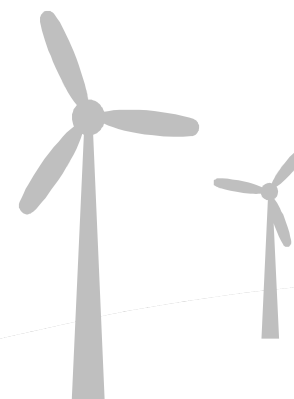




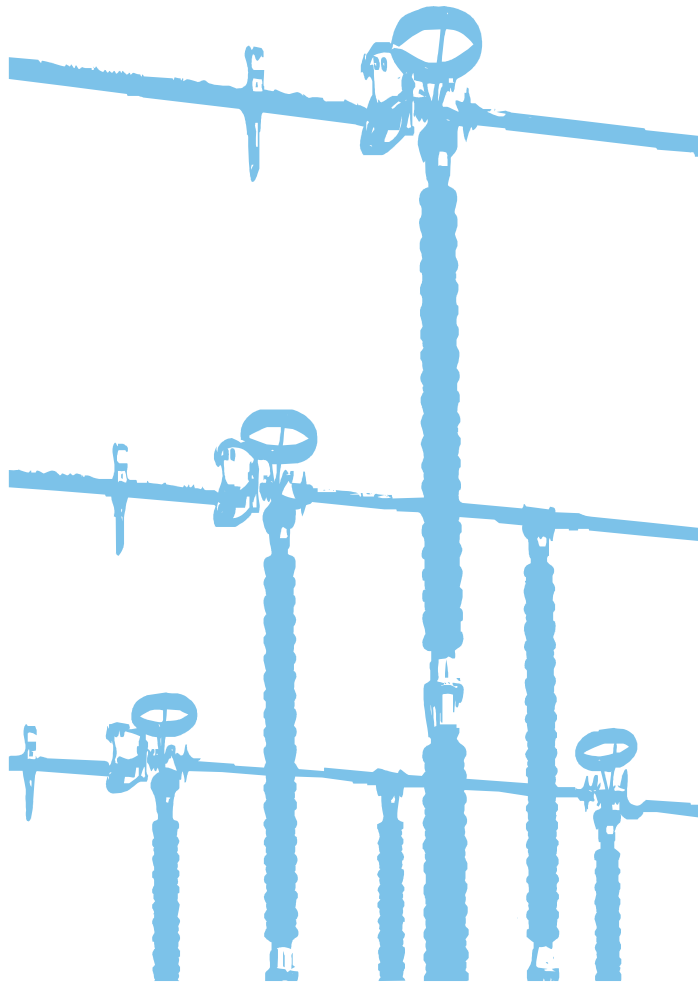
**RED**  
**ELÉCTRICA**  
DE ESPAÑA



## Ancillary Services in Spain: dealing with High Penetration of RES

Ignacio de la Fuente





## Brief review of Spanish Ancillary services scheme

Renewable energy in Spain today

