

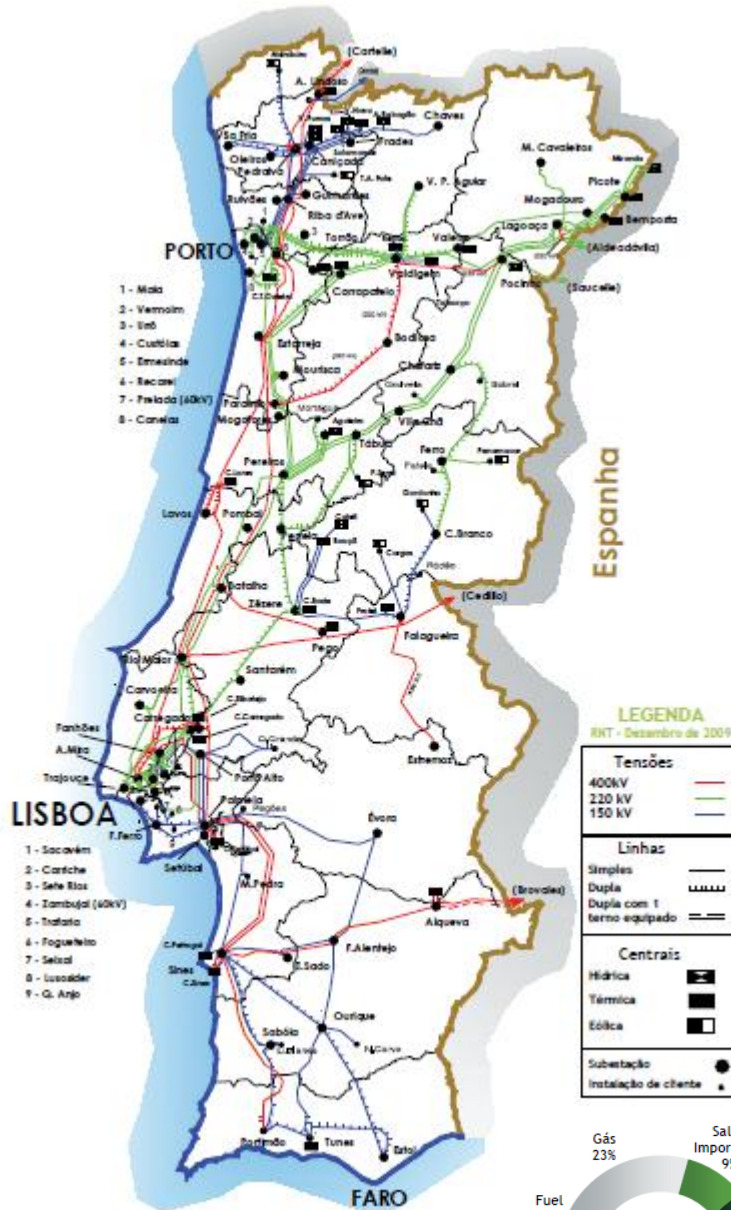
IEA Wind Task on Wind Integration

Operational Experience of Extreme Wind Penetration in Portugal

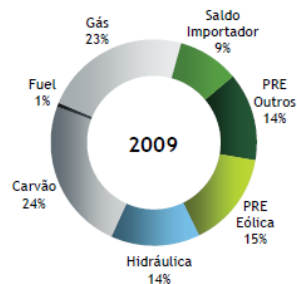
UWIG Fall technical Workshop, Quebec 15th October 2010

Ana Estanqueiro

The future is happening now!...



2009 Data:
Peak Consumption - 9217 MW
Annual consumption - 49.9 TWh
Wind energy share - 7.5 TWh



INSTALLED CAPACITY (DEC. 2009)	[MW]
Total	16 738
Hydro Power Stations	4578
Thermo Power Stations	6 690
Coal	1776
Fuel	1476
Fuel/Natural Gas	236
Gasoil	165
Natural Gas	3036
Independent Producers	5470
Thermo/Co-generation	1631
Small Hydro	405
Wind Power	<u>3357 (3535)</u>
PV	75
Wave Power	2

Wind capacity penetration (end 2009) was 21%

Wind energy penetration (2009) was **15%**



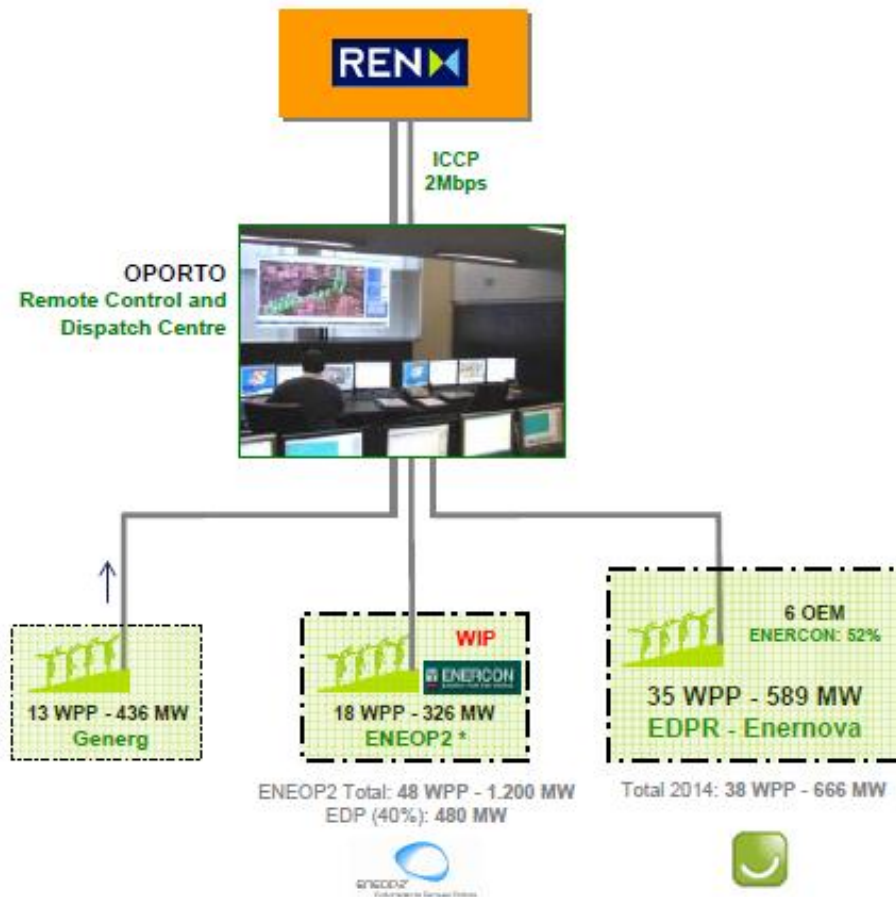
Thinking of high wind penetration, the Portuguese Power System was designed for that...

