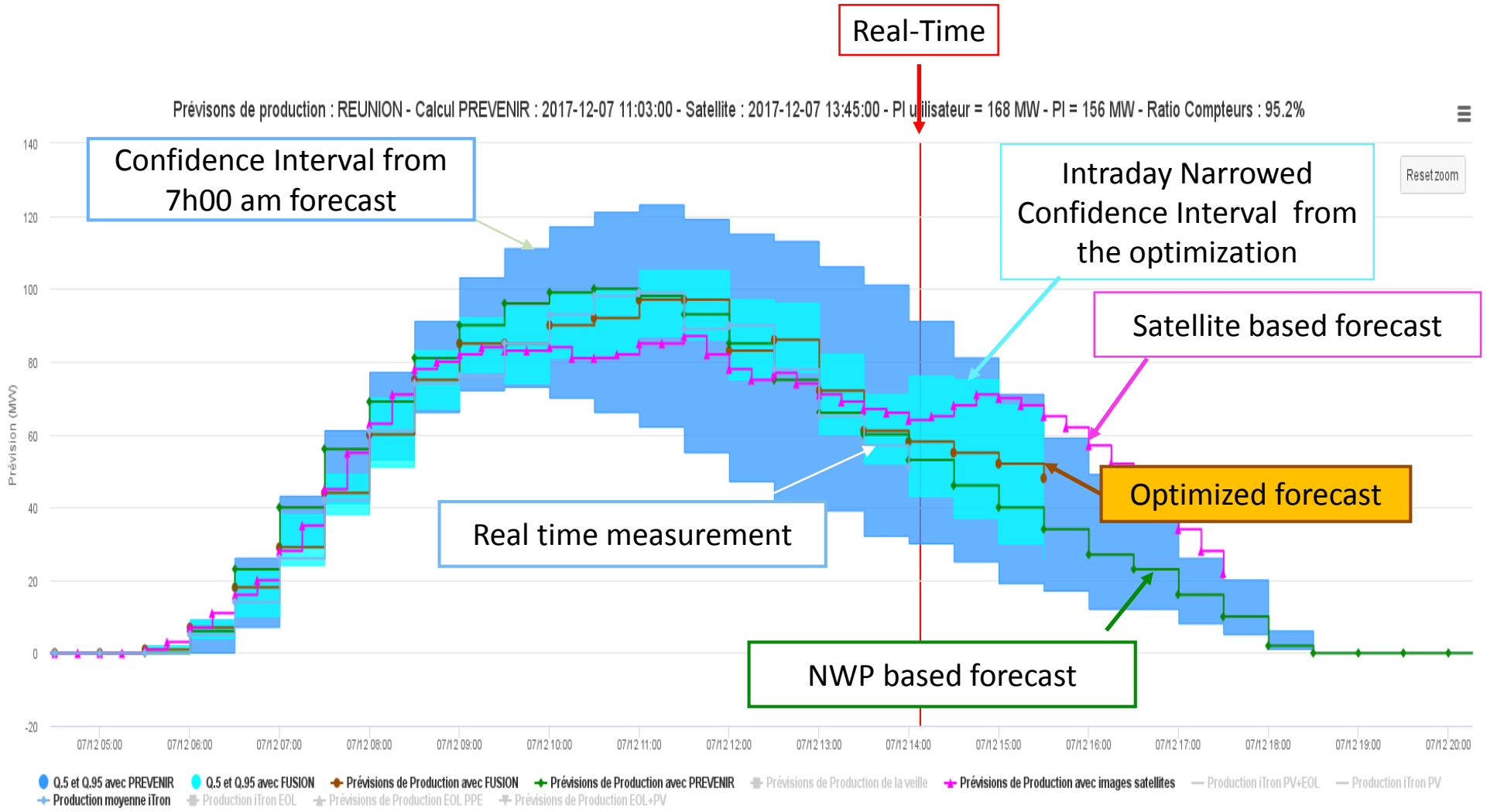


Data Fusion → Determnistic & probabilistic forecasts

Patent



Solar Forecasts – Real-time visualization tool



Solar Forecasts: performance

MAPE at Aggregated Scale (continental France)

Solar Power	D	D+1	D+2	D+3	Climatology
% of installed capacity	3,6	4	4,6	5,1	9,4
MW for PI= 7 GW	250	280	320	360	660

Maximum of the Mean Absolute Error (in the middle of the day)

At local scale :

- Error 2 or 3 times greater than at country scale

EDF R&D winner of the benchmark COST WIRE 2012 (local forecasts)

