Research Thesis Title

Impact of Climate Change on Power Generation and Consumption in France and Aquitaine

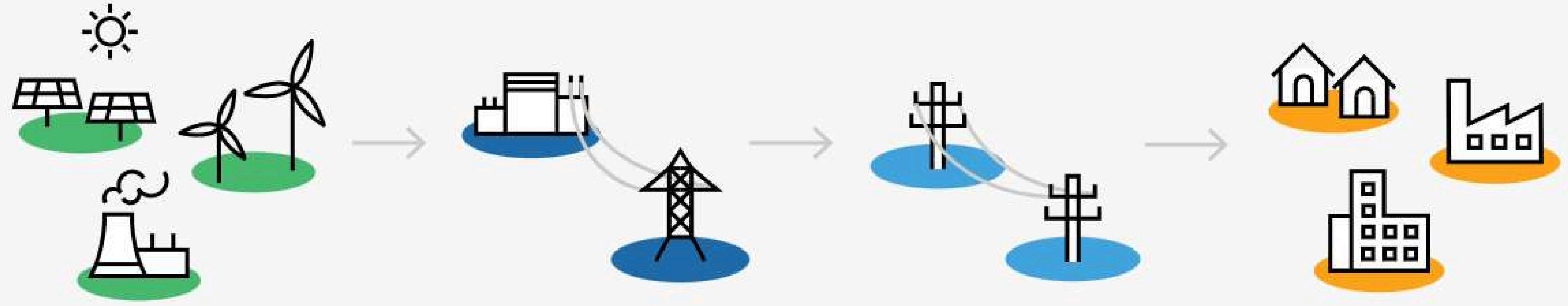
Our main focus area

Understanding the effects of climate variability on electricity production and demand.

Context

- Energy generation
- What is Grid
- Importance of Stability
- Penalty And their formulas
- How to avoid that
- Project
- AI ML
- Prediction
- Data Info
- Code Info
- Company
- Goals

How this system works?



A

Large-scale generation
Electricity is generated in power plants – such as wind and solar farms, thermal and hydro units. Large-scale generators are typically connected directly to the transmission grid, other generators such as small solar PV units are connected to the distribution grid.

B

Transmission
The skeleton of the electricity grid – high-voltage lines that connect main substations, carrying electricity between key generation and demand centers. This also includes cross-border connections between neighboring countries.

C

Distribution
Medium and low-voltage lines and transformer stations. The distribution network carries electricity from transmission grid nodes to end users.

D

Consumption
End users of electricity such as households, factories, office or public administration buildings.

Basics of Power Generation

Primary Power Sources:

- Fossil fuels (coal, gas, oil).
- Renewable sources (wind, solar, hydro, biomass).
- Nuclear energy.

Why we are focusing on renewable enargy

Free, Low maintenance, no pollustion

Then whats the problem

Basics of Power Generation

Low gerenation

Depends on weather conditions.

- Ensure demand-supply balance.
- Avoid blackouts and maintain grid stability.
- Minimize costs from penalties and emergency energy imports.

Grid?

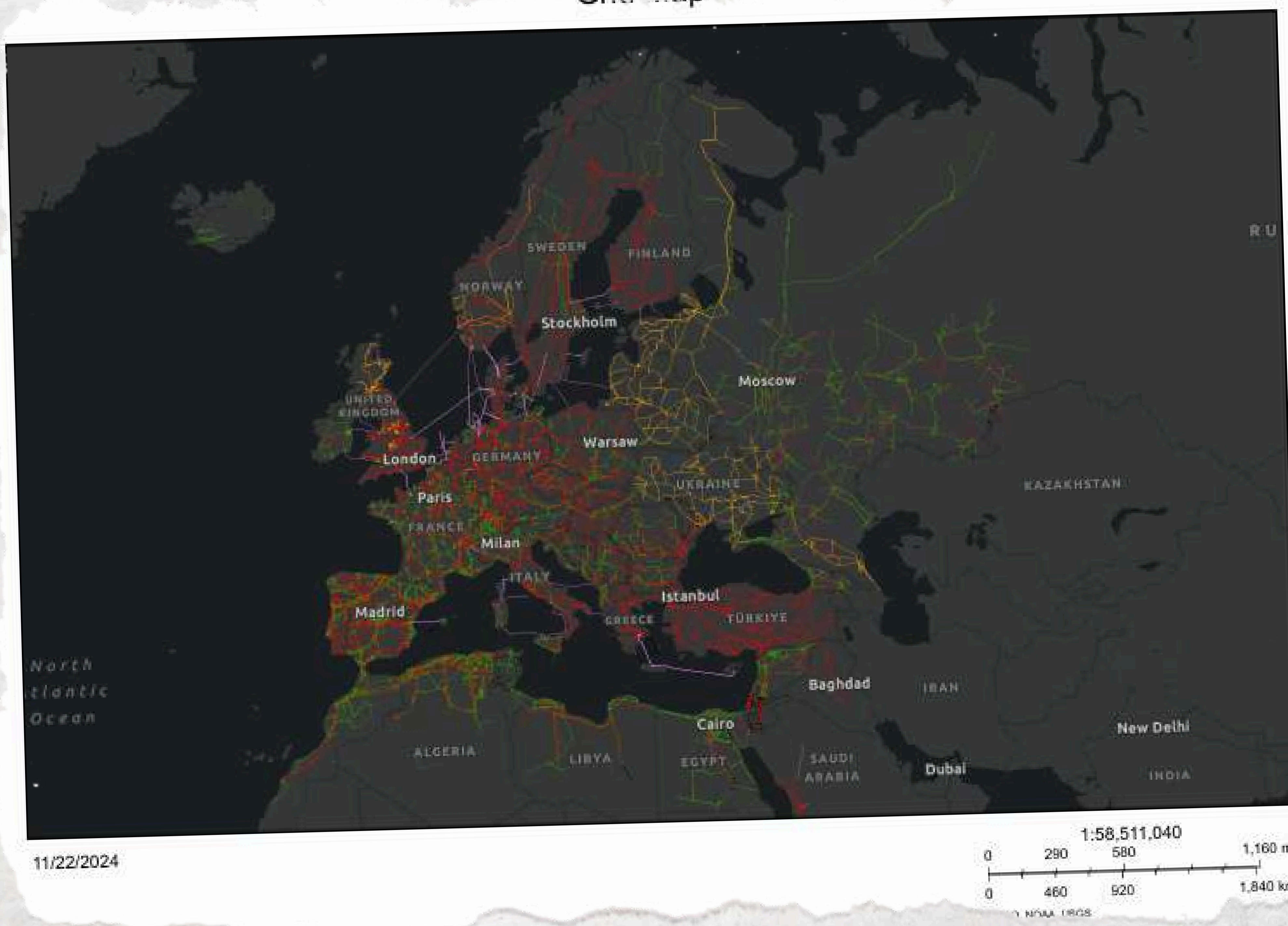
Introduction to Power Grids

What is a Power Grid?

