17th May 2018

Integration of renewable energy sources into the electrical grid

Technological needs: vision of TSOs & Utilities

REN

REN: the Portuguese Electricity and Natural Gas integrated TSO

Electricity

Transmission network

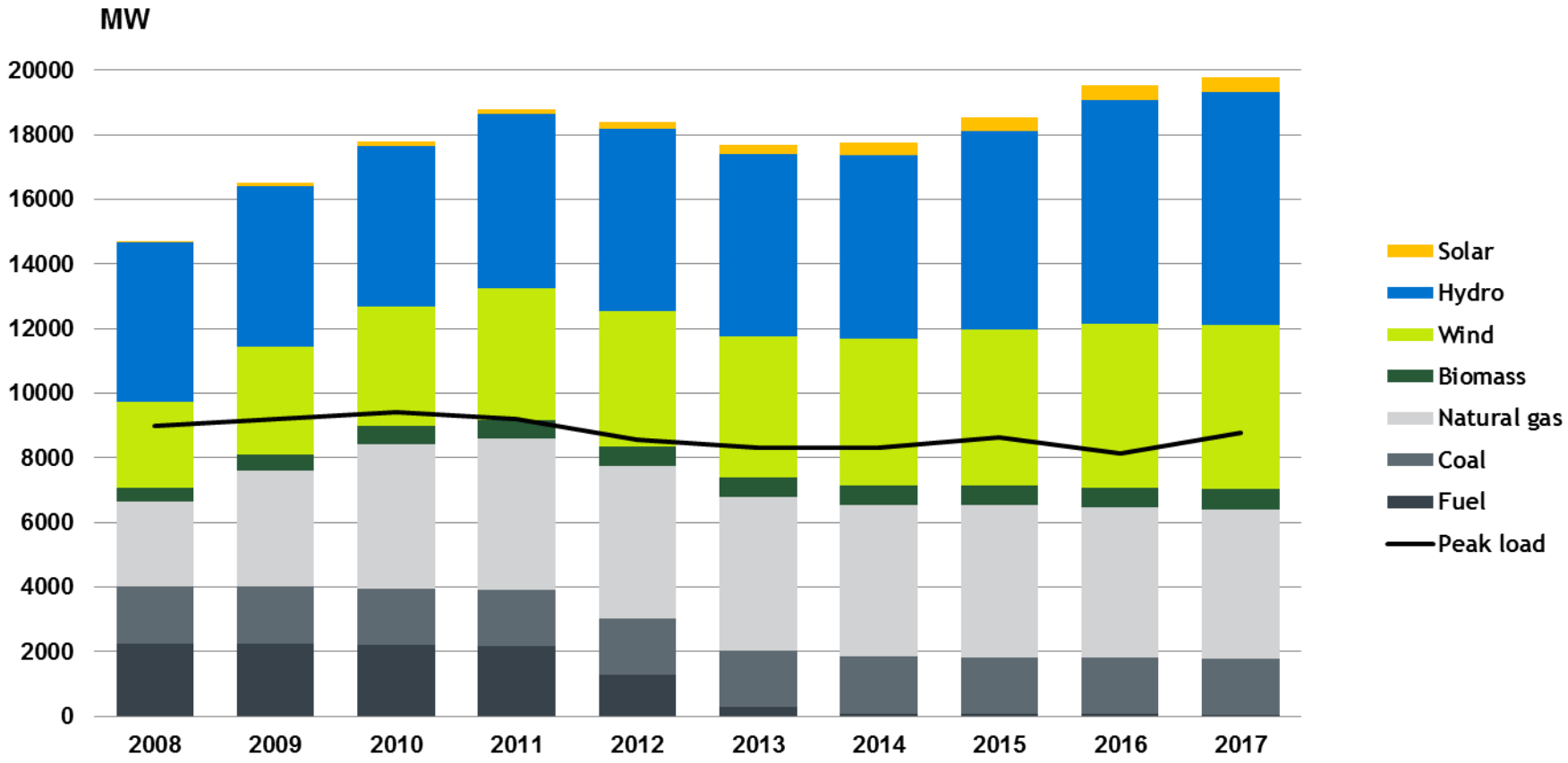
- 8.907 km of HV OHL and underground cables (400 kV, 220 kV e 150 kV)
- 67 Substations (37.382 MVA)
- 9 interconnections (6x400 kV + 3x220 kV)

Natural Gas

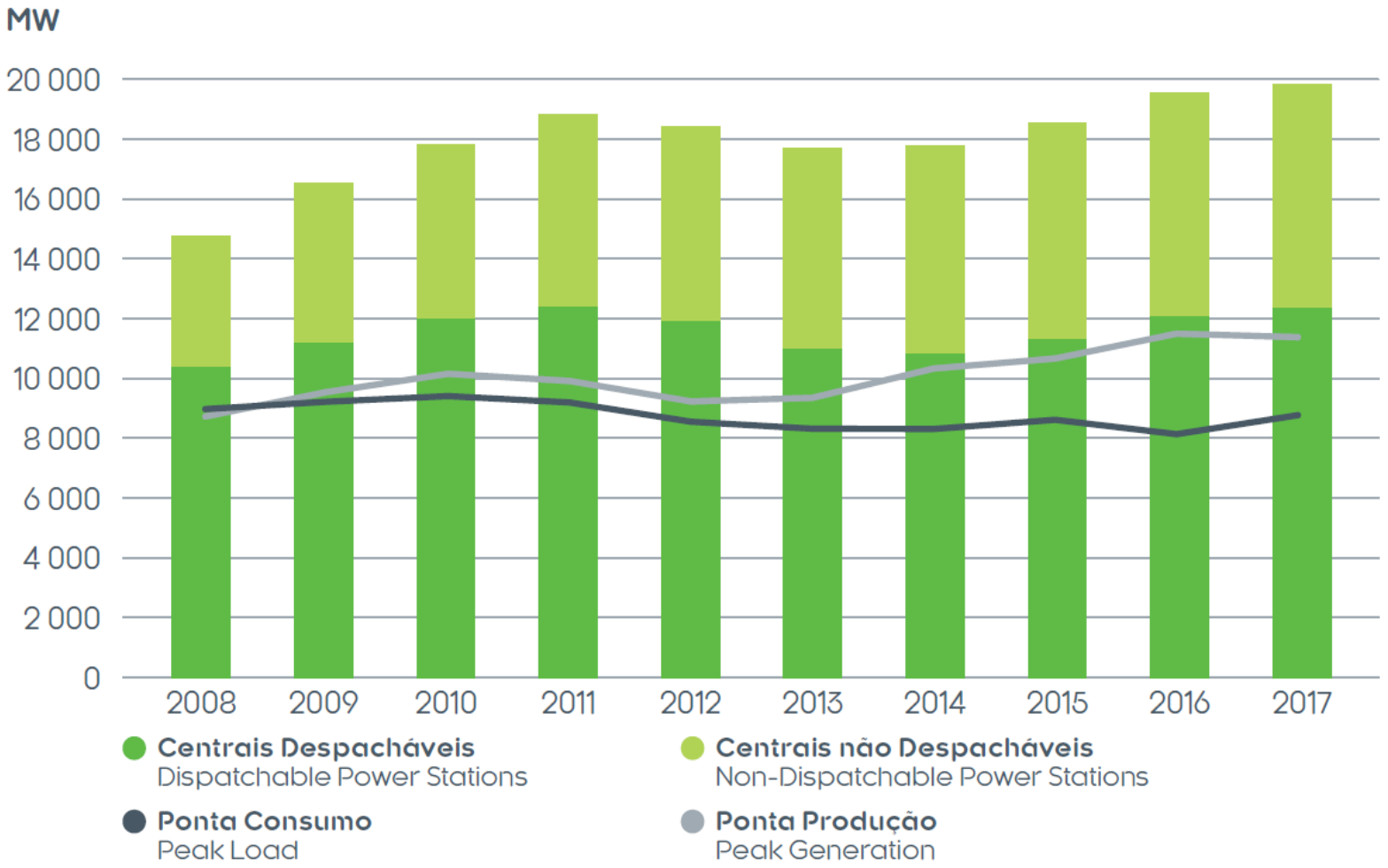
Transmission network + Terminal + Underground storage

