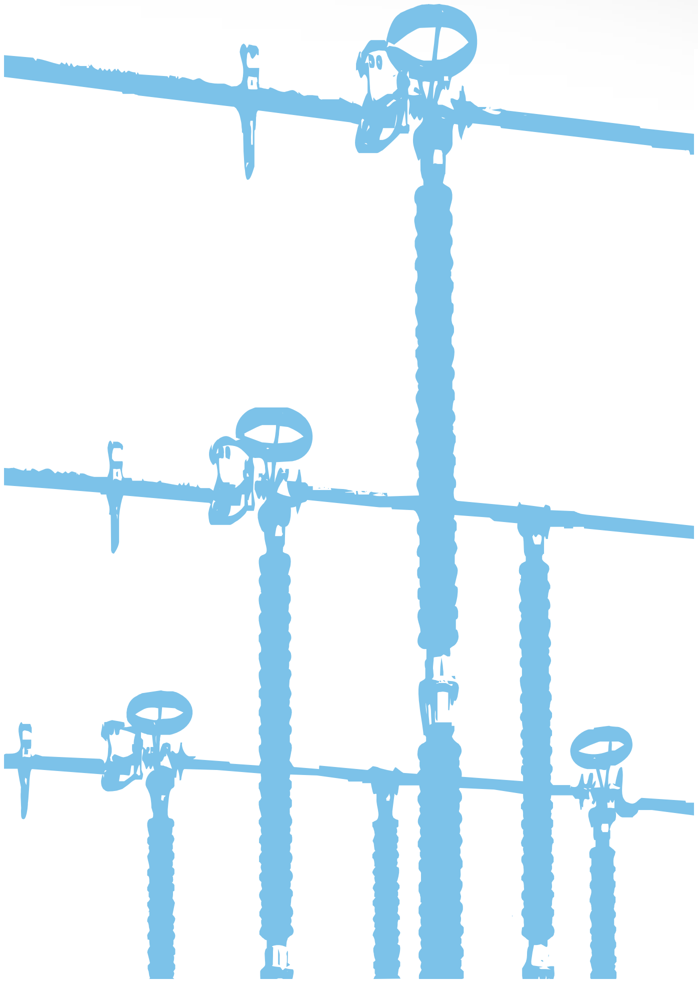
Wind
Development and Integration Issues and Solutions

The Northwest Wind Integration Forum
Portland (Oregon) July 29-30th 2010



- System Overview
- Market integration of renewable energy
    - Technical Constraints management
    - Deviations from schedule
- Renewable energy in Spain today
- Challenges integrating renewable energy nowadays
    - Wind forecast and use in reserve calculation
    - Influence of wind power on balancing reserves
    - Probabilistic sizing of reserves
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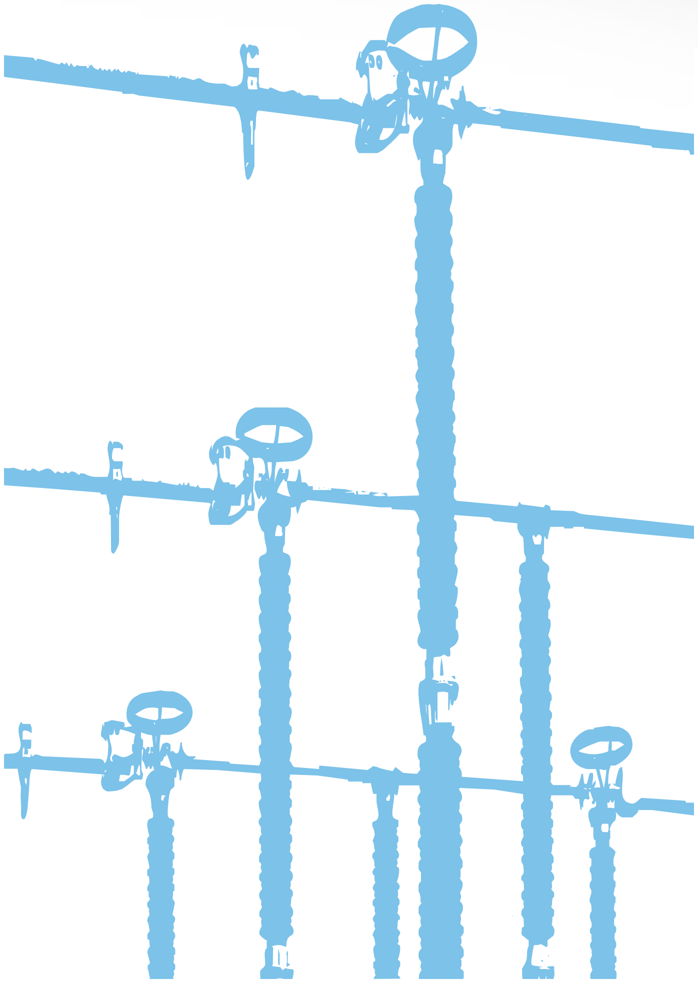
    - Control centre for renewable energies (CECRE)
- Challenges integrating renewable energy for tomorrow
- Conclusions



System Overview

Market integration of renewable energy

- Technical Constraints management
- Deviations from schedule

Renewable energy in Spain today

Challenges integrating renewable energy nowadays

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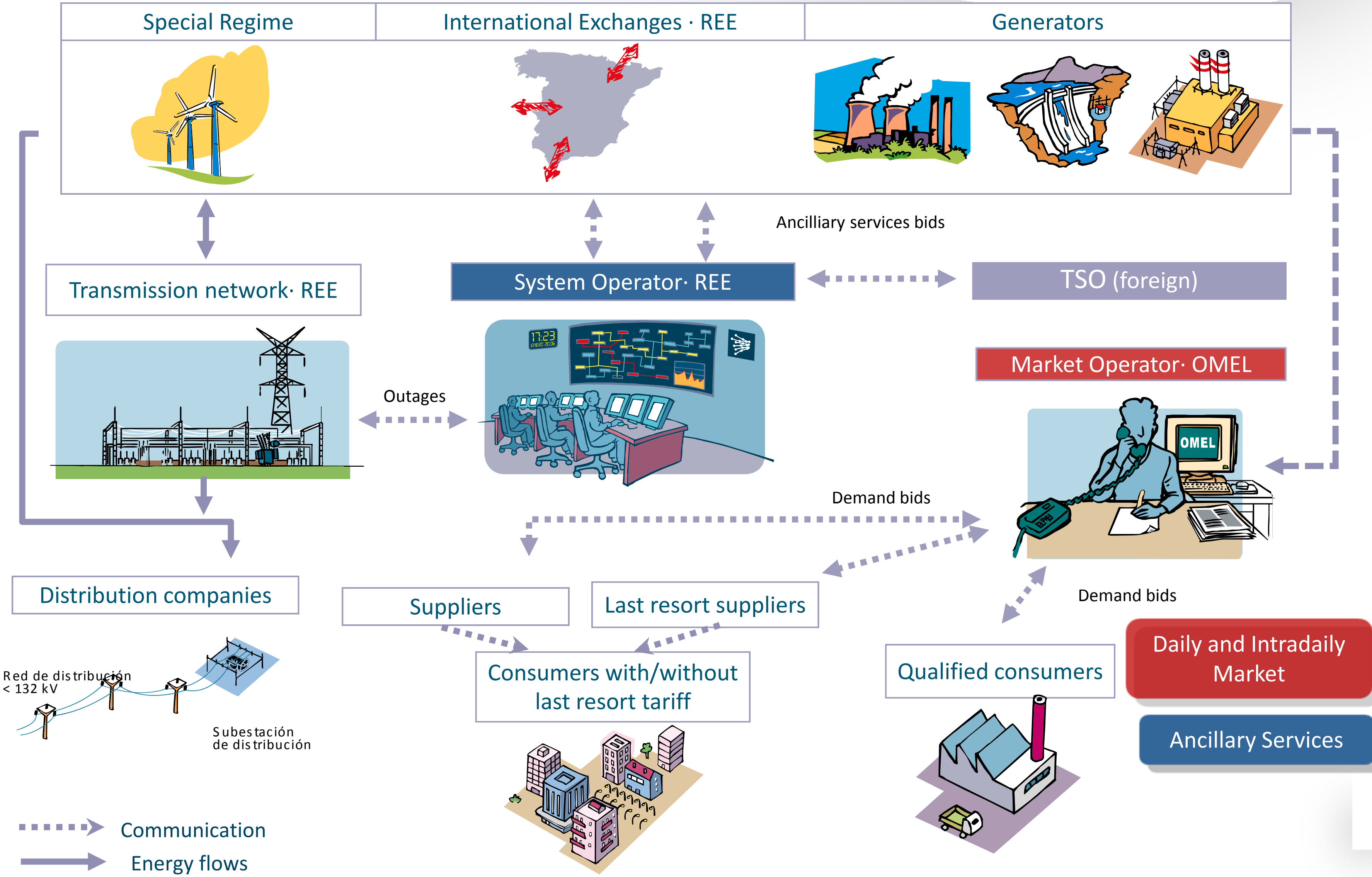
Challenges integrating renewable energy for tomorrow

Conclusions

Spanish Electrical System

RED ELÉCTRICA DE ESPAÑA



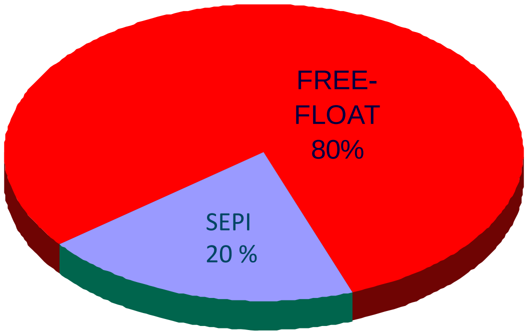
REEE:
Mission and principles

RED ELÉCTRICA DE ESPAÑA

- **System Operation (Since 2006 also in the extra-peninsular systems)**
  - *Operate the grid & coordinates its uses with the generation facilities in order to ensure the security and continuity of the electricity supply.*
- **Transmission (Since 2007 as exclusive transmission company):**
  - *The development and the maintenance of the transmission facilities*
  - *Provide maximum service reliability*
  - *34000 km of lines and 60000 MW of transforming capacity*

Transmission Grid Main magnitudes (SPPS)		Closure 2009 REE	vs. TOT
Lines	400 kV [km ct]	17 977	99,8%
	≤ 220 kV [km ct]	16 777	98,4%
Subst.	≤ 220 & 400 kV [nº bays]	3 385	96,8%
	Transformers 400/X kV [MVA]	66 259	98,8%

SHARE CAPITAL (Closure 2009)

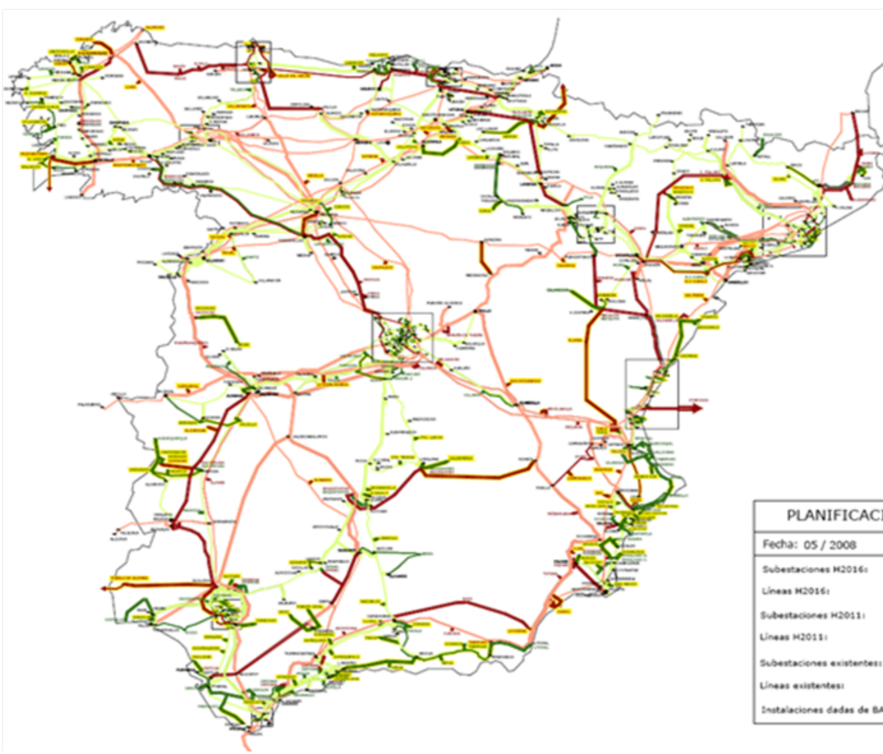


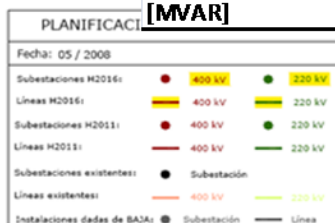
SEPI: Spanish Stated Owned Holding Company

Transmission:

- *400 and 220 kV substations and lines.*
- *400/220 kV transformers.*
- *All the Reactances and capacitors connected to the transmission grid.*
- *All the International interconnections (any voltage level).*

Planned reinforcements 2009-2016, partly due to RES integration:





	Whole planned infrastructure			Specific infrastructure planned to integrate RES		
Lines and cables	**Total**	**400kV**	**220kV**	**Total**	**400kV**	**220kV**
New ones [km]	12656	7488	5168	4465	3504	961
Refitting [km]	8308	3850	4458	1730		
Substations	**Total**	**400kV**	**220kV**	**Total**	**400kV**	**220kV**
New bays	3476	1163	2313			
New substations	399	106	293	39	20	19
Extension of substations	405	76	329	59	18	41
Transformers	**Total**	**400 / 220 kV**	**400 / 132 kV**	**Total**	**400 / 220 kV**	**400 / 132 kV**
Additional capacity [MVA]	68540	52450	16090	5305	3500	1805

Reactances and Capacitors	Total	400kV	220kV
[MVAR]	3900	2800	1100

System Operation: REE's Control Centres

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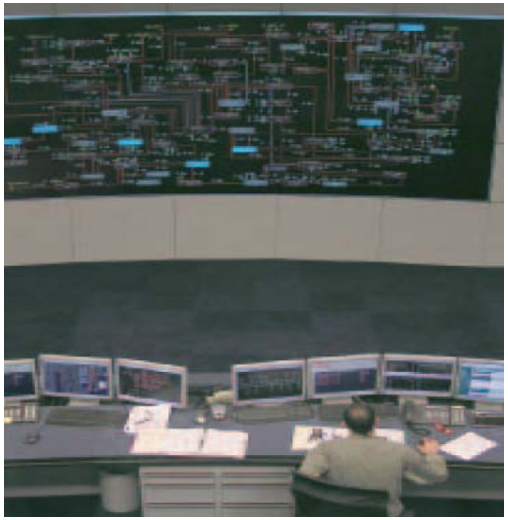
Grid Control Centre

(CECORE)



Electrical Control Centre (CECOEL)

+

Special Regime Control Centre

(CECRE)

- Control Centres' permanent availability
- Two Control Centres with symmetrical backup capability

Production Markets And Operation Markets

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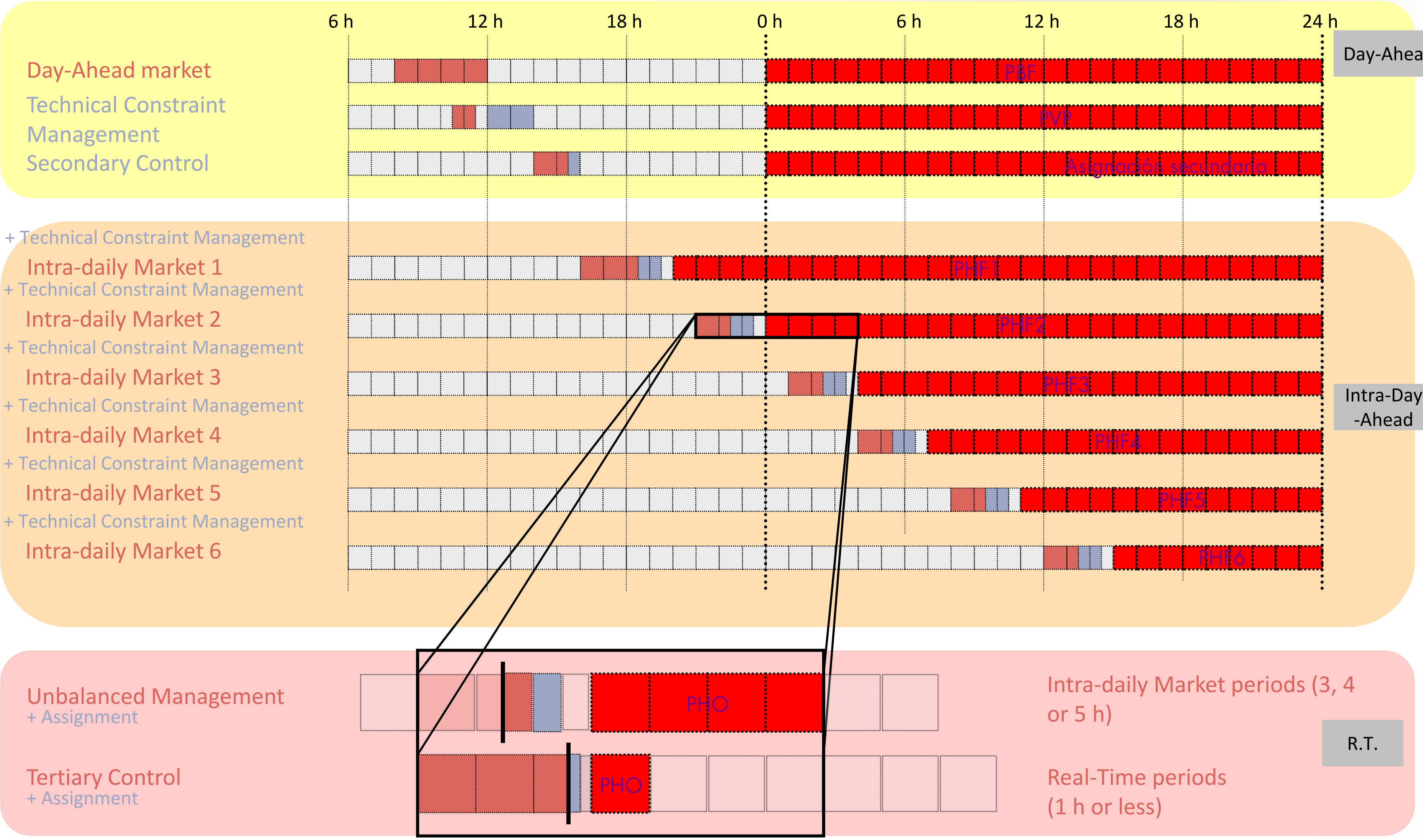

Daily Load demand

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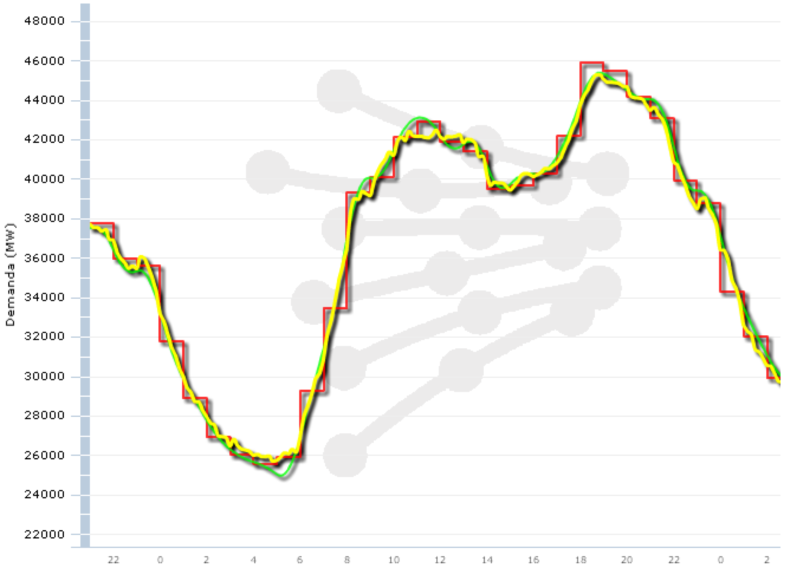
Winter load demand record

Maximum demand 45.455 MW

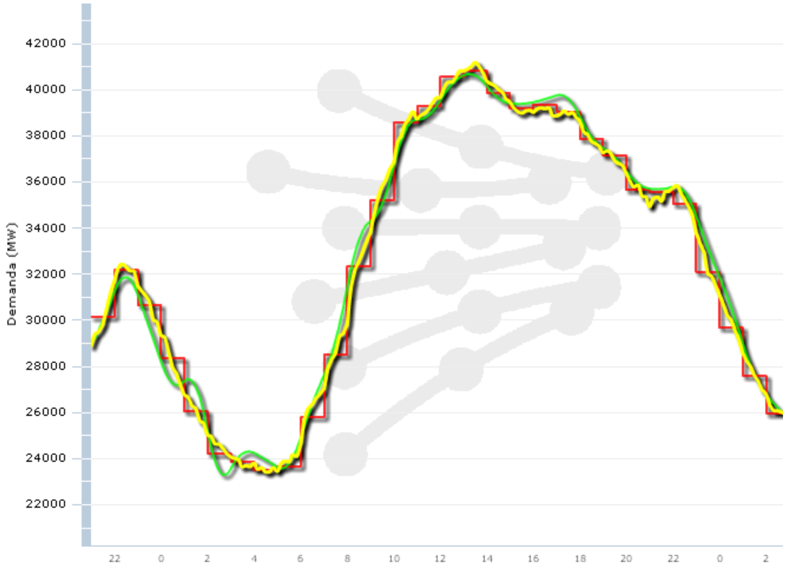
18:50 h 17/12/2007



Summer load demand record

Maximum demand 41318 MW

13:26 h 19/07/2010



- Spanish peak demands 45 GW and off-peak demands of 19-25 GW.

Daily Load demand: Special events

RED ELÉCTRICA DE ESPAÑA

Demonstration against terrorist attack of 11th March: 15’

Stop at 12:00 h and demonstration at 19:00 h.