An interconnected system delivering electricity from producers to consumers.

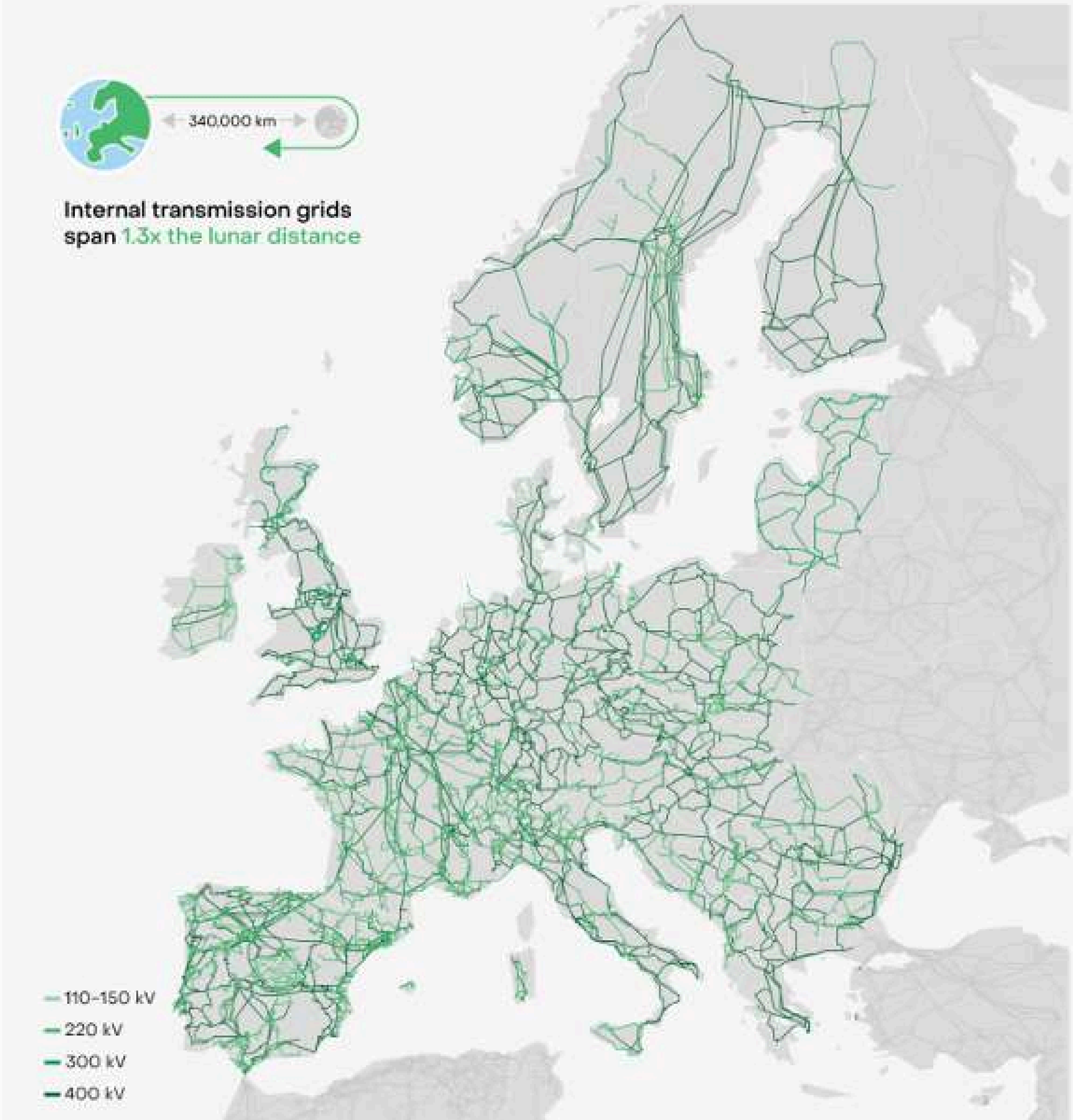
How It Works:

- Balances generation with consumption.
- Connects various energy sources.
- Facilitates energy trade between countries.