Challenges integrating renewable energy nowadays

Wind forecast and use in reserve calculation

Influence of wind power on balancing reserves

Real time actions to restore system reserves

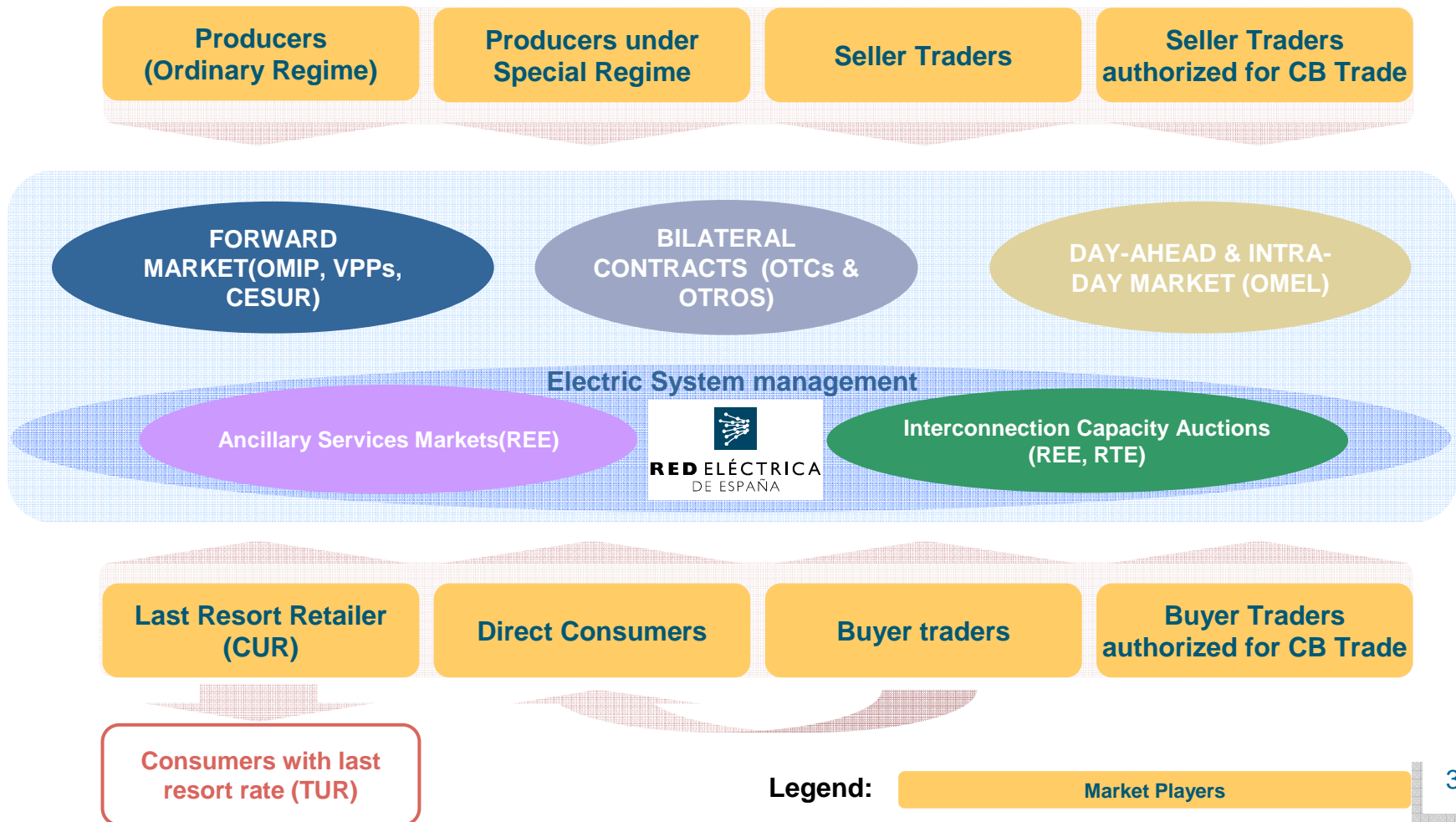
Control centre for renewable energies (CECRE)