Daily Load demand: Special events

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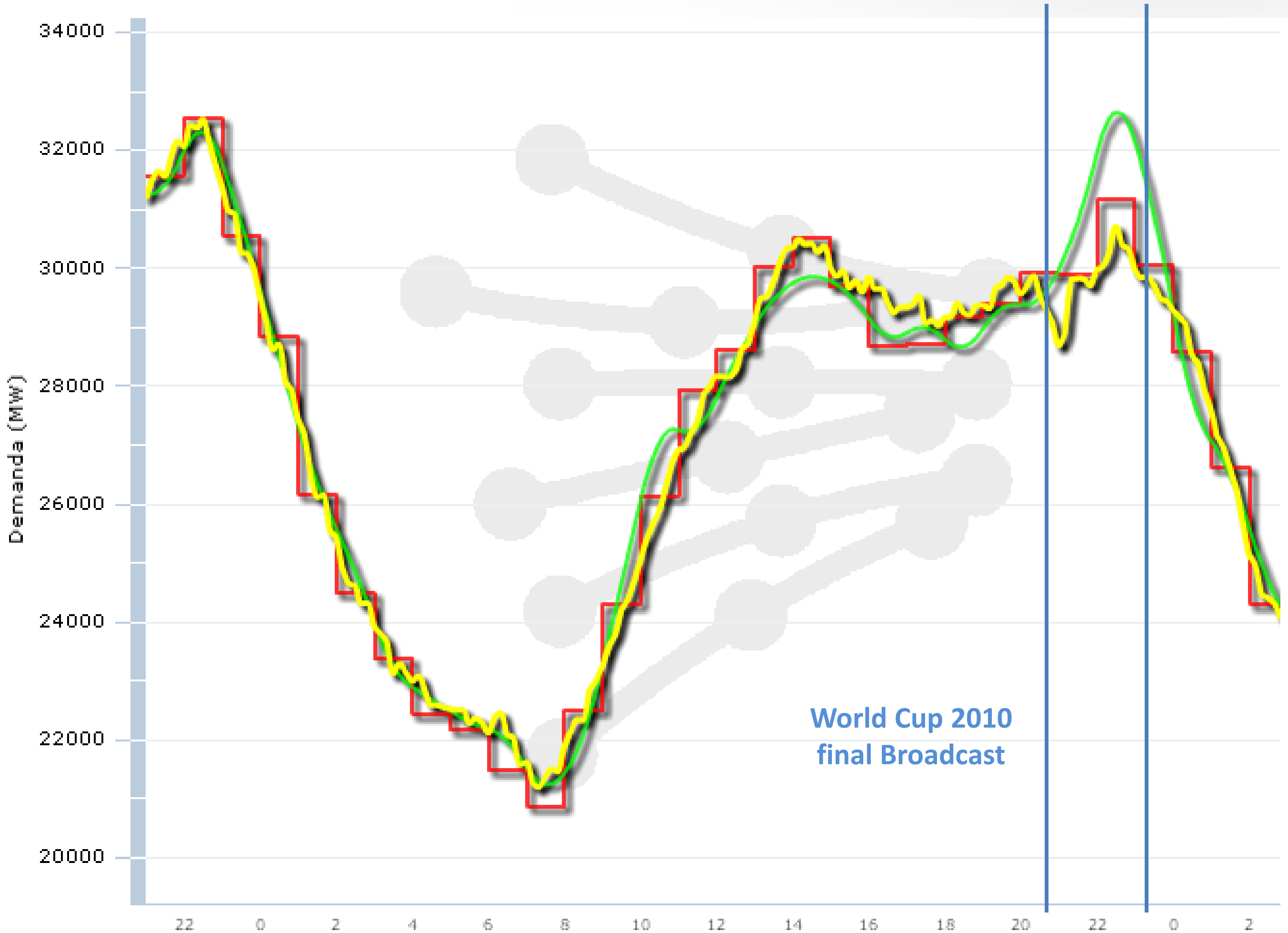
World Cup 2010 final in South Africa (11th July 2010)



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Daily Load demand: Special events

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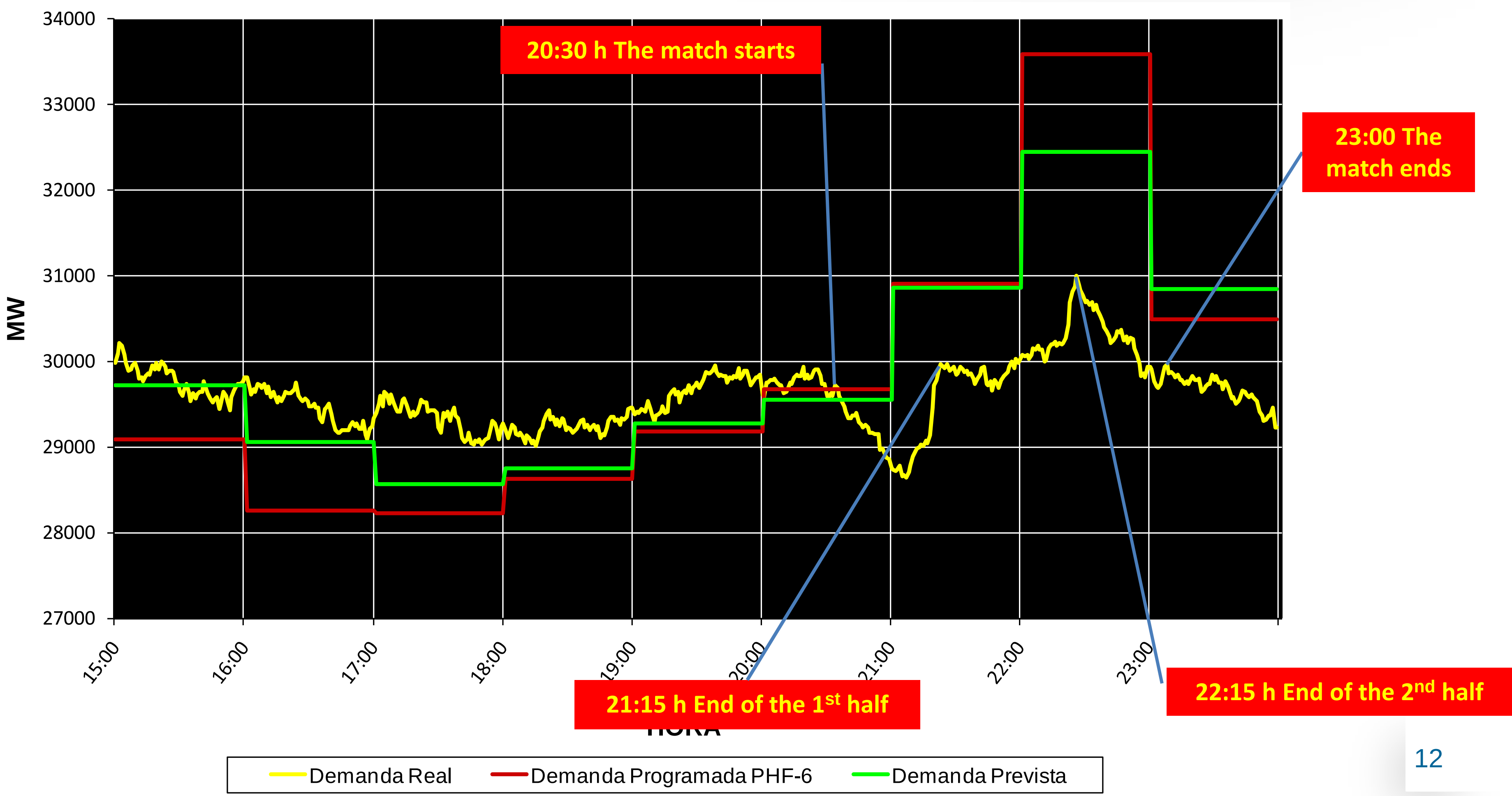

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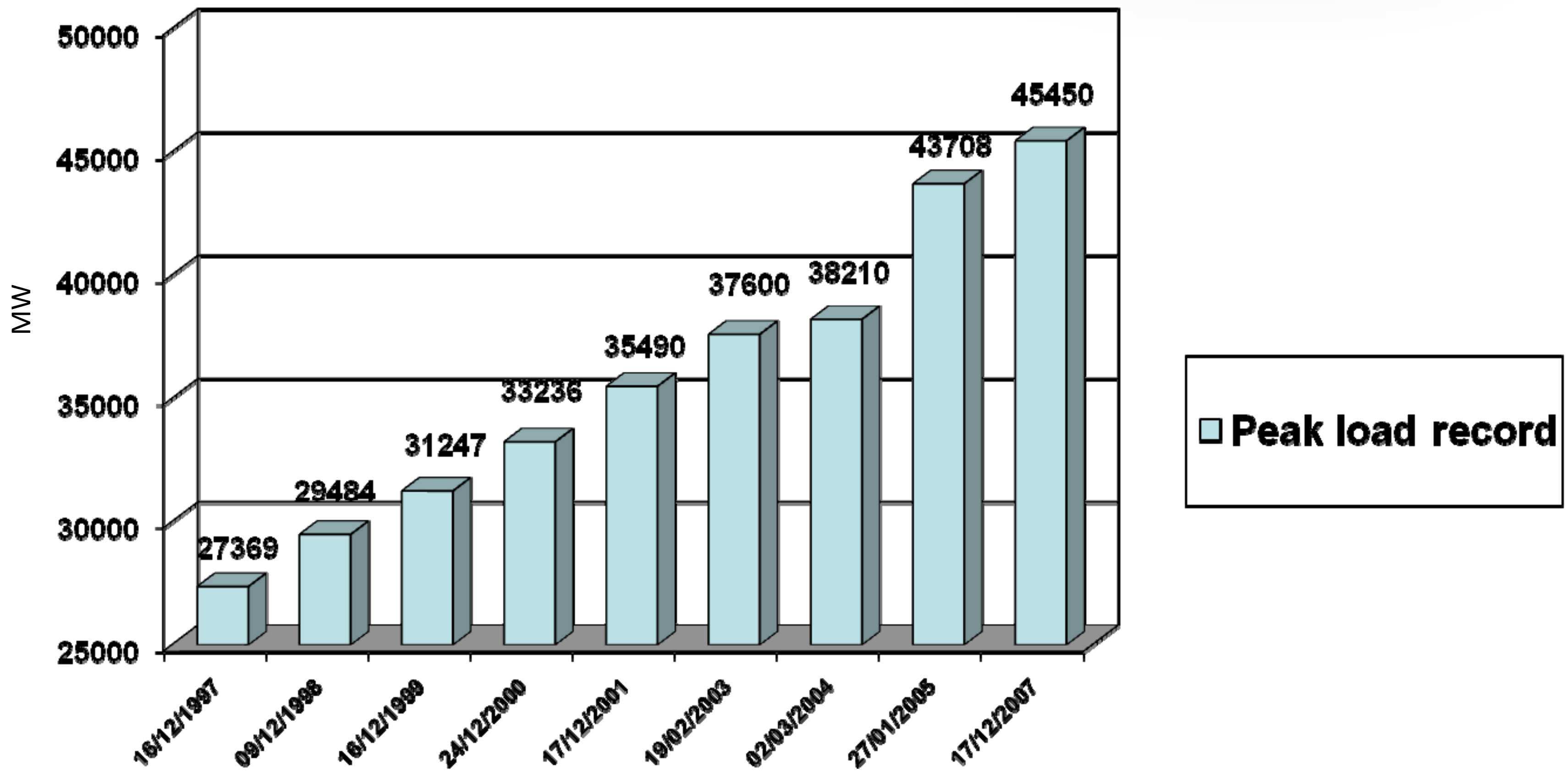
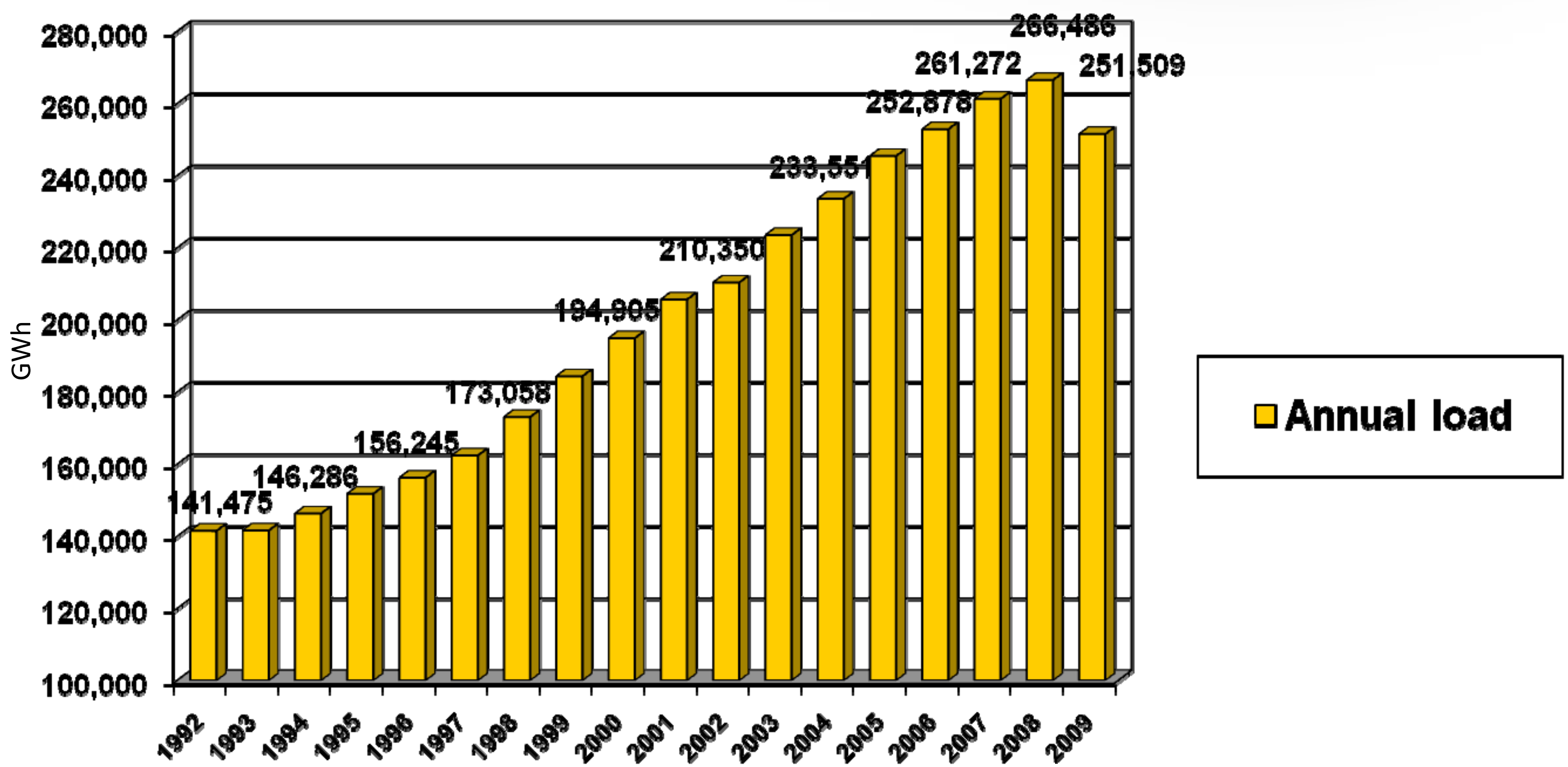
Load evolution (power)



Load evolution (energy)



Installed power and maximum demand

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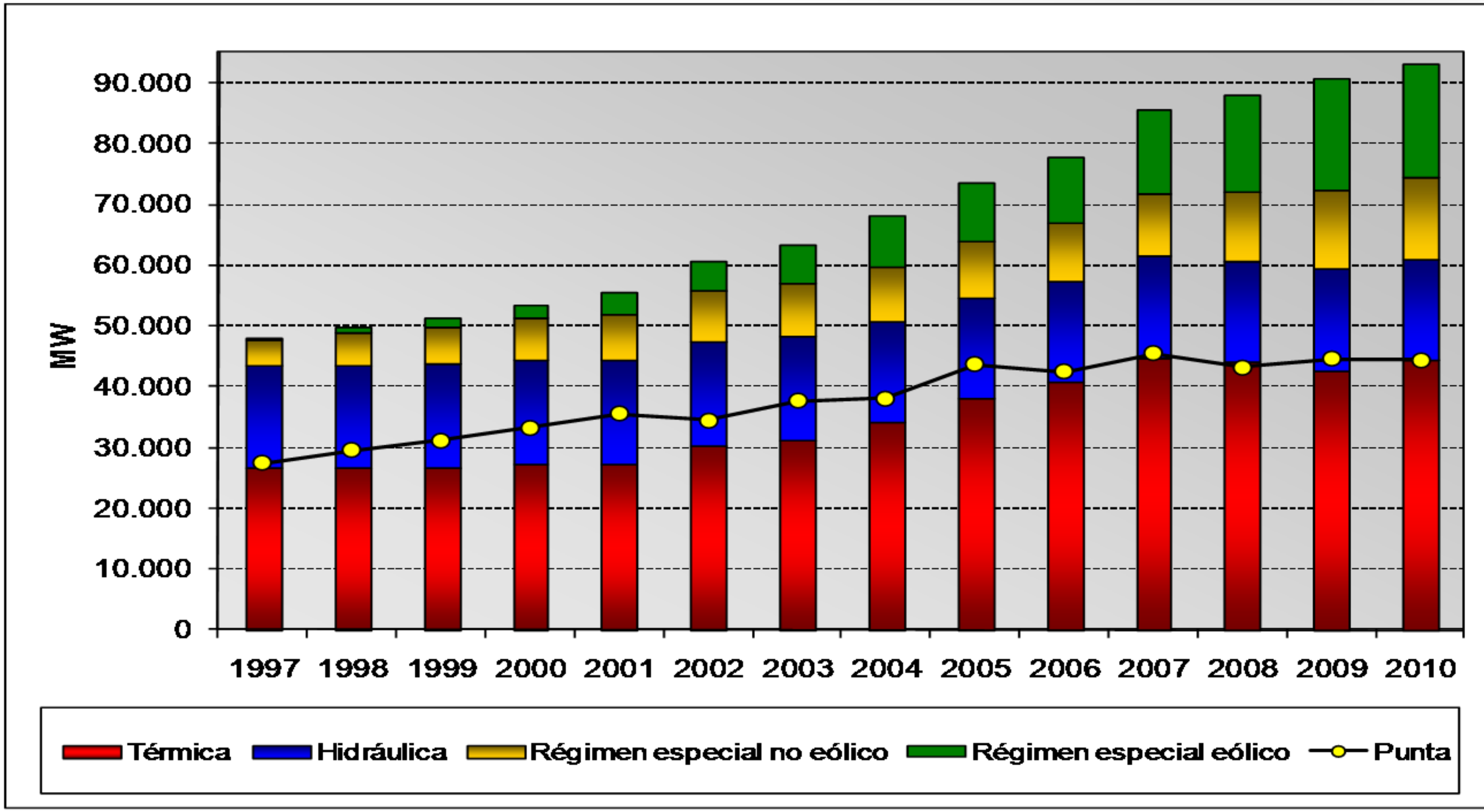

Installed power combined cycles evolution

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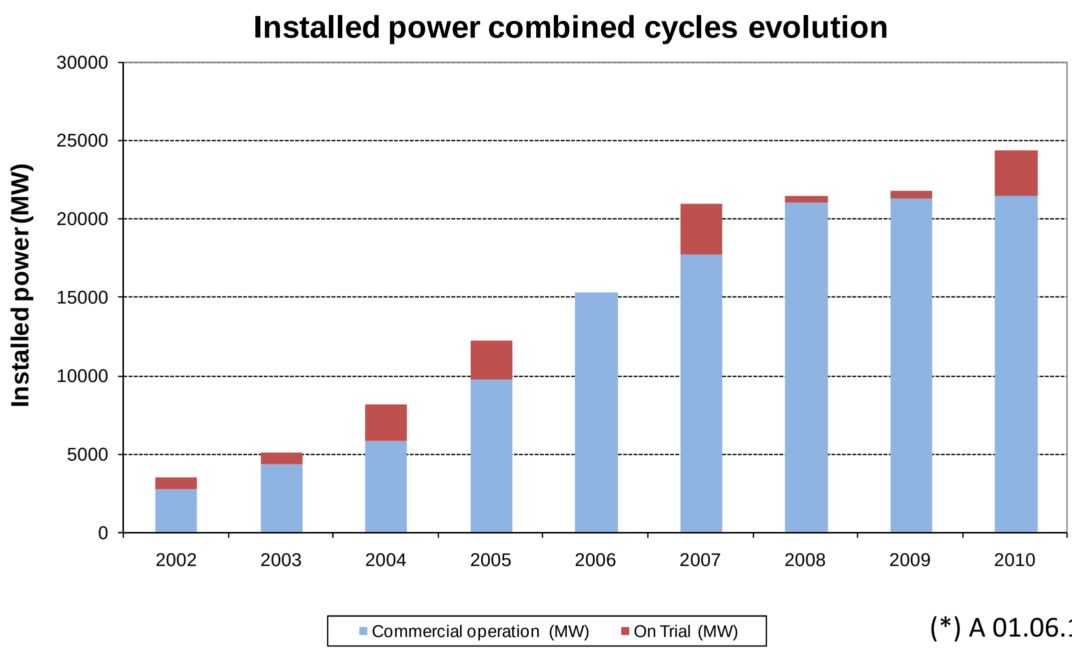
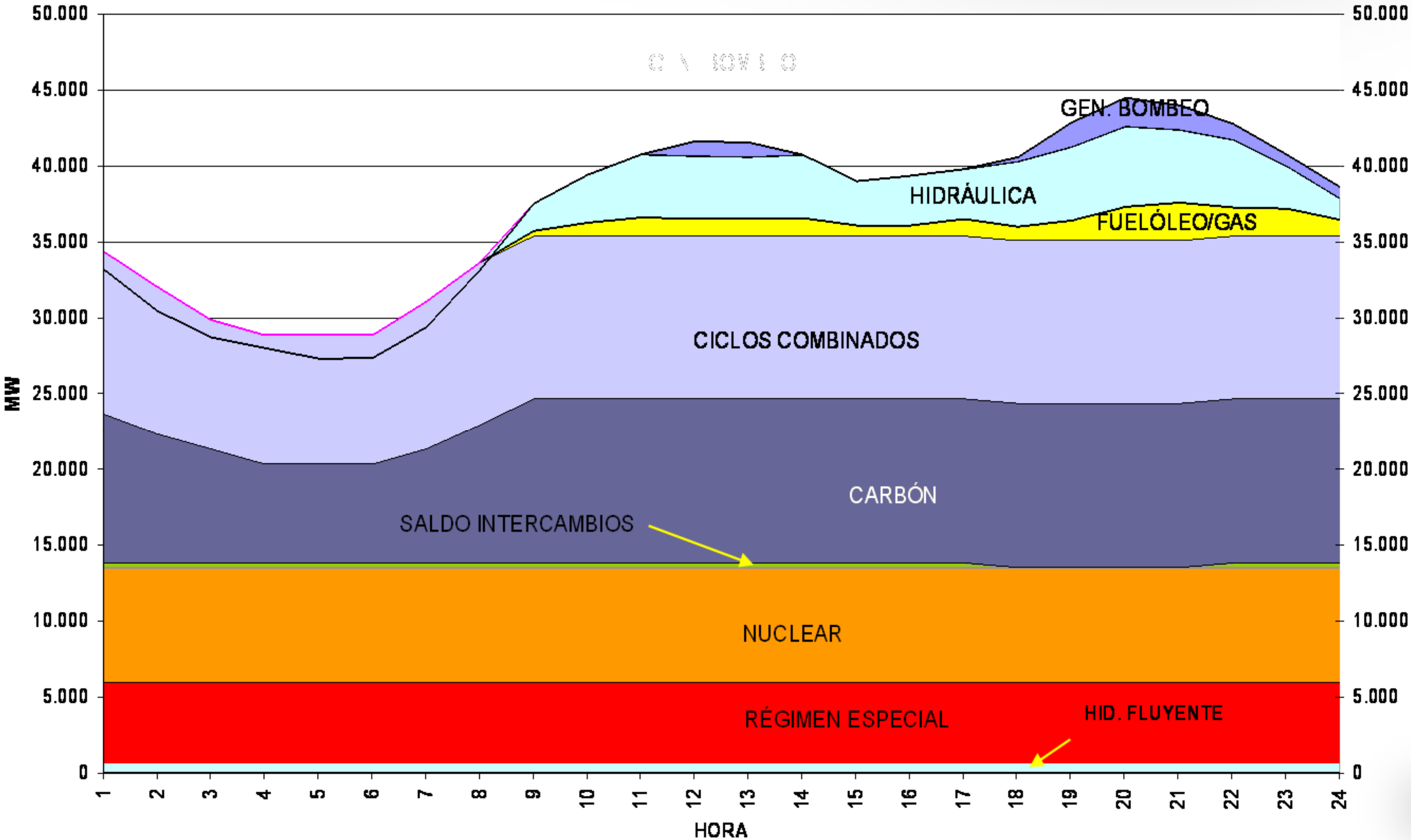


