EDF Solution for Massive Renewables integration

March 13th 2018

On the 11th December 2017, EDF President Jean Bernard Levy announced 25Mds€ for the installation of 30 GW PV in France between 2020 and 2035, bringing PV to approx. 25% of the installed capacity of the country.

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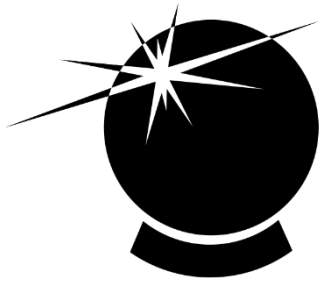
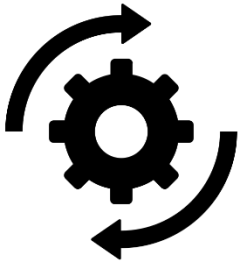
Before : In the “good old times”



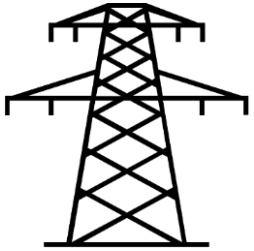
Predictable Power Generation
(thermal, hydro, nuclear)



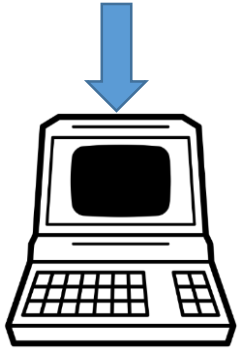
Spinning machines

High Inertia

Stability of the system



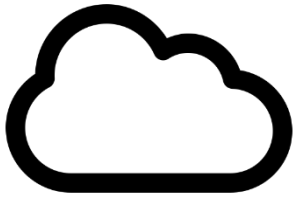
Power generation connected on the
Transmission connection



Precise Monitoring
of transmission System

We knew every thing, every where, all the time

Now : Renewable energies call for change



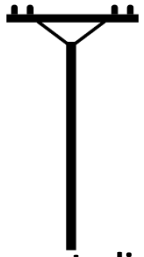
Variability (follow weather conditions)
Uncertainties (follow weather changes)

Flexibility needs
- Higher ancillary services for conventional means
- Needs for DSM

Interface to the grid
through power electronics devices

Lower inertia

Lower stability
- Need adapt the system
(*e.g.* synchronous condenser, or Smart Inverters in R&D phase)



Decentralized
Electricity Generation

Need to monitor more precisely distribution systems

EDF Proposal: Provide Performant & Reliable System Solutions in an evolving world

Task 1: Data collection

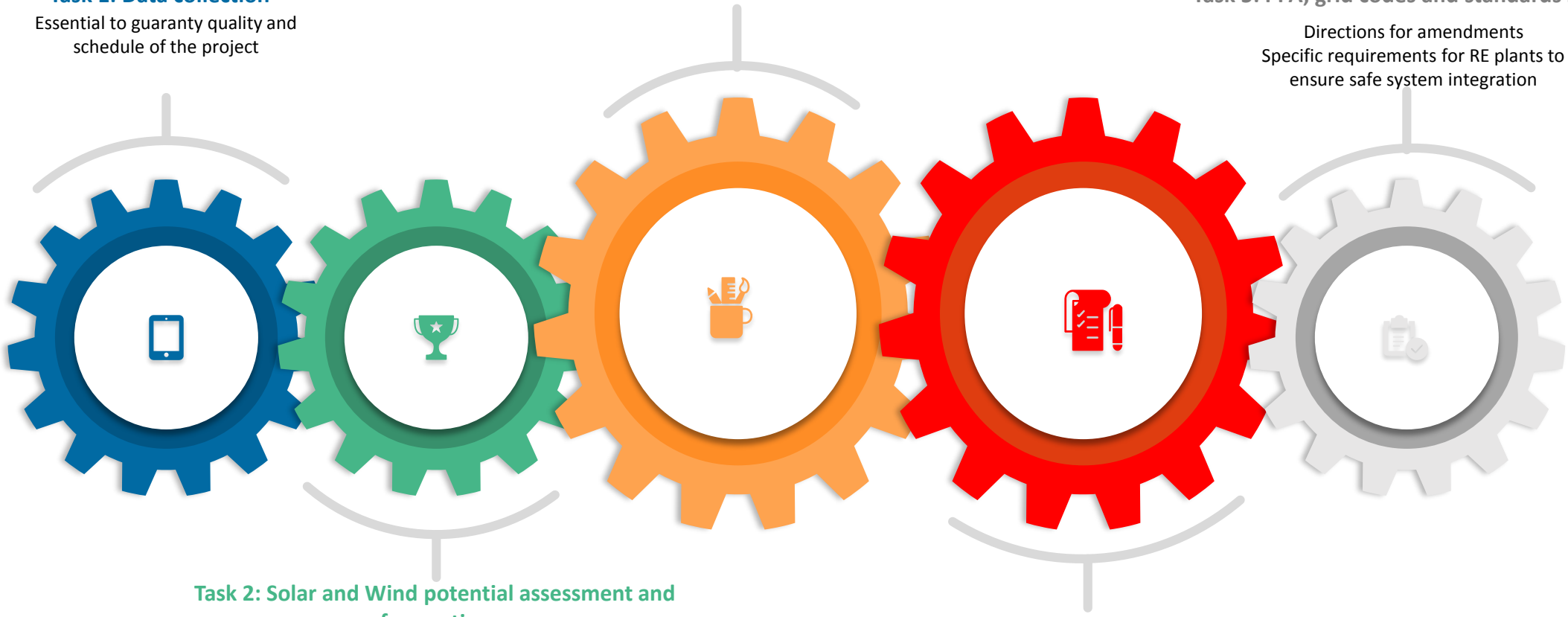
Essential to guaranty quality and schedule of the project