- 1.375 km of pipelines (84 bar, 10'' - 32'')
- 203 Stations (85 GRMS)
- 2 interconnections (1x 28'' + 1x20'')
- LNG Terminal in Sines
- 6 Underground Salt Cavities (4 TWh)

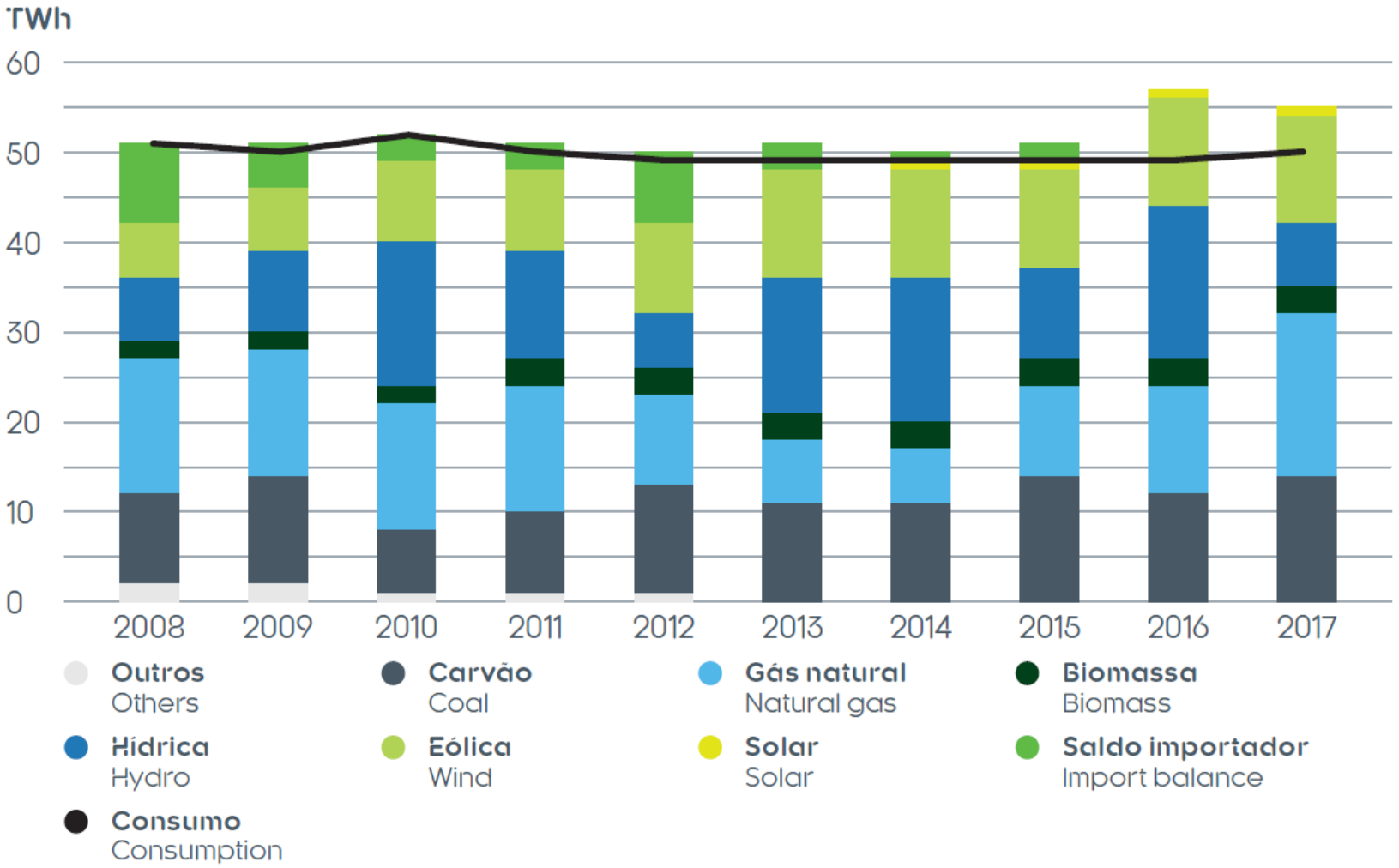
Generation capacity per technology



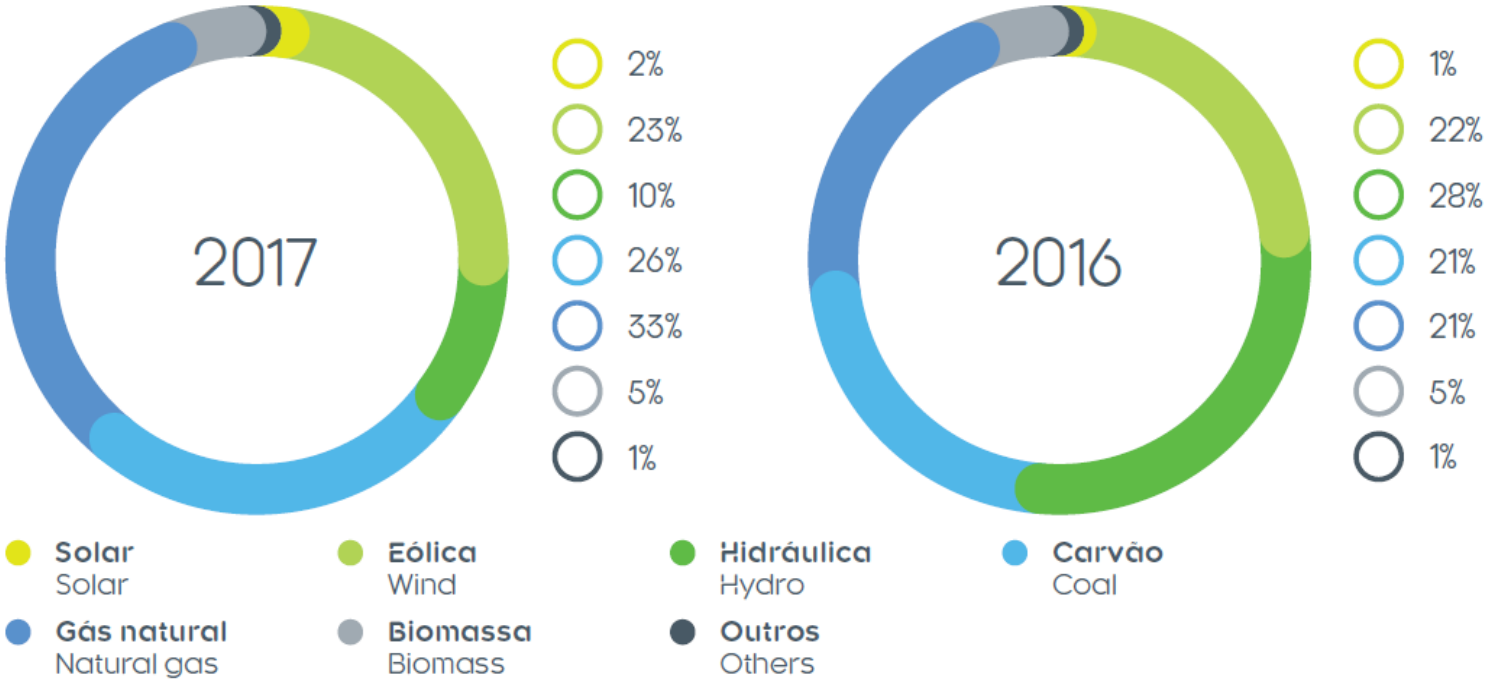
Dispatchable Generation capacity

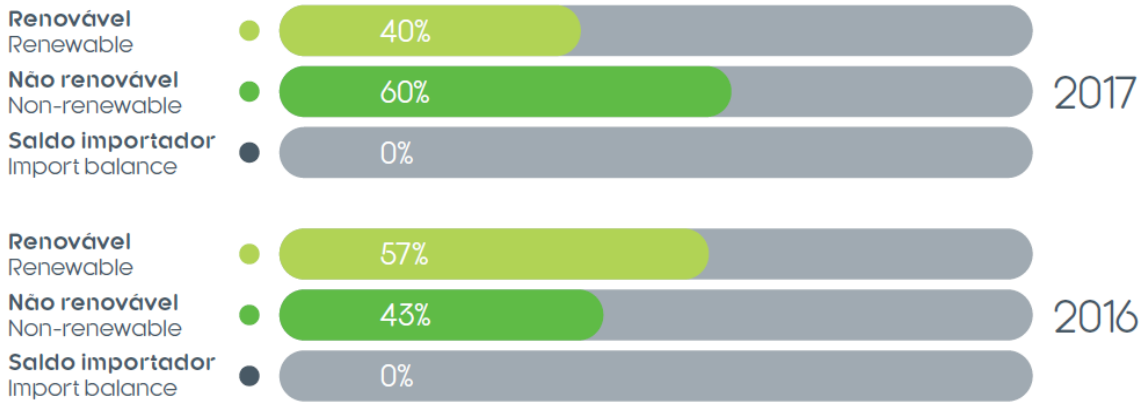


Energy mix to cover the supply



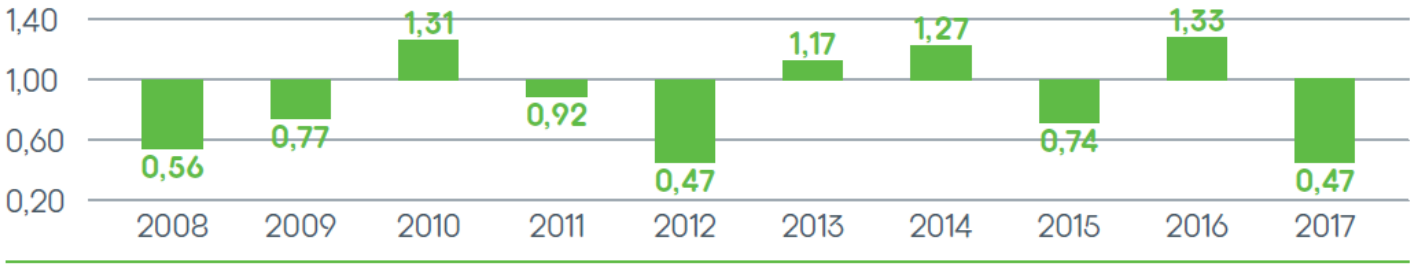
Energy mix to cover the supply



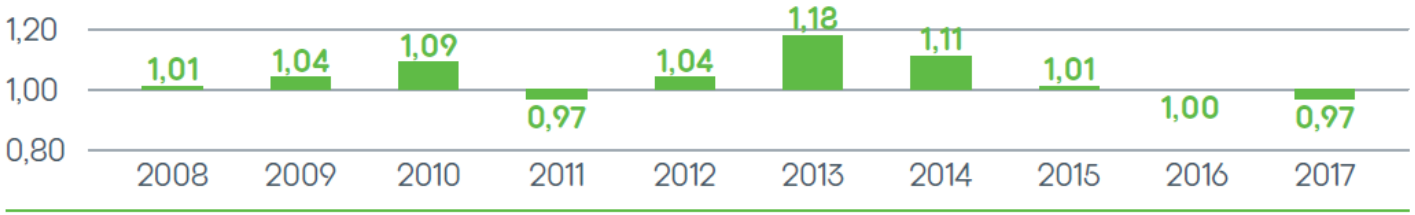


Capability Factors

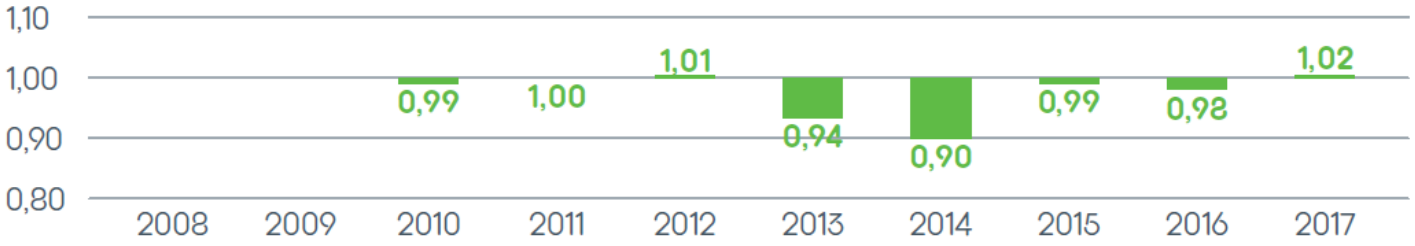