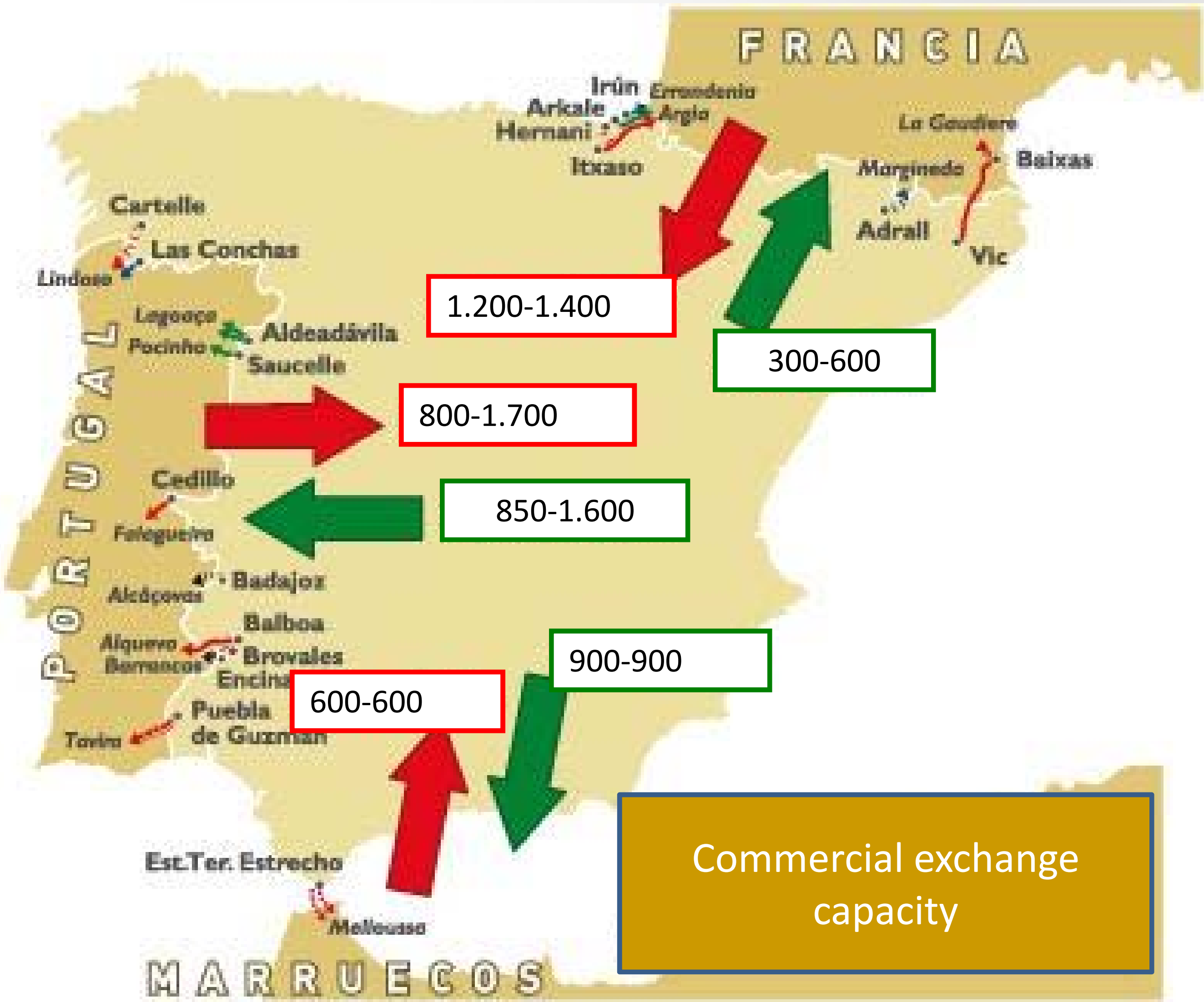
(*) A 01.06.10

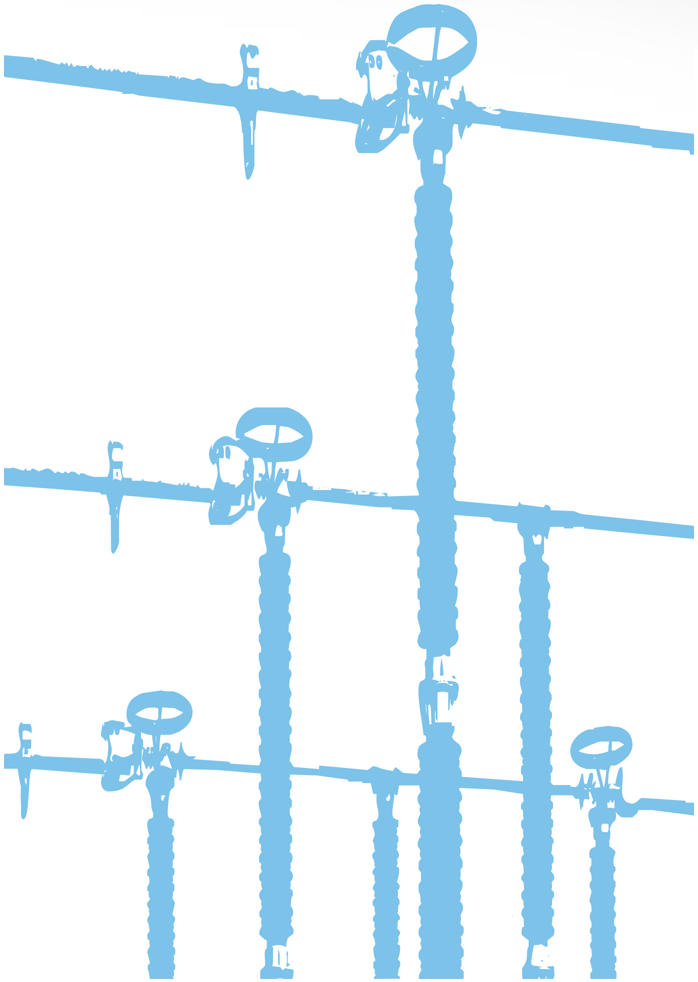
Year	Commercial operation (MW)	On Trial (MW)	Cycles combined (MW)
2002	2.772	785	3.557
2003	4.322	790	5.112
2004	5.889	2.303	8.192
2005	9.762	2.444	12.206
2006	15.318	0	15.318
2007	17.680	3.246	20.926
2008	21.040	418	21.458
2009	21.274	528	21.802
2010	21.491	(*) 2.907	(*) 24.398 (*)

Demand coverage in a maximum load demand day



Commercial exchange capacity.





RED ELÉCTRICA DE ESPAÑA

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Normative frame
Spanish legislation

Special regime generation

Installations whose installed power is no greater than 50 MW and use:

- **Cogeneration** or other forms of electricity generation associated with non-electricity operations, provided they involve high efficiency output
- Whenever **non-consumable renewable energies, biomass or biofuels** of any type are used as primary energy, provided their holder does not engage in generation activities under the ordinary system
- Whenever **non-renewable waste** is used as primary energy.

Renewable non manageable generation

Renewable generation which:

- **Primary energy is neither manageable or storable**.
- Are **not able to control their generation output** following system operator instructions without losing primary energy
- **The certainty in generation prognosis is not** enough to be consider as **a schedule**, although it could be consider as a forecast.
- In Spain the SO determines whether to consider a facility as manageable or non-manageable according to tests.

Market integration of renewable energy

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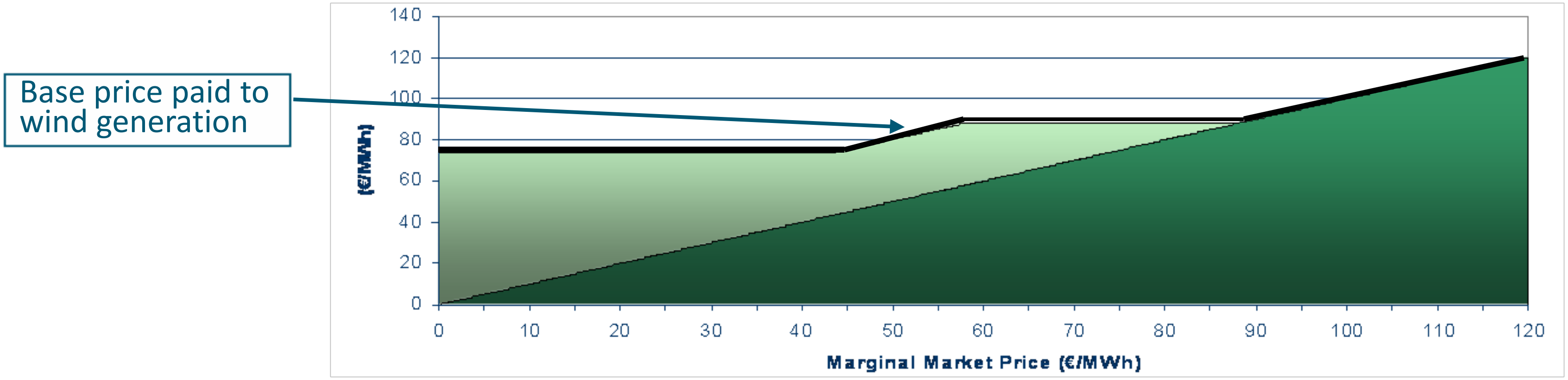
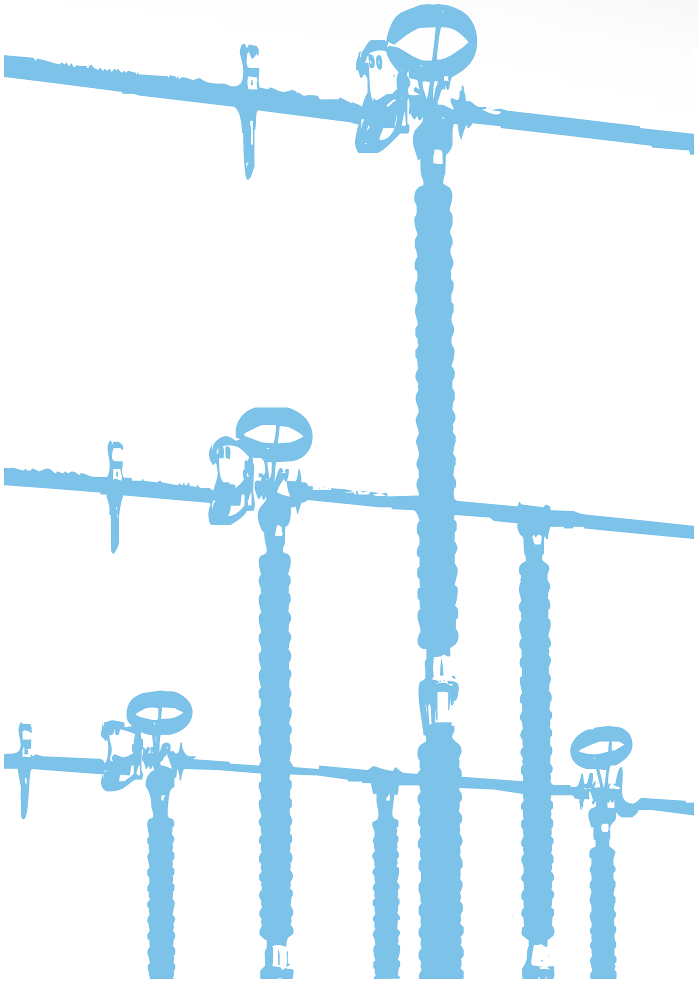
- <u>Production integration mechanisms:</u>
  - Two payment options for wind promoters :
    - Regulated Tariff → Production price = Fixed price per produced MWh.
    - Market → Production price = Hourly market price + Prime.



- <u>All the Wind (Including the one choosing the regulated tariff):</u>
  - Are obliged to offer all their production (= their best forecast) to the market.
  - Possibility of accessing the daily wholesale market and updating the schedules in the intra-day markets according to new production forecasts.
  - As any type of generation, agents must assume the cost of their deviation and pay for the balancing energy needed to counteract their deviation.



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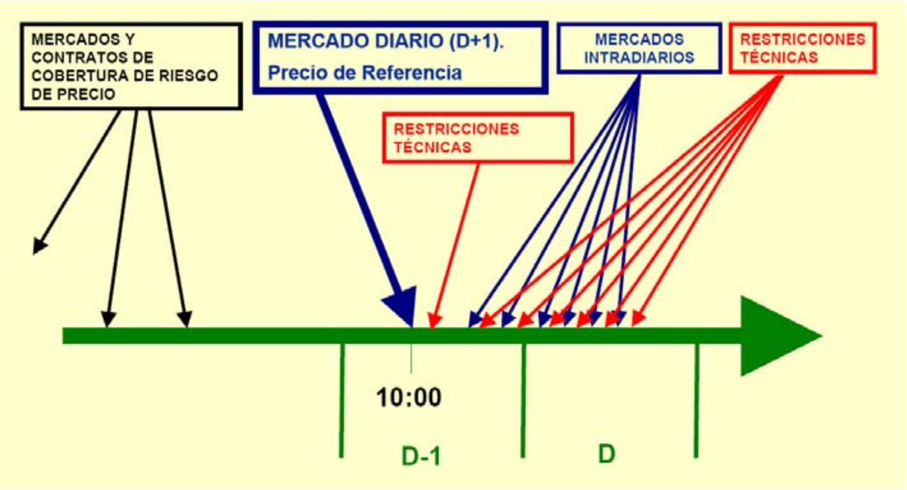
Technical Constraints

Any constraint in the electricity system that affect the security, quality and reliability of the electricity supply of electric energy distribution according (PO 3.2).

- <u>**Technical constraints types (PO 3.7)*:**</u>
  - **Offtake generation congestion**
  - **Stability:**
    - Voltage dips tripping
    - Over-speed tripping
  - **Short circuit power**
  - **Insufficient Secondary and Tertiary Reserve.**



- **Renewable non manageable generation will be reduced only in those cases in which it became the only way to solve the technical constraint.**

* Technical constraints types which could imply renewable and non manageable generation reduction.

Technical Constraints

Congestion management (PO 3.2)

In case several plants that have a minimum of sensibility to a congestion need to be redispatched to solve the congestion the following order must be applied:

- Ordinary regime. In decreasing sensibility order.
- Non-renewable manageable special regime
- Renewable manageable special regime
- Non-renewable non-manageable special regime
- Renewable non-manageable special regime

If there is no other solution than reducing renewable non manageable generation (PO 3.7):

- The reduction is proportional to the production schedule (constraint after the daily market) or proportional to the production (constraint in real time)
- Generators must adapt their production to the given set-point within 15 minutes.
- If there are more than 3 reductions in a month or more than 10 reductions in a year the SO must prepare an investment plan in order to solve this technical constrain.

Technical Constraints Management for renewable and non manageable generation

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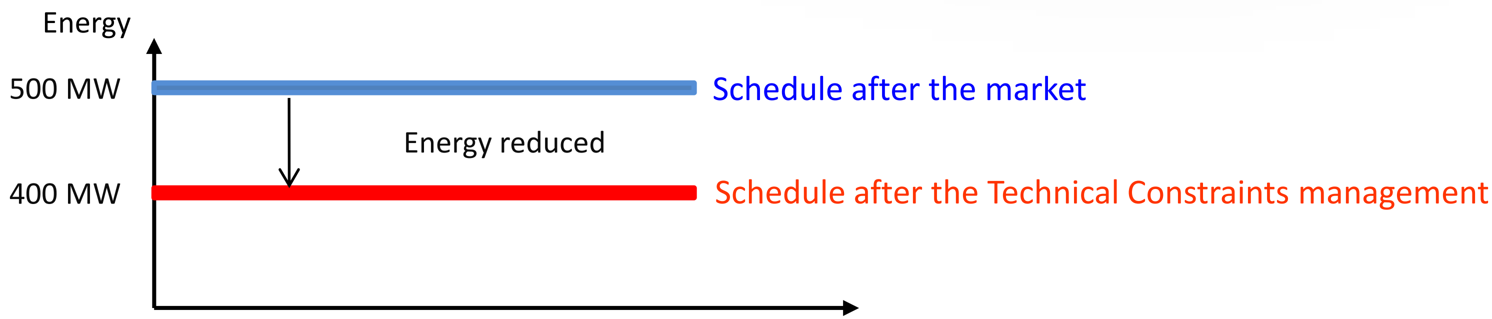
When for one of the mentioned reason (congestions, stability, not enough reserve) reducing renewable and non manageable generation is the only way to solve the technical constraint:



Production price= 50 €MWh

Reduction applied after the day ahead or intra day market:

They refund what they have earn for the energy reduced

Income = [(Production price x Energy Schedule) - (Production price x Energy reduced)] = [(500x50)-(100x50)]= 20.000 Euros*

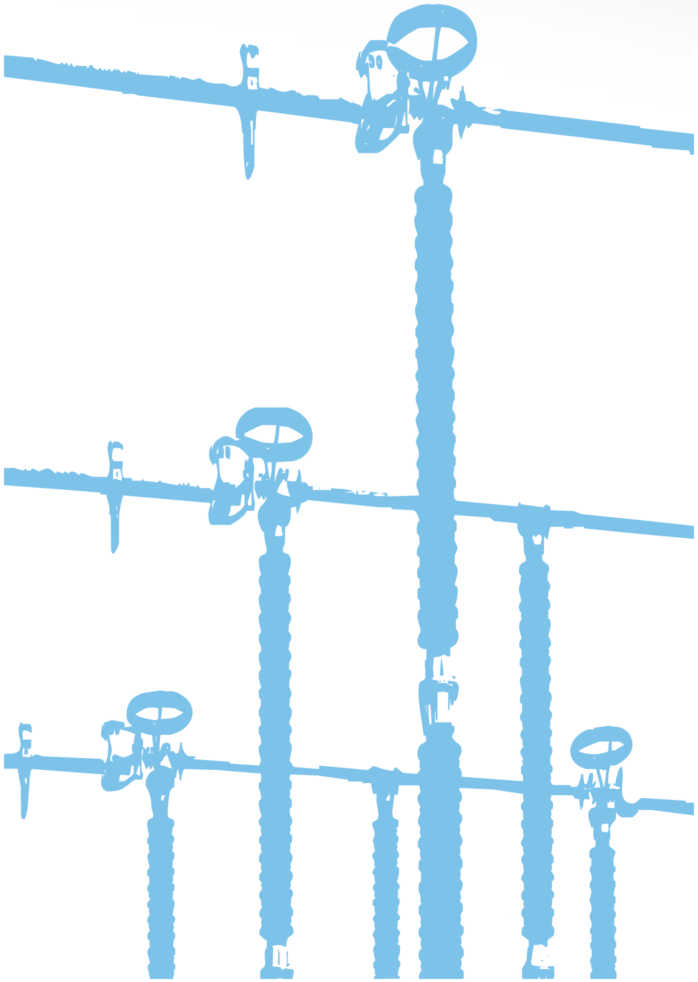
Reduction applied in real time:

They refund 85% of what they have earn for the energy reduced (They get 15 %)

Income = [Production price x Energy Schedule]- (Production price x Energy reduced x 0.85) = [(500x50)-(100x50x0.85)]= 20.750 Euros*

*The new schedule will be (Schedule – Energy Reduced). The deviations will be measured related to this new schedule.
The prime will be applied to the energy produced (Taken into account the restrictions and the deviations).