Innovative Characteristics of the Wind Power Plants and the Power System

- Management of wind parks by clusters (“local wind power dispatch centers”) – already in use in Spain and Portugal;
- Active voltage regulation through additional variable reactive power control: e.g. $\tan \phi$ within [-0.2, +0.2];
- Curtailment of wind production for forecasted no-load periods (recent contracts);
- Participation in the primary frequency control (5% of P);
- LVRTF – Low voltage *ride through fault* capability;
- Solutions for “Wind/RES energy storage”, e.g. in pumping stations, when available and cost-effective, electric vehicles and others...
- Phase shift transformers are already operating in two substations
- Main transmission lines are monitored for wind speed and temperature

Wind Power Control: DSOs and Virtual Wind Power Plants

1st Wind Dispatch Centre in Operation: 1200 MW



Wind Power Dispatch Centres operational principles

- ❑ Infrastructures and HR to guarantee 24h/day, 365 days/year operation.
- ❑ Real time operational data exchange with the portuguese TSO – REN through a dedicated, redundant 2 Mbps link.
- ❑ ICCP (IEC- 60870-6-503, TASE 2) used as data communications protocol.
- ❑ WPP meteorological, electrical data and # WTG available gathered and sent with 12s sampling frequency;
- ❑ Cluster has the ability to send commands to the WPPs;
- ❑ Contractually prepared to receive and execute P, Q set-points defined by the TSO.



Wind Power Control: DSOs and Virtual Wind Power Plants

Testing of wind power control centre currently underway:

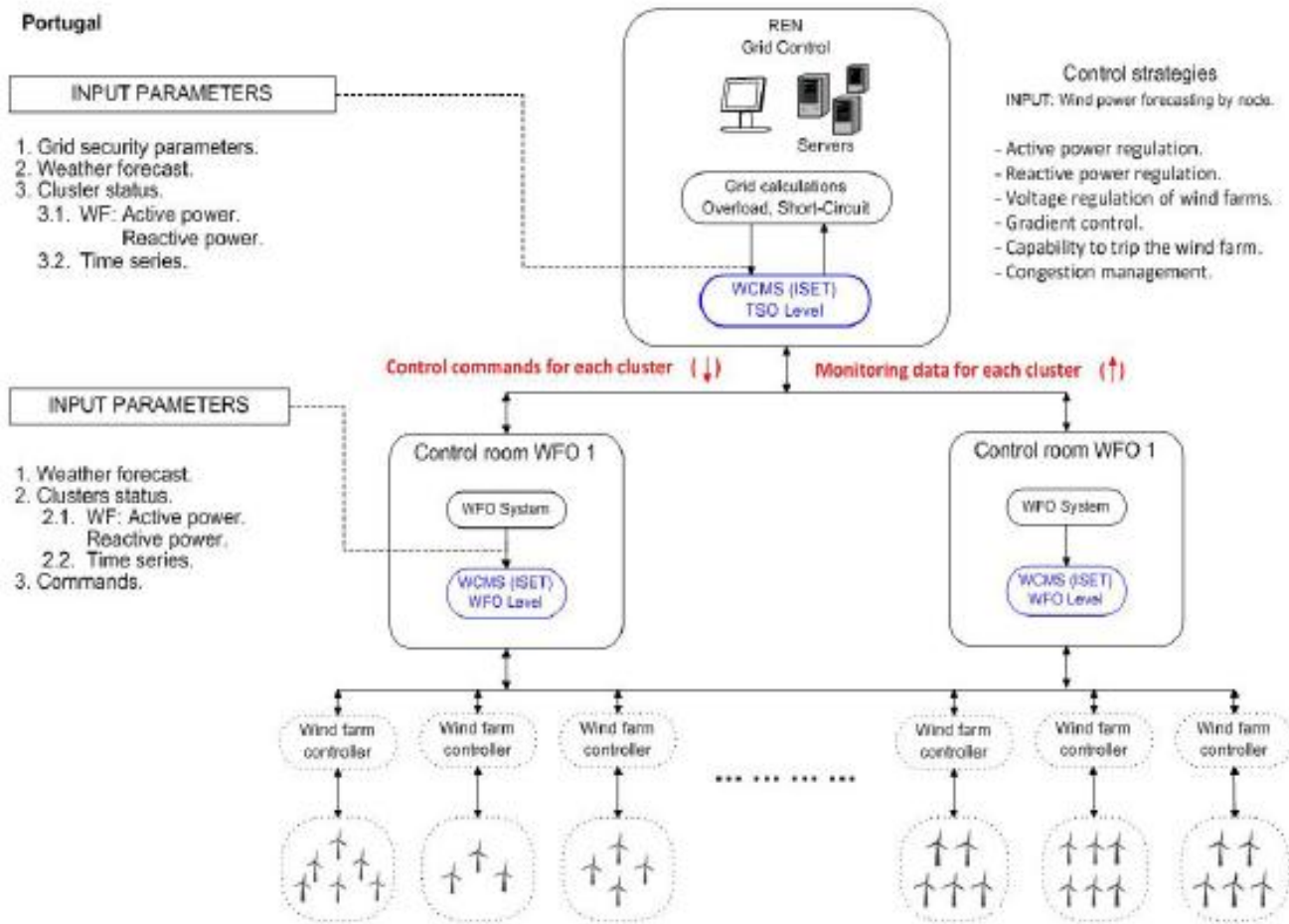


Figure: Monitoring and control flow for the WCMs in Portugal



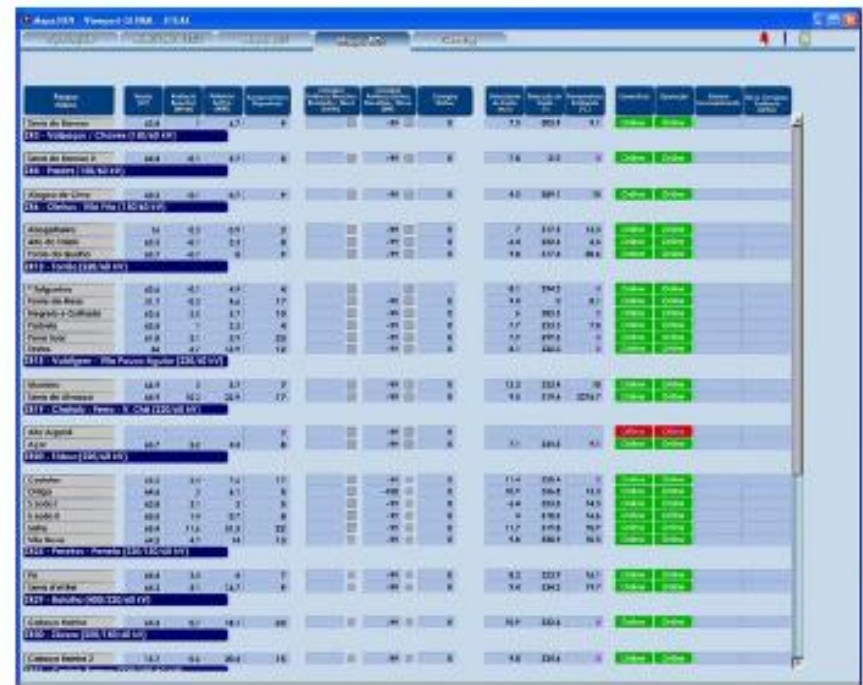
Wind Power Control: DSOs and Virtual Wind Power Plants

Testing of wind power control centre currently underway:

Wind Power Plants Matrix:



Interface with REN:



source: REN, EDPR (Project Windgrid)