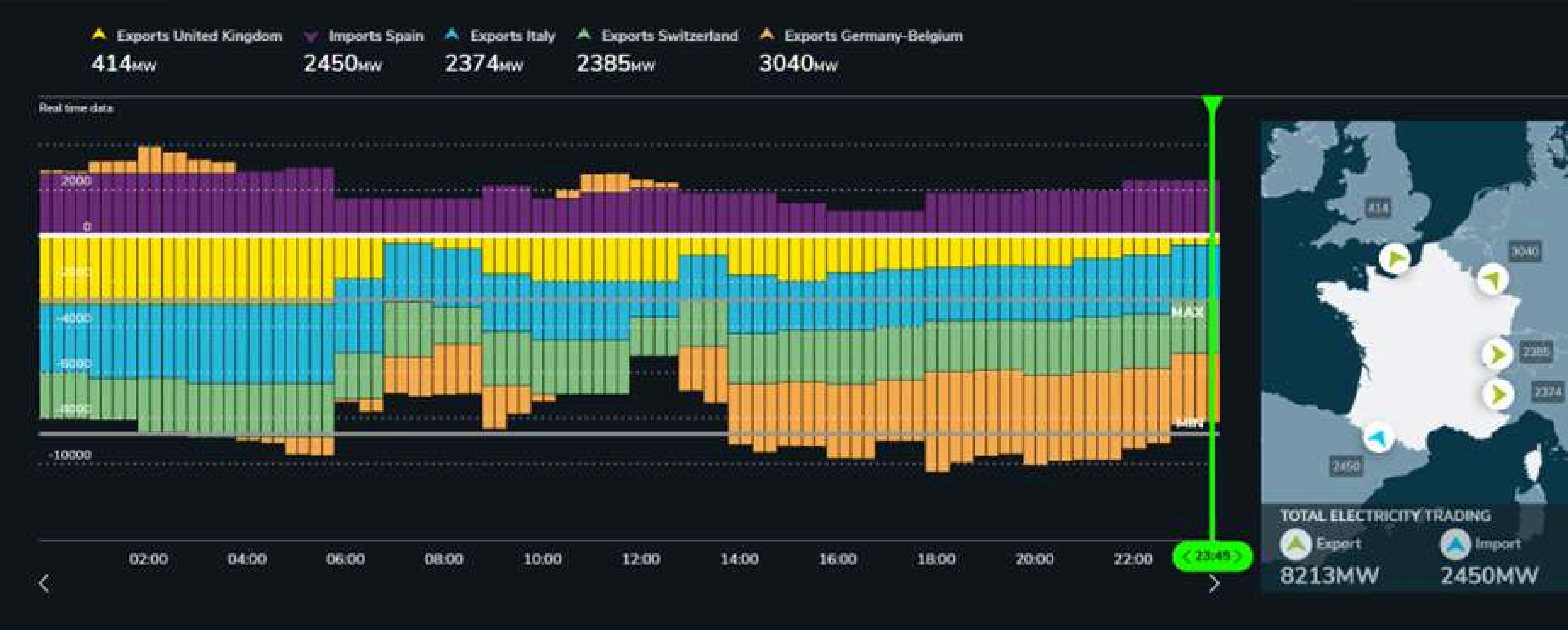
European Grids

ENTSO-E (European Network of Transmission System Operators for Electricity).
RTE (France).
REE (Spain).