Hidroelétrica Hydro



Eólica Wind

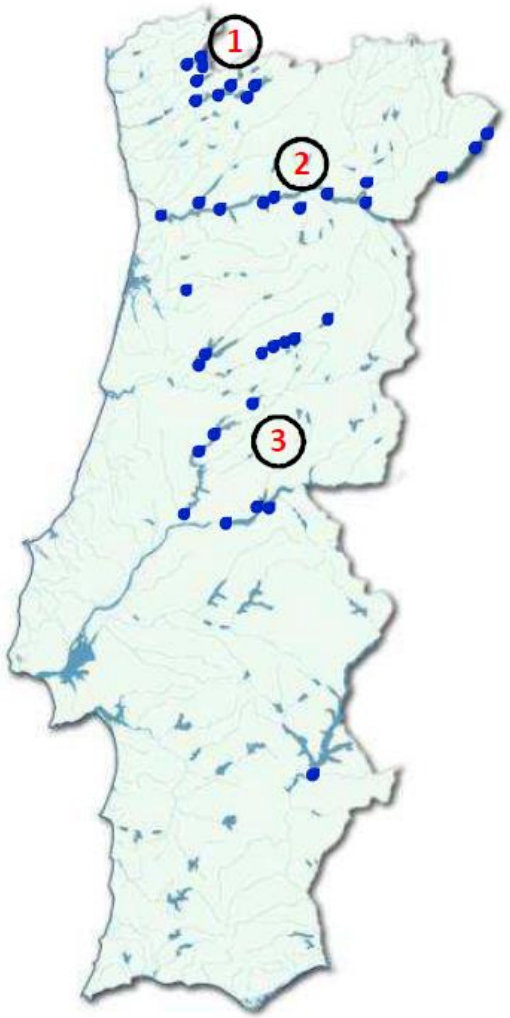


Solar Solar



Location of Renewable Energy Sources – Hydro (EDP)

Hydro Power Plants(> 10 MW)



The new Hydropower Schemes developed by EDP

TOTAL – 7,2 GW

EDP Produção has in operation 80 hydro power plants, with a total installed capacity of 5 895 MW.

About 1 567 MW are installed in reversible units, allowing the operation in turbine and pump modes: Alto Rabagão, Frades, Salamonde II, V. Furnas, Torrão, Baixo Sabor, Feiticeiro, Aguieira, Alqueva e Alqueva II.