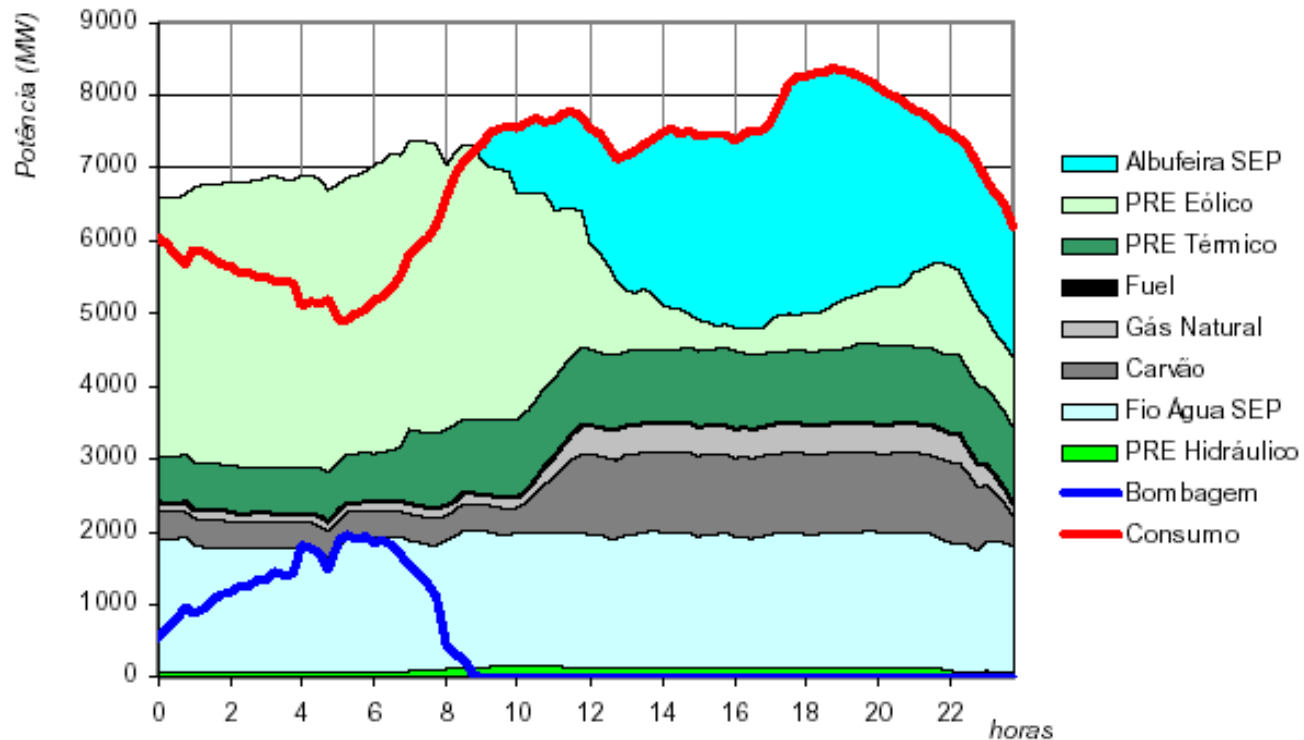
Set-points of P, Q and voltage are being tested.

Already detected an excess of Q generation in the transmission's connected WPPs.

**The design constrains for Portugal
were a wet windy day in 2011!...**



PT Energy mix in 2011: the need for storage and added flexibility



**Scenario of generation profile for a
wet windy day in 2011.**

*The constraint in Portugal is excess of renewable generation
(wind + run-of-river hydro) during the no-load hours*

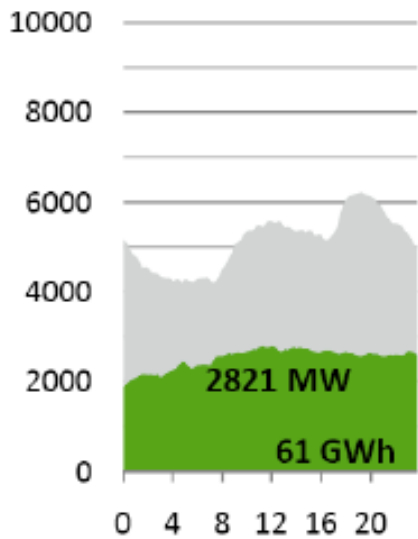
But, with all the planning, care and concerns, were we prepared for last winter?



Well, it has just happened in 2009...

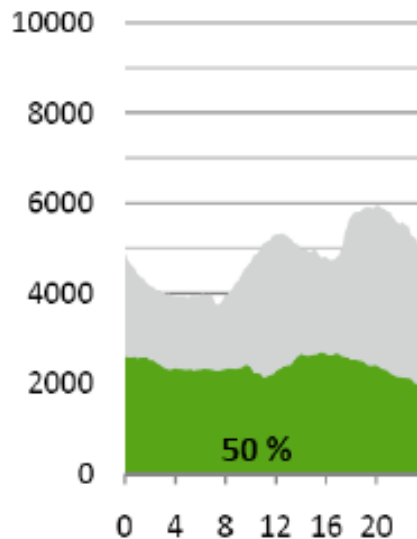
November 2009, the month of all records....

Wind peak production
7. Nov. 2009



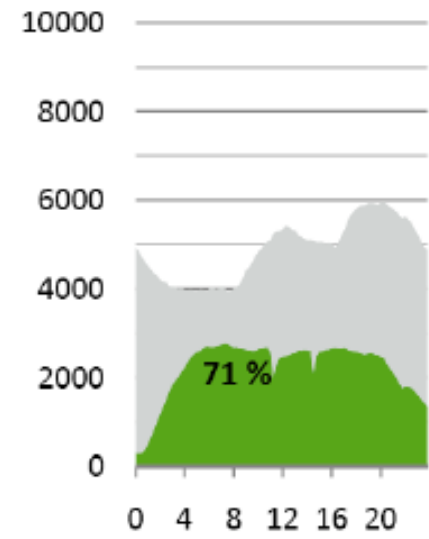
■ Wind ■ consumption

Highest % daily
consumption by wind
8. Nov. 2009



■ Wind ■ consumption

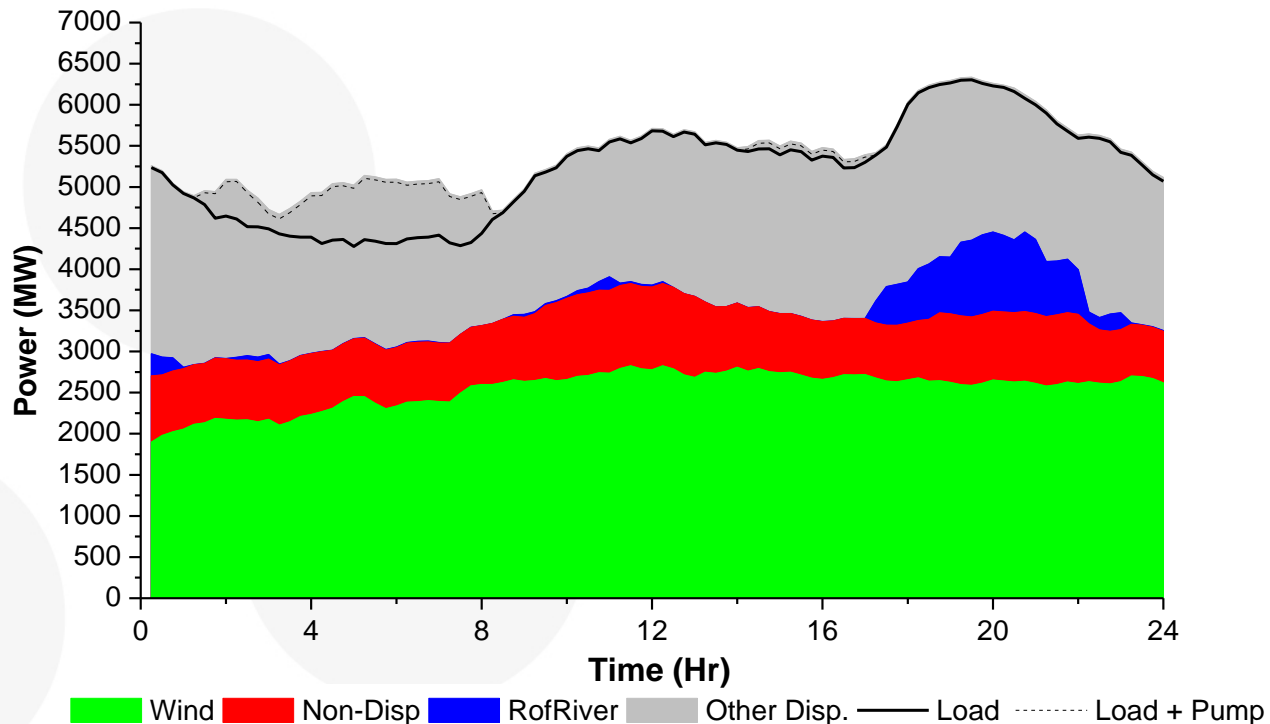
Highest instantaneous
% power penetration
15. Nov. 2009