Task 3: Generation study

Ancillary services assessment
Storage assessment if relevant
Flexibility assessment

Task 5: PPA, grid codes and standards review

Directions for amendments
Specific requirements for RE plants to ensure safe system integration



Task 2: Solar and Wind potential assessment and forecasting

Selection of optimal PV and Wind locations

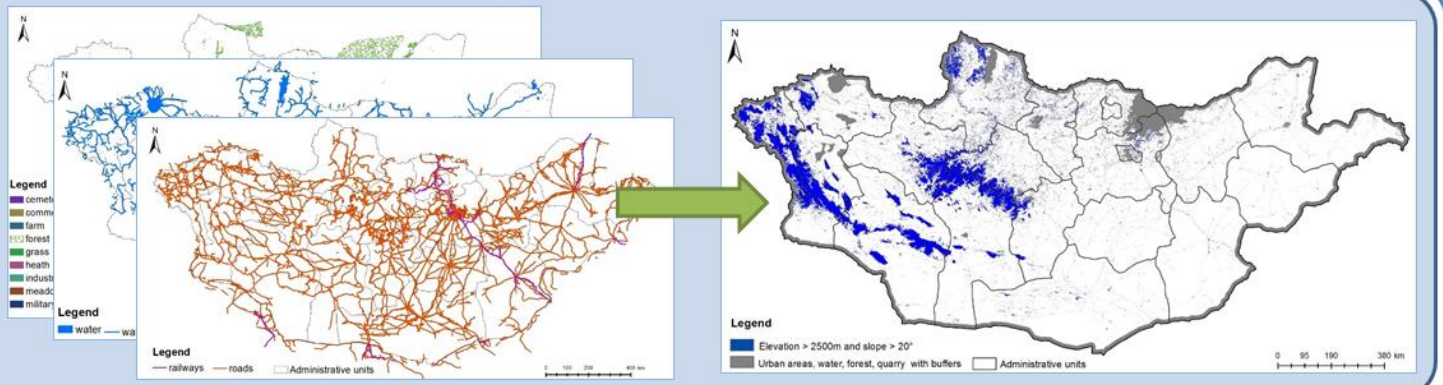
Task 4: Transmission study

Multi variable scenario approach
Only relevant investments emerge from the study
Prevent overinvestments

Mongolia case : Solar potential assessment

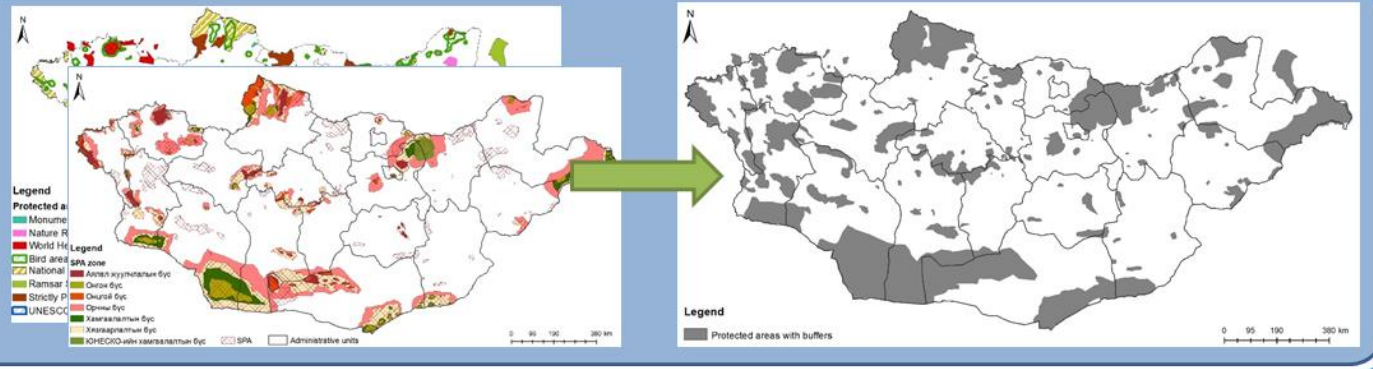
Obligatory constraints:

- Elevation above 2500 m
- Slope > 20°
- Waterland, Rivers
- Urban areas
- Railways, Roads
- Forest
- Airport zones (with 5 km buffer)
- Tourist camps (with 5 km buffer)
- Existing RES plants
- Quarry, mines
- Border with 15 km buffer