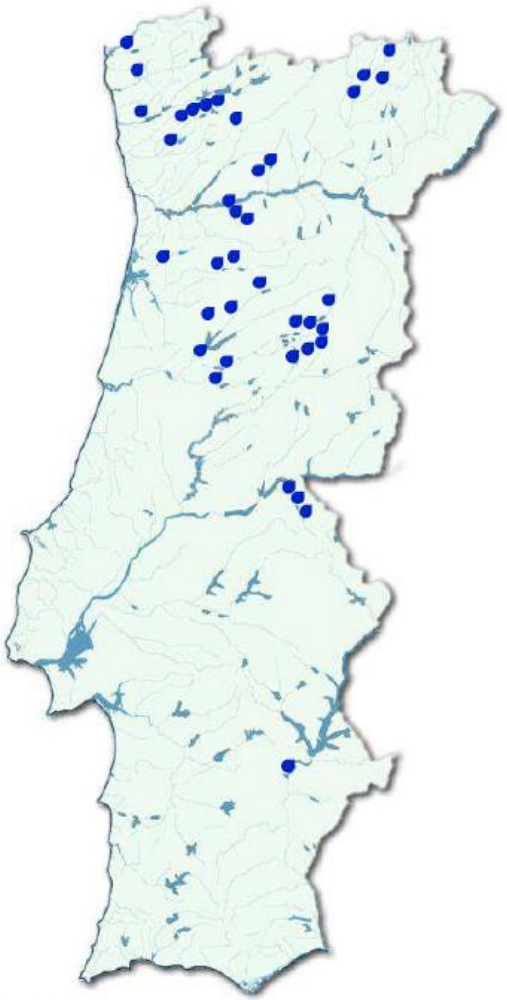
They are manly located in the North of Portugal in the 3 major watersheds:

- Cávado-Lima (1)
- Douro (2)
- Tejo-Mondego (3)

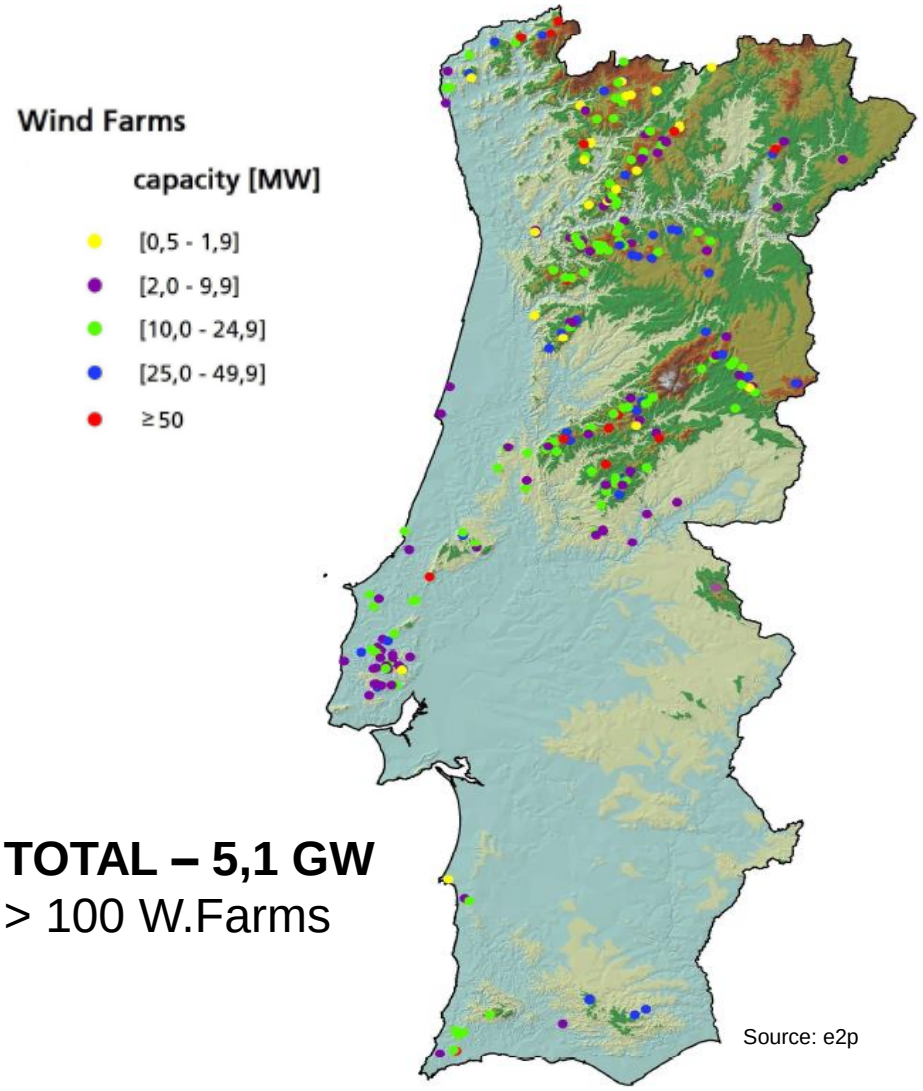
EDP (2016) data
2017 – Foz Tua

EDP Produção
Direção de Engenharia de Barragens

Small Hydro(≤ 10 MW)