France Grid Network

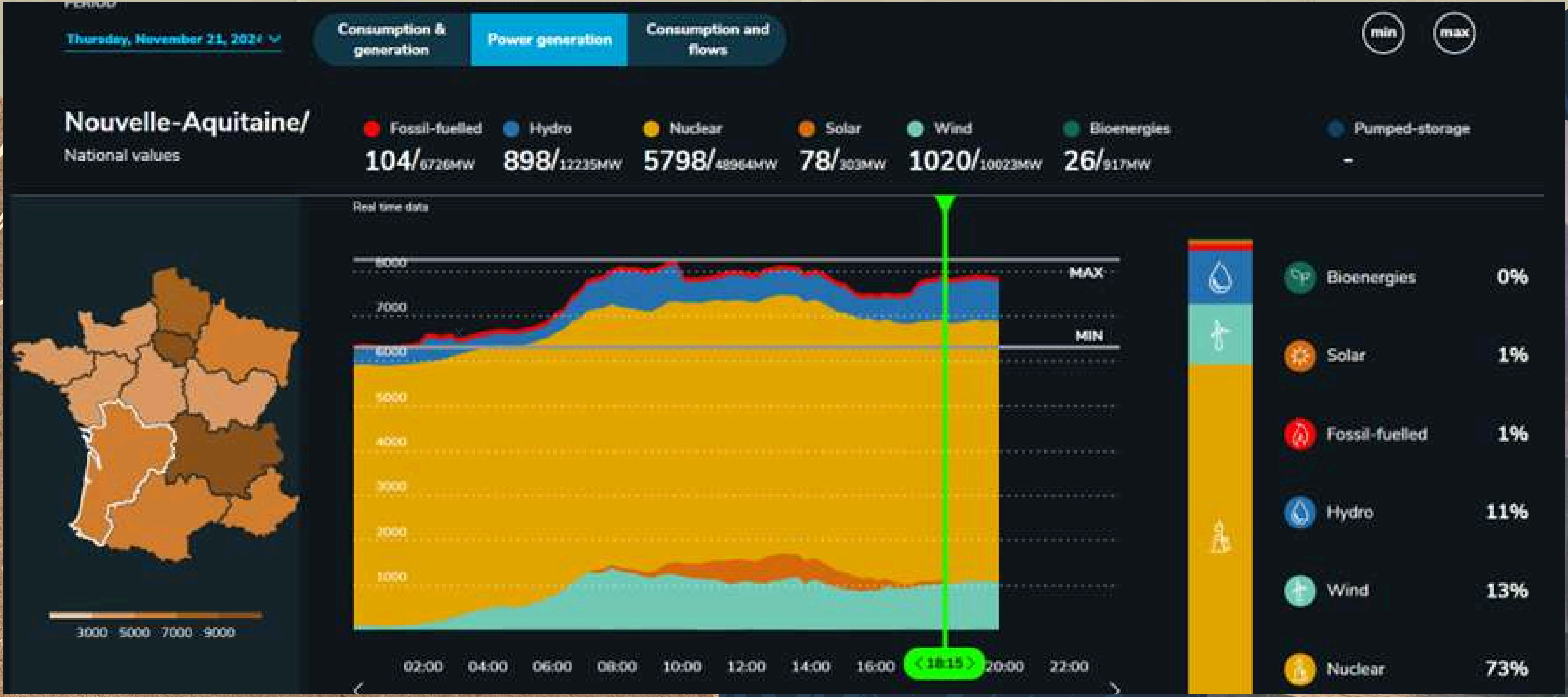
Imports and Exports



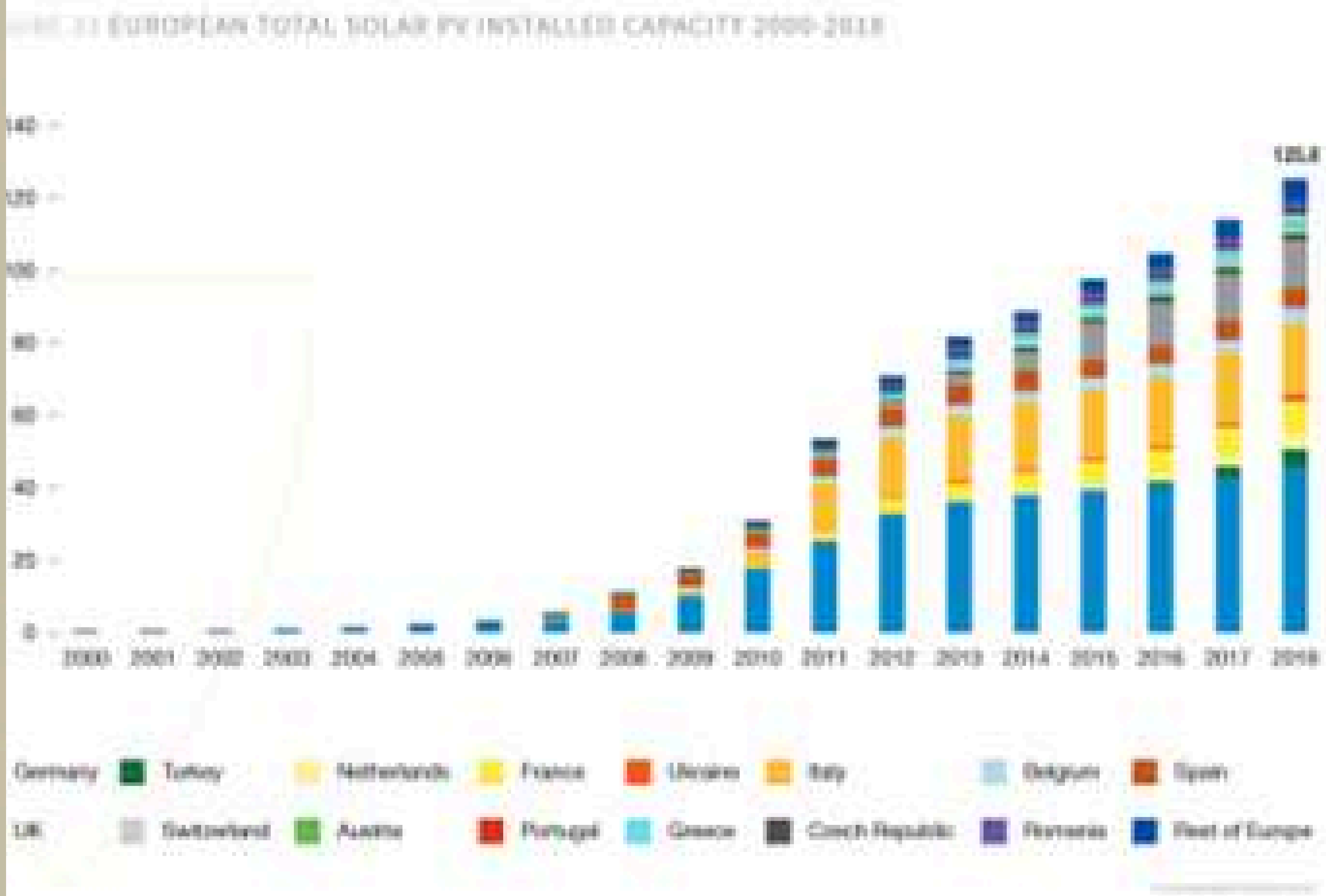
Consumption and Generation In Aquitaine

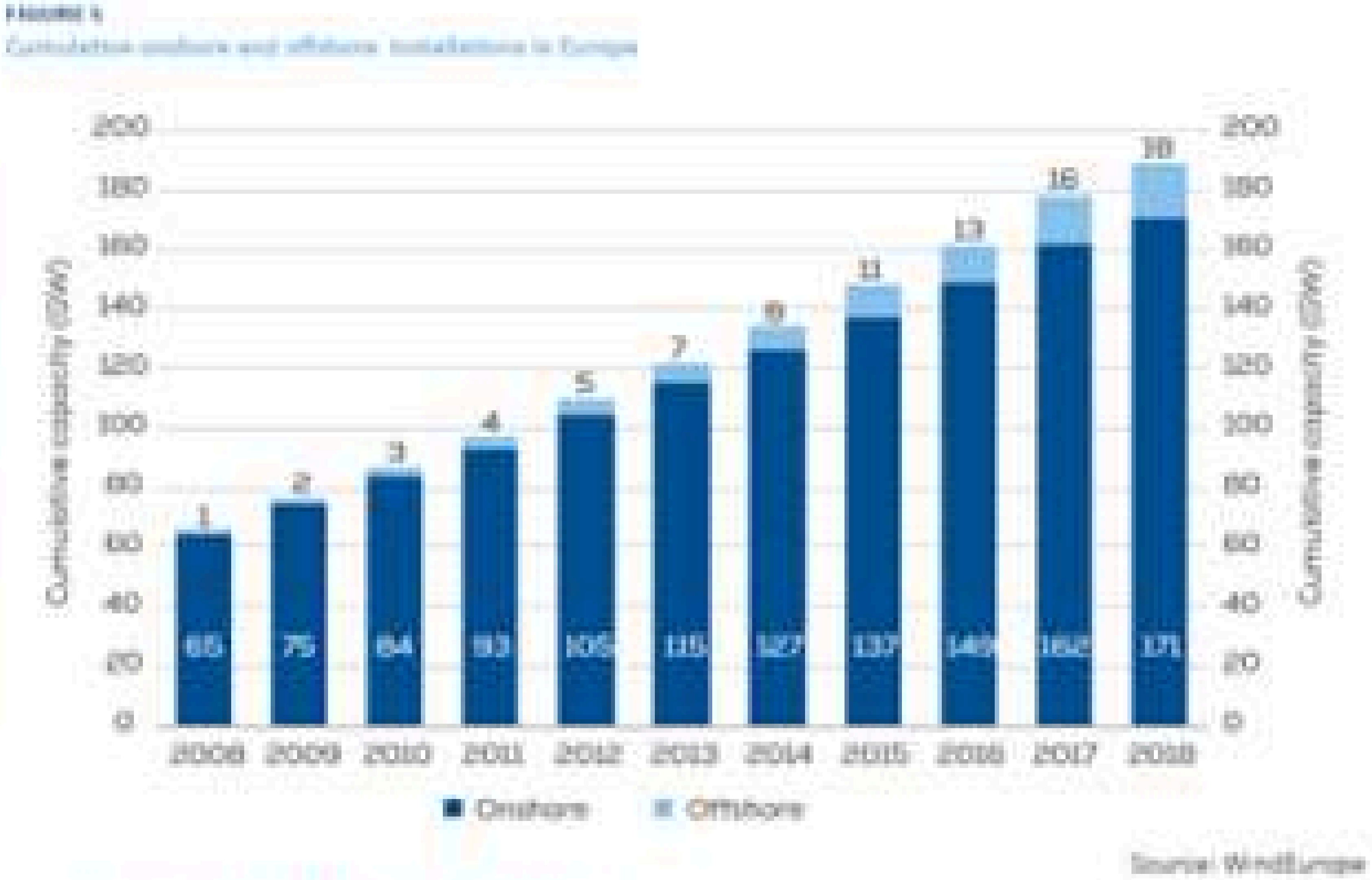
Consumption and Flow in Aquitaine

Power Generation In Aquitaine



Evolution of Solar PV and Wind generation in Europe





Solar +11 GW in 2018
Wind +11 GW in 2018

Challenges in Renewable Energy Integration

WE Can't store Energy. Not at this level;.
We don'thave that technology

AC SYSTEM

1. More economical
2. Transmission cost is low
3. 95 % of our system use AC
4. 50-60hz Frq
5. R,Y,B Phase (3 wire) cost

DC SYSTEM

1. +500Km Transmission line DC is more economical (Req Converters)
2. ZERO Losses
3. No Frq