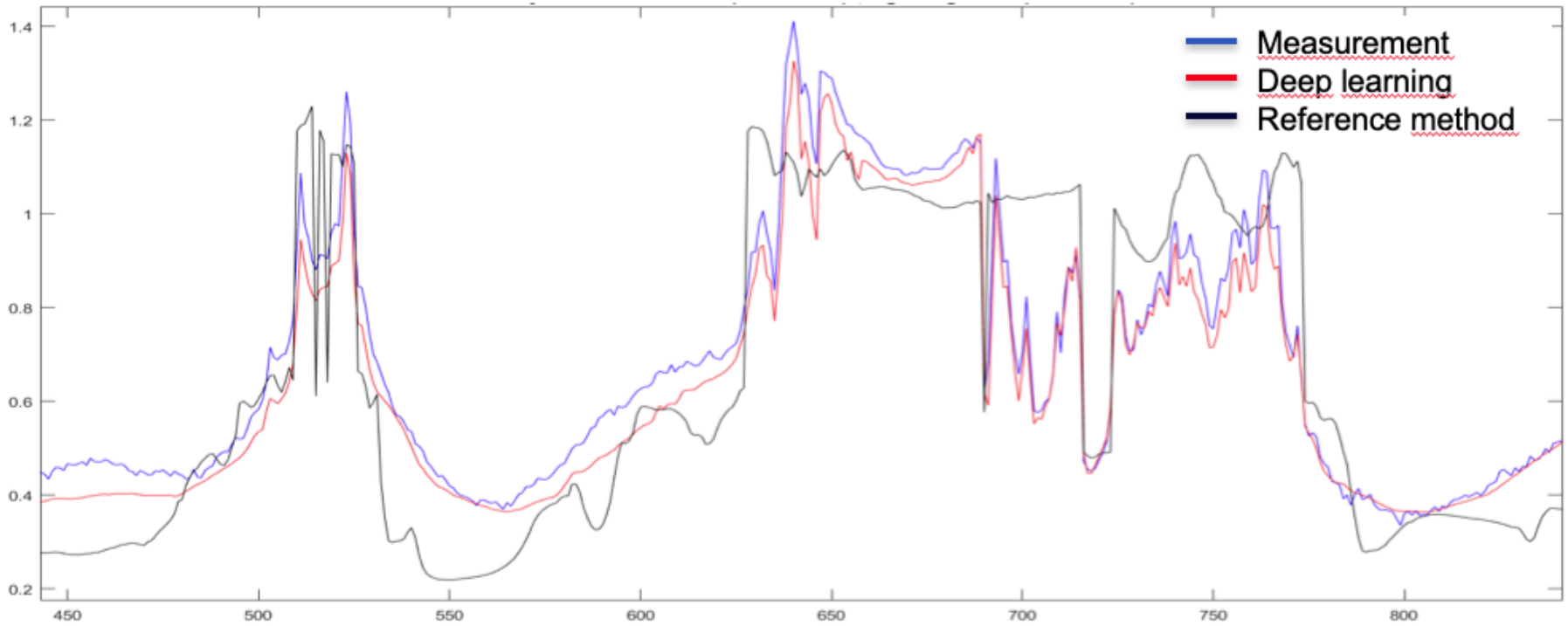
Recent results with ground cameras

Patent

These results may enable to use ground cameras as pyranometers

Method	RMSE	nRMSE
Reference	0.146	21.6%
Deep Learning	0.033	4.8%

GHI estimation error over one year



Real time estimation of GHI with ground images (10 sec. step)