RED ELÉCTRICA DE ESPAÑA



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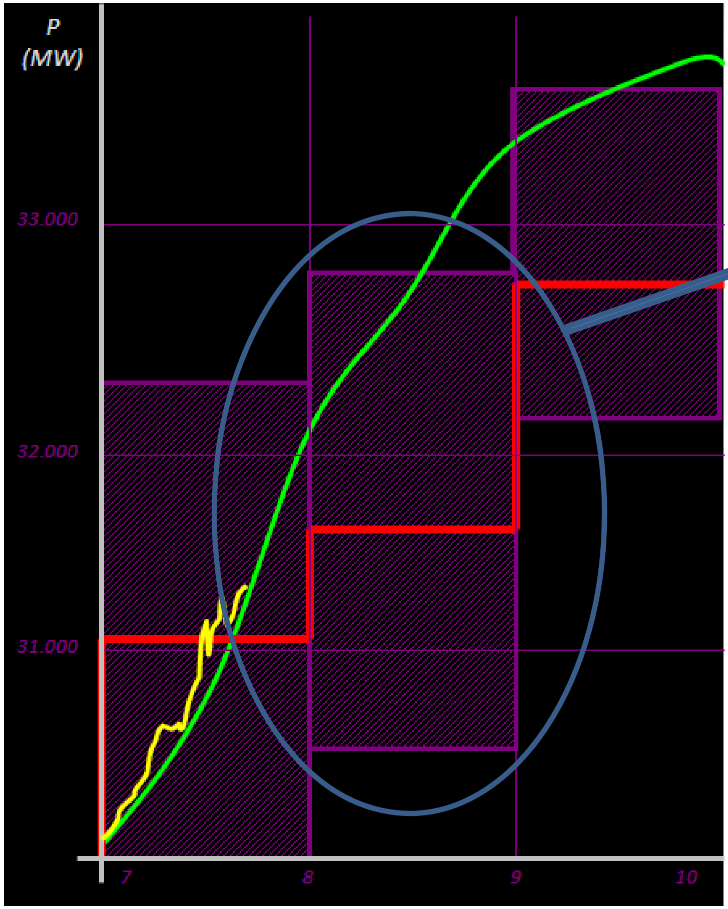
RED ELÉCTRICA DE ESPAÑA

Deviations from the Schedule and regulation

- The agents (of every type of generation) must assume the cost of their deviations and pay for the balancing energy needed to counteract their deviation.



Upward Energy Price= Price (UM, 3ª, 2ª)

Downward Energy Price= Price(UM, 3ª, 2ª)

Types of deviations:

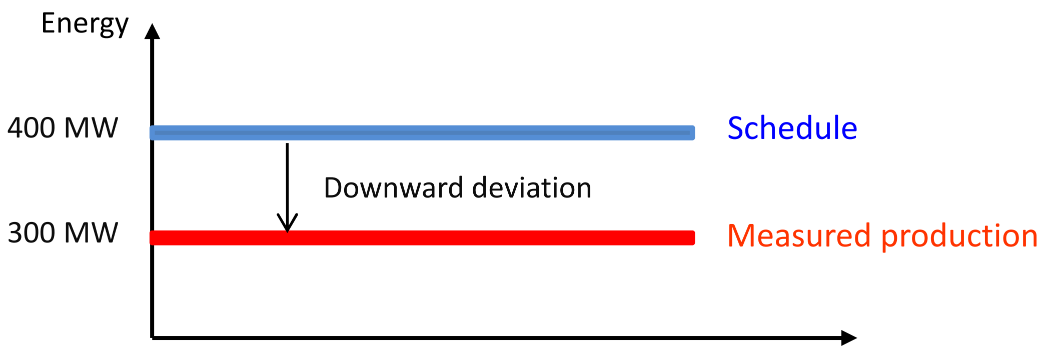
- In Favor of
- Against

the necessity of the system

Deviations from the Schedule

Less wind production than scheduled

- The generation that provides upward reserve gets paid for **the energy produced.**
- The generation deviated pays for the energy required to counteract their deviation (**the energy not produced**).



Upward Energy Price = 60 €/MWh

Market Price = 50 €/MWh

Deviation in favor of the system → Pays the market price.

- Income= [Schedule price x Energy scheduled] - [Market Price x Energy deviated] = (400*50) – (100*50) = 15.000 Euros

Schedule | Deviation

Deviation against the system → Pays the Max (Price Up.Reserve , Market Price)

- Income = [Schedule price x Energy scheduled]] - [Upward Energy Price x Energy deviated] = (400*50) – (100*60) = 14.000 Euros

Schedule | Diviation

Deviations from the Schedule

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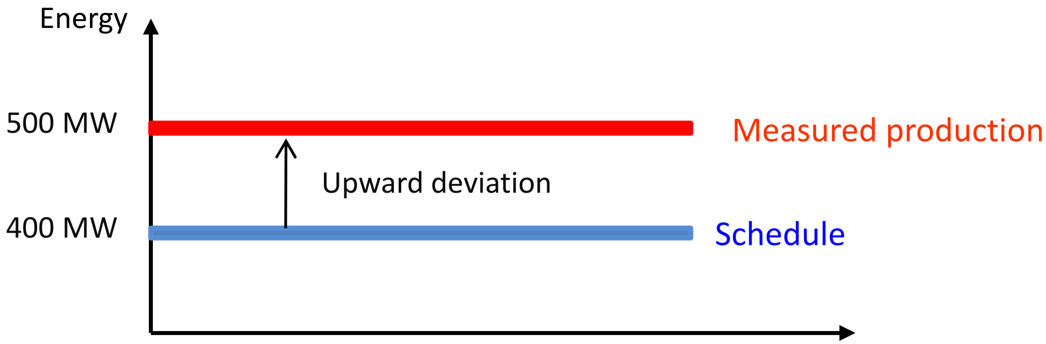
More wind production than scheduled

- The generation that provides downward reserve pays for **the energy not produced.**
- The generation deviated gets paid for the energy retired to counteract their deviation (**the energy produced**).



Downward Energy Price = 30 €/MWh

Market Price = 50 €/MWh

Deviation in favor of the system → Gets paid the market price.

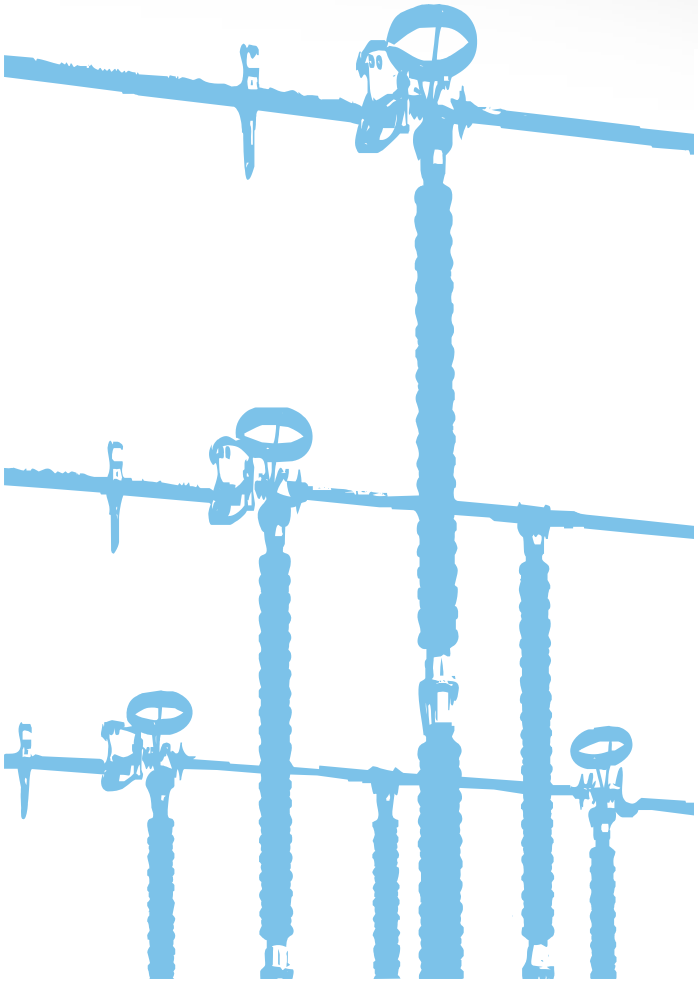
- Income = [Schedule price x Energy scheduled] + [Market Price x Energy deviated] = (400*50) + (100*50) = 25.000 Euros

  Schedule — Deviation

Deviation against the system → Gets paid the Min (Price Down.Reserve , Market Price)

- Income = [Schedule price x Energy scheduled] + [Downward Energy Price x Energy deviated] = (400*50) + (100*30) = 23.000 Euros

  Schedule — Deviation



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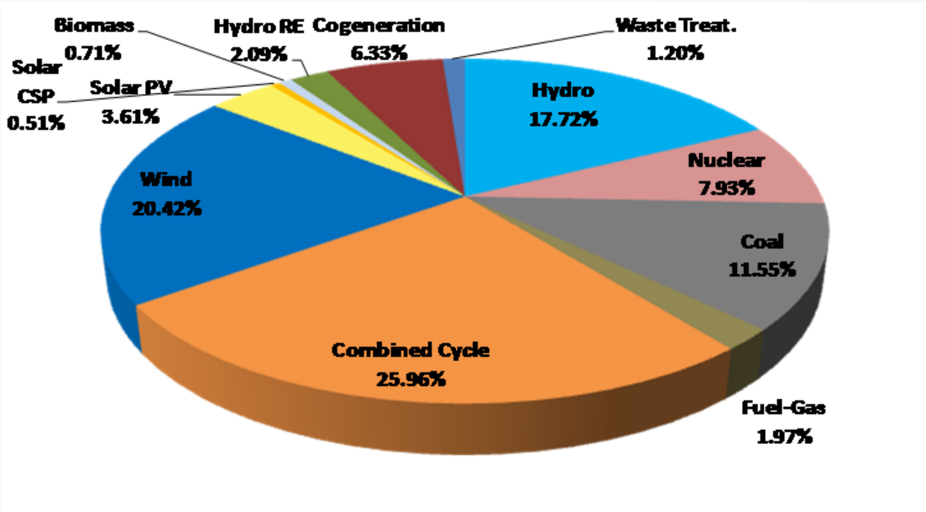
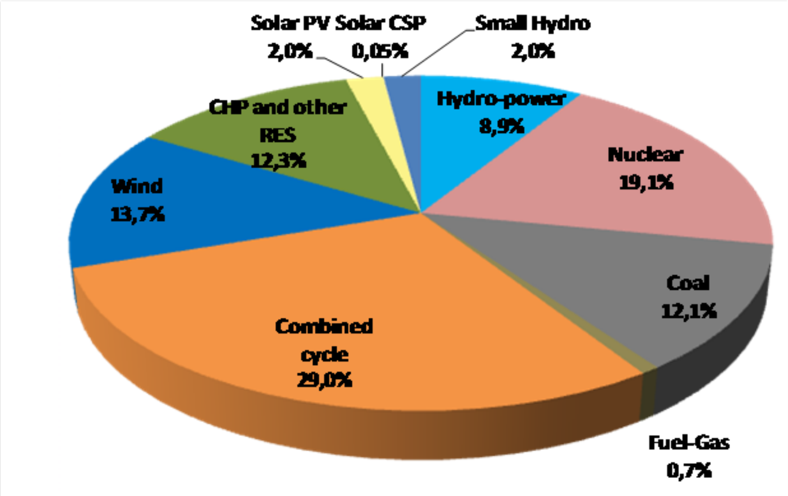
Installed capacity and demand supply 2009

Installed capacity July 2010



Demand supply 2009



Technology	MW	%
Hydro-power	16.657	17,7
Nuclear	7.455	7,9
Coal	10.856	11,6
Fuel-Gas	1.849	2,0
Combined cycles	24.398	26,0
Total (ordinary regime)	61.215	65,1
Wind power generation	19.195	20,4
Solar PV	3.392	3,6
Solar CSP	481	0,5
Biomass	667	0,7
Special regime hydro	1.965	2,1
Cogeneration	5.946	6,3
Waste treatment	1.124	1,2
Total (special regime)	32.469	34,9
Total	93.684	

+181.614 GWh Net Ordinary Regime
+ 81.785 GWh Net Special Regime
- 3.770 GWh Hydro-pump storage
- 8.120 GWh International exchange
251.509 GWh

Solar:
Influence in system operation of:

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Solar photovoltaic

- Reduced observability by the SO. Must be solved.
- Behavior in summer in accordance to demand requirements.
- In winter, peak demand is in the evening. No contribution.
- Connection to Transmission/Distribution: 2/98%

YEAR	SOLAR PV PRODUCTION (GWh)
2005	40
2006	103
2007	466
2008	2 477
2009	5 347

Source CNE

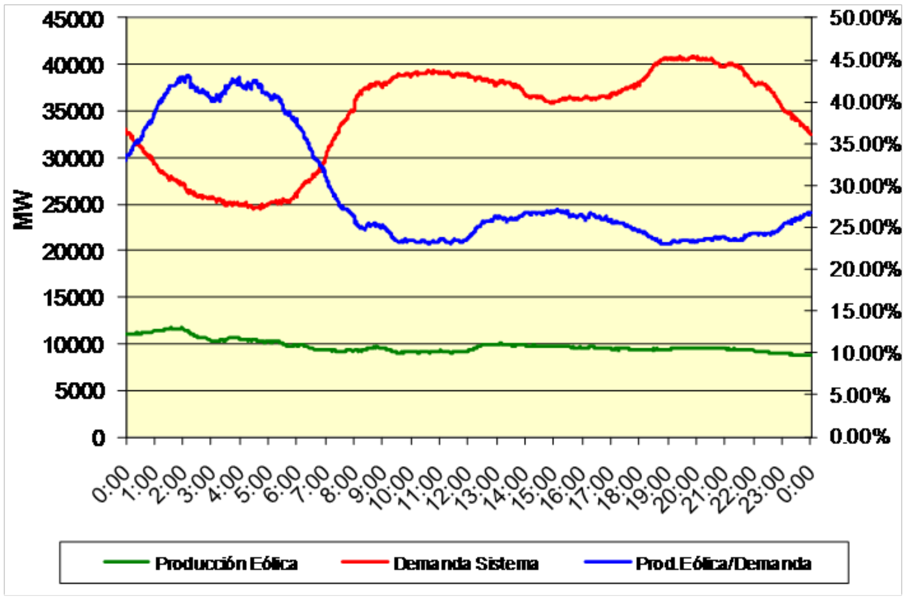
Solar thermoelectric

- Two technologies: parabolic trough and tower.
- Behavior in summer in accordance to demand requirements.
- In winter molten salt storage and hybridation with natural gas allow production during the daily load peaks.
- Connection to Transmission/Distribution: 54/46%

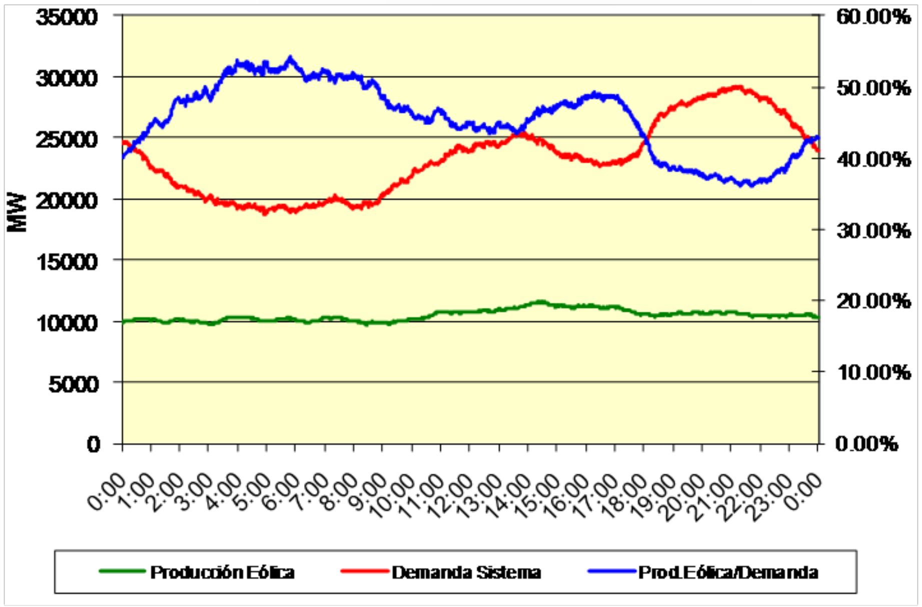
Wind energy production records

RED ELÉCTRICA DE ESPAÑA

MAXIMUM PRODUCTION



DEMAND vs. WIND PRODUCTION

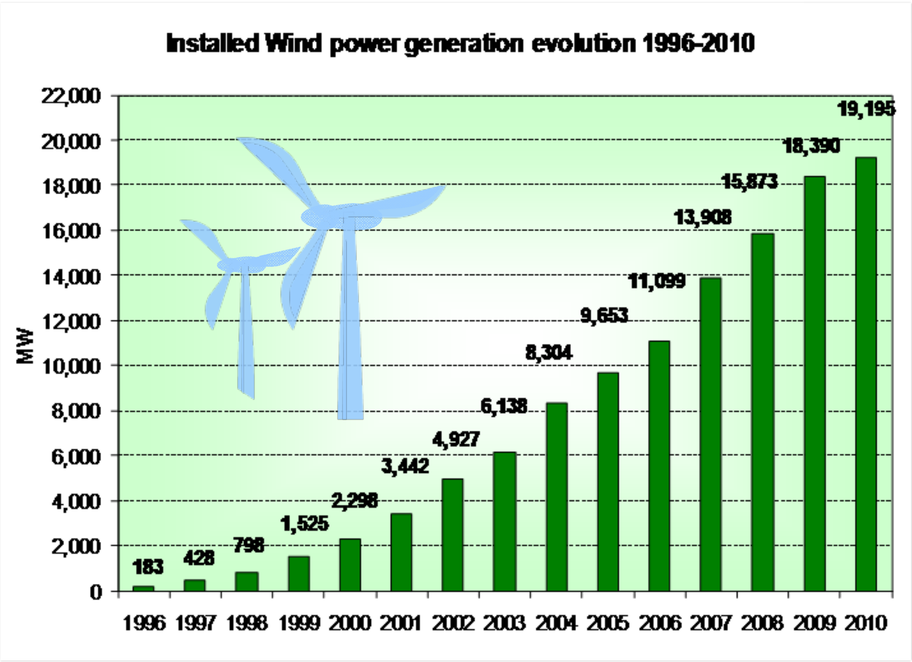


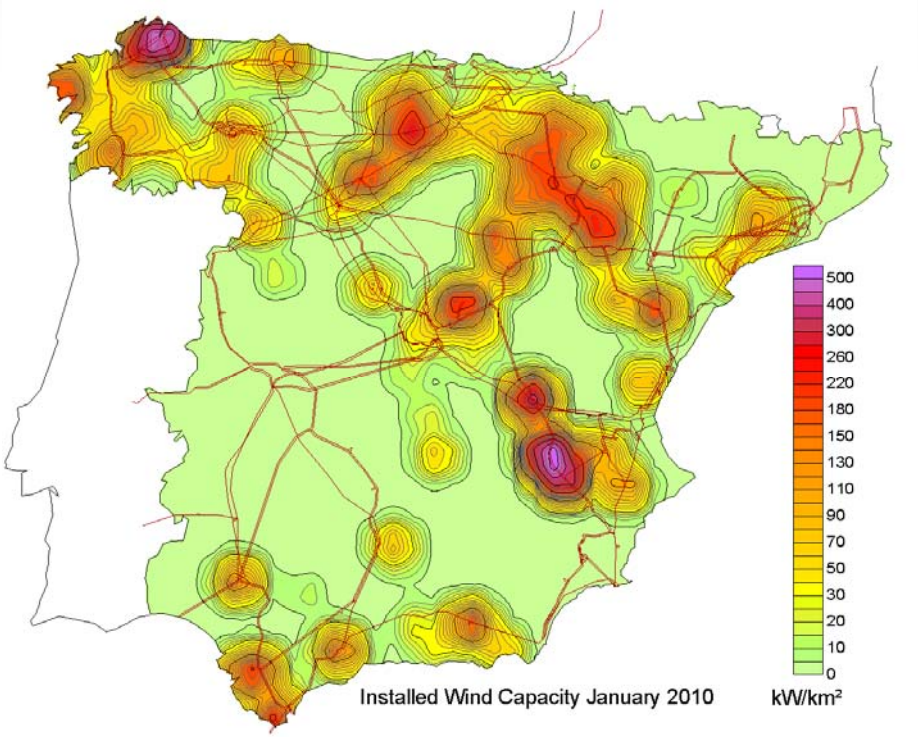
- **Maximum production: 12.916 MW (24/02/2010).**
- **Minimum production in one year: 164 MW (03/06/2009).**

- **Maximum coverage: 54% of demand coverage by wind energy (08/11/09).**
- **Minimum coverage: less than < 1% of the demand (27/08/09).**

RED ELÉCTRICA DE ESPAÑA

Wind power capacity: Present and evolution





Installed Capacity Expected for 2016:

- **Wind: 29 000 MW**
- **Solar: 4 500 MW**

Spanish regulatory framework (20/20/20)

Further increase expected for compliance with approved EC initiatives (20% of primary energy must come from renewable).