Challenges in Renewable Energy Integration

Prediction Needs:

Accurate power generation forecasts.

Match supply with consumption.

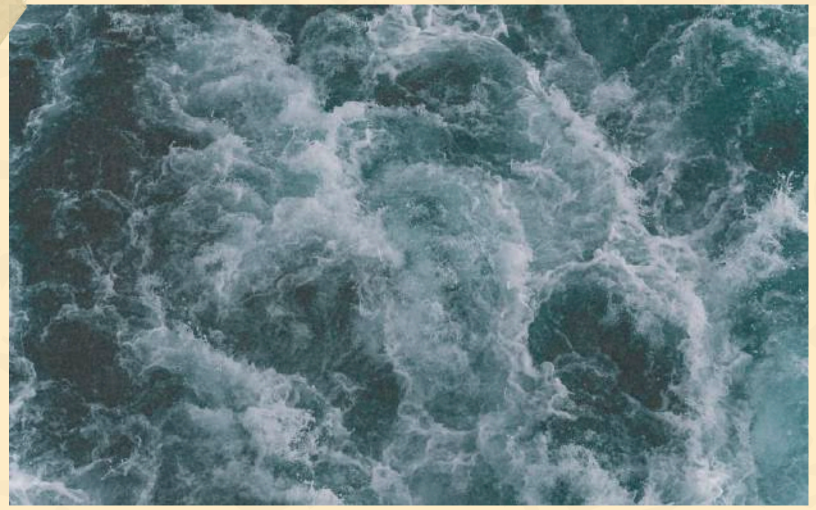
- Renewables like wind and solar are variable and less predictable.
- Stability issues in grid connection.
- Incorrect predictions can lead to blackouts or penalties.

Technical requirements addressed by the NC RfG

	Requirement	A	B	C/D
Frequency stability	Operating frequency ranges	X	X	X
	RoCoF withstand capability	X	X	X
	Limited Frequency Sensitive Mode - Overfrequency	X	X	X
	Constant active power output regardless of changes in Frequency	X	X	X
	Limitation of power reduction at underfrequency	X	X	X
	Automatic connection	X	X	X
	Remote ON/OFF	X	X	
	Active power reduction remote control		X	
	Additional requirements related to frequency control			X

	Requirement	A	B	C/D
Robustness	Fault-ride-through		X	X
	Post-fault active power recovery		X	X
System restoration	Coordinated reconnection		X	X
General system management	Control schemes and settings		X	X
	Electrical protection and control schemes and settings		X	X
	Priority ranking of protection and control		X	X
	Information exchange		X	X
	Additional requirements to monitoring			X
Voltage stability	Reactive power capability		X	X
	Fast reacting reactive power injection		X	X