■ Wind ■ consumption

7.Nov.2009

First wind power record – 2825 MW

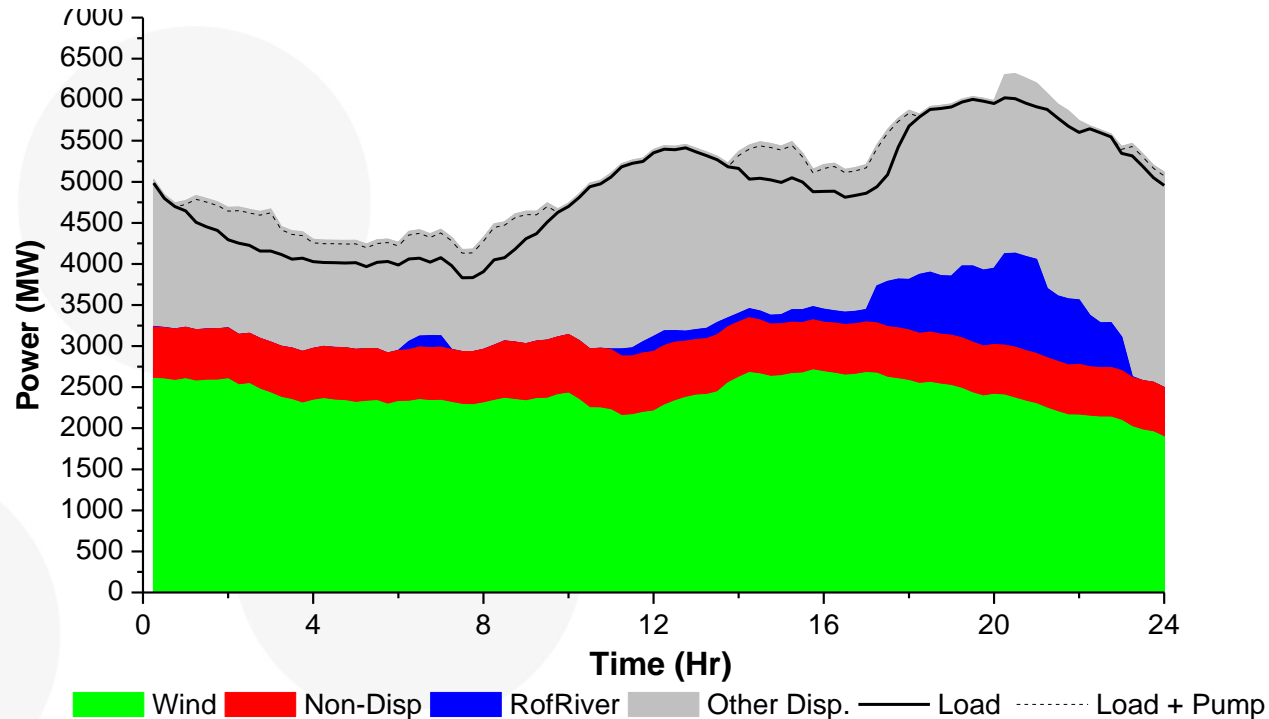


**80% of installed capacity, the max. percentual design value.
Everything went well, the excess was stored.**

source: REN

8.Nov.2009

Record of 50% of daily energy consumption by wind!



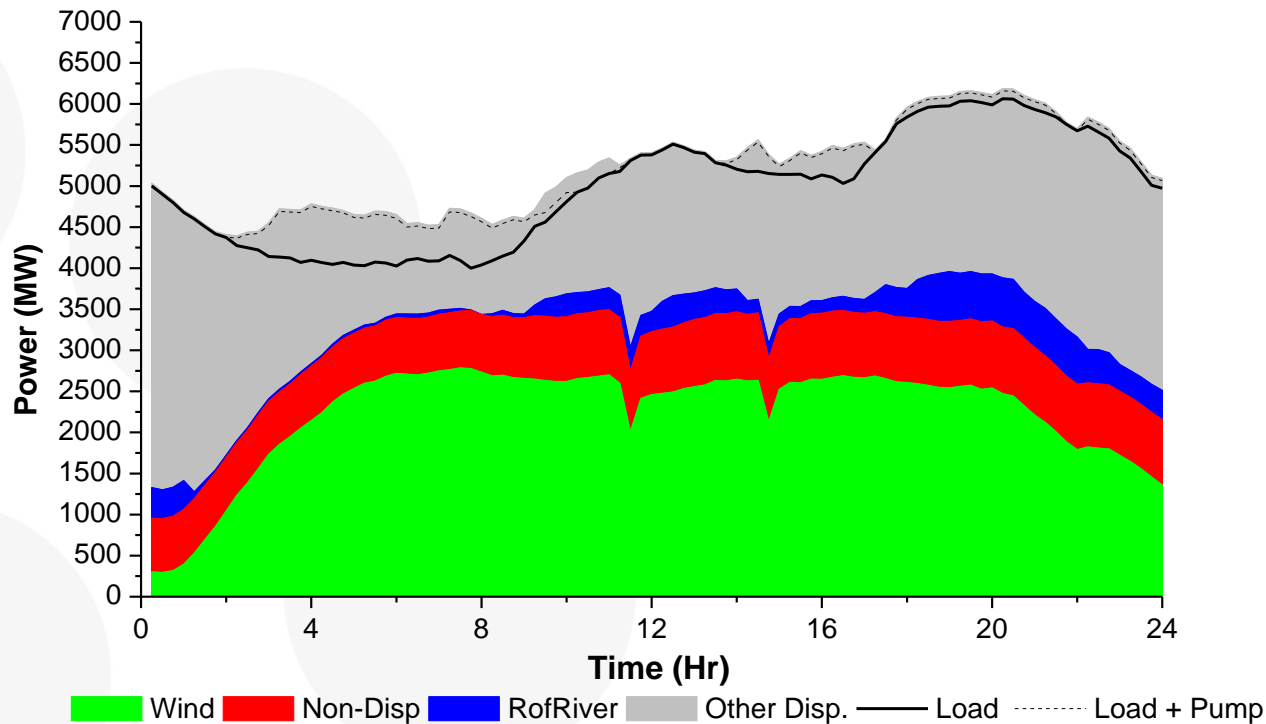
Same situation. Storage of RES excess and a little export.
Almost no run of the river

source: REN



15.Nov.2009

71% of instantaneous wind penetration!