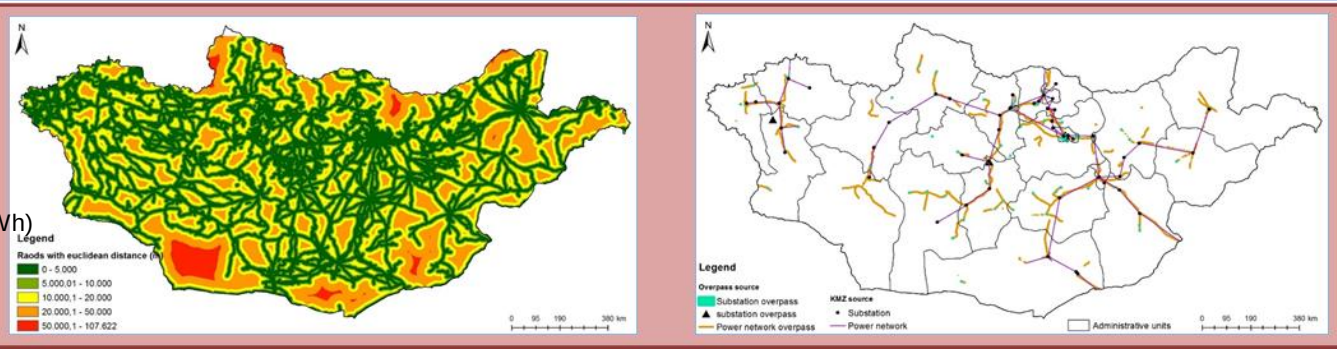
Protected areas (with 1 km buffer):

- Ramsar sites
- Important bird areas (2 km buffer)
- National conservation parks
- Nature reserves
- Monuments (5 km buffer)
- World Heritage Site, UNSESCO
- Local protected areas
- SPA, SPA zone

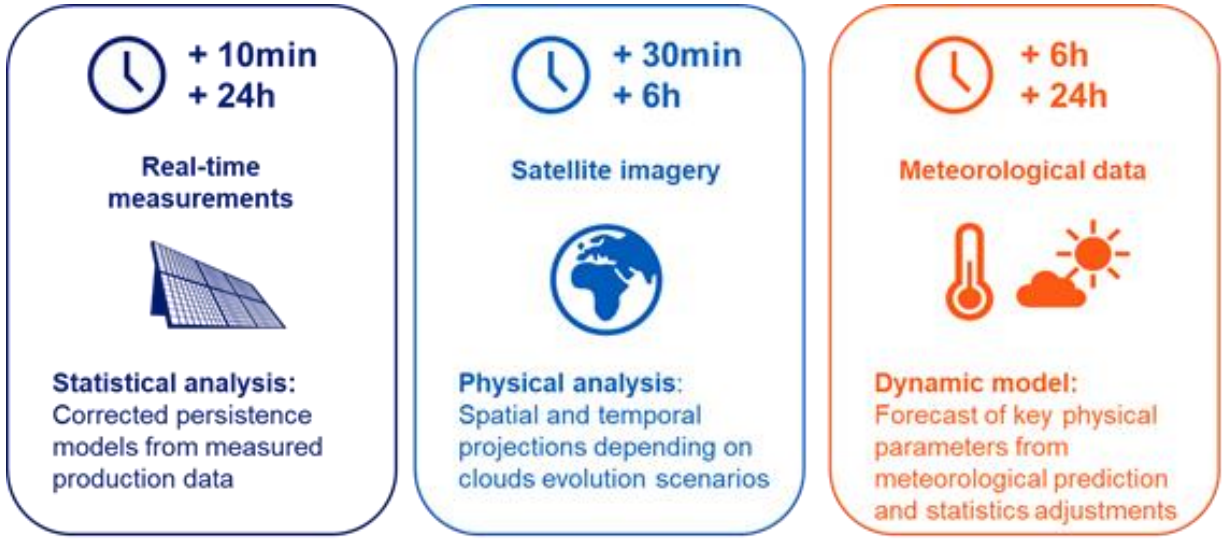


Suitable sites can be ranked

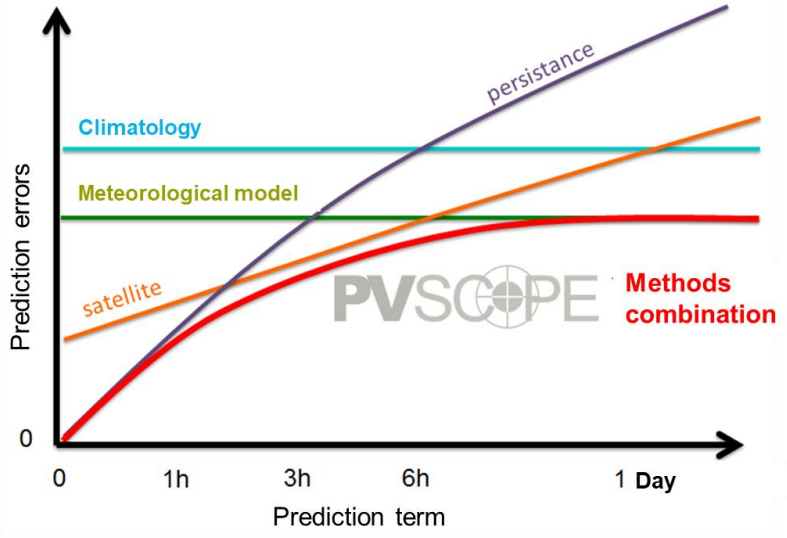
- **according to:**
- Proximity to existing substations
- Proximity to roads
- LCOE (depends on CAPEX, MW & GWh)
- …