Challenges integrating renewable energy for tomorrow

Conclusions



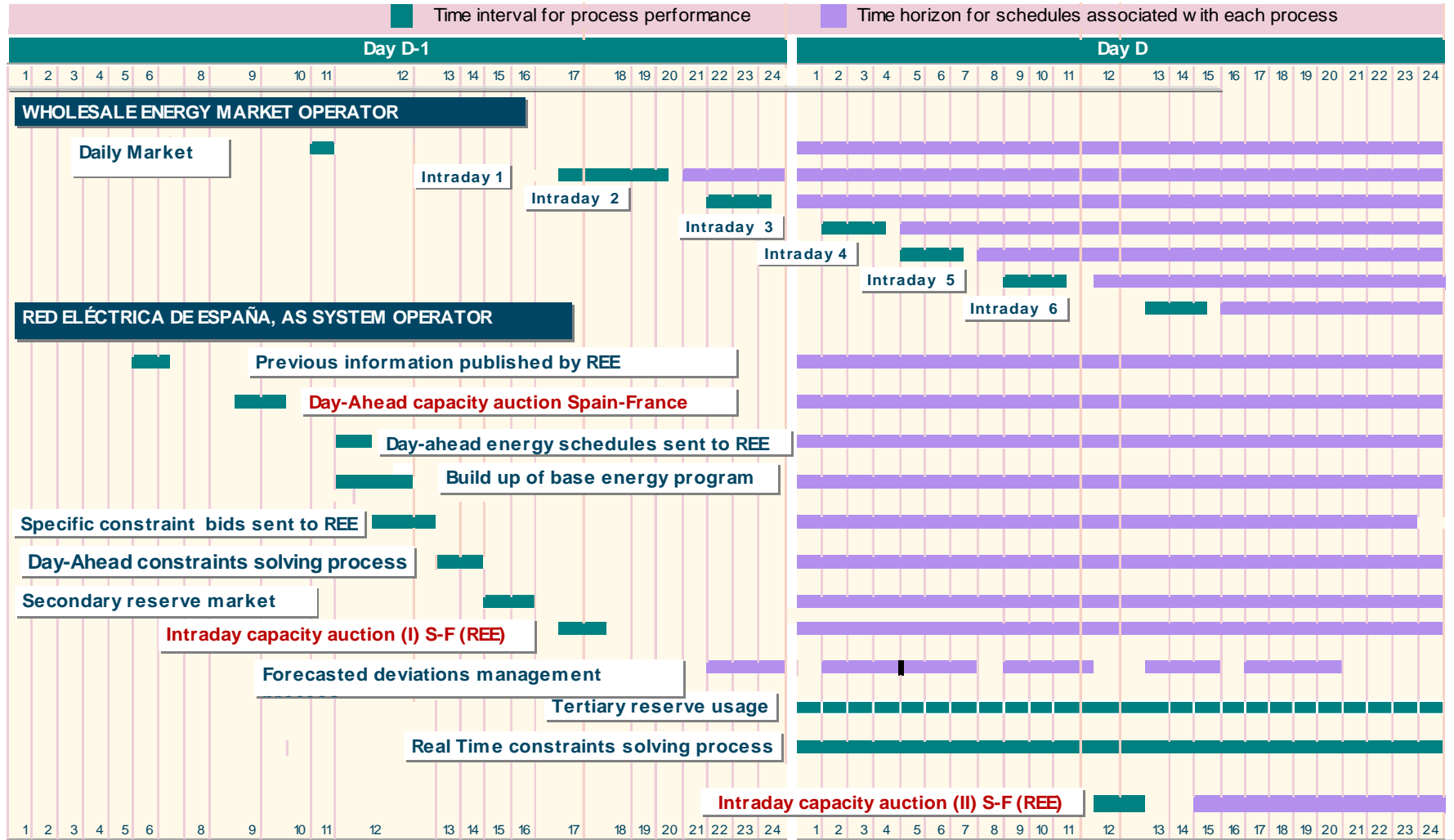
# General scheme of the electricity market