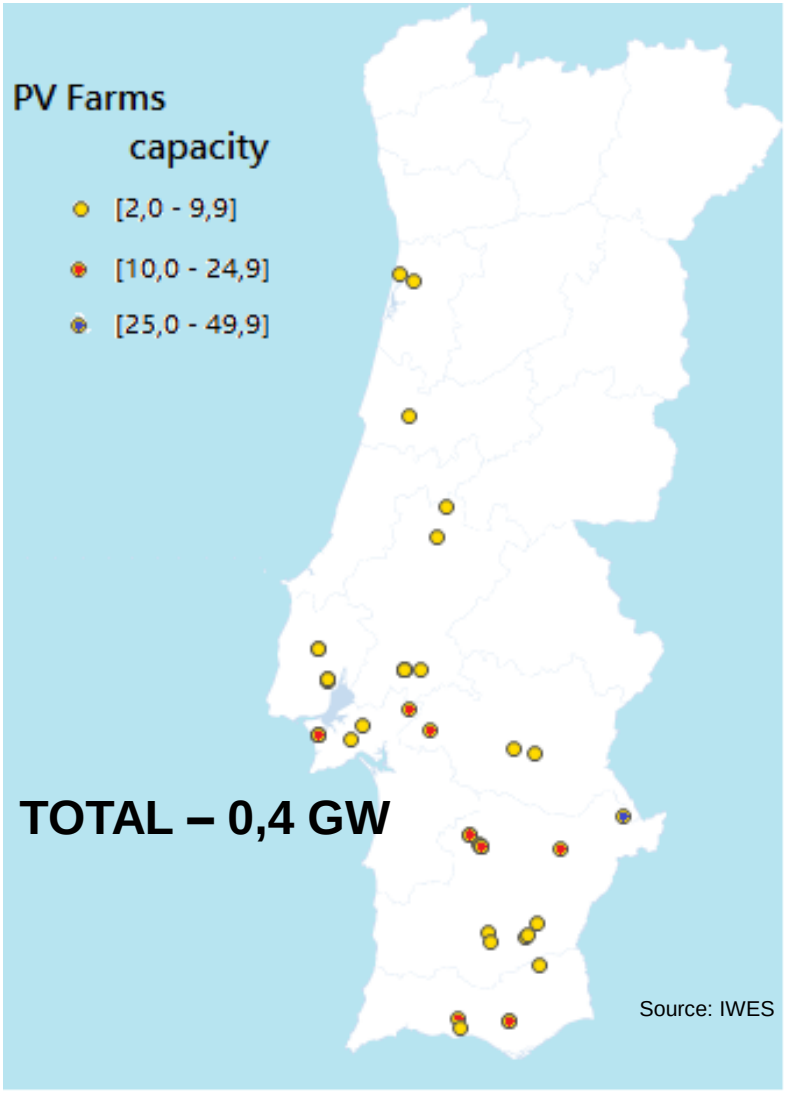


Location of Renewable Energy Sources – Wind & Solar



TOTAL – 5,1 GW
> 100 W.Farms

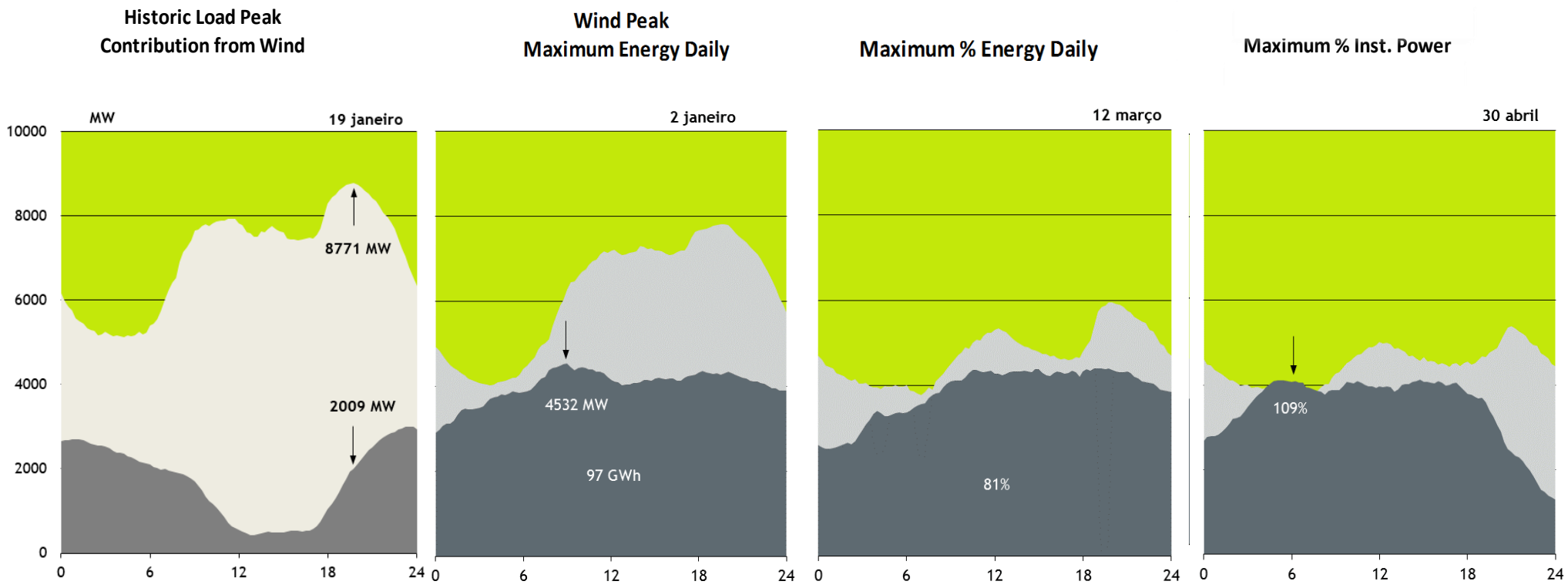
Source: e2p



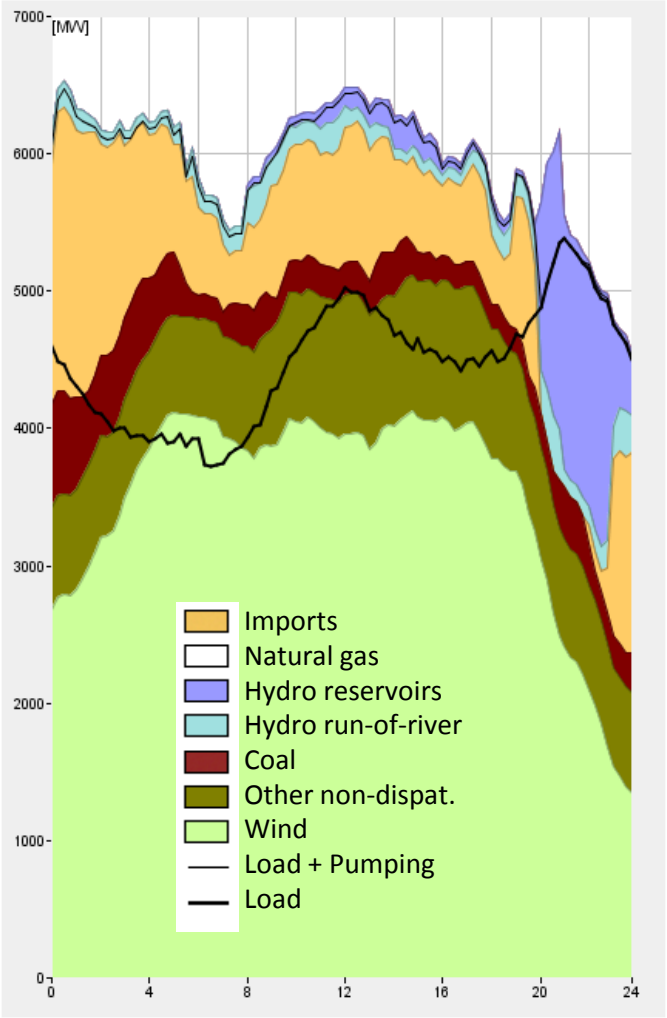
TOTAL – 0,4 GW

Source: IWES

Wind extremes in 2017



Wind extremes in 2017 (30th April)

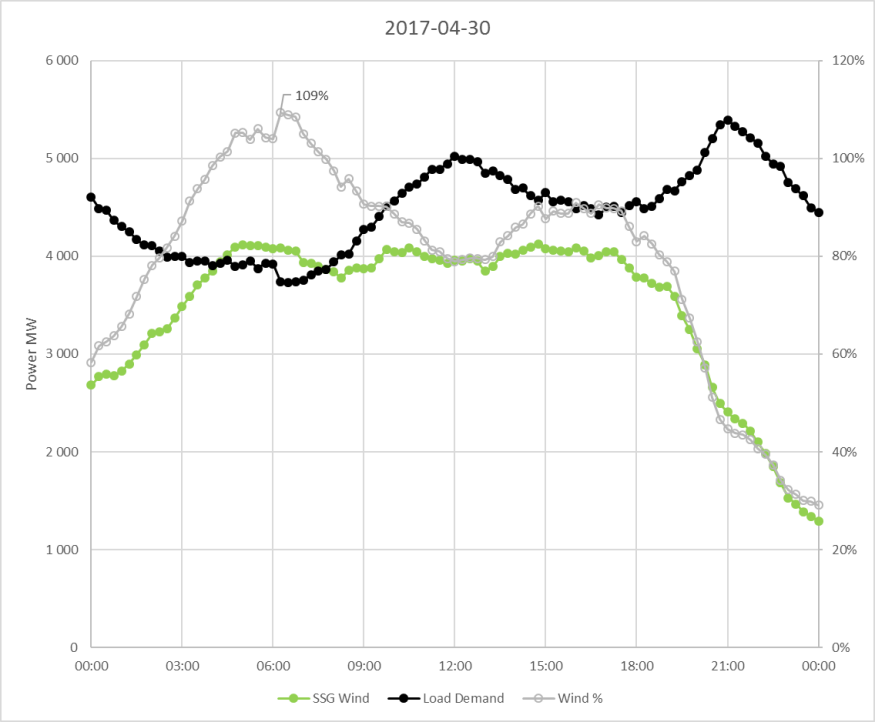


109 % = Wind / Load

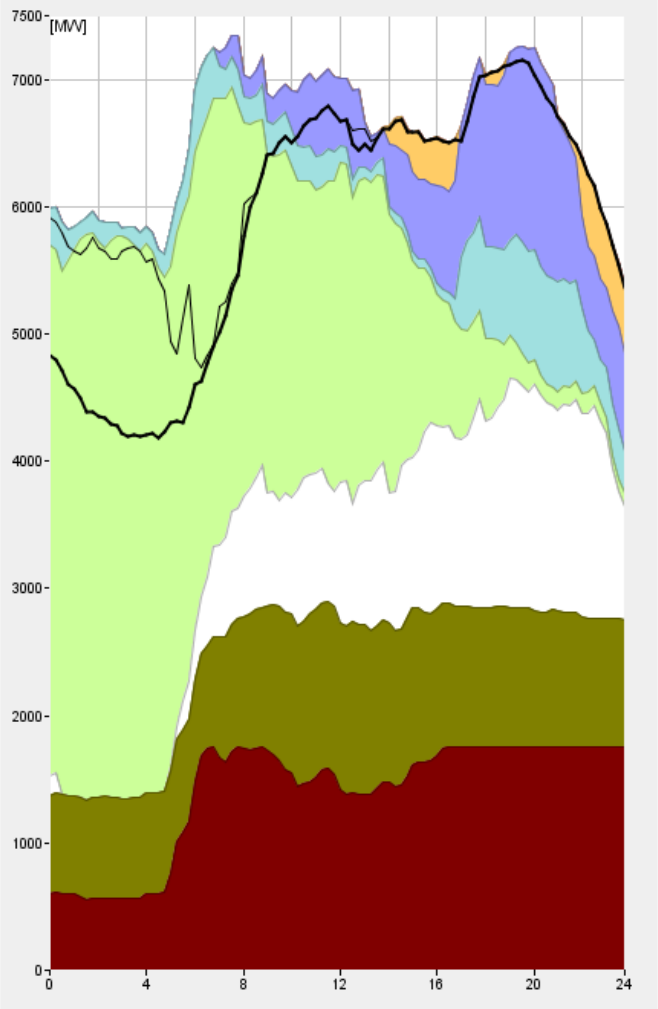
72 % = Wind / (Load + Pumping + Exports + Losses)