Solar and Wind forecasting



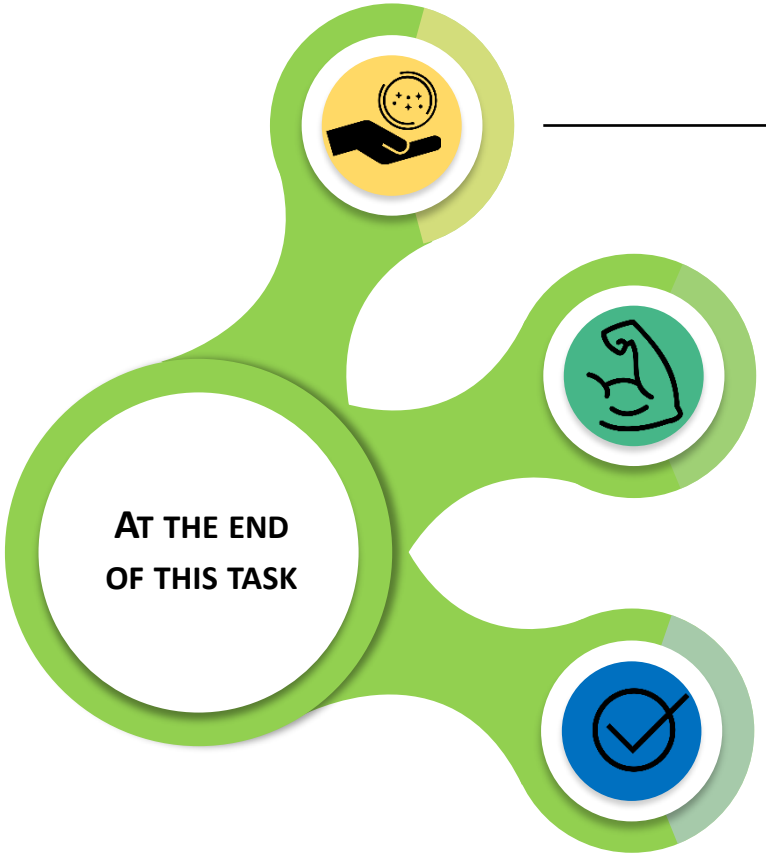
PVSCOPE™ is a forecasting tool that generates **day-ahead and intra-day photovoltaic (PV) power production forecasts**. It was developed in partnership with the Dynamical Meteorology Lab (Ecole Polytechnique, Paris).



EOL SCOPE™ :
similar tool dedicated to wind forecasting

PVSCOPE™ merges meteorological data, satellite imagery and PV production measures. PVSCOPE™ forecasts include the effects of cloud cover.

Task 2: Solar potential assessment and forecasting



Main results
PV / Wind Farm location assessment
associated power and energy as well as LCOE
Short-term forecasts and
recommendations for forecasting tools

The strengths of our proposal
Multi-criteria approach
combining technical & economical indicators
International experts with the EDF Group experience

Decisions making by Client
Selection of the PV / Wind Farm sites location and size