Renewable Generation
The prospects

RED ELÉCTRICA DE ESPAÑA

Particular features for the Spanish System within the European context, emphasise the ambitious objectives in renewables:

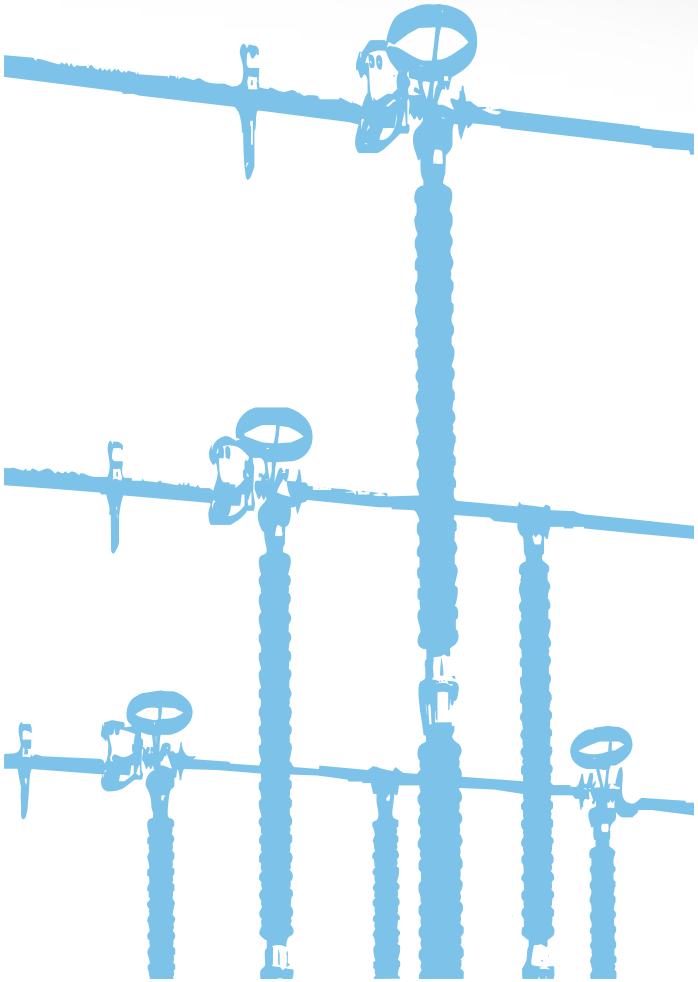
- **In 2010: 12% in Primary Energy (≈ 30% in electric energy)**
- **In 2020: 20% in Primary Energy (≈ 40% in electric energy)**

Generation: Main chapters in RES [MW]	**TODAY**	**FORESEEN**	
		2010*	**2020****
Wind Power: the most significant and **likely** chapter for the Spanish (and European) environmental objectives High expectation from Regional Adm. and agents, with a (currently) very good social support	≈ 18.800	20.000	*40.000*
Solar-Thermoelectric: quite certain and likely to increase	≈ 380	500	*6.000*
Solar Photovoltaic: recent boom due to expected retribution (> 1.200 MW by Sep.08)	≈ 3.300	370	*9.500*
Biomass: very uncertain	≈ 600	1.500	*1.800*

* Official Objective in regulation (approximate)

** Estimation (communicated provisionally to EC as an advance of the National Action Plan)

RED ELÉCTRICA DE ESPAÑA



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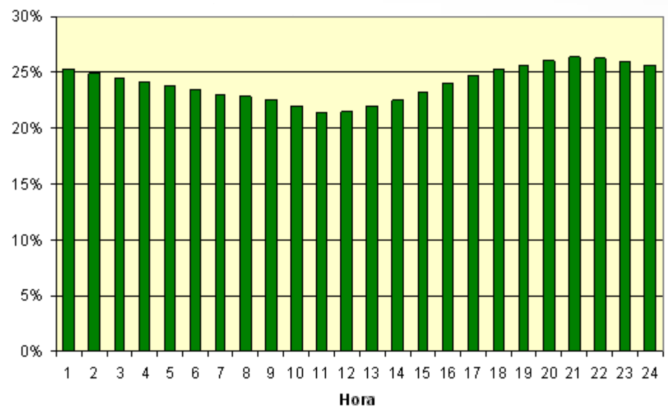
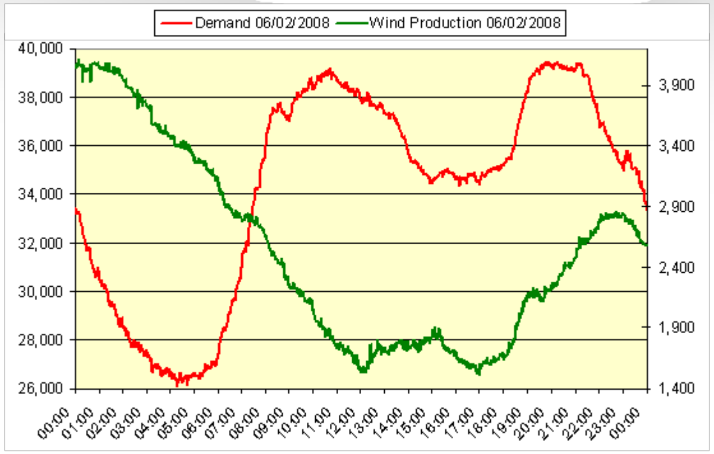
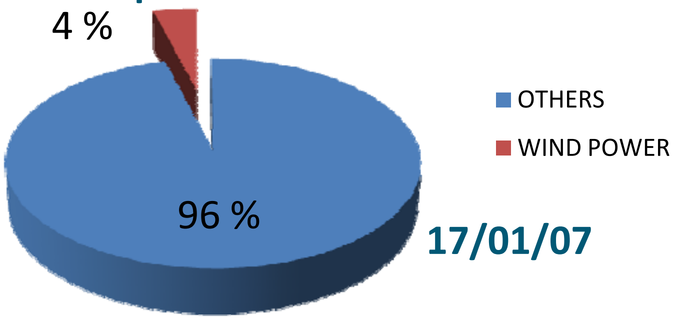
Production not correlated with consumption

HOURLY WIND PRODUCTION DISTRIBUTION (2009)

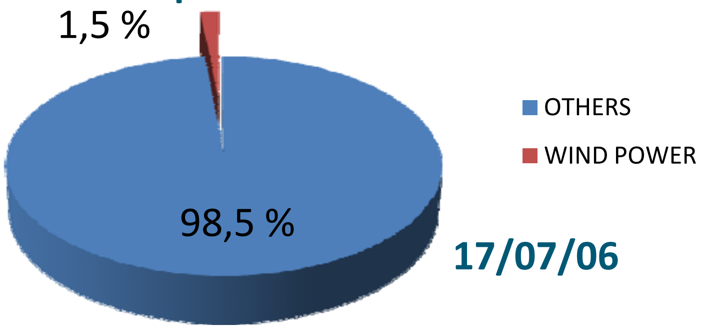




Demand supply: winter maximum demand Max. peak load = 45.450 MW



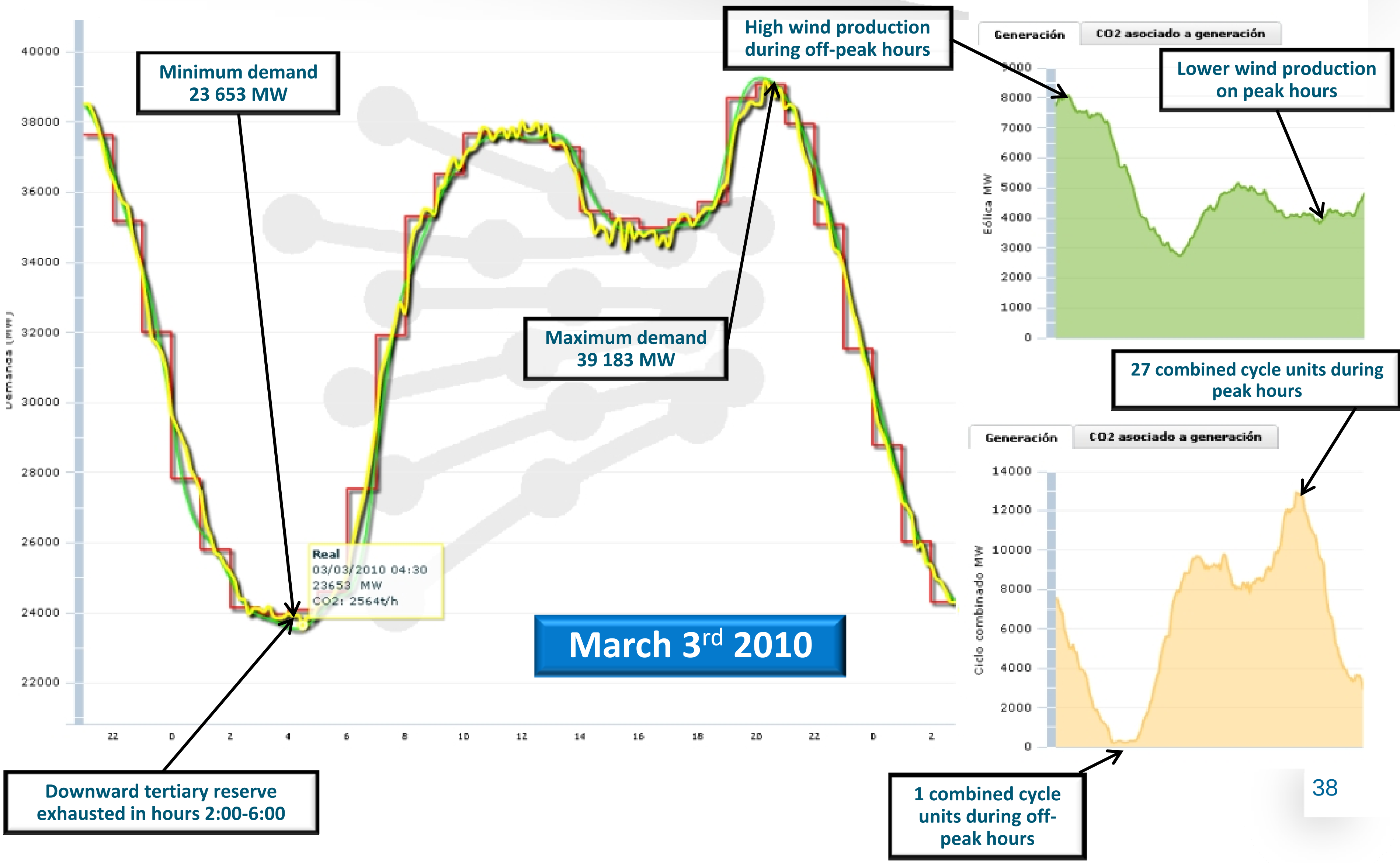
Demand supply: summer maximum demand Max. peak load = 40.730 MW



- **Wind production differs sometimes from demand requirements, specially in summer.**
- **During the mornings downward ramps in wind production often increase ramps of conventional generation.**

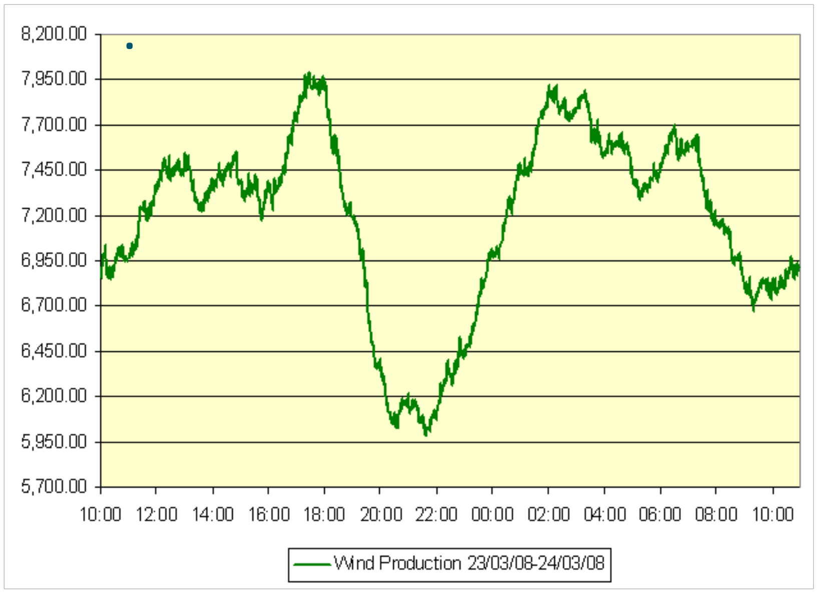
Balance feasibility during off-peak hours

RED ELÉCTRICA DE ESPAÑA



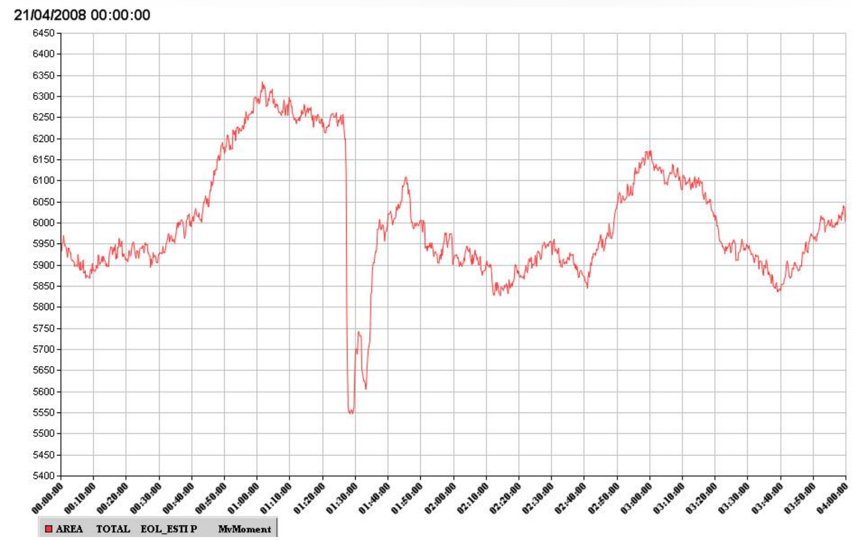
Wind turbines technology

Wind generation tripping due to their over-speed protection



- Wind generation trips if wind speed higher than 25 m/s.
- Wind power variation on this day: 1.800 MW.

Wind generation tripping due to voltage dips



- From January 1st 2008 all new wind facilities must comply with PO 12.3.
- Of the installed wind turbines:
  13.906 MW have been certified.
  1.500 MW have no fault-ride-through capabilities*

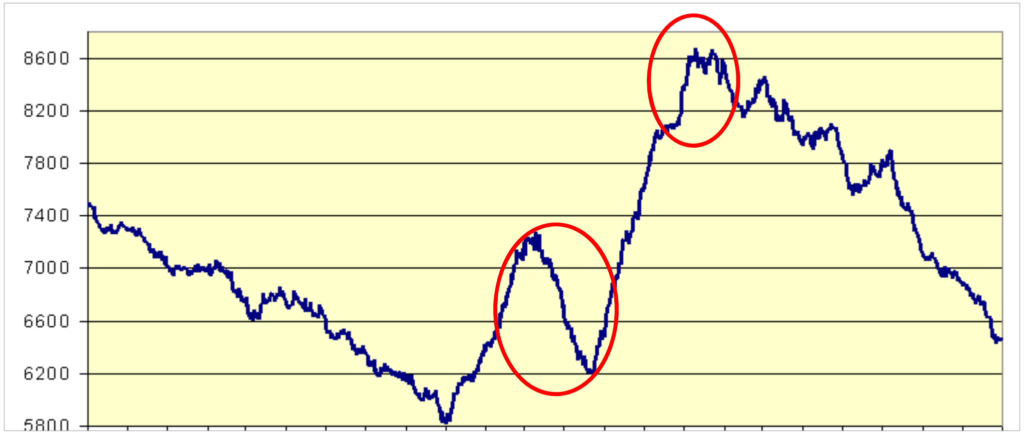
* Faults shorter than 100ms and voltages lower than 85% p.u.

RED ELÉCTRICA DE ESPAÑA

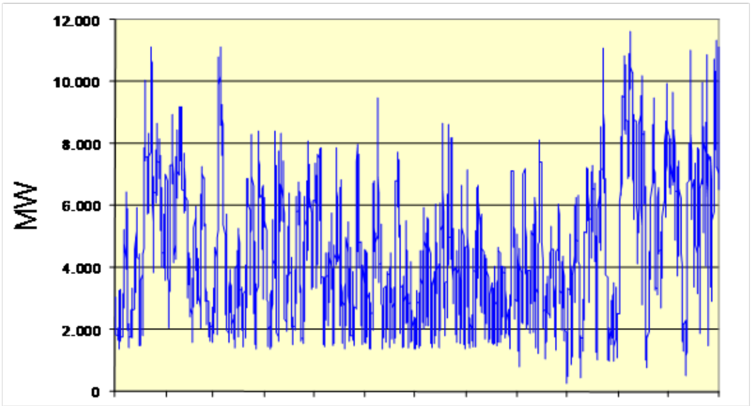
Wind production variability

- Increase of 586 MW in 30 min. Gradient: 1172 MW/h
- Decrease of 1110 MW in 1 h 25 min. Gradient: -785 MW/h
- Non manageable primary energy.
- Very variable production output.

WIND PRODUCTION VARIABILITY

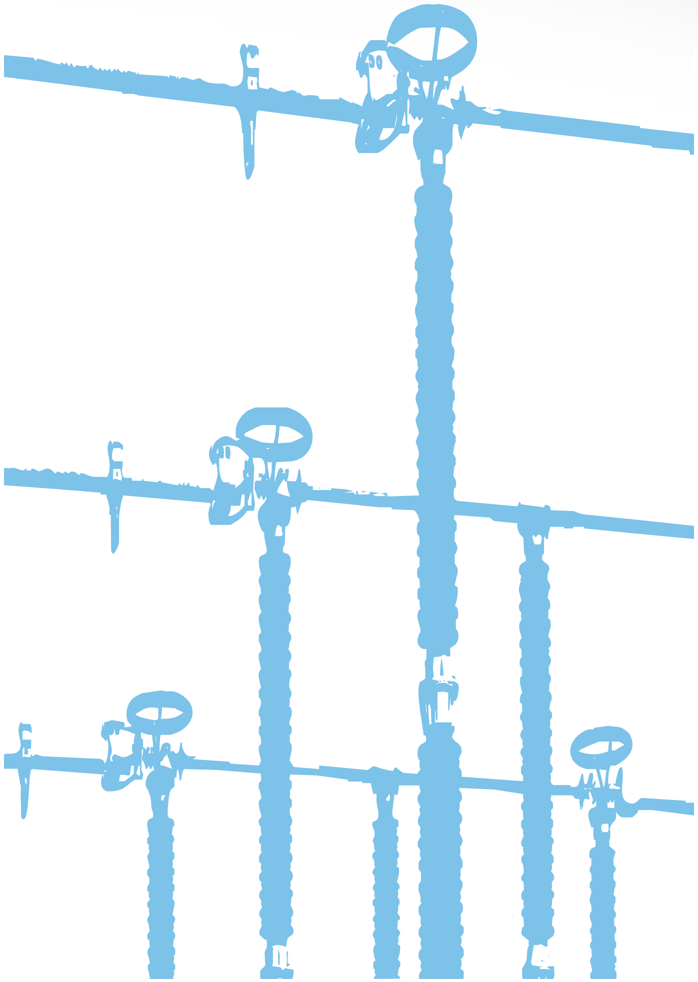


WIND PRODUCTION DURING A YEAR



- At present wind downward/upward ramps may reach ±1500 MWh.
- Wind forecast can mitigate the effects of wind variability for System Operation, but errors must be taken into account and additional reserves must be provided to overcome them.
- Larger forecast errors imply more provision of reserves increasing system costs.

RED ELÉCTRICA DE ESPAÑA



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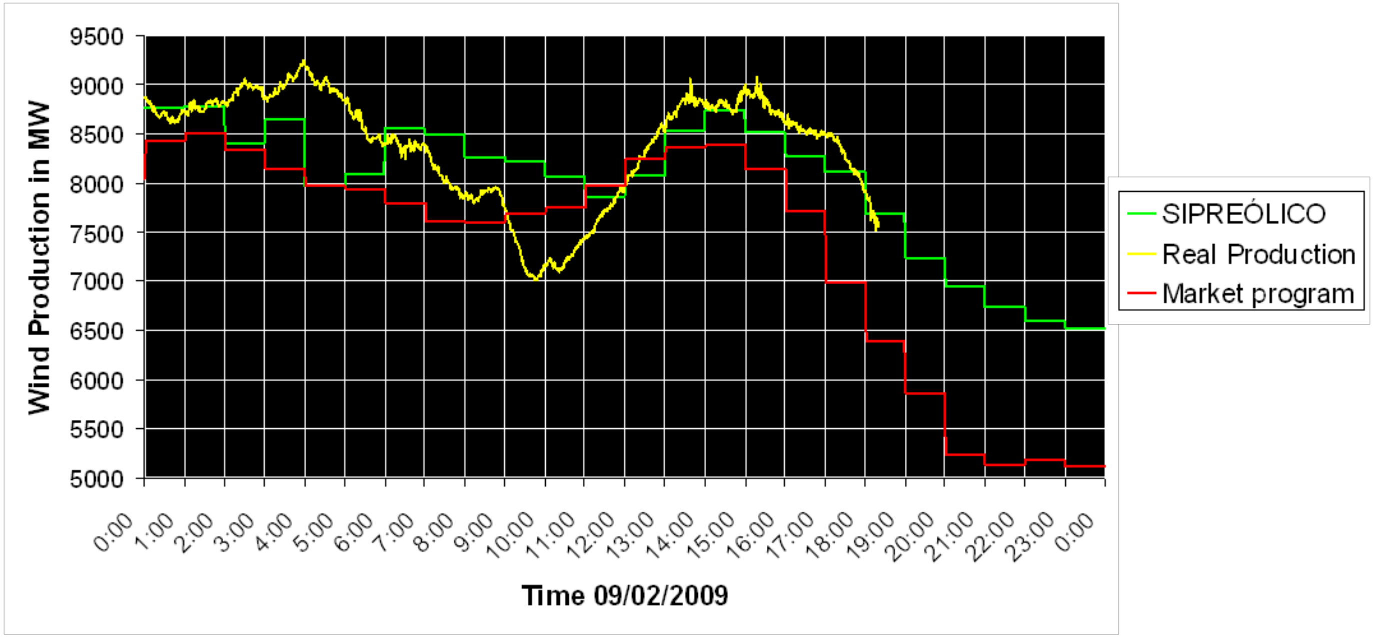
Wind forecasts available to the CECRE

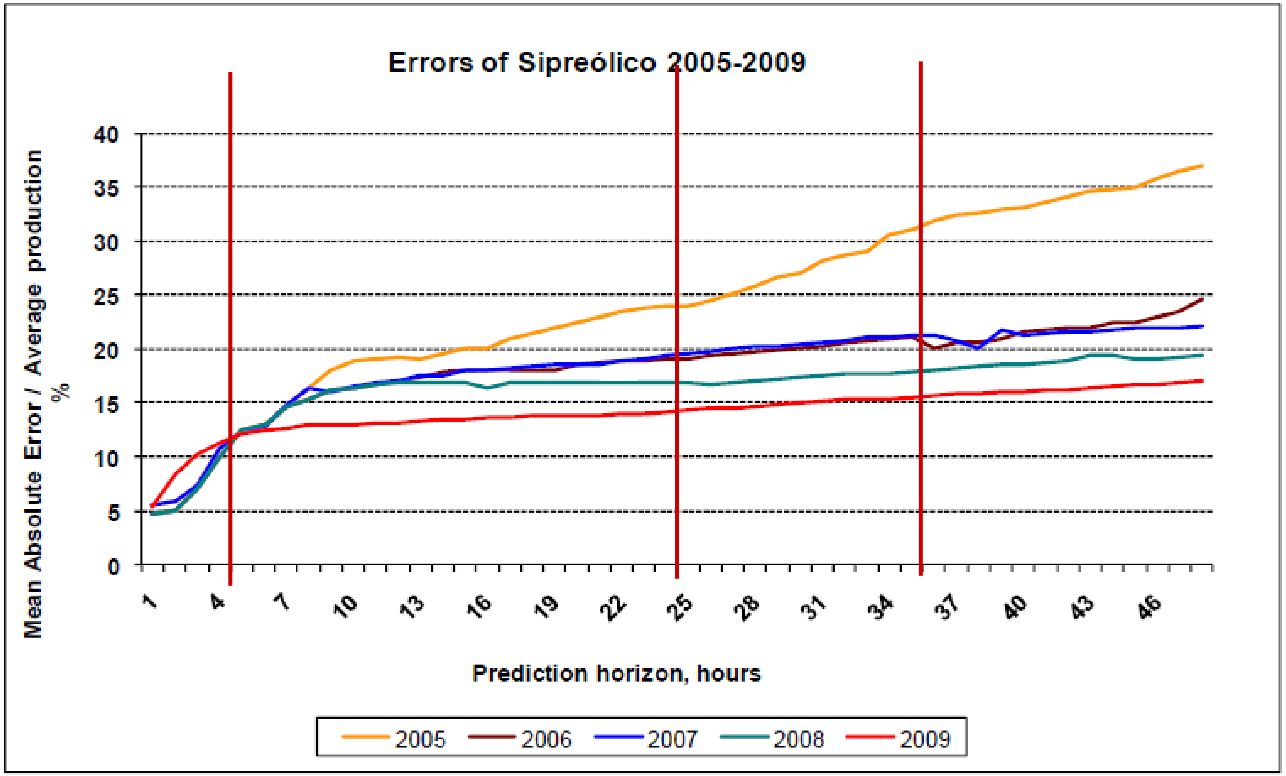
- In order to size reserves and to check the instantaneous need for manageable generation wind forecast becomes crucial for system balancing.
- REE has an internal forecast of all wind parks: SIPREÓLICO
  - Total hourly forecast for next 10 days (update 1 hour).
  - Hourly forecasts for next 48 hours by region or transmission system node (update 15 min.)
  - Hourly stochastic forecast of total production: percentiles 15, 50 and 85.
- Wind park programs matched in the daily market. Agent's forecast.