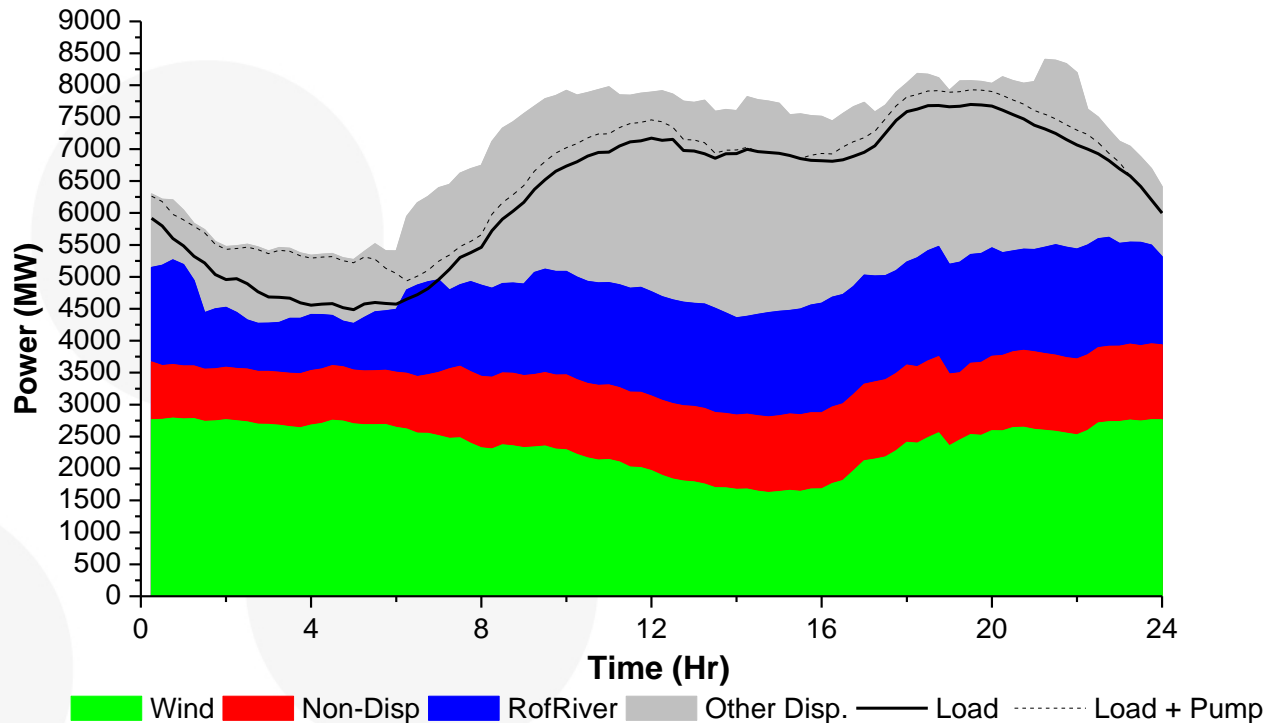
**2785 MW wind power
for ~3700 MW of no-load consumption. Little ROR
and export.**

source: REN



29.Dec.2009

97 % penetration of non-regulated plants

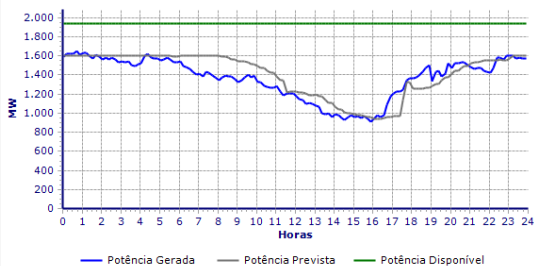
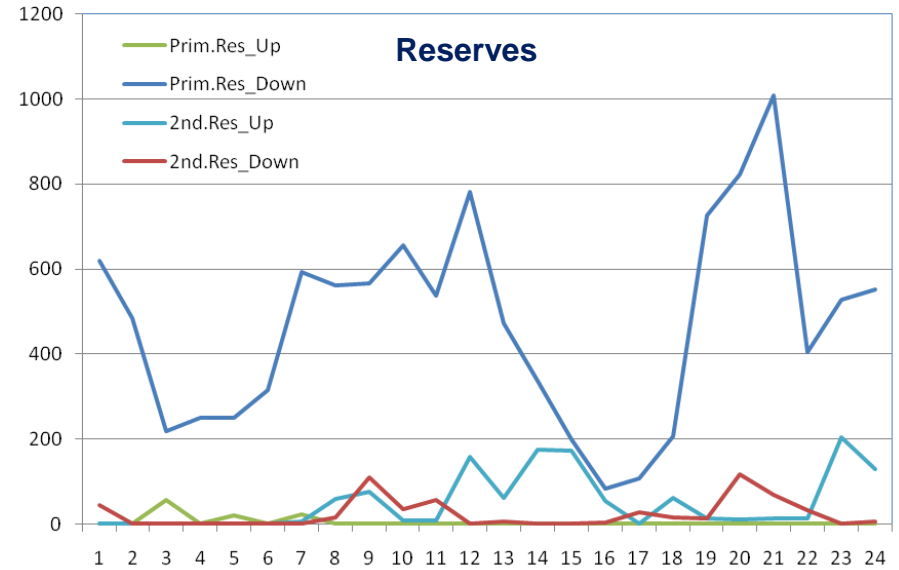
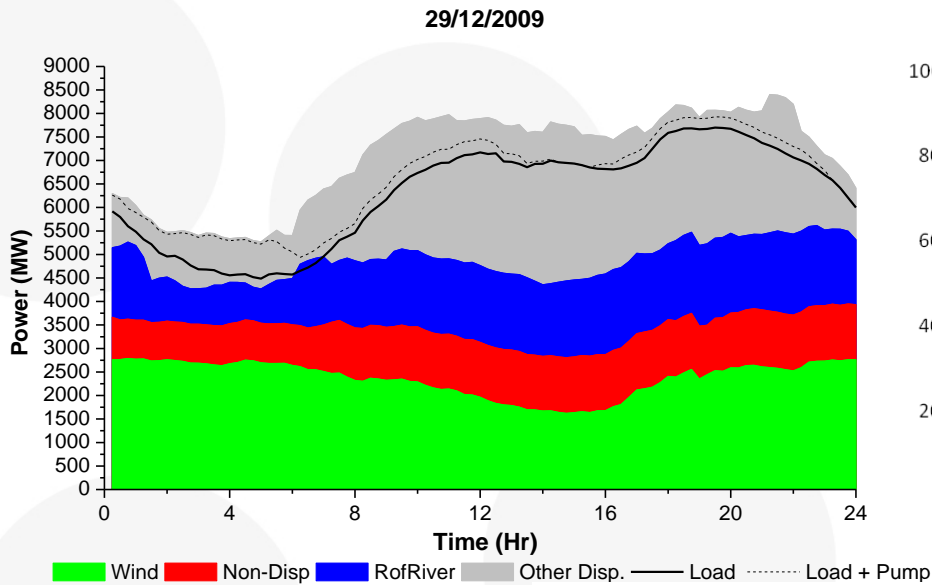