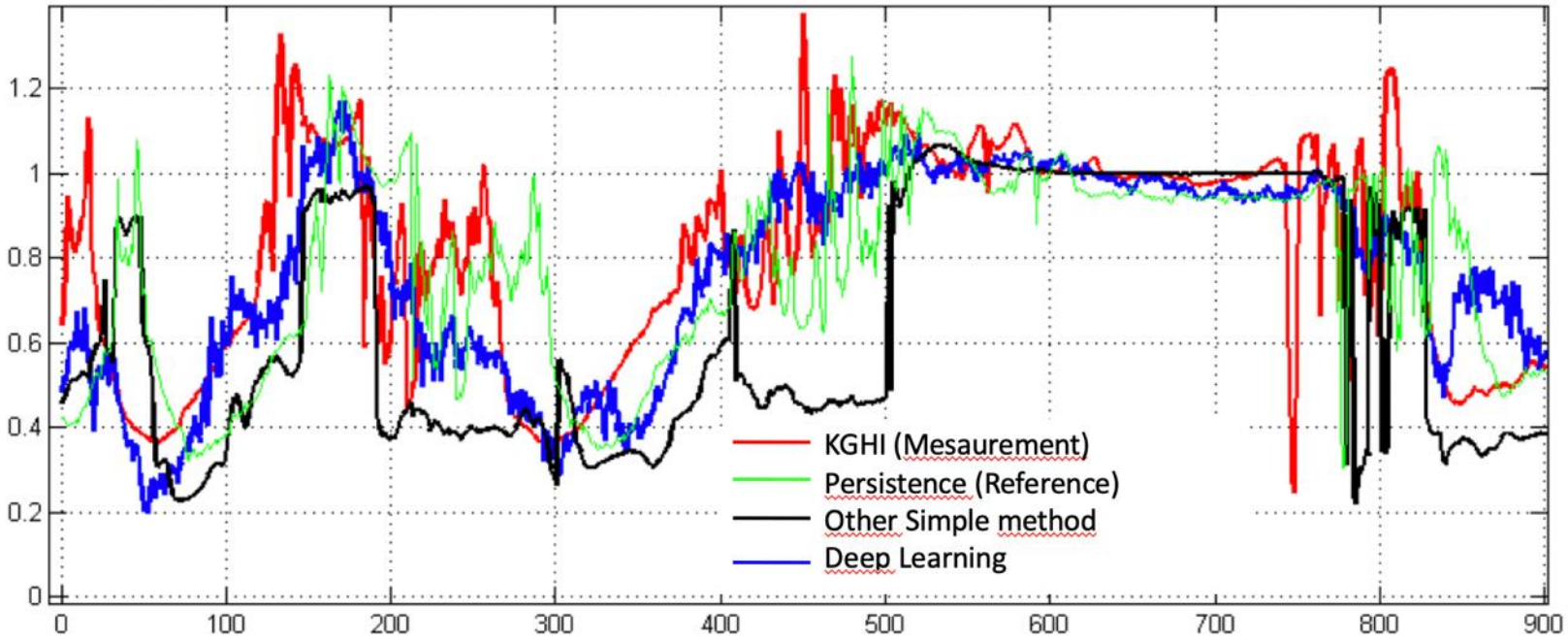
First forecasting results with ground cameras

Patent

First results that will be improved.
The 10 sec time step is very difficult to forecast accurately, a lower frequency gives better results.