RED ELÉCTRICA DE ESPAÑA

Hourly forecasts error based on production for the next 48 hours

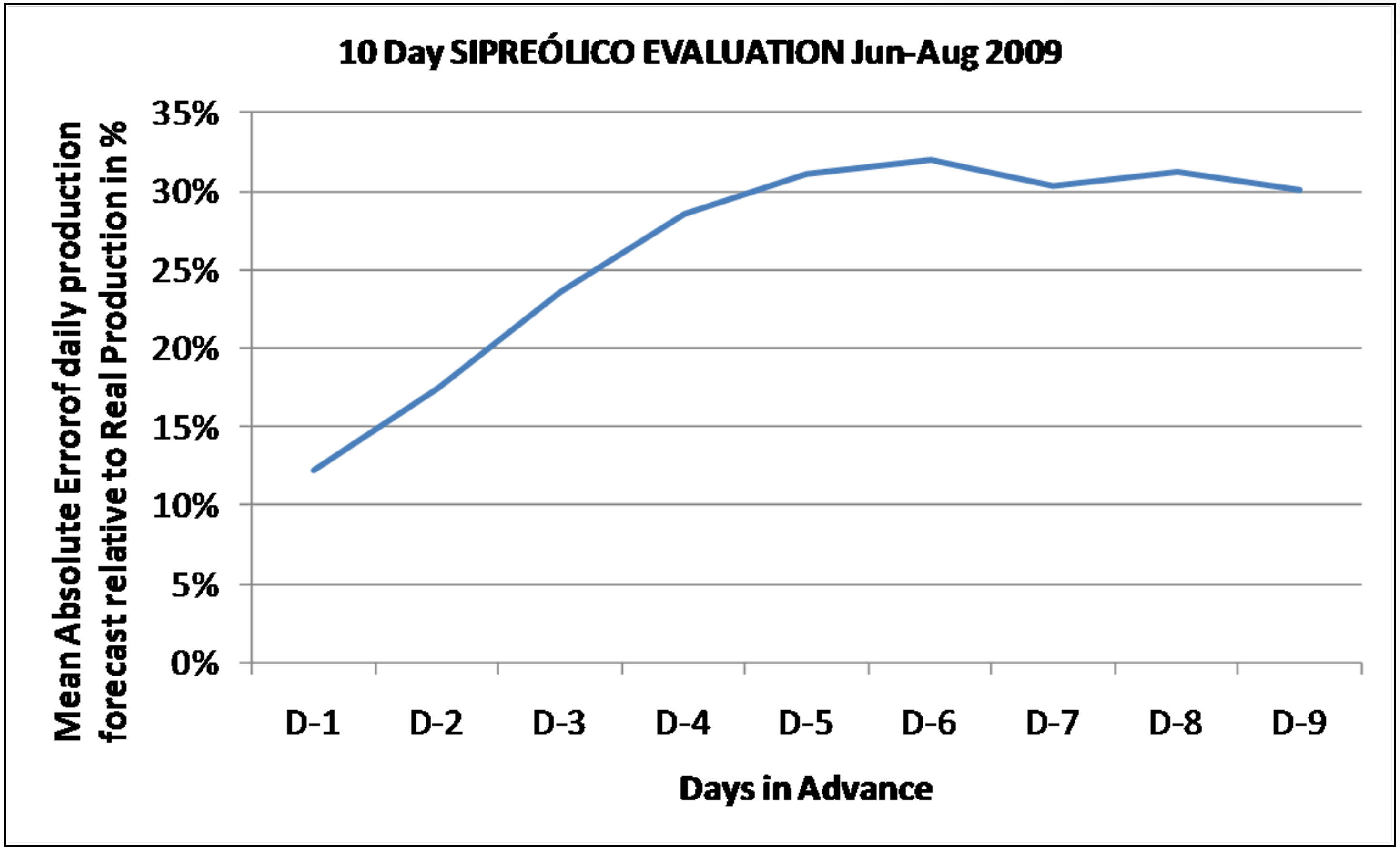
- Critical time horizons are 24 or 32 hours in advance for D-1 reserve evaluation and 5 hours for real-time evaluation.



- Positive evolution in forecast error in the last years has resulted in fewer need for reserves to cover wind forecast errors, specially in D-1.

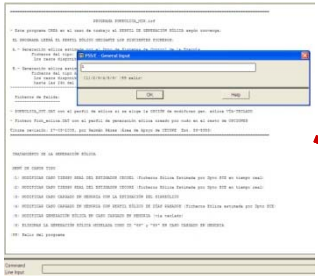
RED ELÉCTRICA DE ESPAÑA

Hourly forecasts error
based on production for the next 10 days

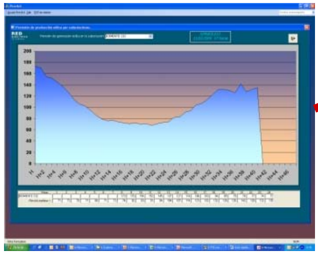


SIPREOLICO

- 73% of installed wind capacity is connected directly to the transmission network or to observable levels. Visibility in EMS and state estimator.
- Rest can be modeled in state estimator on its closest transmission system mode using PSS/E. Thanks to data provided to the CECRE.
- Forecast by transmission node can be modeled for future scenarios in PSS/E.

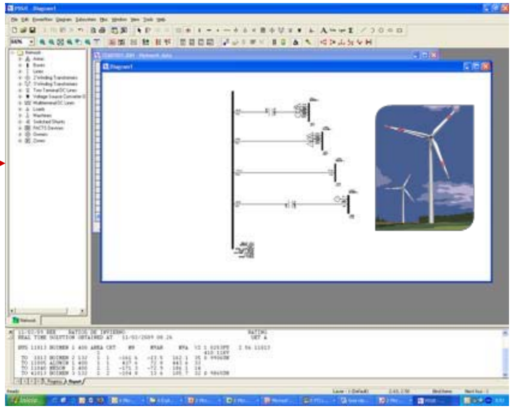


Future scenario



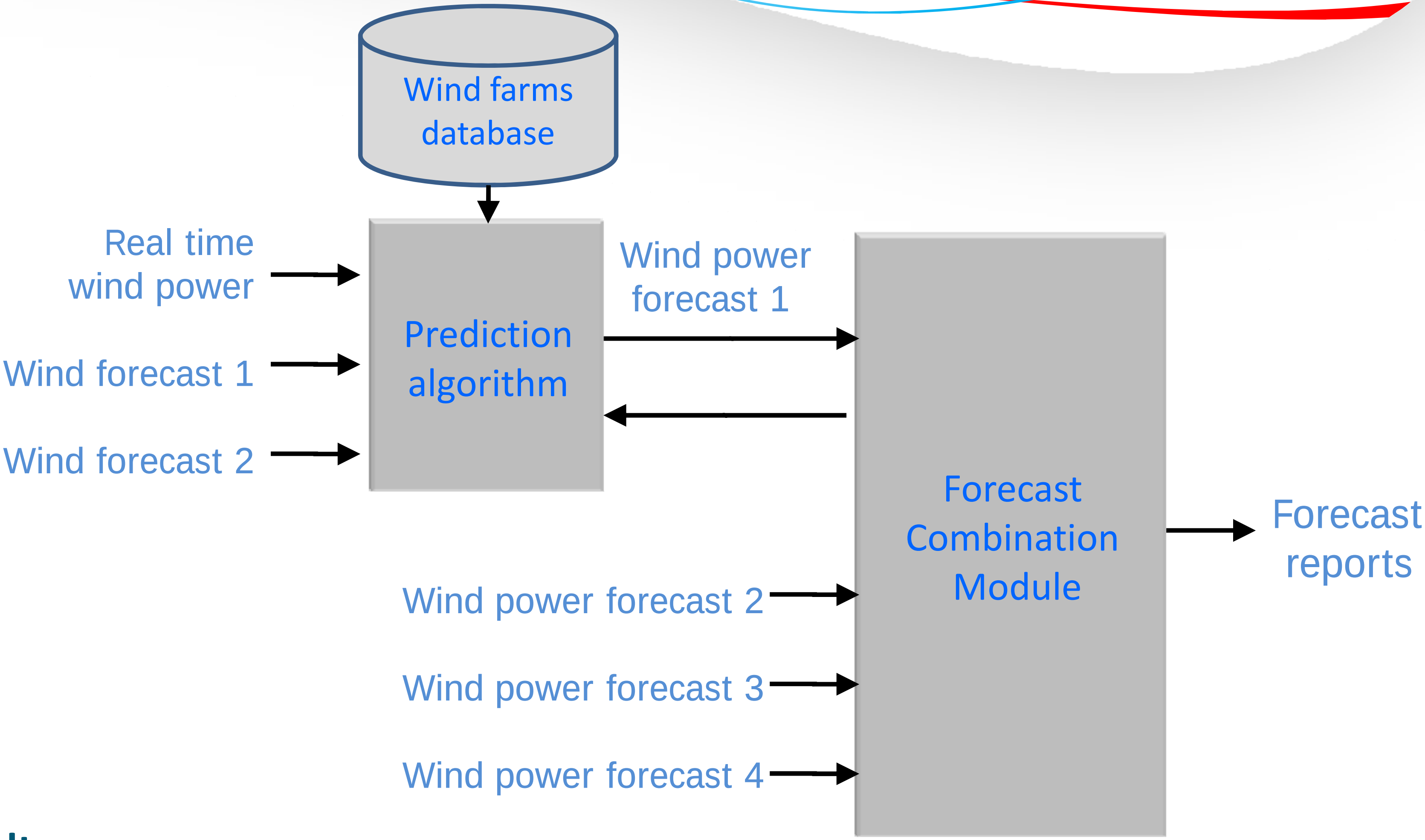
Nodal SIPREÓLICO

Future scenario with modeled wind forecast



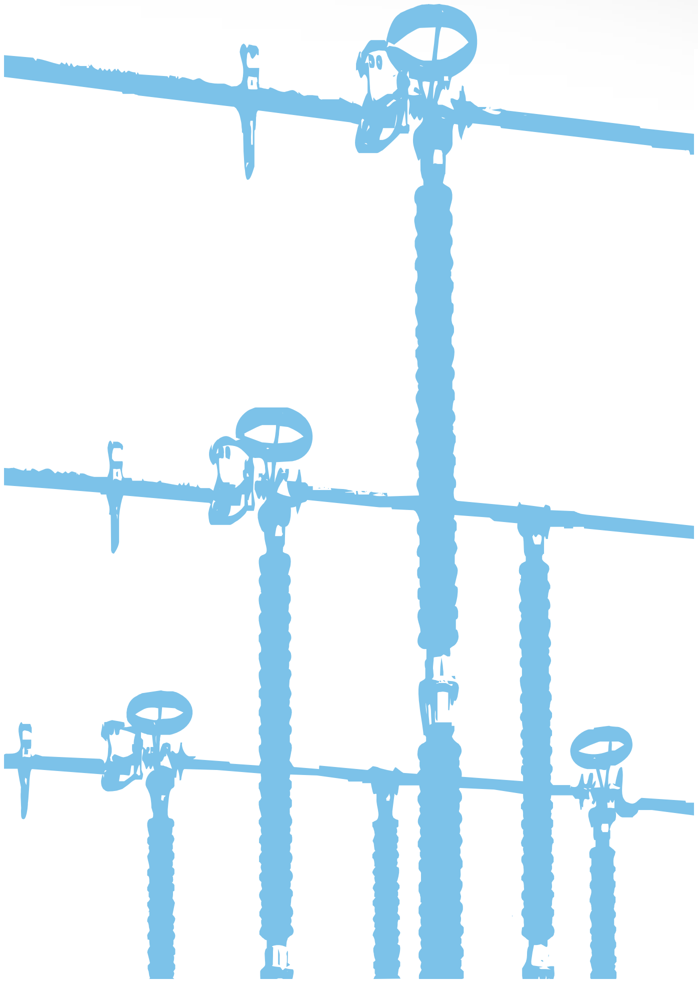
- Observability is important for integration as it allows the SO to monitor production and use it, along many other activities, to analyze wind forecast tools.

SIPREOLICO



Results:

- **Minute or hourly wind power forecast of a single park, group of parks or a larger area.**
- **Probabilistic output with confidence intervals. Useful for sizing of reserves.**



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Challenges integrating renewable energy for tomorrow

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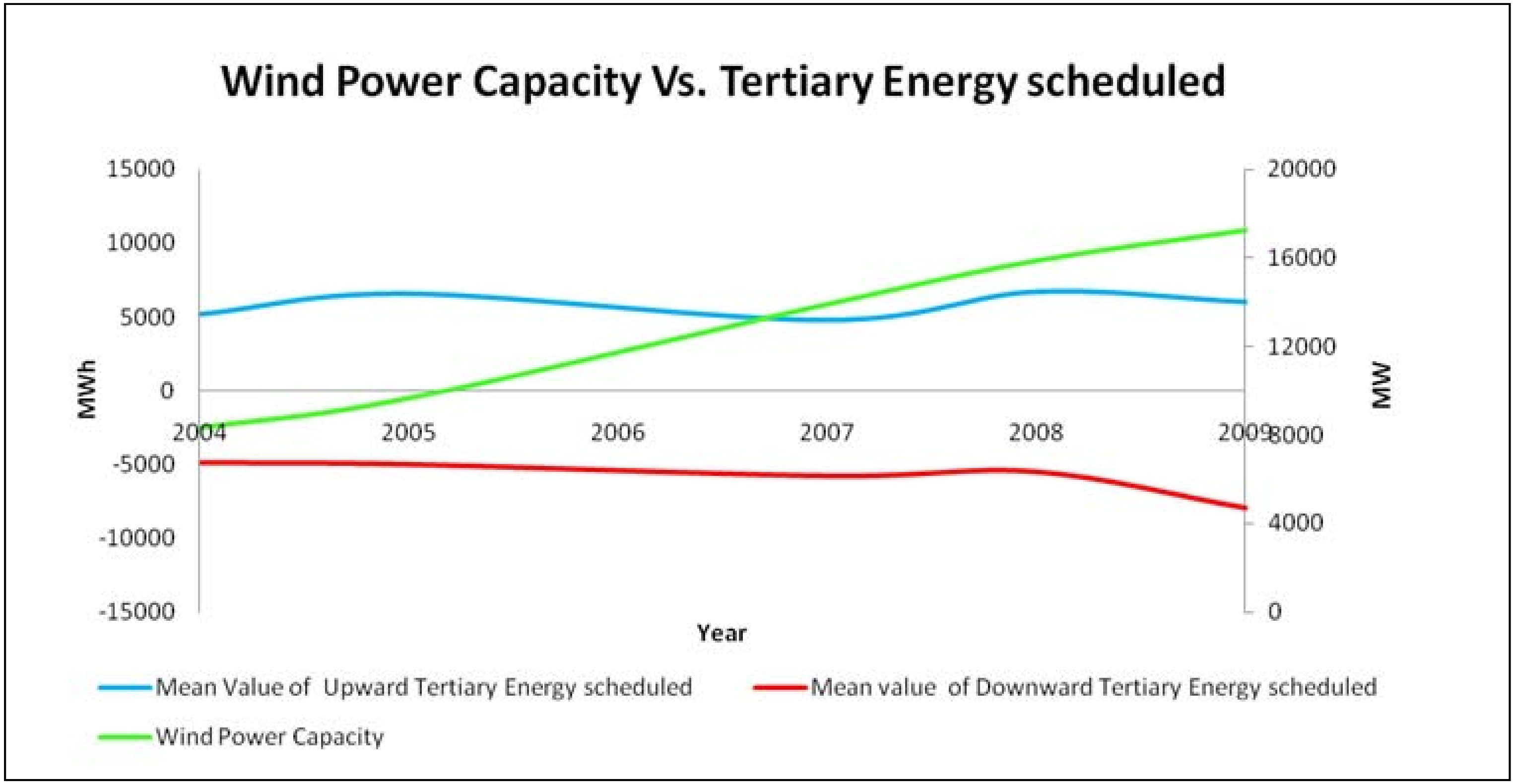
RED ELÉCTRICA DE ESPAÑA

Influence of wind power on system balancing reserves

Type	Definition	Influence of Wind Power on Reserve
Primary Regulation	Action of speed regulators from generator units responding to changes in system frequency (<30 s to 15 minutes)	Not influenced by wind power
Secondary Regulation	Automatic action of central algorithm and AGCs in the generation units that provide this service responding to changes in system frequency and power deviations with respect to France. (≤100 s to 15 minutes)	Only slightly affected by wind generation ramps when these ramps are opposite to system demand. Presently, no need to contract further reserve bands.
Tertiary Regulation	Manual power variation with respect to a previous program in less than 15 minutes. (<15 min to 2 hours)	Only slightly affected by wind generation ramps when these ramps are opposite to system demand.
Running Reserves or Hot Reserves	Manageable generation reserves that can be called upon within 15 minutes to approximately 2 hours. Include tertiary reserves and consist of the running reserves of connected thermal units and hydro and hydro pump storage reserves. (15 min-2 hours to 4-5 hours)	Significant influence of wind power. Reserve provision must be increased to take into account wind power forecast errors. Reserves are checked from day D-1 once market results are received until real time.