72 % = Wind / (Generation + Imports)

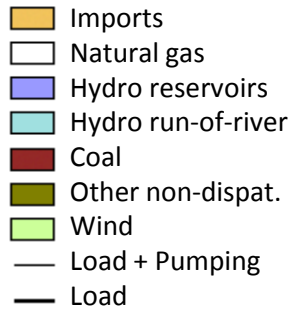
80 % = Wind / Generation

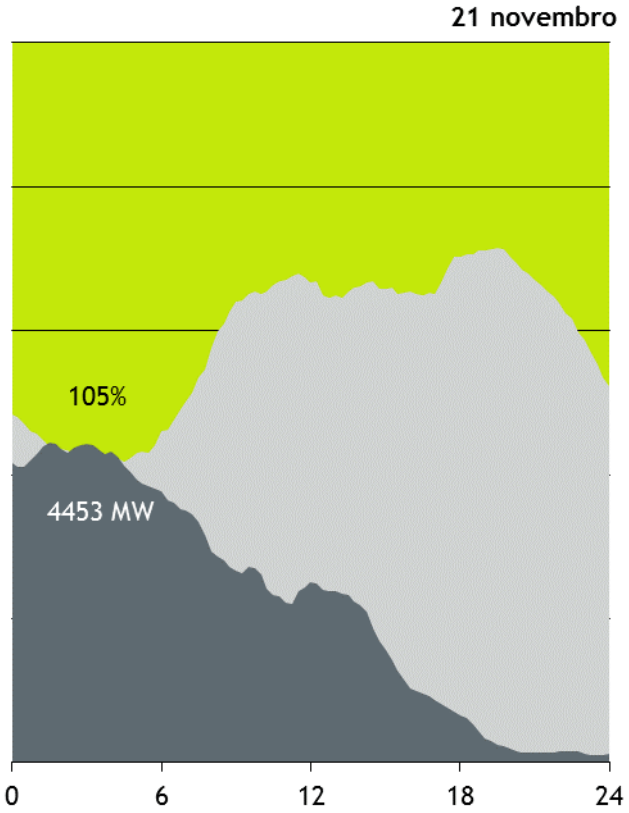


Wind extremes in 2016 (21st November)



From Maximum to minimum (99 MW) in 22 hours

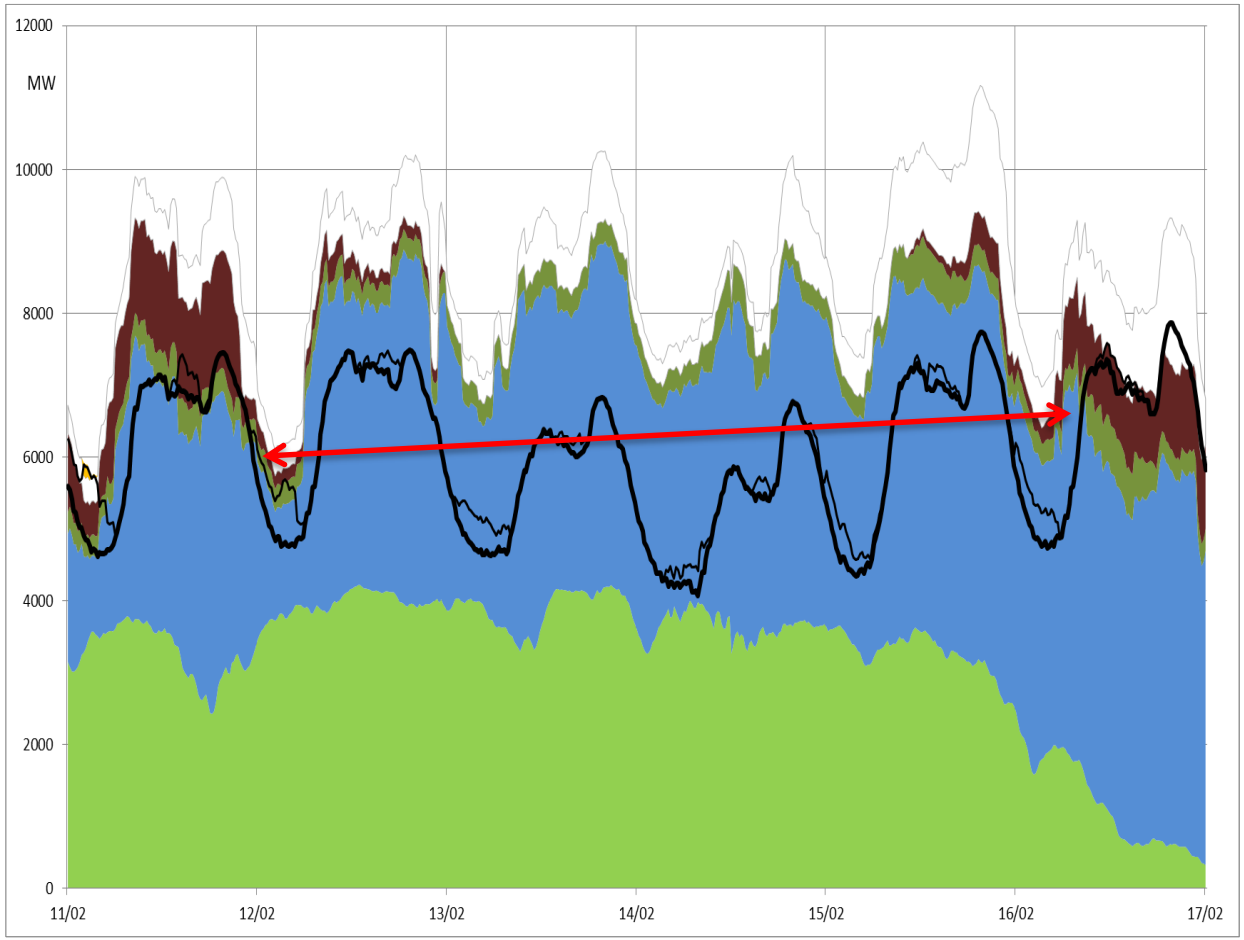




In Fev2016, RES has supplied all national consumption for 4 consecutive days

Wind and hydro were the main RES generation sources

100% of Portuguese consumption fully supplied by RES sources for 106 consecutive hours between 12th and 16th February 2016