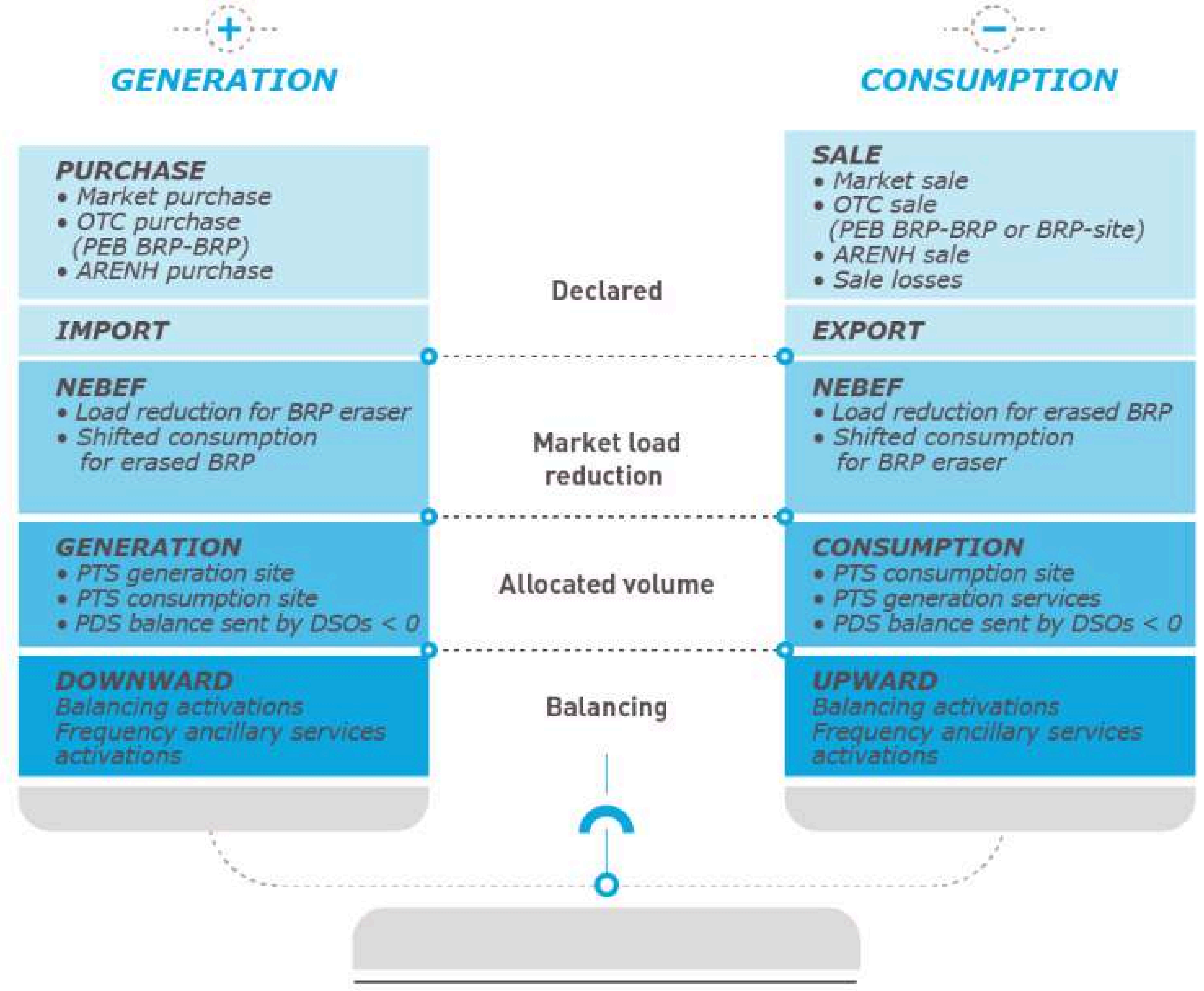
Power Genaration



Prediction

What if we didn’t Do this ?

Penalty How much?



Components for calculating imbalances of balance responsible parties

Definition of generator types

- Definition of capabilities from a systems perspective - largely independent of the technology
  - generator capacity
  - connection level (voltage)
  - transmission grid area

		Capacity (Cont. Europe)	Voltage level
Type D	• Wide-scale network operation and stability • Balancing services	> 75 MW	≥ 110 kV
Type C	• Stable and controllable dynamic response • covering all operational network states	> 50 MW	< 110 kV
Type B	• Automated dynamic response, resilience to events • System operator control	> 1 MW	< 110 kV
Type A	• Basic capabilities to withstand wide-scale events • Limited automated response and control	> 0,8 kW	< 110 kV

aFRR need for French scheduling area

French electricity balancing roadmap

The design of the French balancing model The model implemented in France rests on two fundamental pillars: u provide the balance responsible parties (hereinafter referred to as the “BRPs”) with the option to optimise their portfolios and anticipate the balance of their perimeter up to a timescale that is relatively close to real time; u enable TSOs to make the most appropriate decisions for balancing the system and ensure centralised and coordinated management of the supply-demand balance and network constraints. These decisions rely on predictive analyses produced by the TSO based on data sent by the market parties at different timeframes.

. The way in which the TSO manages balancing is centralised and proactive. Based on analysis and forecast information provided by the market parties, the TSO can decide to activate balancing bids ahead of real time, i.e. before any imbalances are actually recorded. Many countries have adopted this approach (the United Kingdom, Portugal, Spain, Denmark, Norway, Sweden, Finland, etc.)

- VWAPU/D: volume weighted average price of balancing energies activated upward/downward (see article 0.0.2.3 “Volume Weighted Average Price” in the "General Provisions" of the Market Rules).
- The trend is said to be upward if the overall imbalance of the power system is negative or zero (i.e. when the overall balance for France [generation- consumption] of the system is negative), and downward in the opposite case. More details for ~~the calculation~~ of the trend are in article 0.0.2.2 “Trend of the French electricity system” in the "General Provisions" of the Market Rules.
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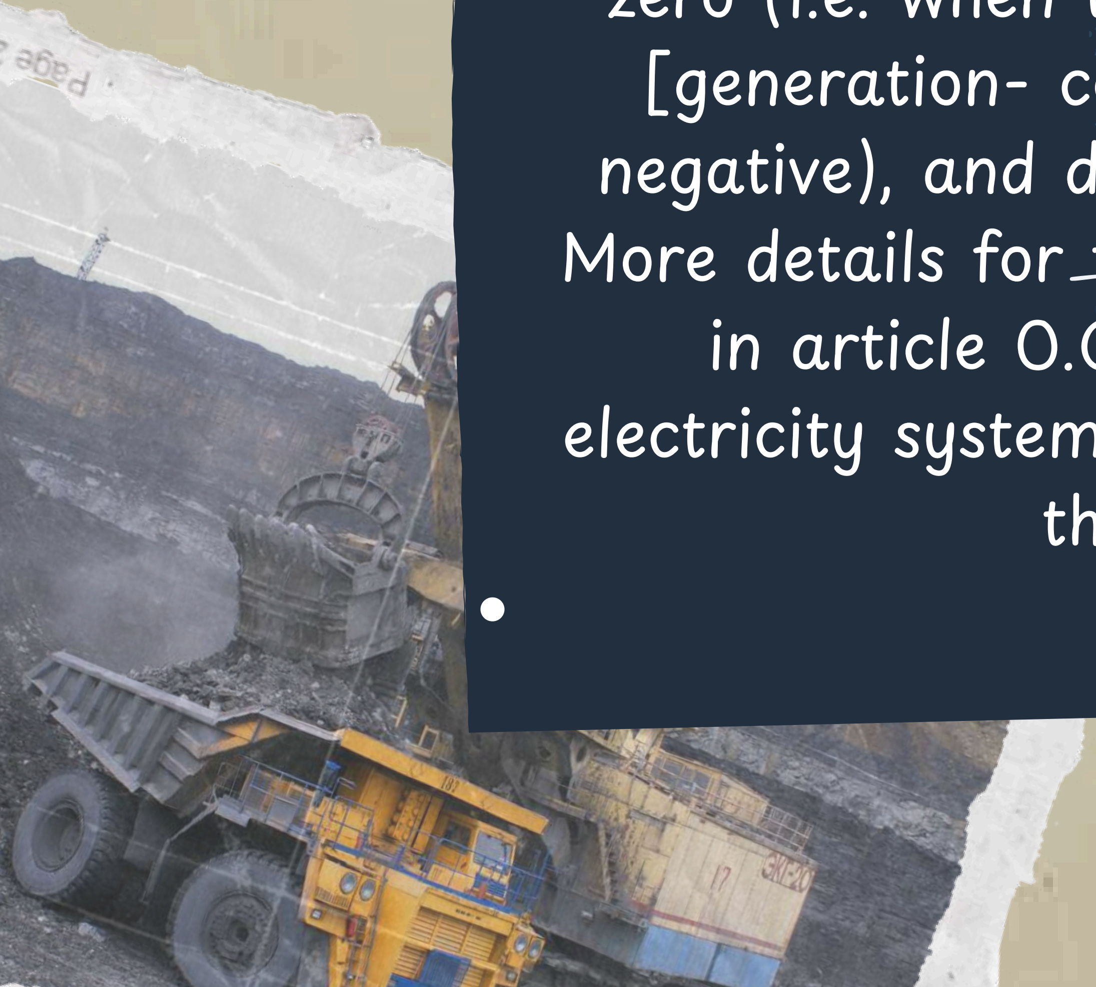
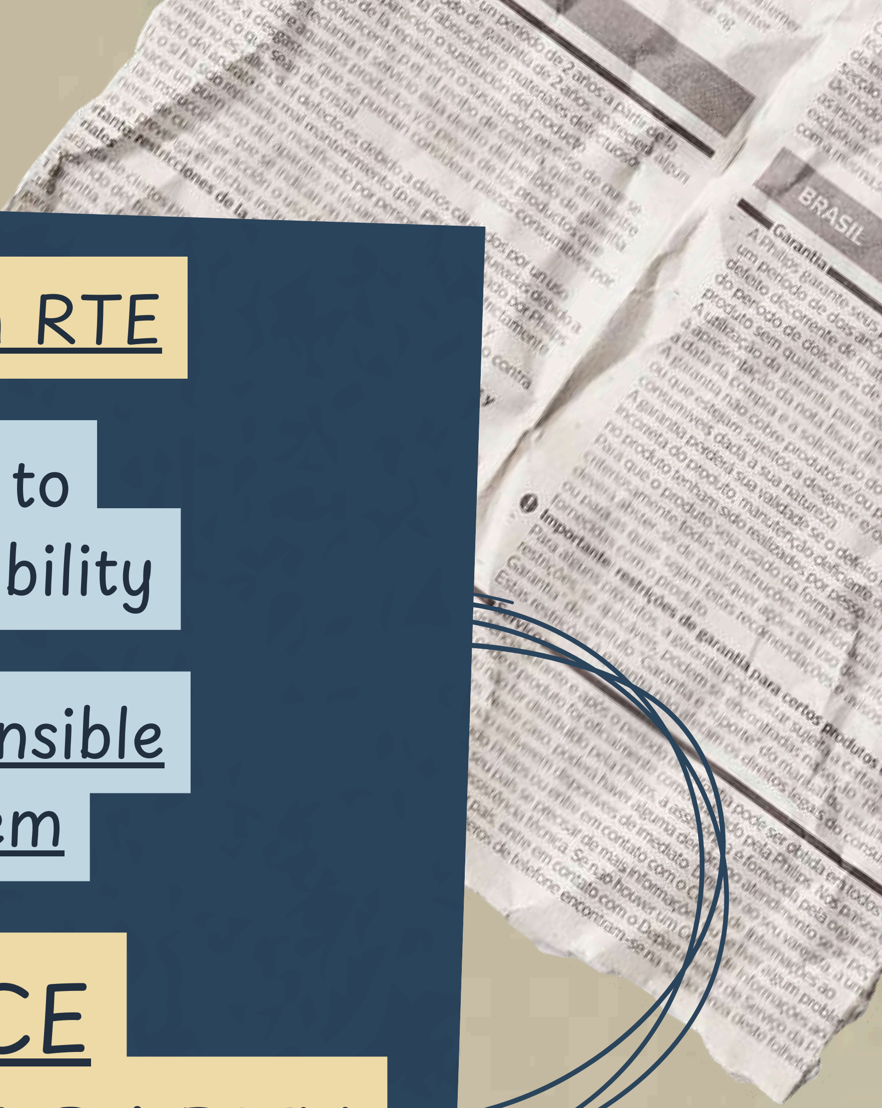