Tertiary energy scheduled

- **Tertiary energy scheduled is only slightly affected by wind generation ramps when these ramps are opposite to system demand.**

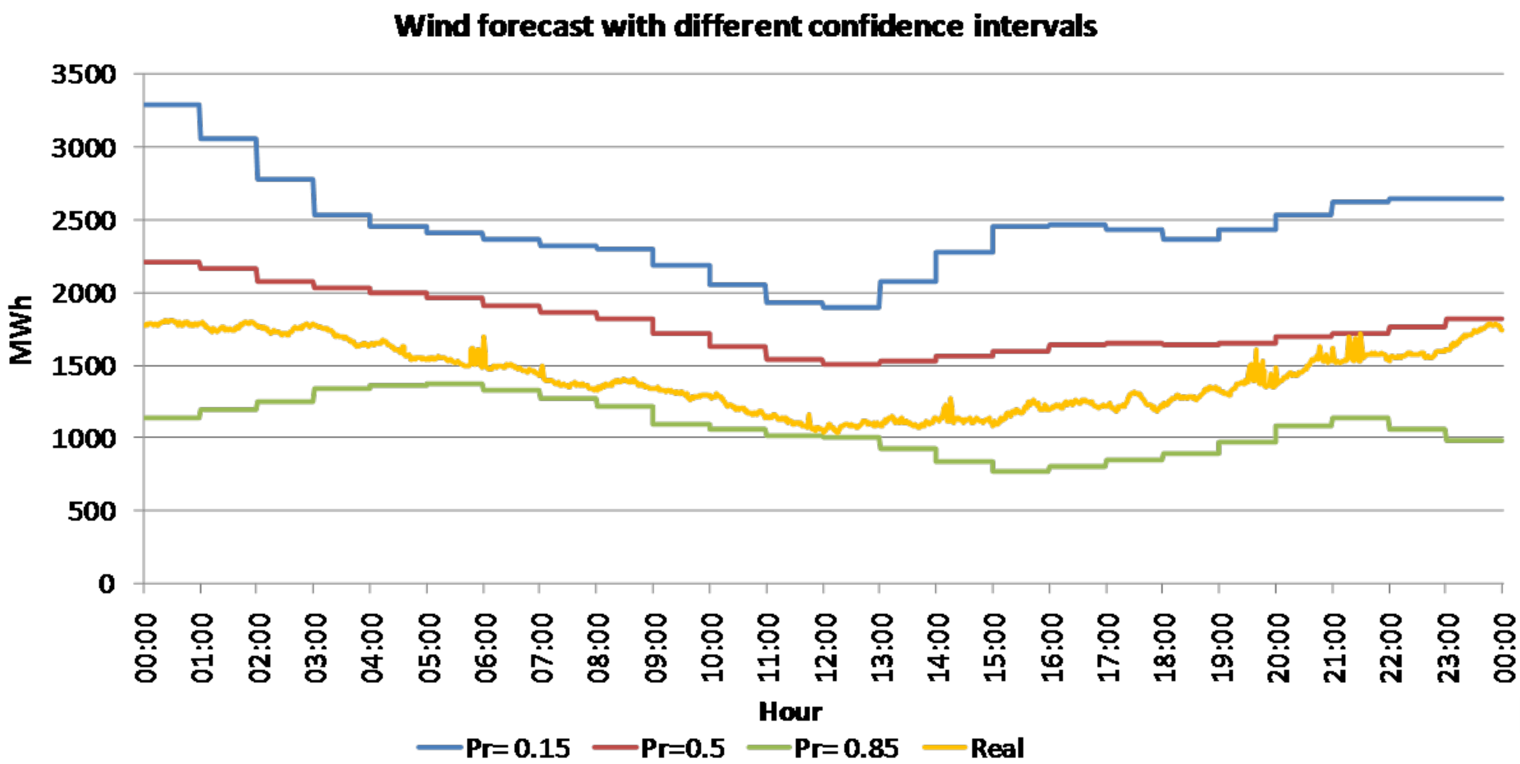


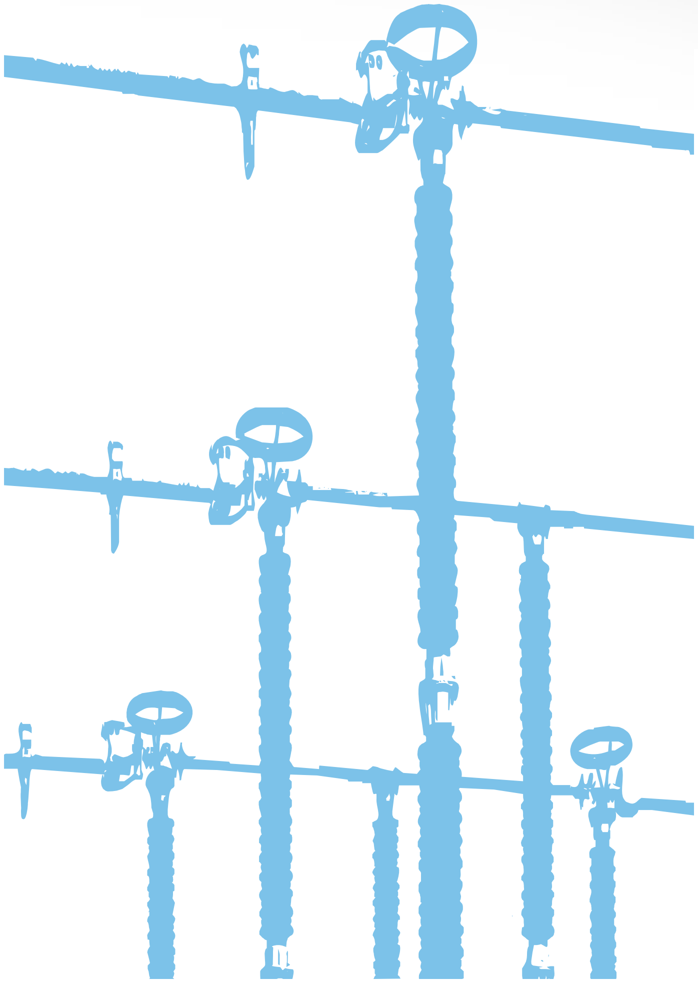
Running reserves scheduled

RED ELÉCTRICA DE ESPAÑA

Wind forecast use for reserve evaluation in D-1

- At 11:00 h in D-1 after market and bilateral contract programs are received, REE checks if there are enough available running reserves for the next day.
- Probabilistic wind forecast used. Percentile 85 of wind production greater than forecast.
- If reserves are not sufficient more thermal plants must be connected to the grid.





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Probabilistic running reserve level calculation

RED ELÉCTRICA DE ESPAÑA

- **Appropriate reserve requirements for load frequency regulation allows the TSO to overcome generation-load unbalances, but minimizing system costs and the generation ecological footprint.**
- **The required reserve levels at every moment are determined in the case of Spanish Power System mainly by the following variables:**
  - **Demand Forecast Error.**
  - **Wind Power Forecast Error.**
  - **Failure of the thermal generation units.**
- **Therefore, a deterministic reserve requirement level should be:**

  Reserve(t)=Demand.Forec.Err(t)+ Wind.Forec.Err(t) + Failure(t)

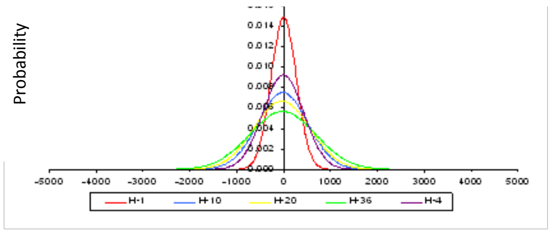
- **The previous variables, analyzed in a time range large enough, has an Stochastic behavior (i.e. random variable). Therefore is possible to calculate its probability density function:**

  pdf_Reser(x,y,z)=pdf_Err.Forec. Demand(x) * pdf_Err. Forec.Wind(y)*failure.(z)

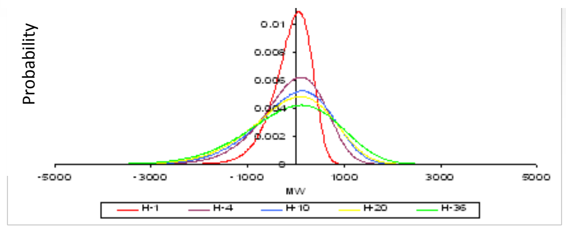
Where * represents the convolution between the different probability density functions that set the reserve levels.

Probability density functions

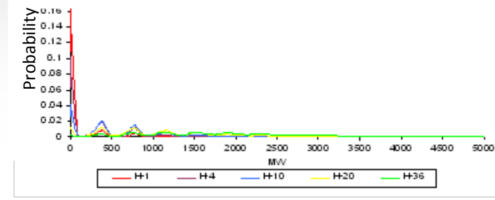
Probability density function of the Demand Forecast Error



Probability density function of the Wind Forecast Error

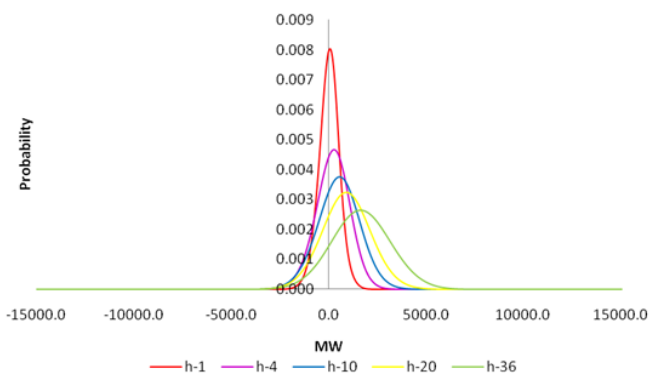


Probability density function of the Non availability units genaration

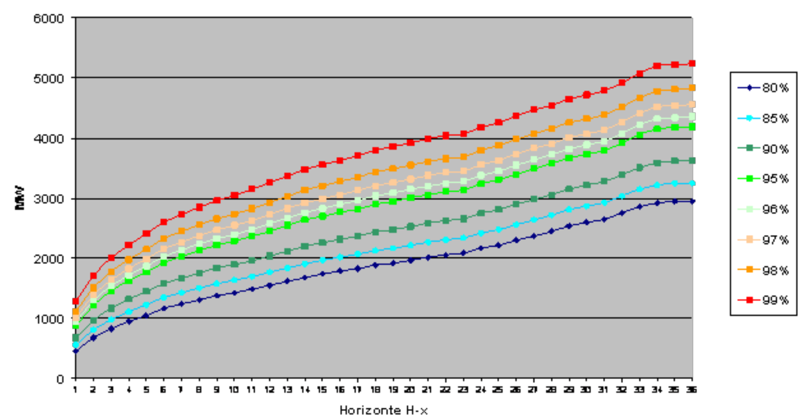


- The convolutions of the previous probability density functions leads to a new probability density function that represents the probability distribution for different time horizons.

Probability density funcion of the required margin

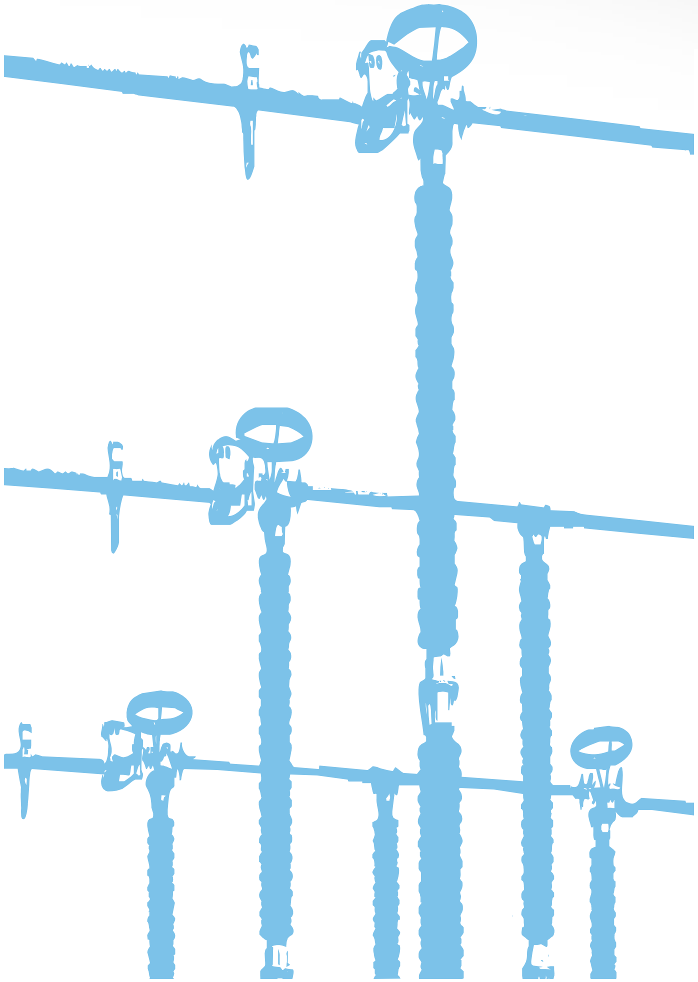


Required reserve margin vs Horizon



- With the help of the combined probability density function, the required reserve levels at different time horizons and with different confidence intervals can be calculated.

RED ELÉCTRICA DE ESPAÑA



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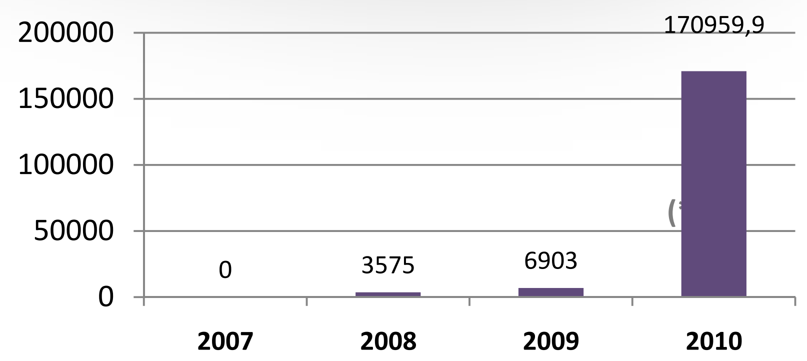
Real time actions to restore running reserves

- **Hot reserves will run out due to the combined influence of:**
  - Tripping of conventional generation plants.
  - Demand prediction errors.
  - Wind or solar forecast errors.
  - Wind generation tripping due to over-speed.
  - Not enough manageable generation connected to the grid (face peaks & deliver ancillary services)

Wind curtailments due to power balance feasibility (MW)



* Datos provisionales a 11.05.10.

- **In the case of running out of:**
  - Upward reserves during peak demands, additional thermal units may be switched on with a real-time re-dispatch.
  - Downward reserves during off-peak, thermal units may be switched off in real-time. If not done enough time in advance (wind prediction errors increasing rapidly) or more manageable generation could not be retired from the system, the TSO, as last resort may issue instructions to reduce wind park production.

Number of reductions due to integration problems:

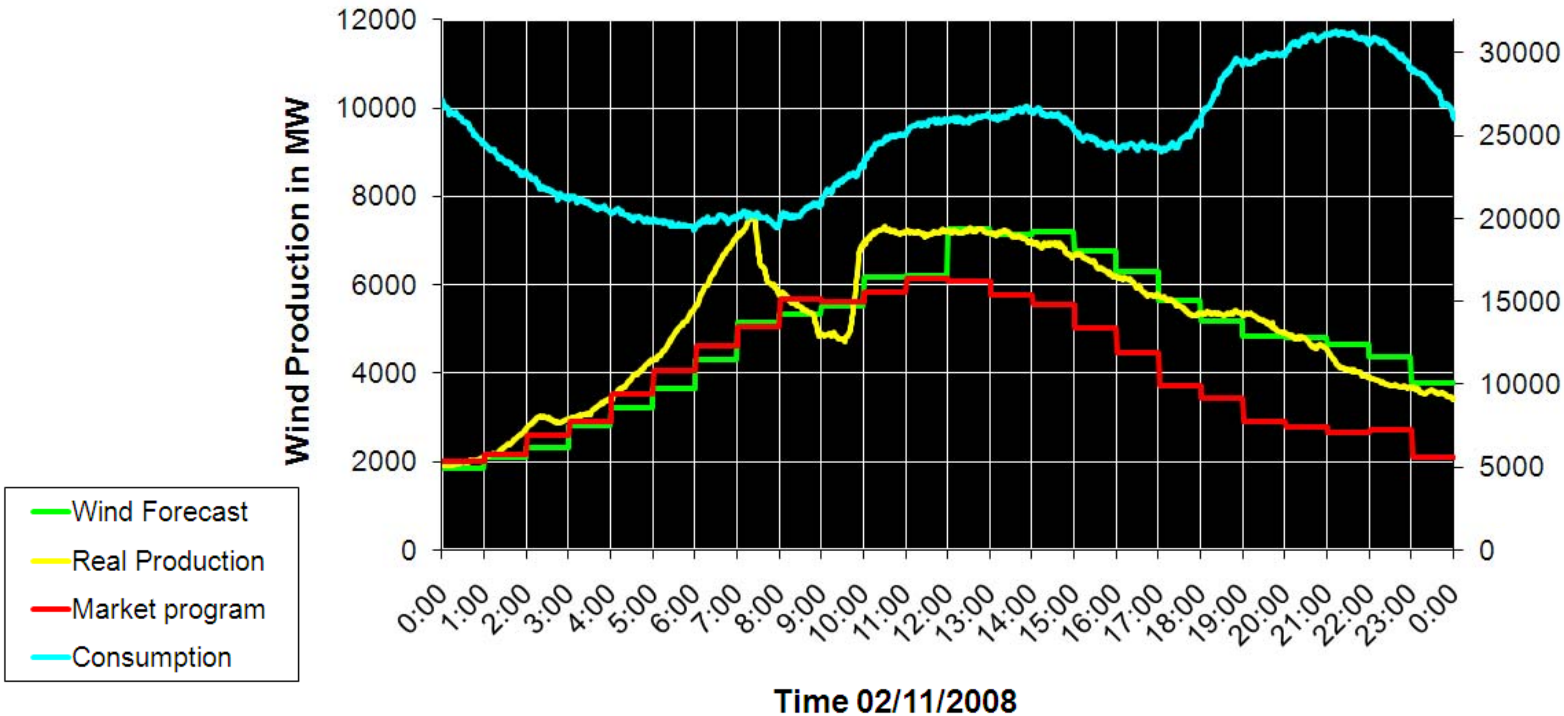
- 2 times in 2008
- 14 times in 2009
- 32 times in 2010 (in the first six months)

RED ELÉCTRICA DE ESPAÑA

Running out of downward reserve due to wind forecast errors

Wind reduction instructions, November 2nd 2008 (I)

- On the morning of Sunday November 2nd at 8:00 h with one of the lowest demands of the year (~20 000 MW), wind prediction error hit 3 200 MW.
- Increase in error from 5:00 to 7:00 h too fast to have time to shut down thermal plants.
- Spanish system ran out of downward reserves very rapidly and the only solution to balance the system was to decrease wind production from 7:22 to 9:30 h.

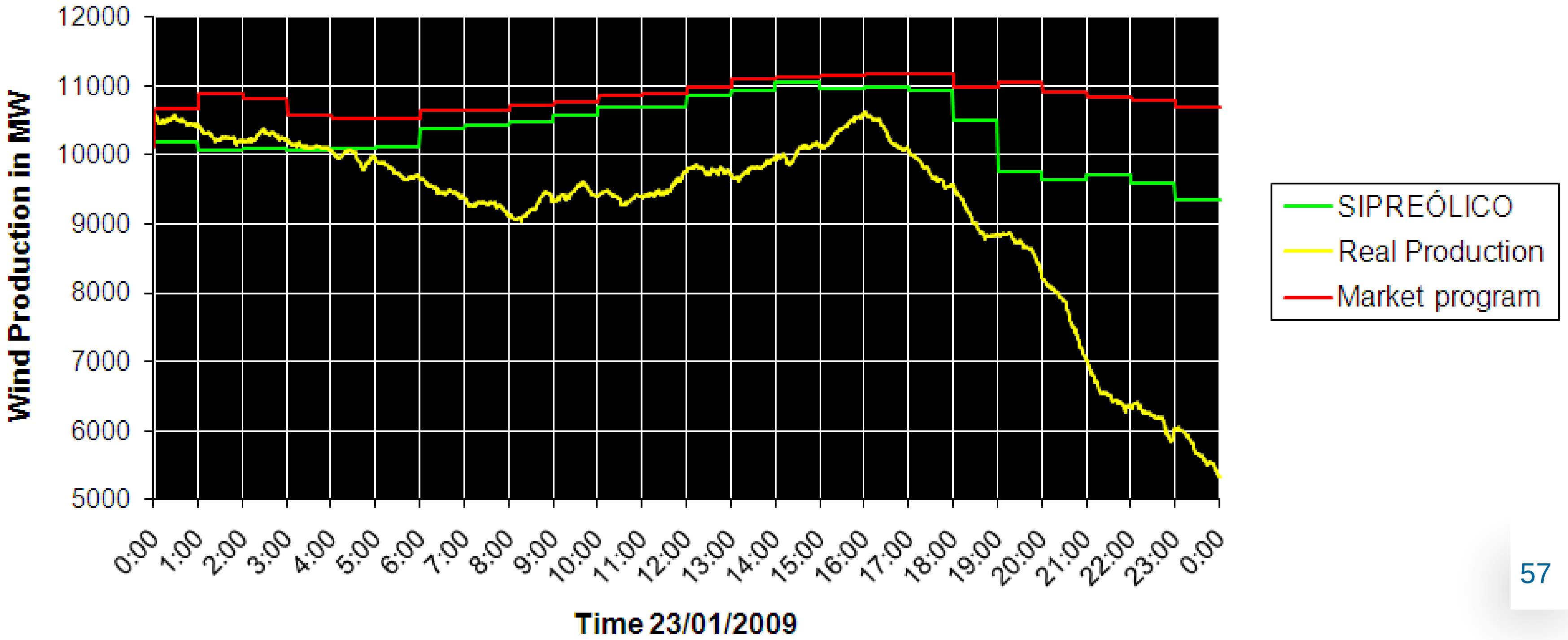


RED ELÉCTRICA DE ESPAÑA

Running out of upward reserve due to wind generation tripping

Wind reduction instructions, January 23rd and 24th 2009

- **January 23rd and 24th 2009: The storm Klaus. Winds up to 220 km/h hit the Iberian peninsula.**
- **Most turbines in the north of Spain shut down due to their over-speed protection.**
- **Difference between real and forecasted wind production was greater than 6 000 MW on some hours, but since demands were low and thermal plants were connected in real time due to alert situation there was enough upward reserve to deal with these errors.**



Voltage Control
RES generation

- **Before 1/4/2009**
  - **Reactive power bonus or penalization.**
  - **From +8 to -4% of 78.44 €/MWh depending on the power factor.**
  - **OS issue particular instructions for solving problems in certain nodes of the system.**

Reactive Power Bonus

Type of	Power Factor	Bonus (%)		
		Peak	Inter	Off-Peak
Inductive	< 0,95	-4	-4	8
	< 0,96 y ≥ 0,95	-3	0	6
	< 0,97 y ≥ 0,96	-2	0	4
	< 0,98 y ≥ 0,97	-1	0	2
	< 1 y ≥ 0,98	0	2	0
	1	0	4	0
Capacitive	< 1 y ≥ 0,98	0	2	0
	< 0,98 y ≥ 0,97	2	0	-1
	< 0,97 y ≥ 0,96	4	0	-2
	< 0,96 y ≥ 0,95	6	0	-3
	< 0,95	8	-4	-4