Method	RMSE	nRMSE
Persistence	0.198	28.5%
Deep Learning	0.168	24.8%

10 sec GHI forecast (horizon 5 min) error over 4 days

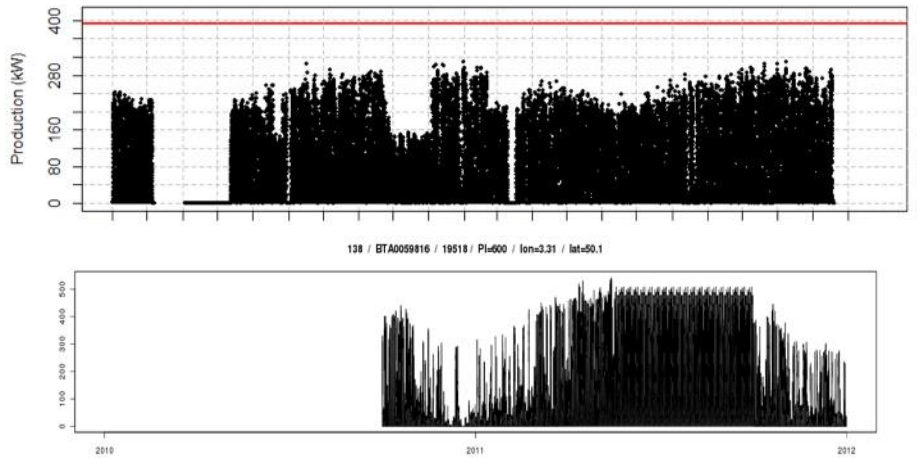


10 seconds GHI forecast 5 minutes ahead

Some Challenges

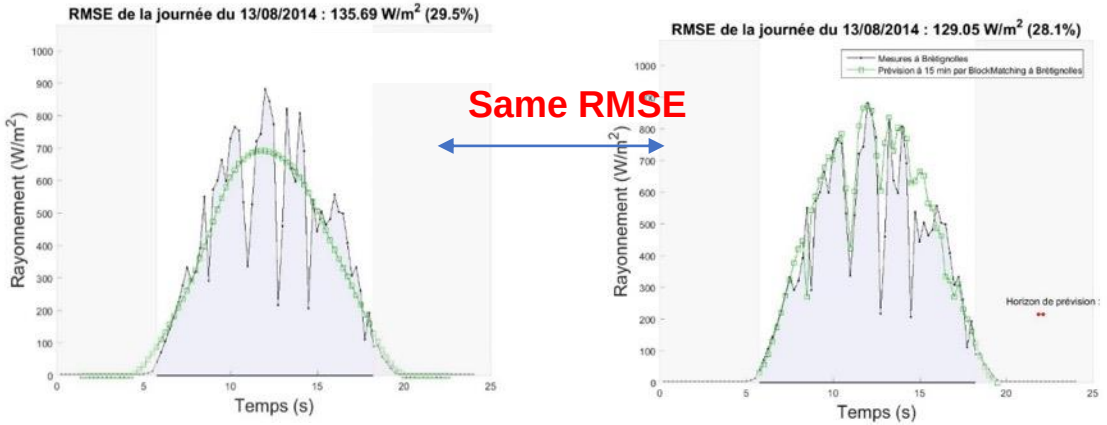
❑ Quality of input data

- ➢ Robustness (real time)
- ➢ Reliability (real time)



❑ Quality of NWP models

- ➢ Spatial and temporal resolution
- ➢ Difficulty in evaluating the contribution of higher resolution models (metrics, availability / relevance of observations)

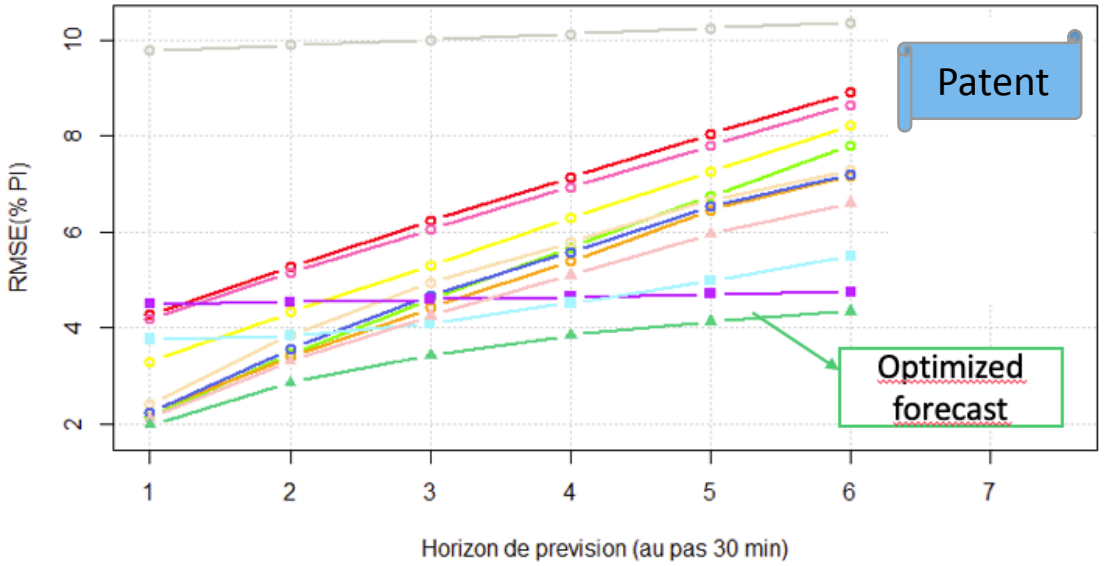


Forecast based on NWP

Forecast based on satellite

Next steps

- **Enhancement of the forecast acuracy at local scale, through:**
  - Models' enhancement (NWP, satellites, ground images, real time production - based)
  - new input data (higher resolution, better quality,…)
  - blending of a large number of forecasts as input data for smart optimization
- **Probabilistic forecasts**
  - still not used in operations
  - WIP



Error vs forecast horizon of different forecasts

Summary

- ✓ Energy transition ~ Low Carbon Electricity Generation
- ✓ Further increase of power systems' dependence on meteorology
- ✓ Space & time scales are interdependant

➔ Need improved information, data & forecasts at all space & time scales (not only for short-term RE integration)

More than ever, we need to

further develop collaboration

between the energy industry

and the weather & climate community

WEMC
World Energy & Meteorology Council

THANK YOU FOR YOUR ATTENTION

Contact : laurent.dubus@edf.fr

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