Contracting with RTE

Costs related to balance responsibility

Balance responsible party system

BALANCE RESPONSIBLE PARTY

Challenges of Grid Integration of Wind Power on Power System Grid Integrity

risks for power grid frequency stability with explainable AI

Imbalance Settlement Price Matrix

If the volume weighted average price (VWAP) is positive or zero

	Upward trend of the French power system and positive or zero VWAPu	Downward trend of the French power system and positive or zero VWAPD
Positive Imbalances	VWAPU*(1+k) Nota 1	VWAPD*(1+k)
Negative Imbalances	**VWAPU*(1-k)**	VWAPD*(1-k) Nota 2

Imbalance Settlement Price Matrix

If the volume weighted average price (VWAP) is negative

	Upward trend of the French power system and positive or zero VWAPu	Downward trend of the French power system and negative VWAPD
Positive Imbalances	VWAPU*(1+k) Nota 1	VWAPD*(1+k)
Negative Imbalances	**VWAPU*(1-k)**	VWAPD*(1-k) Nota 2

Weather Prediction for grid stability

AI Or manual

Which one is better

What we can do ?

Prediction Techniques

Manual Predictions:

- Use wind speed and power generation graphs.
- Basic but less accurate.

AI/ML Predictions:

- Use machine learning models for real-time and historical data.
- Predict wind speed, power output, and avoid penalties.

Mars

Companies Addressing These Issues

Notable Companies:

Siemens Gamesa: Wind power solutions.

EDF Renewable Energy: Solar and wind projects in France.

Vestas: Advanced wind turbines and systems.

Technologies in Use:

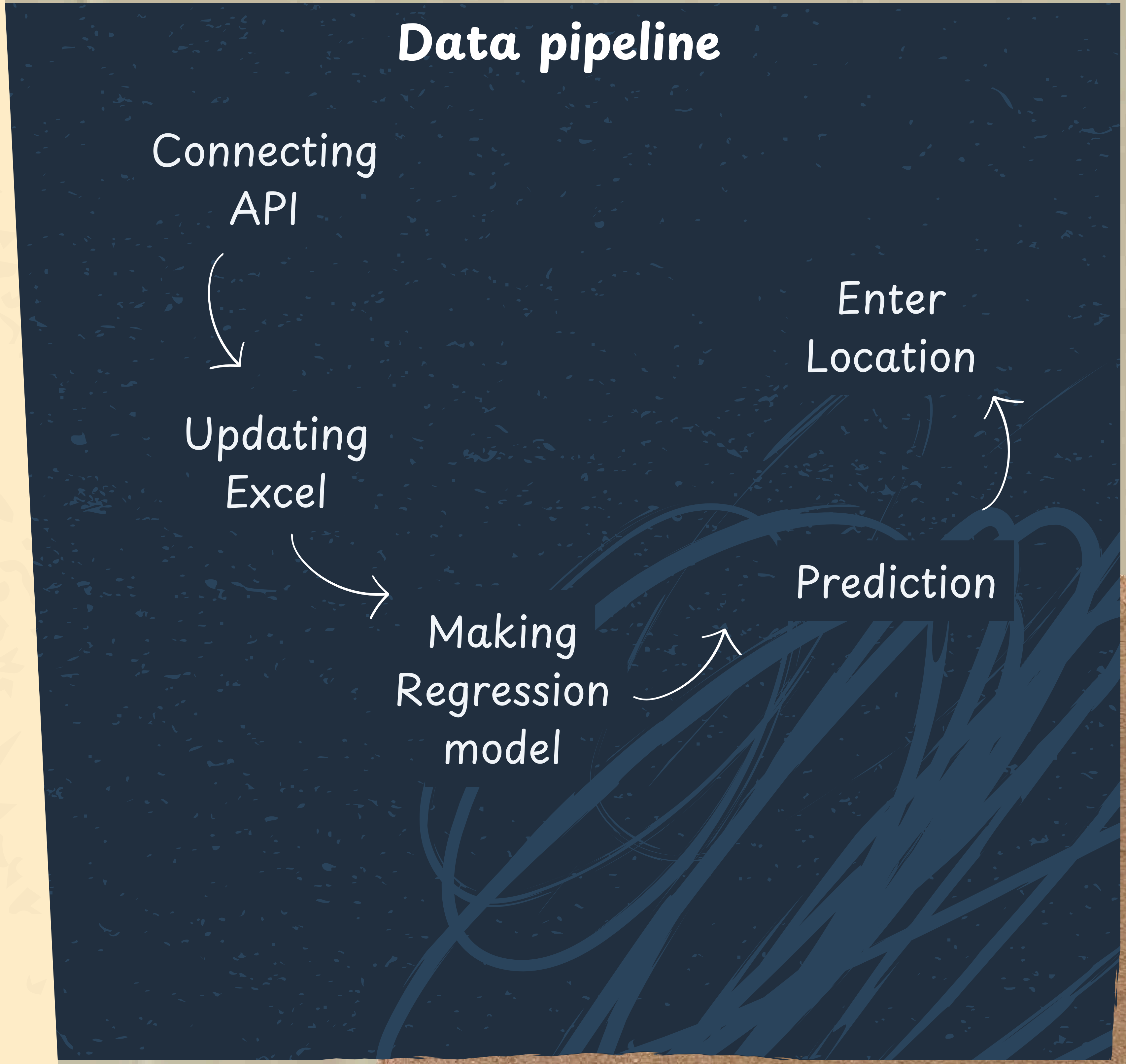
IoT for real-time data collection.

AI for predictive modeling.

My Code

I use API to fetch the current data for a particular location
I use some historical data like wind gusts, wind speed, temp, humidity, and others.
After getting the correct data I Compare it with historical data and use regression analysis to pridict

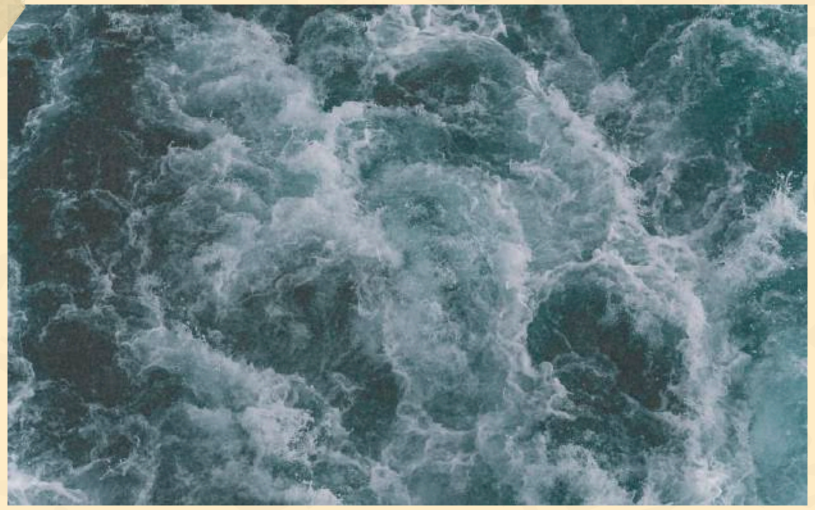
CODE LINK



Goals

Long-Term Goals:

1. Thesis Proposal
2. Coding
3. Analytics?
4. Business?
5. Impact on grid
6. Impact on companys



Thesis Proposal

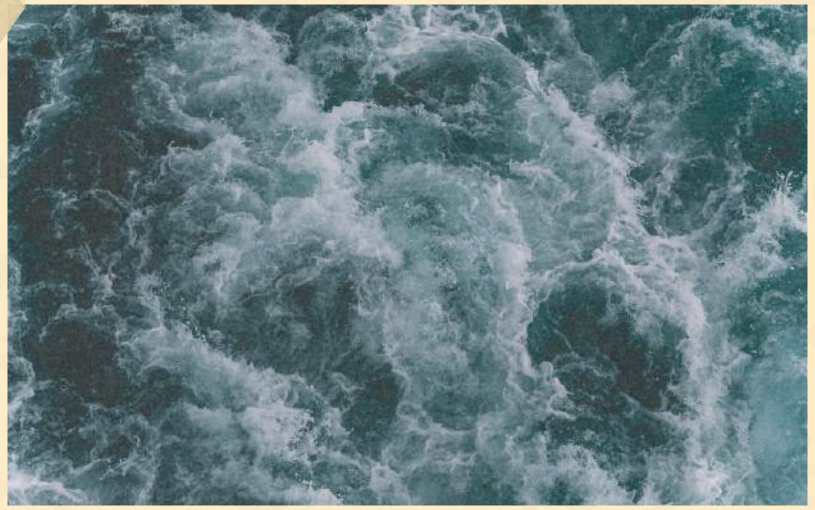
Codeing

Final Thesis

Long-Term Goals and Business Impact

Long-Term Goals:

- Develop reliable prediction models for grid operators.
- Integrate more renewables into the grid.



Cost savings.

Improved sustainability metrics.

Enhanced energy trade efficiency.

Questions and Suggestions