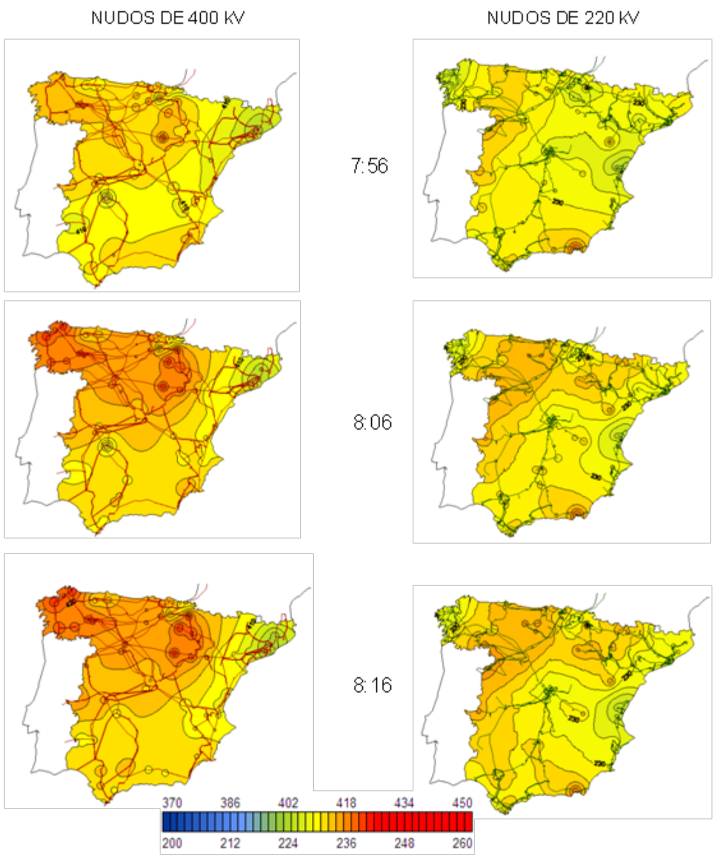
	Invierno			Verano		
Zona	Punta	Llano	Valle	Punta	Llano	Valle
Zona 1	16-22	8-16 22-24	0-8	8-14	14-24	0-8
Zona 2	17-23	8-17 23-24	0-8	9-15	8- 9 15-24	0-8
Zona 3	16-22	8-16 22-24	0-8	9-15	8- 9 15-24	0-8
Zona 4	17-23	8-17 23-24	0-8	10-16	8-10 16-24	0-8
Zona 5	16-22	7-16 22-23	0- 7 23-24	17-23	0- 1 9-17 23-24	1-9
Zona 6	16-22	7-16 22-23	0- 7 23-24	17-23	8-17 23-24	0-8
Zona 7	17-23	8-17 23-24	0-8	18-24	0- 1 9-18	1-9

- **Periods do not distinguish between labor days or holidays so producers might behave contrary to system requirements.**
- **In reality it leads to simultaneous connection/disconnection of capacitors.**

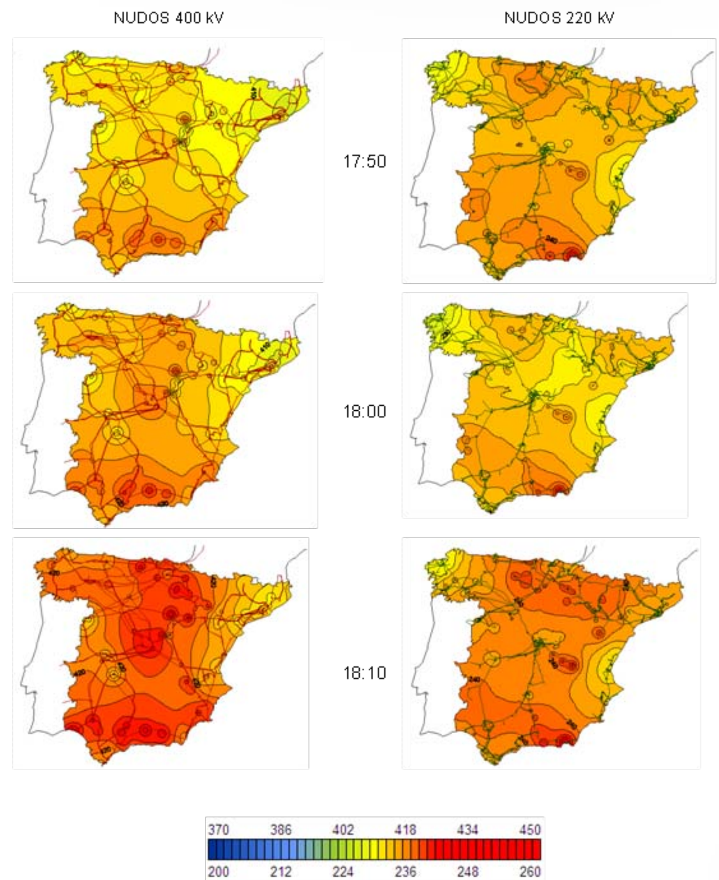
Voltage Control
RES generation

RED ELÉCTRICA DE ESPAÑA

Voltage variations during off peak to peak periods (9/3/2009)



Voltage variation during intermediate to peak periods. (7/2/2009)



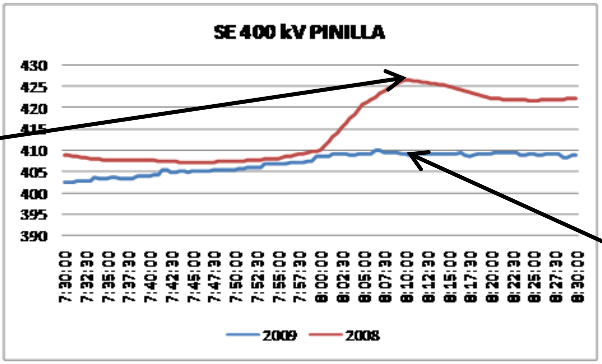
Voltage Control
RES generation

- **From 1/4/2009:**
  - **All the special regime installations higher than 10 MW are obliged to maintain an inductive power factor between 0.98 and 0.99.**

    In order to:
    - Eliminate sudden changes in the voltage profile corresponding to the transitions off peak-intermediate-peak periods.
    - Avoid high voltage problems in the system.

- **Effectiveness of the measure. The sudden change in the voltage profile disappear.**

23/3/2008.
Minimum demand: 19 997 MW.
Wind production (8:00 h): 7.160 MW



12/4/2009.
Minimum demand : 17 666 MW.
Wind production (8:00 h): 5.460 MW

Voltage profile in 2008 and 2009 Easter Holiday

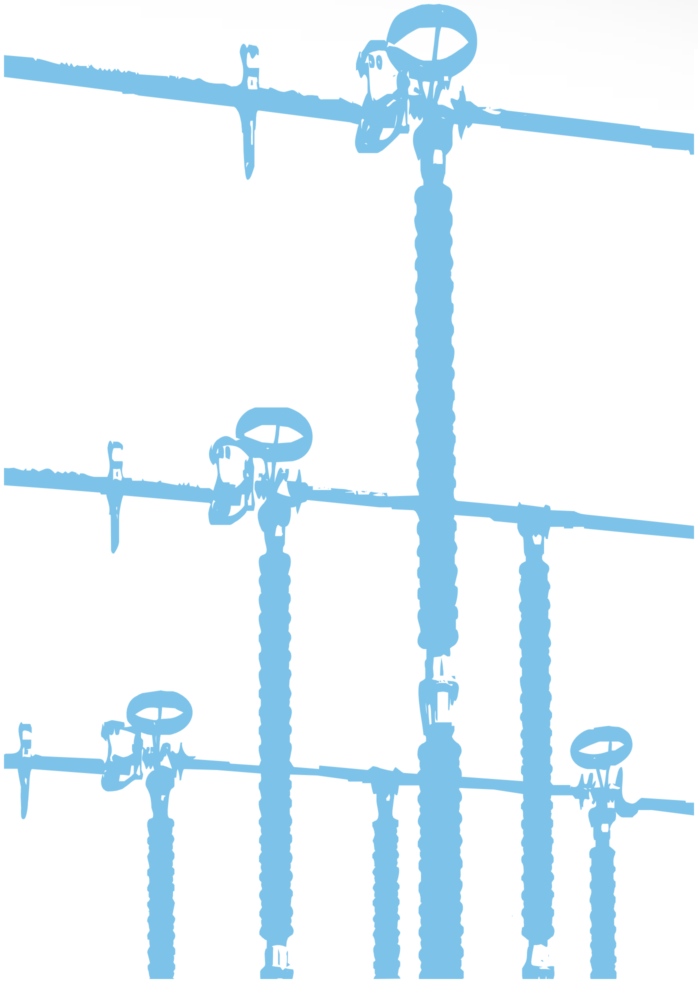
- **Final Solution:**

Voltage control with set-points issued by the CECRE and dynamic voltage support

Wind power dispersion

- More than 700 wind farms, each belonging to different companies with different policies for operation, switching and maintenance and hidden from the System Operator.
- Very slow contact in case of emergency reductions, outages or maintenance planning of the transmission assets next to connection points for generation.
- If actions and supervision takes longer and risks are higher, stricter limitations must be in place and planned further in advance reducing RES production and installation.

- Solved by grouping facilities in control centers with real-time contact with the System Operator through the CECRE.



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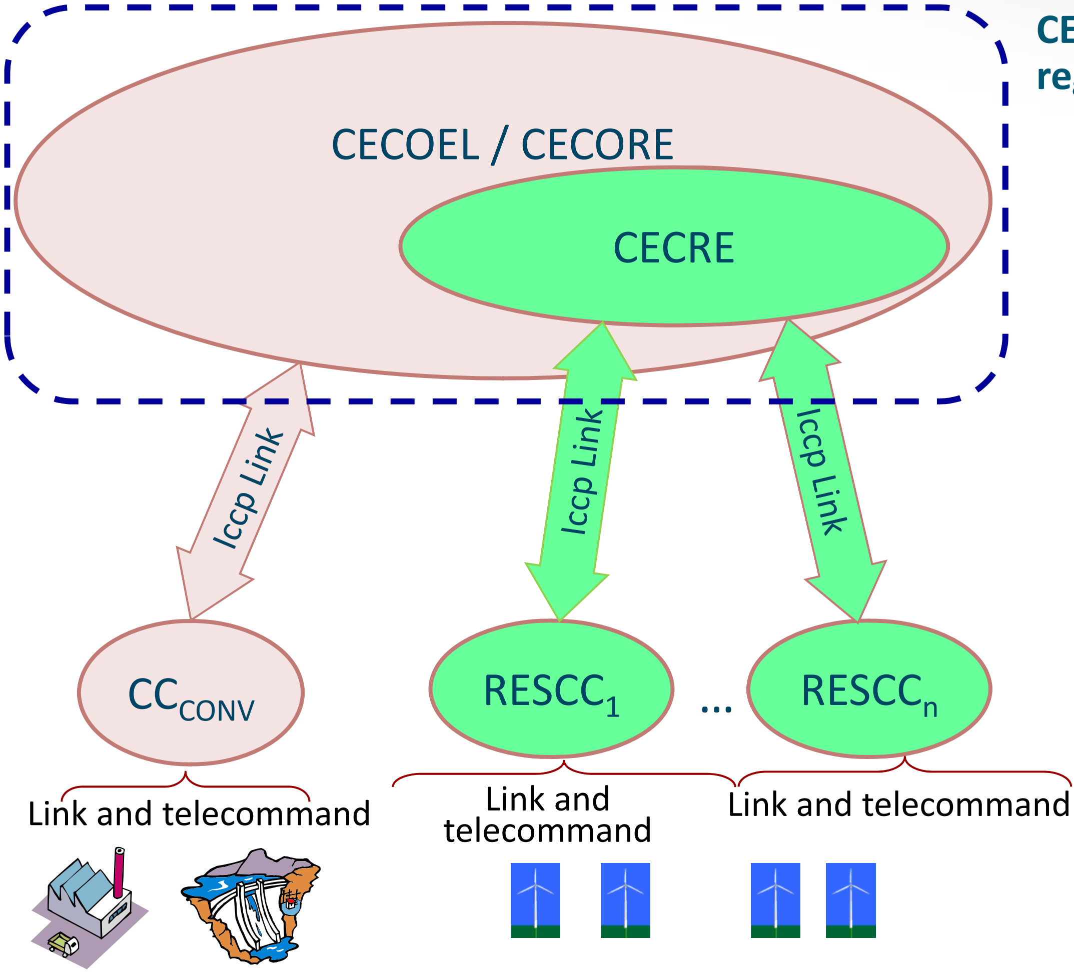
Control Centre for Renewable Energies (CECRE)

CECRE: Functional Scheme

RED ELÉCTRICA DE ESPAÑA



RESCC: Renewable Energy Source Control Centre

CC$_{CONV}$: Control Centre for conventional generation

CECRE is a control centre devoted to special regime generation and specially to Wind Power:

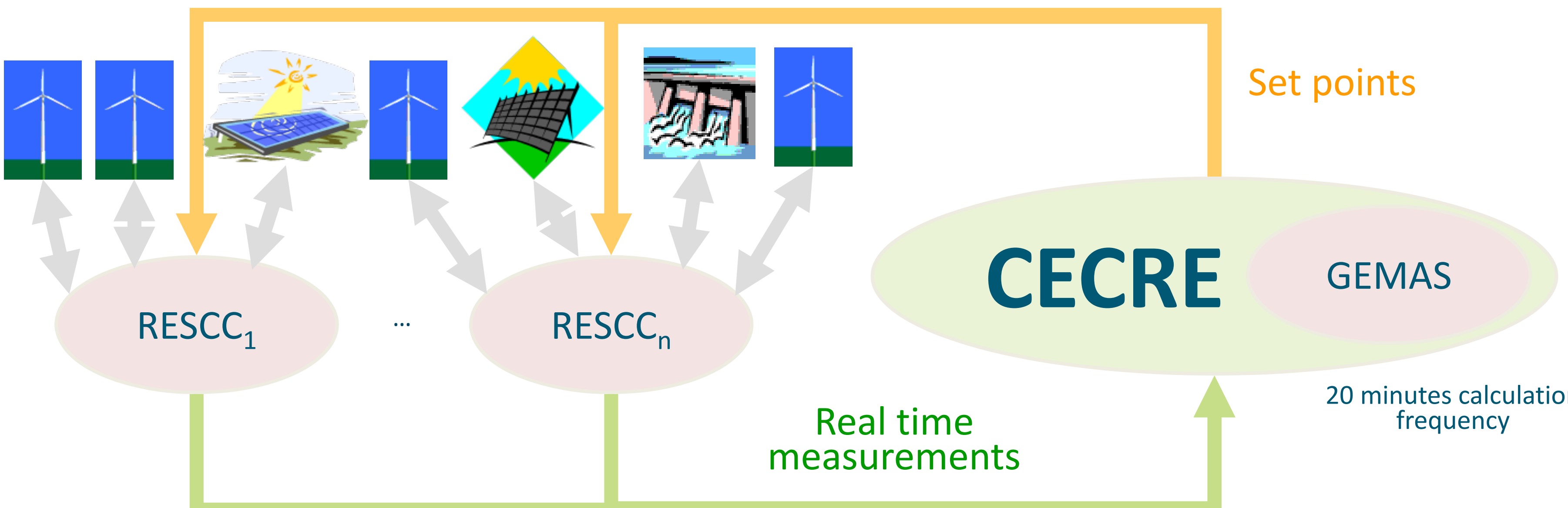
- **Integrated in REE's control structure.**
- **Communication with generation Control Centres for supervision and control instructions.**
- **According to RD661/2007 all special regime facilities >10 MW must be connected to a RESCC.**
- **CECRE issues generation limitations through the SCADA system to the Control Centres.**

Special Regulation Regime

Renewable:	Non Renewable:
Minihydro	Cogeneration
Biomass	Coal
Wind	Fuel - Gas oil
Industrial waste	Refinery gas
Urban waste	Natural gas
Solar	

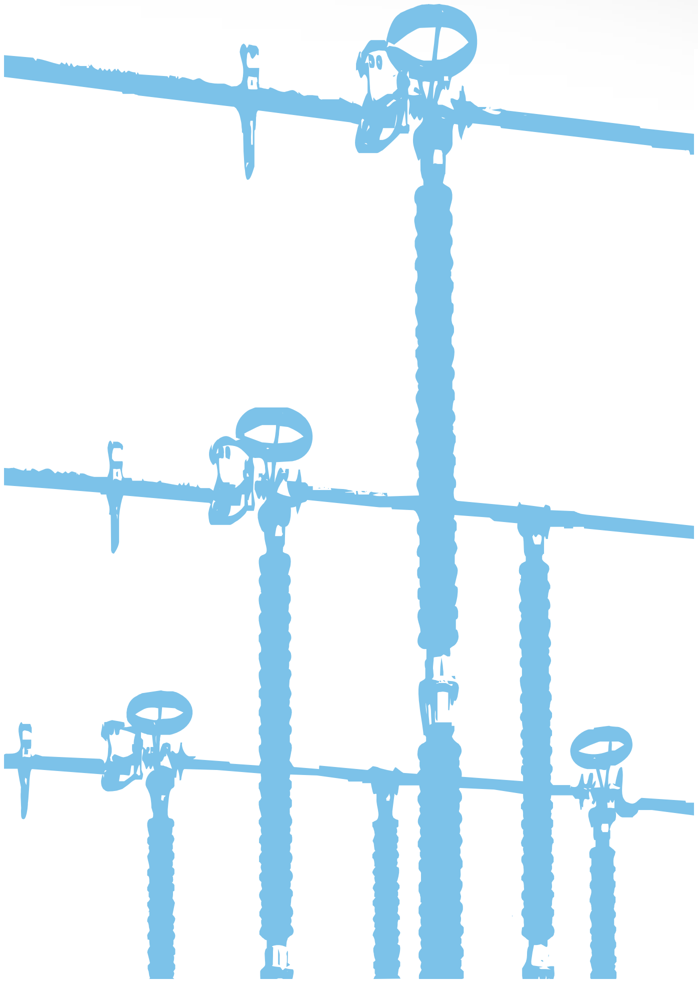
Checking the security with the real-time wind scenario

- **CECRE analysis in real time the maximum wind generation supported by the system.**
- **If curtailments are needed, wind generation set-points are calculated and sent.**
- **Wind parks must adapt their production to the given set-point within 15 minutes.**



- **Presently only done for wind generation, but a similar methodology can also be applied for all renewable energy sources.**

GEMAS: Analysis in real time the maximum wind generation supported by the system.



System Overview

Market integration of renewable energy

- Technical Constraints management
- Deviations from schedule

Renewable energy in Spain today

Challenges integrating renewable energy nowadays

- Wind forecast and use in reserve calculation
- Influence of wind power on balancing reserves
- Probabilistic sizing of reserves
- Real time actions to restore system reserves
- Control centre for renewable energies (CECRE)

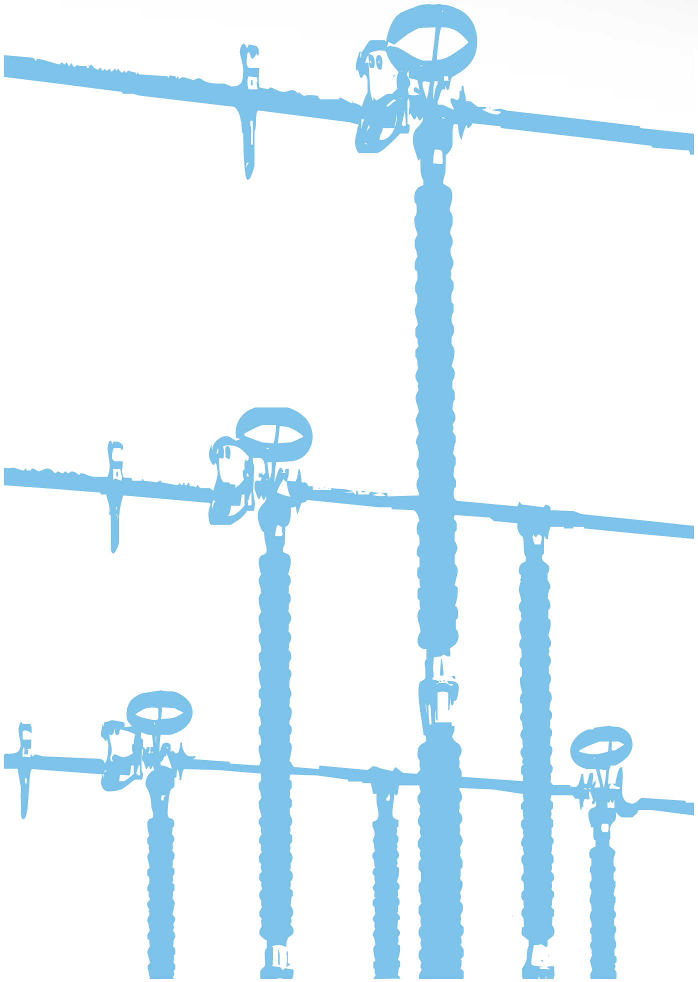
Challenges integrating renewable energy for tomorrow

Conclusions

Challenges for the future

- **Short term measures: 2011 (20 000 MW wind installed capacity)**
  - **Balance feasibility in off-peak hours could be an issue now.**
  - **Voltage control with set-points issued by the CECRE and dynamic voltage support.**
  - **Voltage dip tripping should no longer be a problem due to compliance with the grid code.**

- **Long term measures: beyond 2011 (up to 40 000 MW wind installed capacity)**
  - **Capability both technical and economical for wind generation to provide frequency control (primary reserve, inertia emulation…).**
  - **Increase the international exchange capacity.**
  - **Storage such as hydro-pump units and very fast thermal plants (open cycle gas turbine).**
  - **Correlation between wind and solar production.**
  - **Evolution of wind and solar forecast.**
  - **Demand side management.**



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RED ELÉCTRICA DE ESPAÑA

Conclusions

- Integrating non manageable generation is a challenging task: Low availability, production not correlated with consumption, lack of firmness of generation programs and power balance difficulties.

- Although these, CECRE and the RESCC have helped to reach a high penetration of special regime generation in the System making these technologies compatible with security of supply.

- There is not a significant influence of the present wind capacity on primary, secondary or tertiary reserves.

- Wind forecast has been improving in the last years, being now a basic tool for hot reserve evaluation. Its accuracy for time scopes from 5 hours to 24 hours in advance affect required levels of reserve and helps dispatching manageable generation to counteract wind fluctuations.

- Some days due to the lack of downward reserve wind energy reduction are unavoidable in order to keep system balance. Thanks to the CECRE and the RESCC curtailments take less time to be done so we could plan and place less stricter limitations increasing RES production and installation.

Thanks for your attention!