Training sessions also available

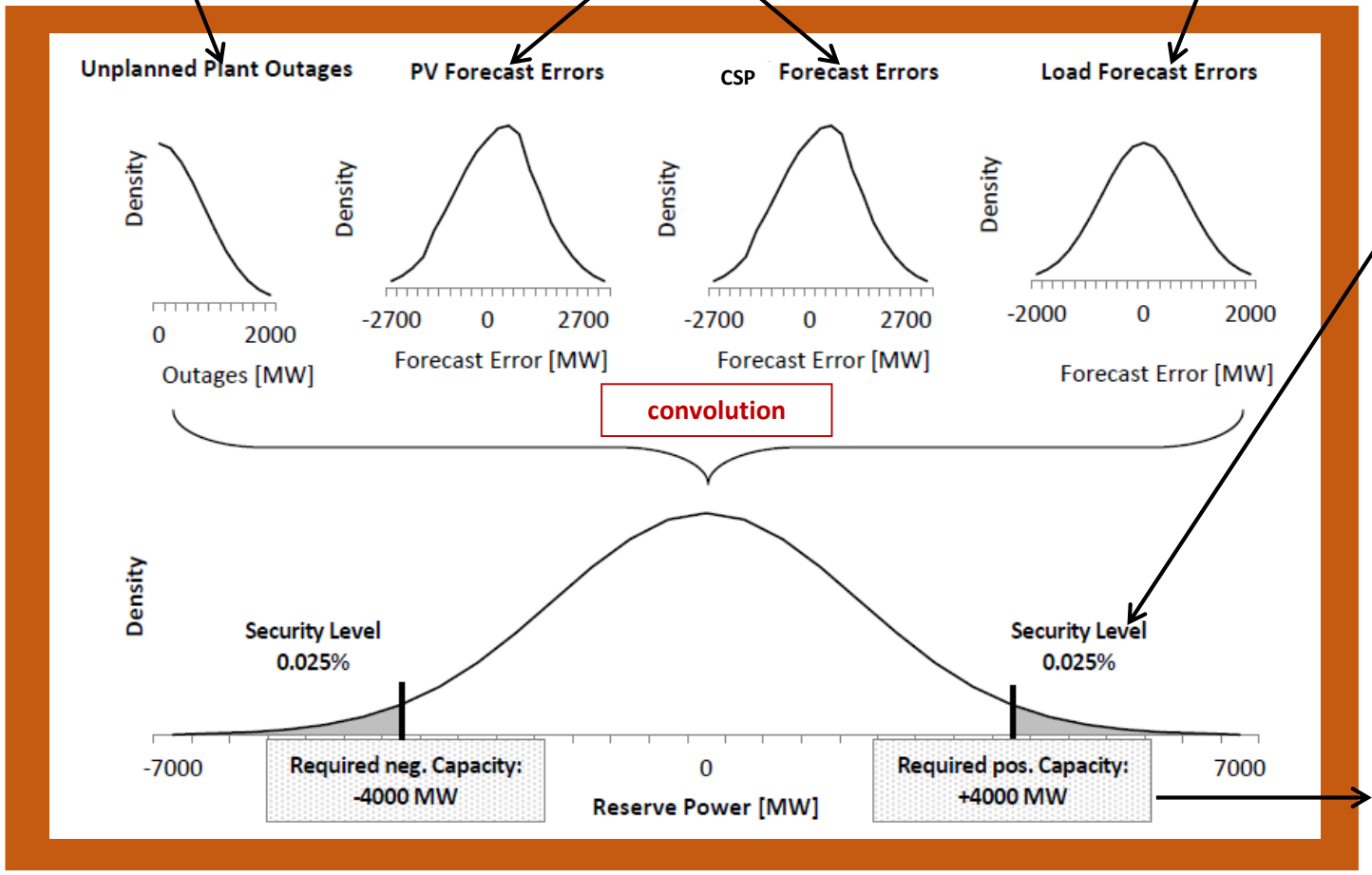
Probabilistic approach to reserves calibration sizing

Conventional generation: Average running time and number of failures/year

Renewable generation: Time series of measured and (expected) forecasted generation, or expected level of forecast errors

Load: Time series of measured and forecasted load, or levels of forecast errors

Level of risk: % of cases not covered, up and down



In house tool, developped by our R&D

Forecasting errors will increase, as well as requirred reserves capacities in order to maintain de same level of risk

Storage need assessment

Mc Henry, USA
20MW/8,5 MWh

Concept Grid
France

West Burton, UK
Hybride 49MW/30min

Determining efficient usages

Reserve, congestion, arbitrage, peak shaving…

Comparing and sizing the technologies
Batteries, CSP, pumped hydro storage, fly wheels

De-risking

Hybridization
Connecting a battery on an existing CCGT

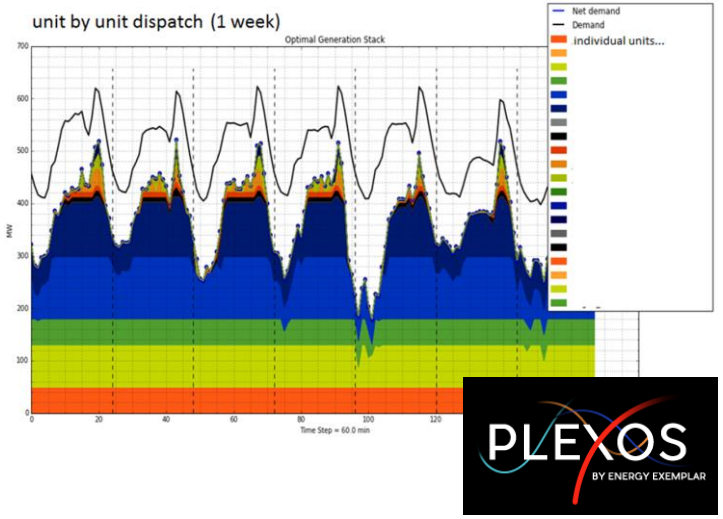
Trainings

Costs of batteries have dropped,
they can **technically** offer many services,
but only few of them are
the most **economically** efficient option

We will assess the value of batteries to provide primary reserve considering the cost of saved fuel

Other examples of EDF know-how

Hourly Generation Dispatch



Global costs of operation

Flexibility analysis

Impact on conventional units solicitations

Curtailment, load shedding

CO_2 emissions

Coupling power generation and Water (if any)