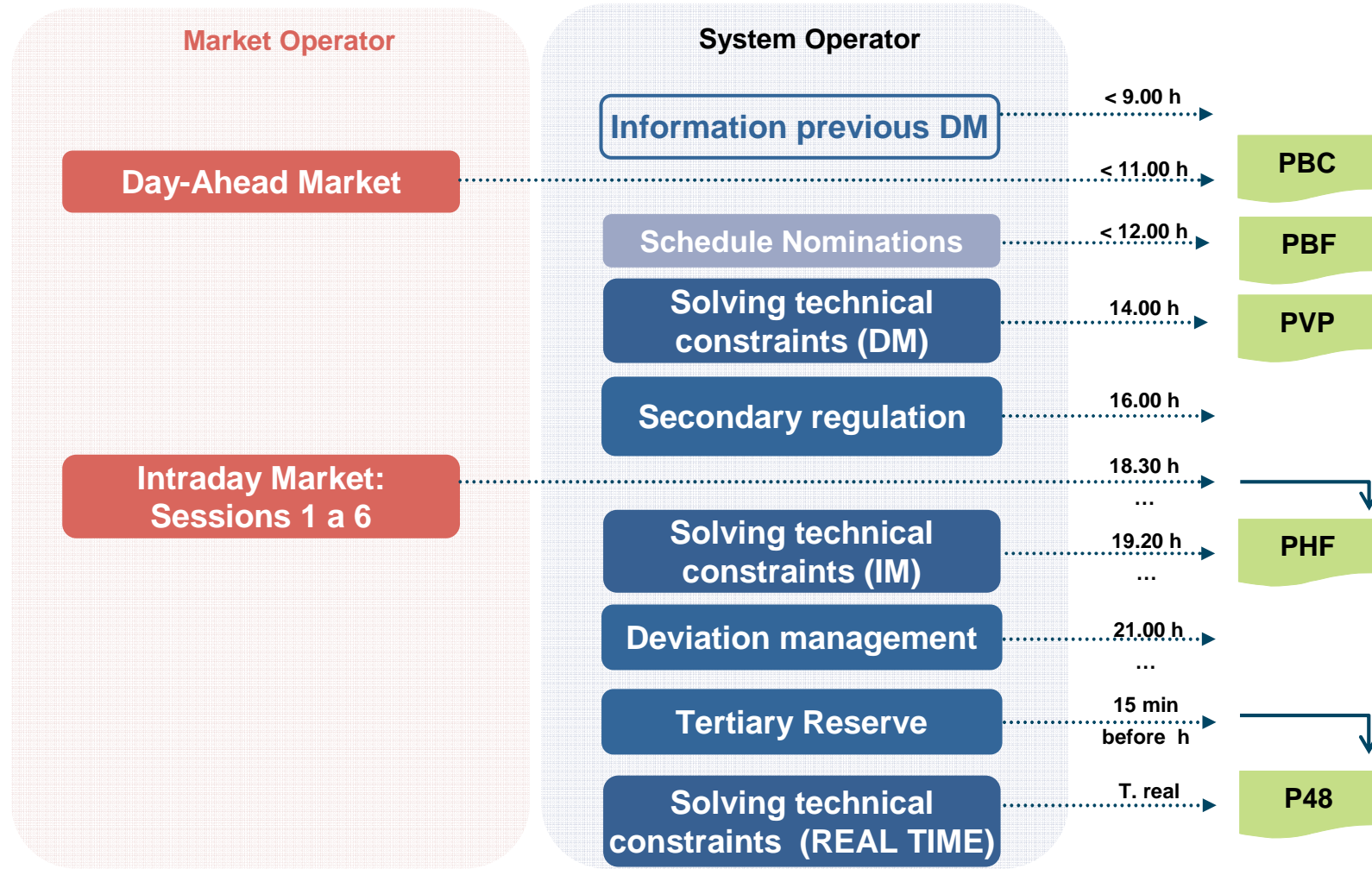
## System balancing services

Type	Definition
<b>Primary Regulation</b>	Action of speed regulators from generator units responding to changes in system frequency (<30 s to 15 minutes)
<b>Secondary Regulation</b>	Automatic and hierarchical control that faces changes in system frequency and power deviations with respect to France-Spain exchange program. ( $\leq 100$ s to 15 minutes)
<b>Tertiary Regulation</b>	Manual power variation with respect to a previous program in less than 15 minutes. (<15 min to 2 hours)
<b>Slow reserve</b>	Running reserves of connected thermal units (30 min. to 4-5 hours)

# Generation Scheduling (I)



## Generation Scheduling (II)





## Primary Regulation

### Objective:

- ❑ Maintain the frequency system stability

### Providers:

- ❑ Generation units: Mandatory and non-paid service

Ancillary service provided by the automatic modification of the power generated: Generation unit speed regulators facing frequency system deviations.