**After 1,5 month of intense rain. ROR peaking...
During no-load ~4300 MW out of 4500 MW were non-
dispatchable! No pumping/storage required capacity.**

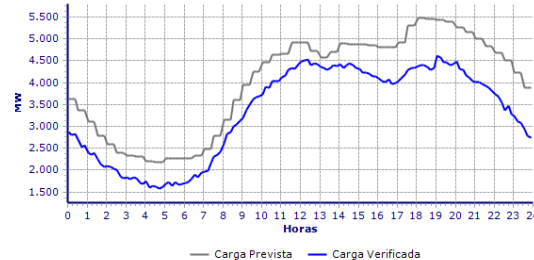
source: REN

29.Dec.2009

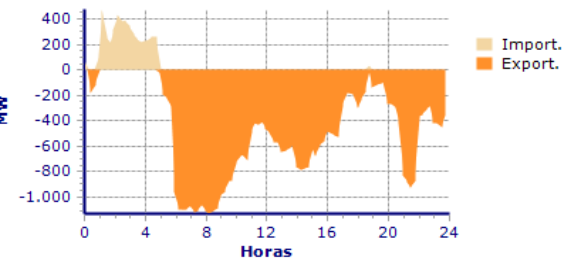
Operational reserves determined dynamically (EC project Anemos.Plus)



Wind forecast



Load forecasts



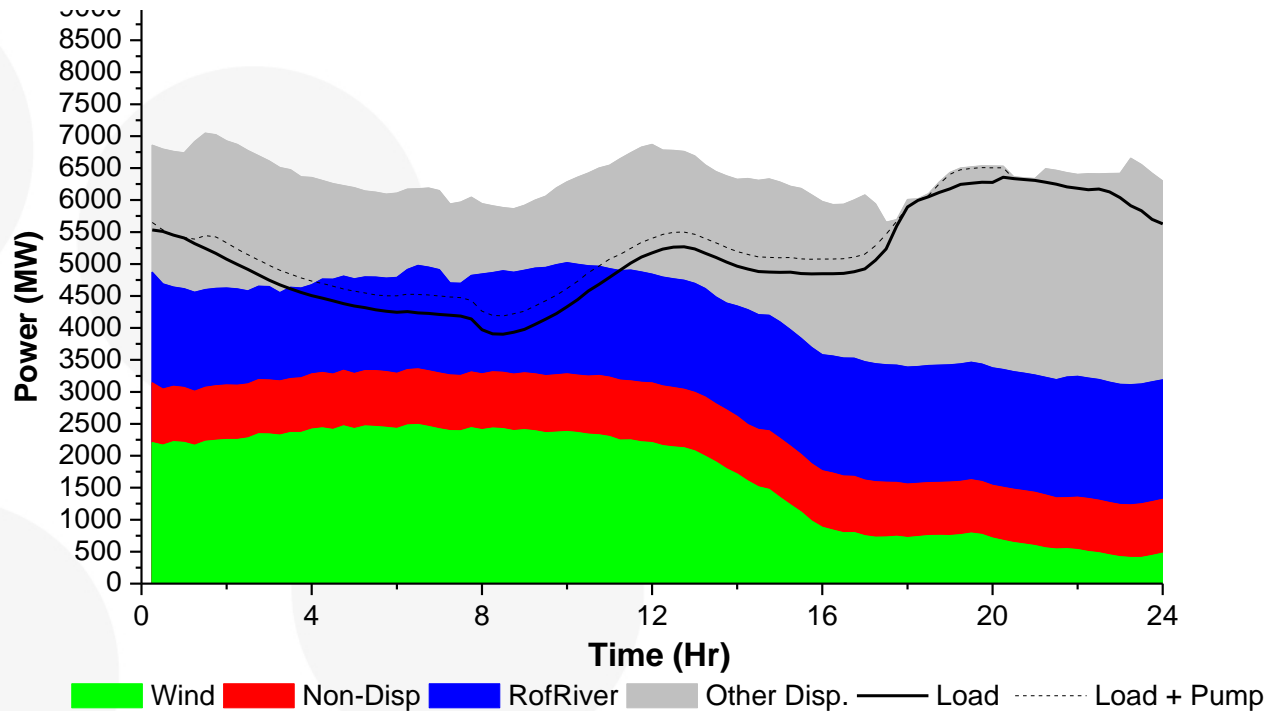
Import/export



LNEG

1.Jan.2010

117 % penetration of non-regulated plants (8am, aprox.)

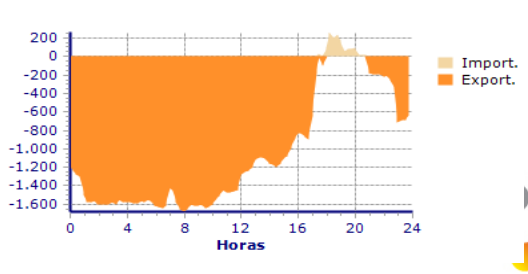
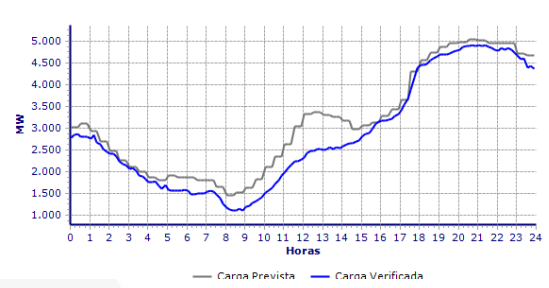
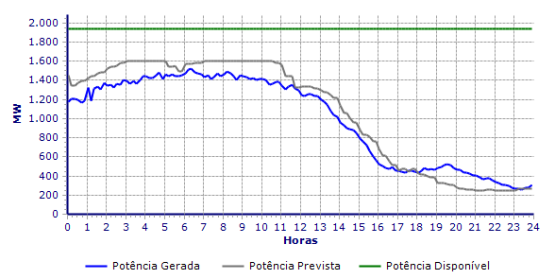
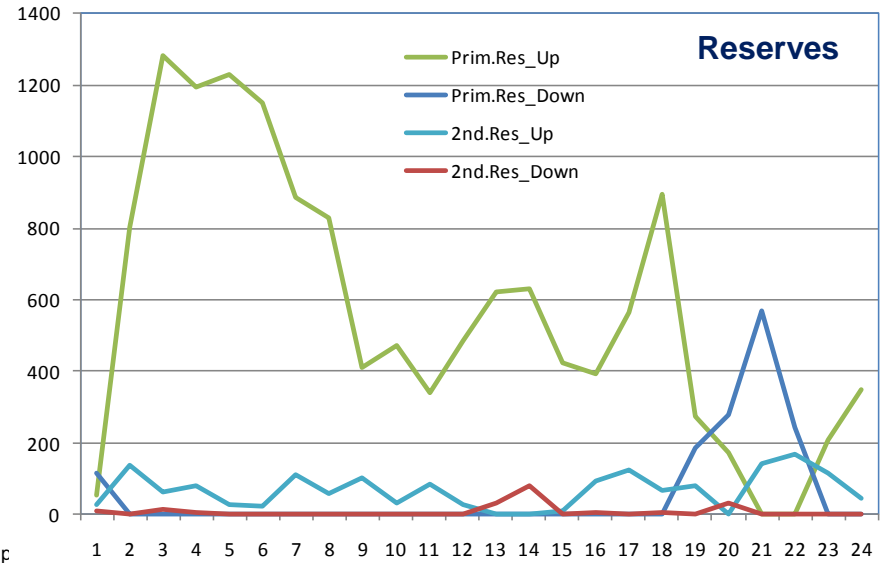
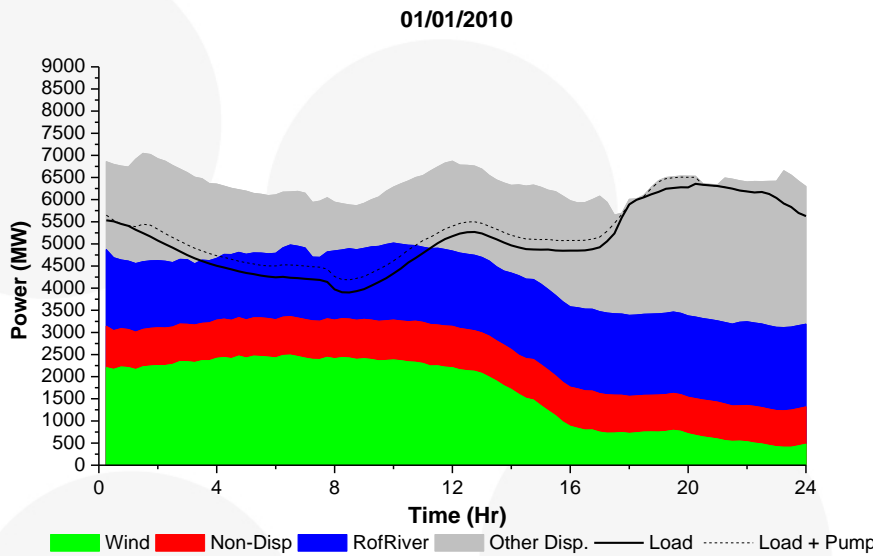