Jamaica
Ministry of Science, Technology, Energy, and Mining

Maximal Renewable Integration

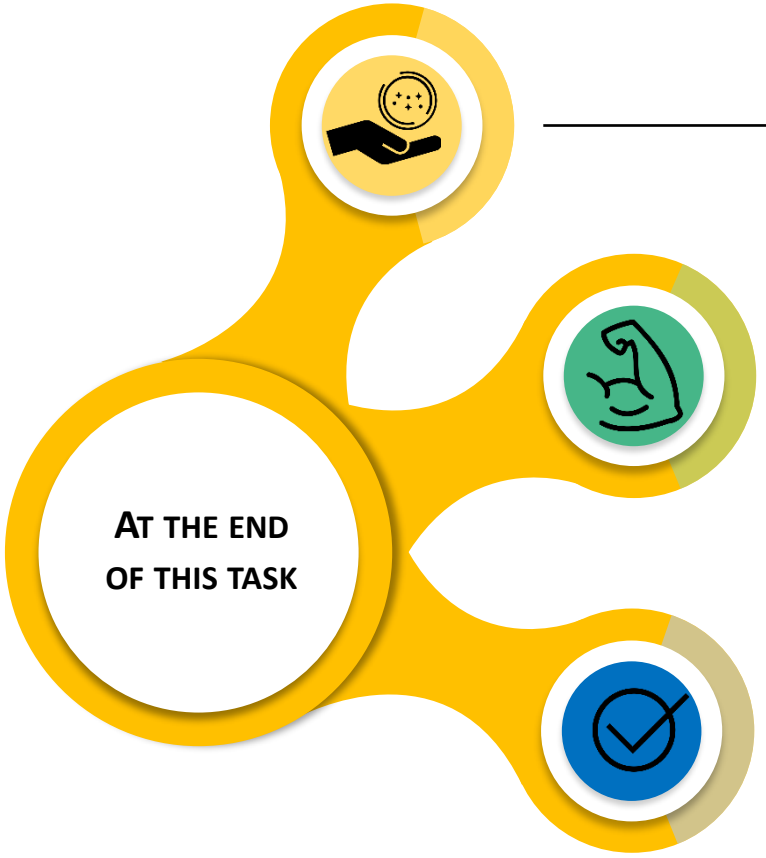
ELECTRA

ديوا dewa

المكتب الوطني للكهرباء
Office National de l'Electricité

Morocco

Task 3: Generation study



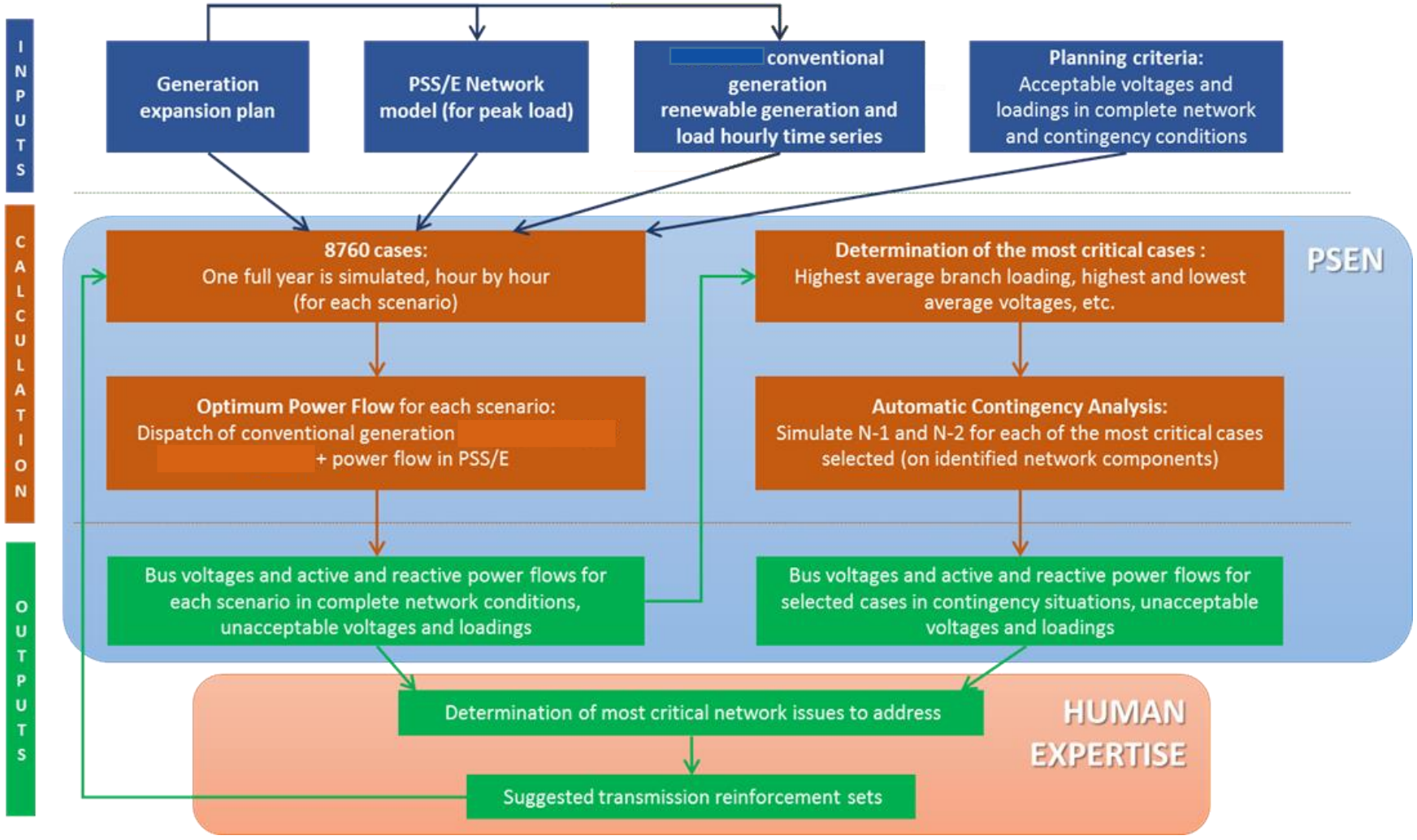
Main results
Reserve calibration
Storage assessment
Flexibility analysis