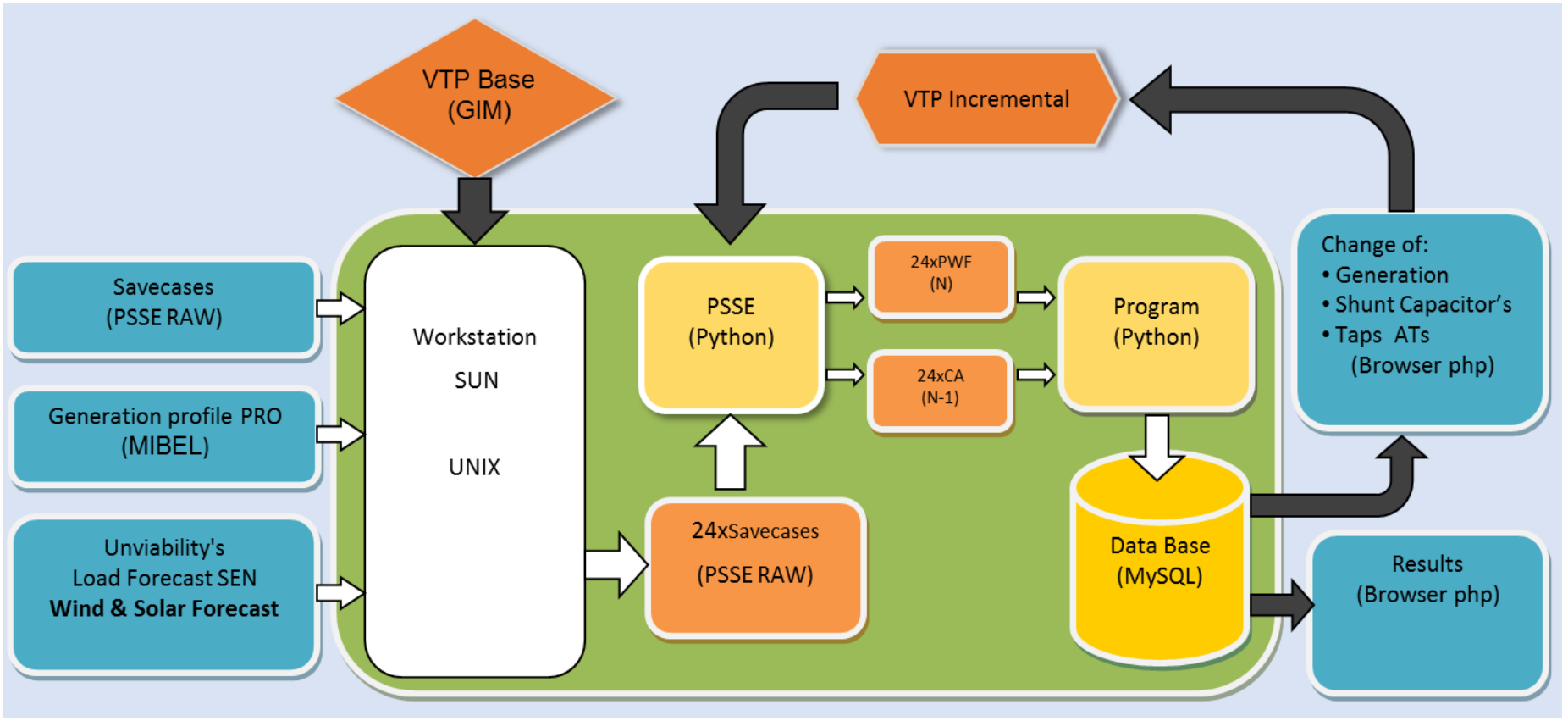


- Imports
- Natural gas
- Hydro reservoirs
- Hydro run-of-river
- Coal
- Other non-dispat.
- Wind
- Load + Pumping
- Load

Minimum demand load	4.078 MW
Maximum demand load	7.737 MW
Average wind share	60%
Average hydro reservoir share	36%
Average hydro run-of-river share	33%
Other RES share	5%

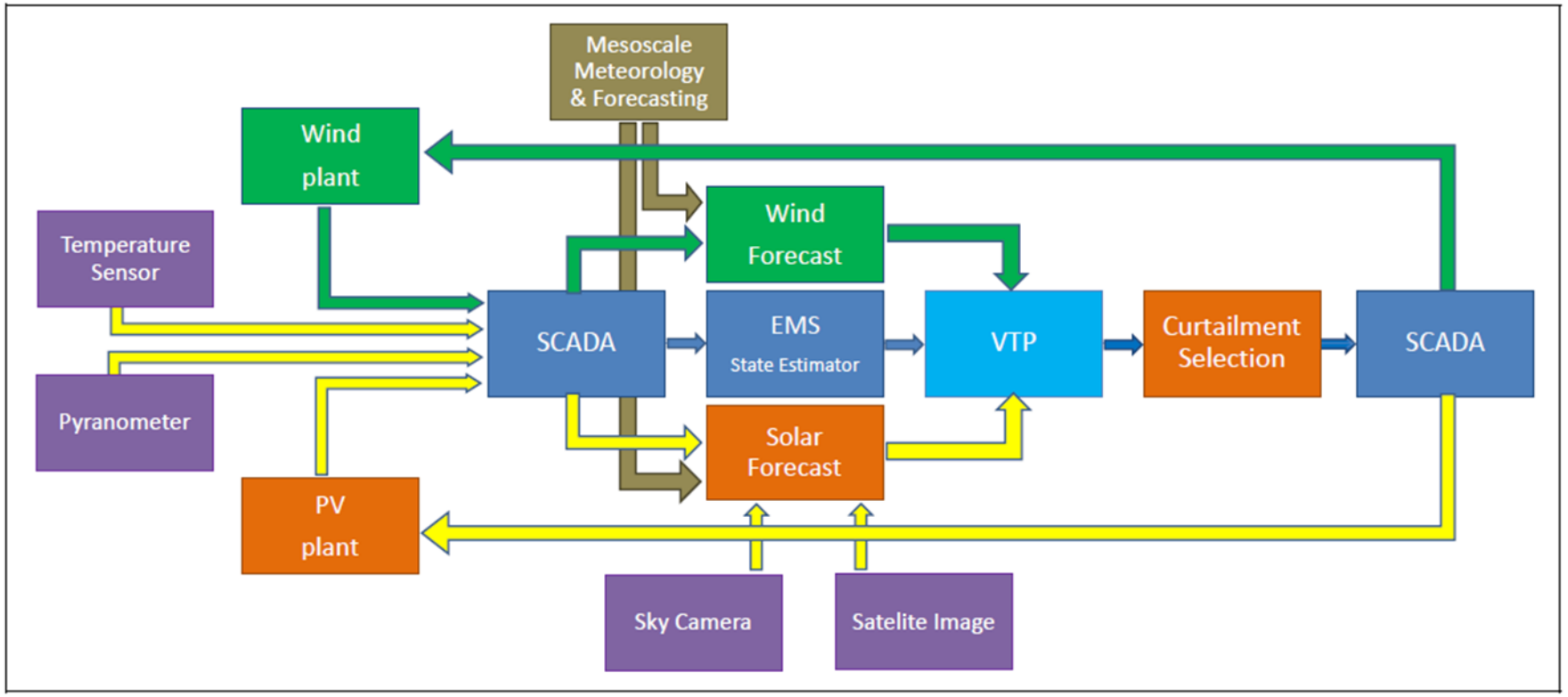
Security Analysis process

REN developed internally a tool for the validation of the day ahead market, that takes in consideration the last wind and solar forecast:



Wind & Solar forecast with SCADA

REN has meteorological sensor's at the substation that can improve the very short term forecast:



Major challenges and risks for system operation

A. Balancing the system

❖ **RES curtailment versus import capacity reduction**

- For TSOs there is a tradeoff between maximizing capacities for the market and reducing the risk of RES curtailments.
- We have in place a merit order to curtail RES
  - we have only curtail once!

❖ **Increased reserves (deterministic formula)**

- Upward Reserves = Biggest Generator + 0,02 Load + 0,10 Wind
- Downward Reserves = Biggest Pump + 0,02 Load + 0,10 Wind

Major challenges and risks for system operation

B. Security of supply – no issues because :

- Strong interconnections with Continental Europe Synchronous System
- Enough back-up CCGT power stations (~~with capacity payments~~)
- "Ride trough fault capability" retrofitting done in 90% of wind parks connected to transmission grid.