1st of January -the demand had a very low value while the wind and run of the river plants were both peaking... The system had the absolute maximum penetration of 117% of non-regulated power plants...

source: REN

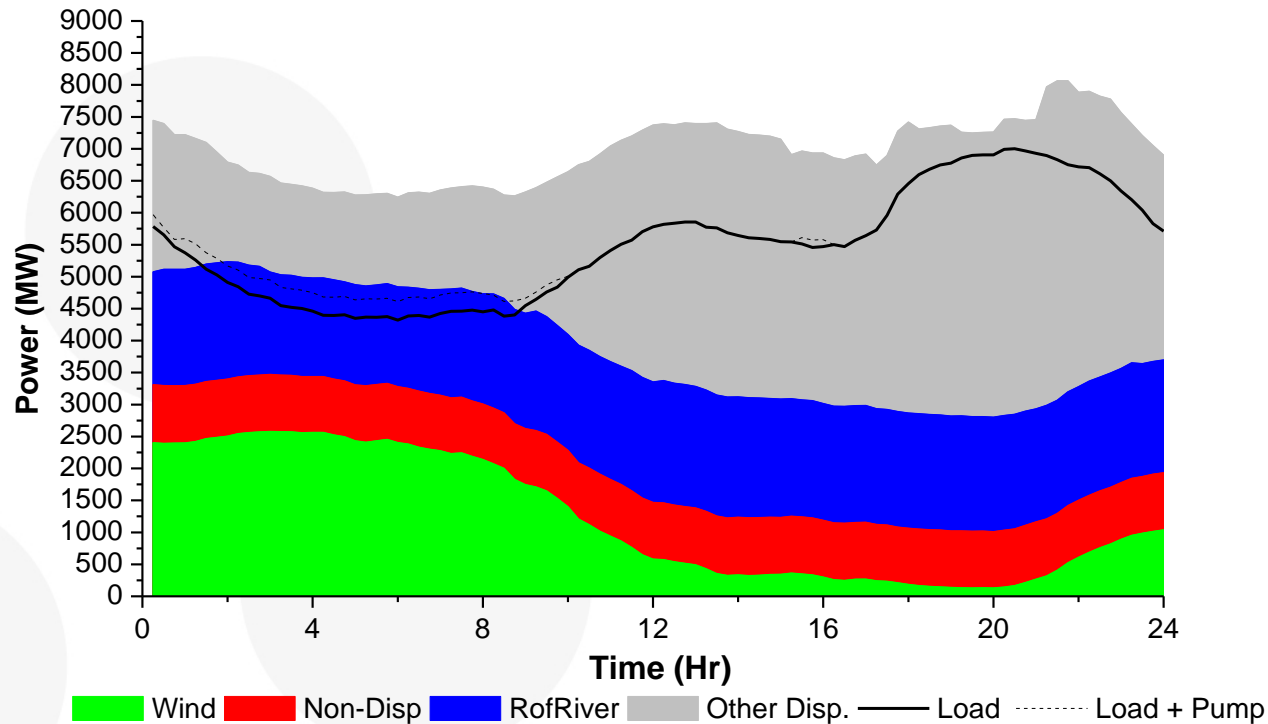
1.Jan.2010

117 % penetration of non-regulated plants (8am, aprox.)



3.Jan.2010

106 % penetration of non-regulated plants, 49% of wind



During the no-load period of the 3rd of January, almost no pumping capacity was used (or available) in the reversible hydro plants, due to the technical and safety limitations due to too high water levels.

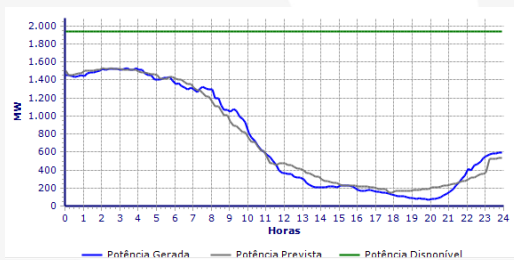
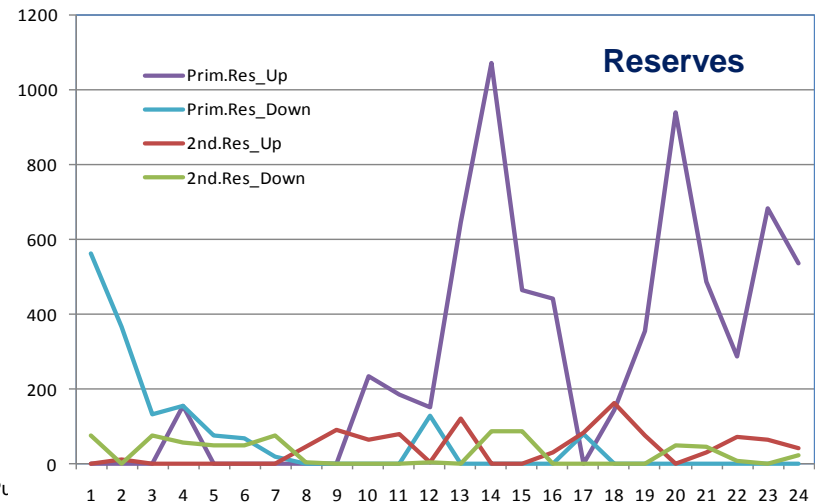
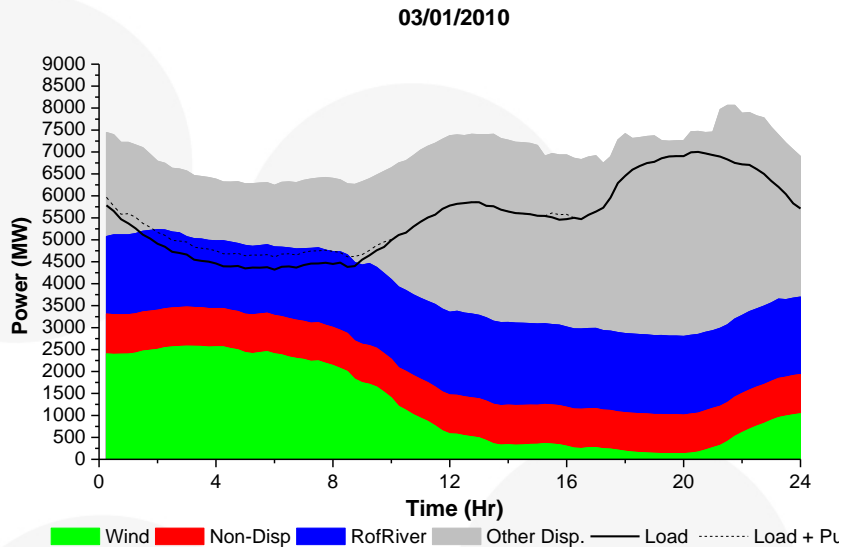
source: REN