The strengths of our proposal
Strong experience on similar projects especially
Ability to model power and water (if any)

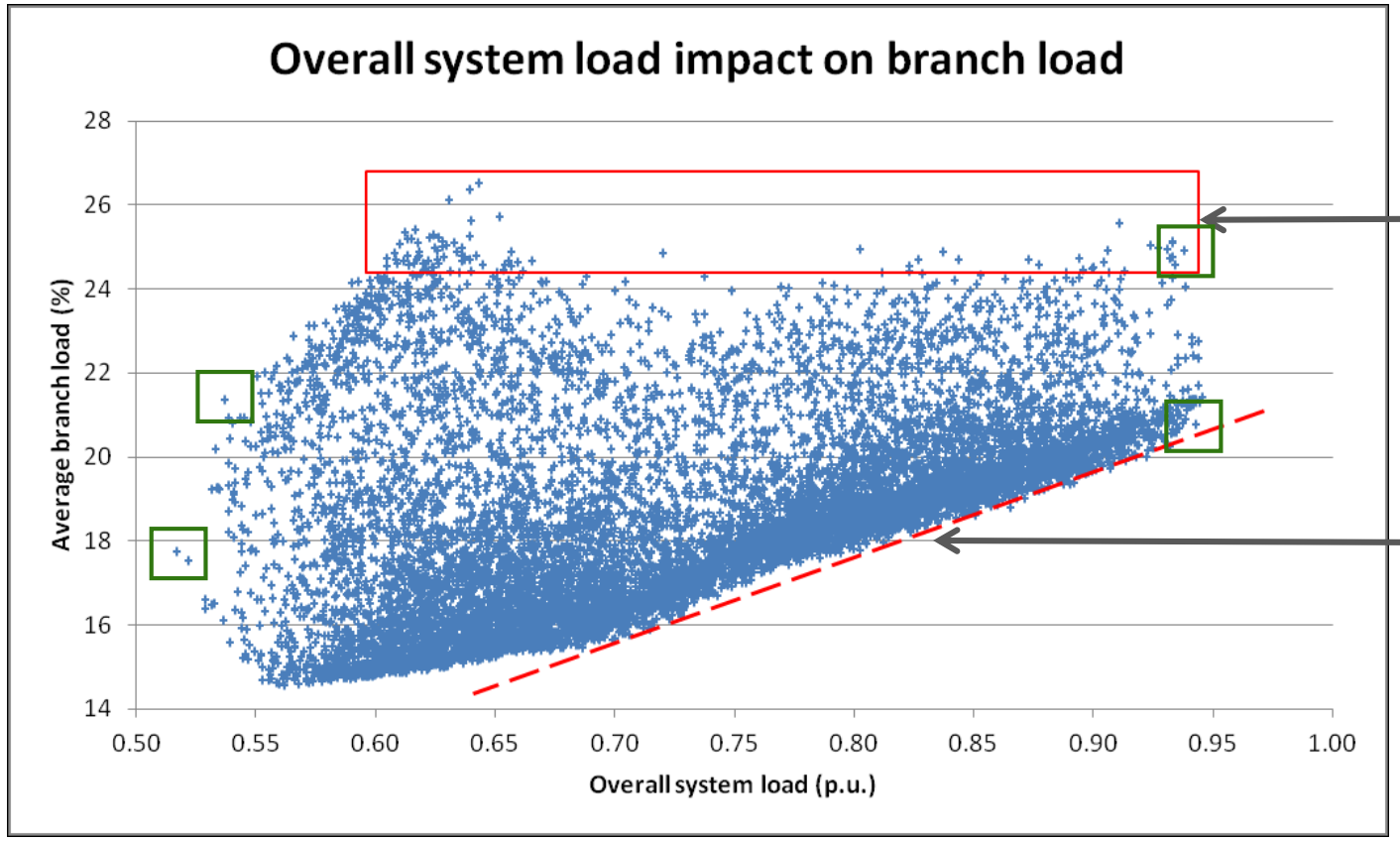
Decisions based on risk level
Level of reserve
Storage usage and size

Training sessions also available

Static study methodology



Highlight some non-intuitive results



Worst cases also happen at mid or low load levels

A classic study would miss many problematic situations

Chosen cases in a classic study

The power flow increases with the demand

→ Analysing a fixed number of extremely rare events is likely to result in overinvestment

→ Probabilistic approach prevents the loss of information and will help Clients in their choices to build (**or not**) new transmission assets, and put them in the right place.