C. Voltage/reactive power control

- **Problem** - Wind and Solar has no participation in reactive control
- Solution (among others) - Installation of reactance's in 400 kV network

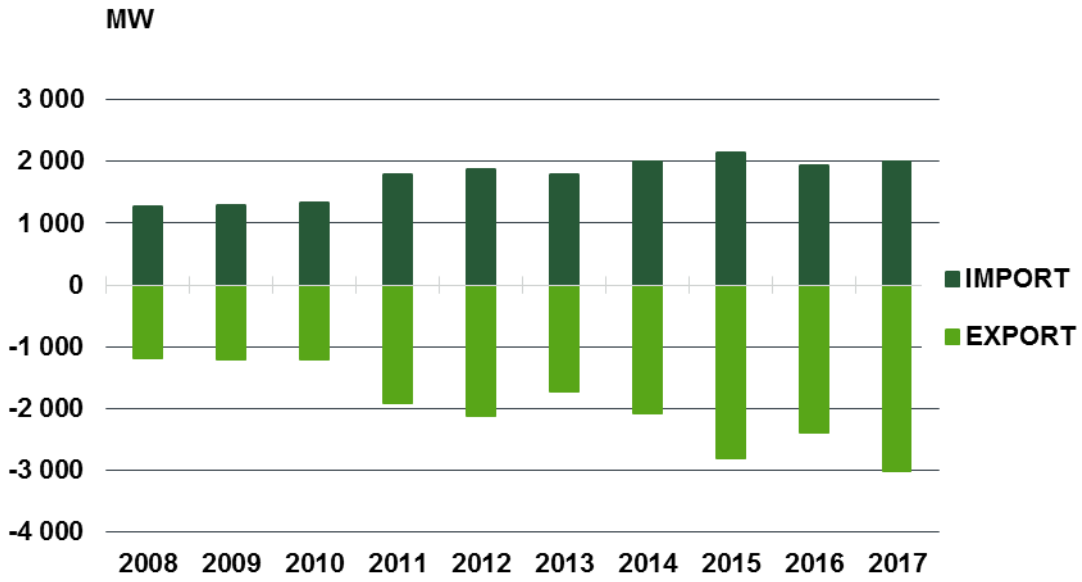
D. Frequency/active power control

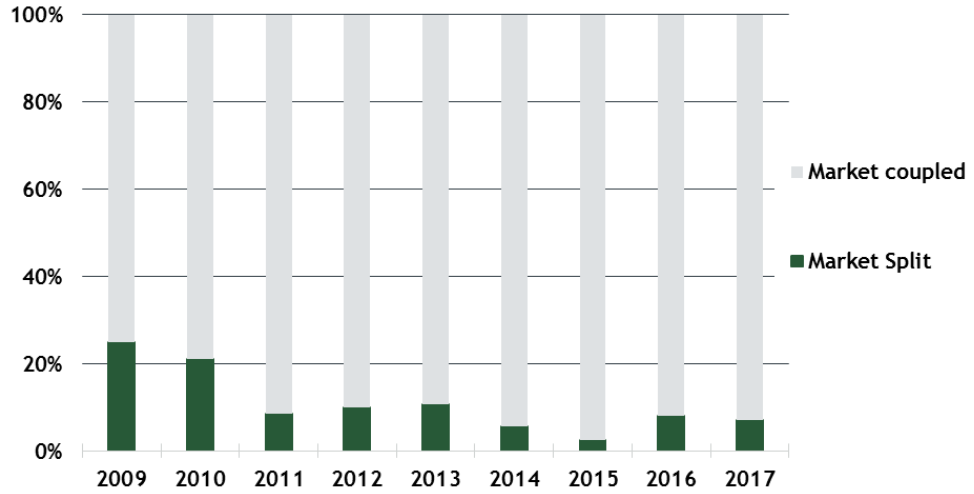
- **Problem** - Wind has no participation in **under** frequency control
- **Problem** - Solar has no participation in frequency control

E. Market uncertainties and variability

- Interchange capacity is increasing

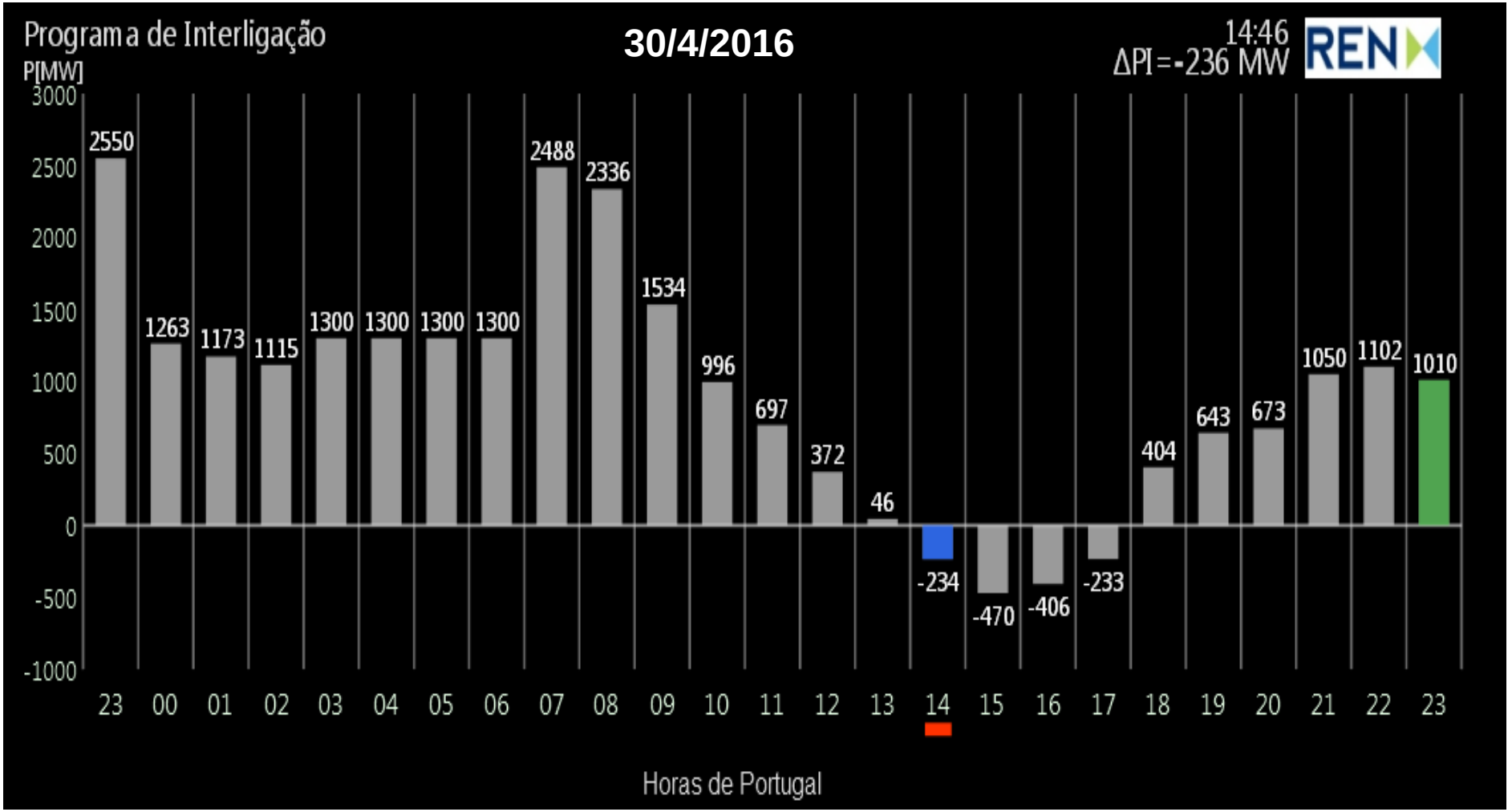
Market and interconnection capacity





Major challenges and risks for system operation

Market programs with transitions > 1.000 MW are a challenge for system balance



Thank you for your attention

Gracias

Obrigado

Questions?

rui.pestana@ren.pt