final slide 1/2

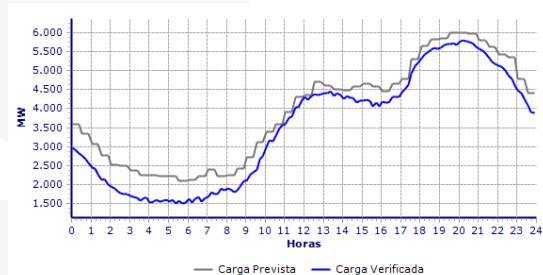


3.Jan.2010

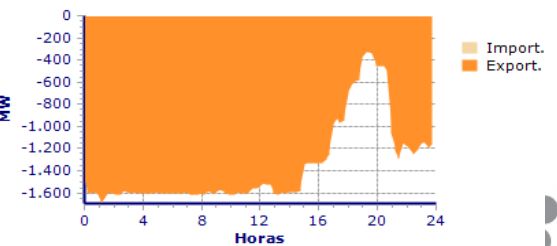
106 % penetration of non-regulated plants, 49% of wind



Wind forecast



Load forecasts

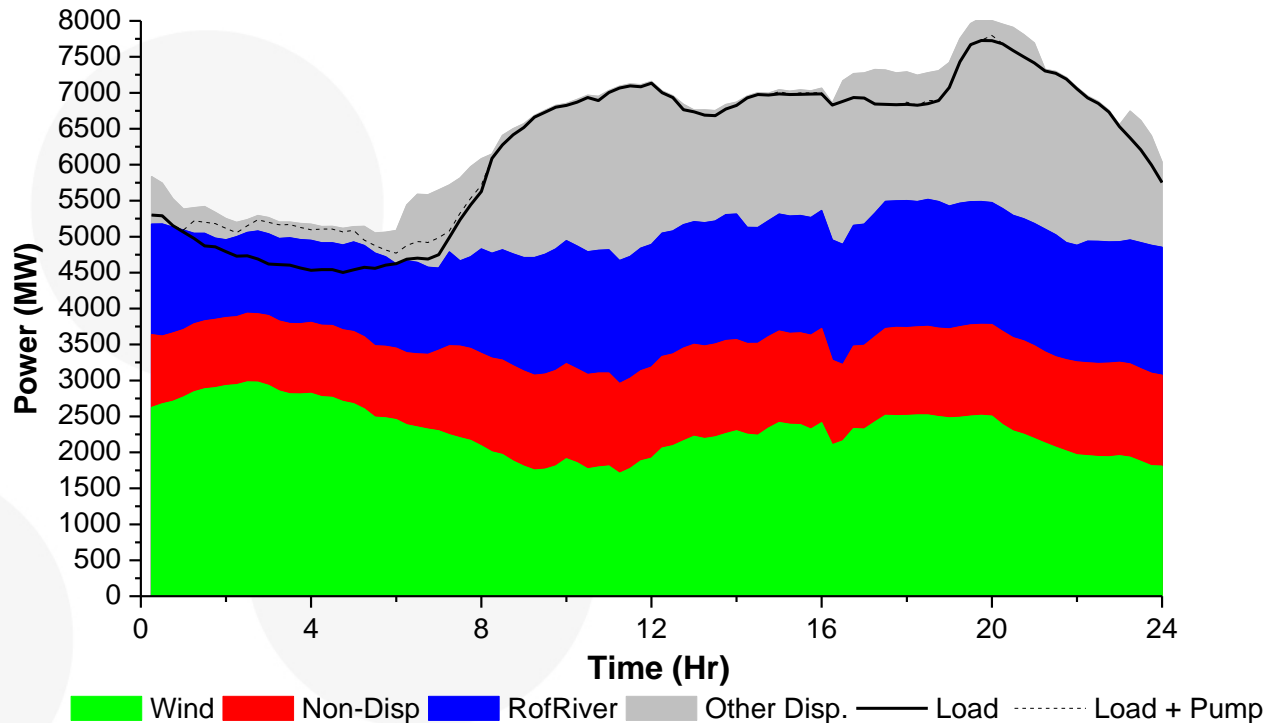


Import/export



25.Mar.2010

2978 MW out of 3500 installed (85%...); 103% non-regulated, almost no pumping capacity...



**>100% theoretically non-dispatchable
at 7am... But back to normal!...**

source: REN

Extreme penetrations of non-regulated plants in the 2009/10 winter

	Day	Minimum Load [MW]	Minimum Load & Pumping [MW]	Maximum Wind Power [MW]	Maximum Non-regulated Power [MW]	Maximum Wind Penetration [%]	Maximum Penetration (incl. pump.) Non-reg. P [%]
November	7.Nov.09	4277	4614	2825	4451	63%	73%
	8.Nov.09	3831	4132	2807	4129	66%	72%
	15.Nov.09	3708	4365	2785	3958	70%	78%
December	29.Dec.09	4486	4938	2786	5615	50%	97 %
	30.Dec.09	4472	4802	2836	5493	51%	100 %
	31.Dec.09	4448	4679	2745	5773	48%	99%
January	1.Jan.10	3900	4188	2488	5020	50%	117%
	3.Jan.10	4321	4608	2579	5233	49%	106%
	4.Jan.10	4370	4370	2287	5432	42%	101%
March	14.Mar.10	4178	4364	2002	4596	44%	103%
	25.Mar.10	4502	4770	2978	5516	54%	103%
	30.Mar.10	4610	5159	2959	5493	54%	99%

... and recently it was announced...

- **...That the actual ~3500 MW of installed wind capacity (plus the 2000 MW already licensed till 2013) were going to be raised to 8500 MW!...**
 - **roughly giving an annual wind energy penetration of 30 to 35%...**
- **Plus 2000 MW of hydro power (hopefully with storage!..)**
- **And 1500 MW of solar (PV +CSP)...**

Things went well so far, but how do we plan for this new scenario?...



Recent moves after this experience...

- **Portugal maintained the onshore wind capacity goals for 2020;**
- **But (!) indexed the increase of wind capacity after 5100 MW to the consumption growth up to 2020;**
- **Already reduced to goals of offshore wind to 500 MW for 2020;**
- **In May 2010 new legislation introducing the possibility of wind power curtailment was published.**



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