Dynamic study methodology

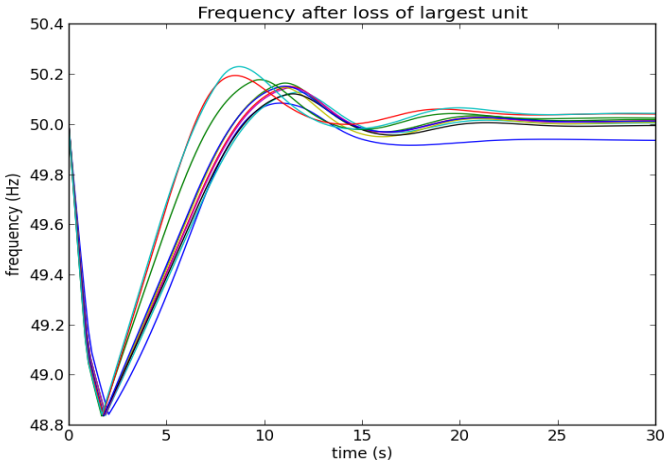
INPUTS

- Merit-order generation dispatch and load for a multitude of scenarios
- Dynamic models of conventional generators (inertia, droop, reserve liberation time constants)
- Dynamic model of load (frequency dependency, load-shedding threshholds)

CALCULATION

Simulate generator tripping for each scenario

Rapid Assessment of Frequency (RAF)	*Commercial Software (PSSE, PowerFactory)*
First order model of swing equation, speed governor control, and load	Full dynamic modelling and RMS simulation of generators and loads

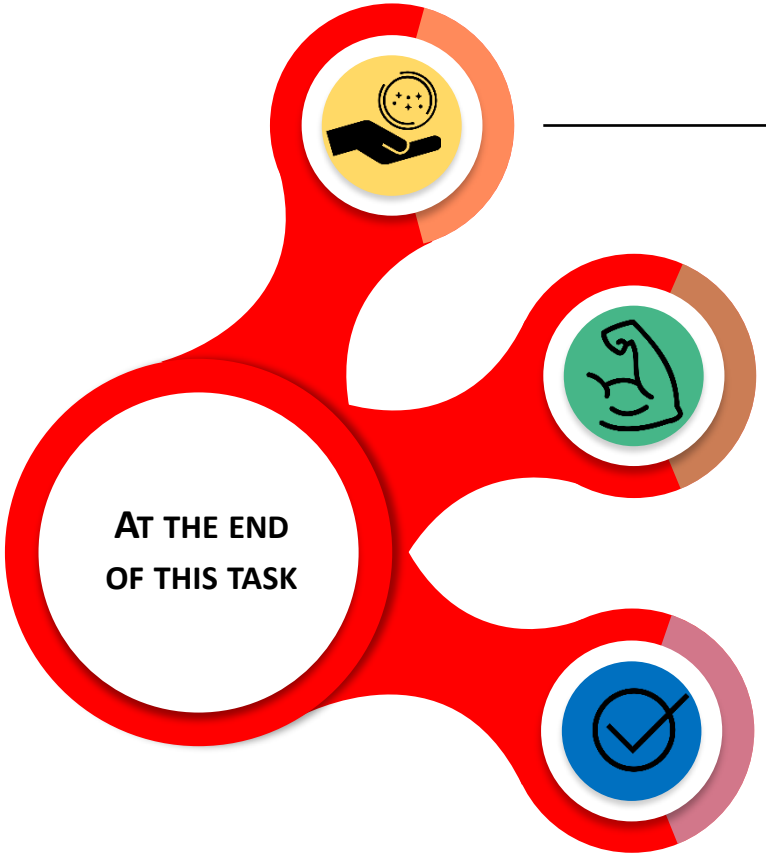


OUTPUTS

- Minimum frequency achieved for each scenario and potential risk of load shedding
- Development of operational rules to mitigate issues

→ Impact on effectiveness of load shedding schemes
→ Impact on conventional generating units' stability

Task 4: Transmission study



Main results
Required transmission reinforcements

The strengths of our proposal

Exhaustive and innovative multi-scenario approach
Correlation factors between variable based on in depth analysis of datas

Decisions making based on exhaustive situation analysis

Training sessions also available

Recommendations for an evolution of regulation

→ To understand the actual Grid codes

→ To propose directions in Grid code amendments

→ To propose amendments for new requirements to be fulfilled by RE plants


Any questions ?
Thank You