- ❑ Load variation: 1,5% of the nominal power
  - ❑  $t \leq 15$  sec. with frequency deviations  $\leq 100$  mHz
  - ❑ Lineal variation  $15 \leq t \leq 30$  sec. with frequency deviations between 100 y 200 mHz

### Requirements

- ❑ Established by UCTE rules

# Secondary Regulation

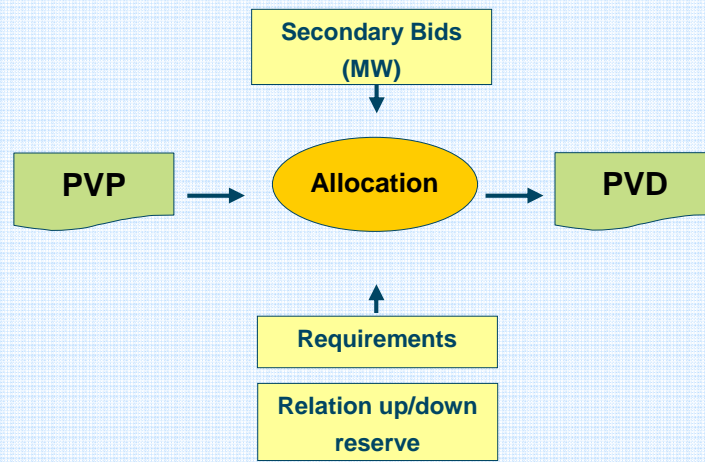
## General

- Bids:
  - Licensed generation units: Power band to be increased and reduced (MW) and power band price (€/MW)
- Reserve allocation:
  - Economic merit order
- Operation:
  - The regulation deviation is measured by the TSO Regulation Master and the requirement for each Regulation Area is distributed (every 4 sec.) according to the reserve allocation
- Service fulfilment control by Regulation Area

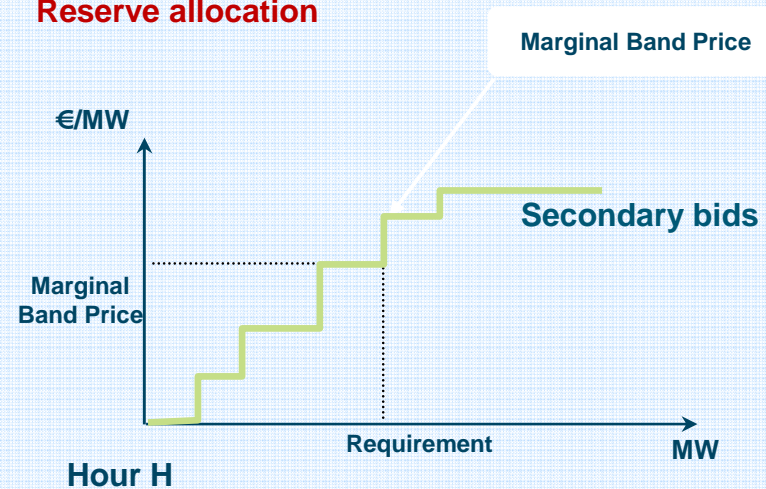
## Provider remuneration and overcost

- Service remuneration prices:
  - Power band: Hourly marginal price
  - Penalty / Bonus depending on real time fulfilment
  - Used energy: Marginal price for tertiary regulation that would have been necessary to use instead (using tertiary bid ladder)
- Overcosts:
  - Power band cost paid by demand proportionally to metered energy (except pumping consumption and exports)
  - Energy over-cost paid by generation and demand units which deviate from their programmes

## Process



## Reserve allocation





# Tertiary Regulation: Face unforeseen deviations and short term foreseen deviations

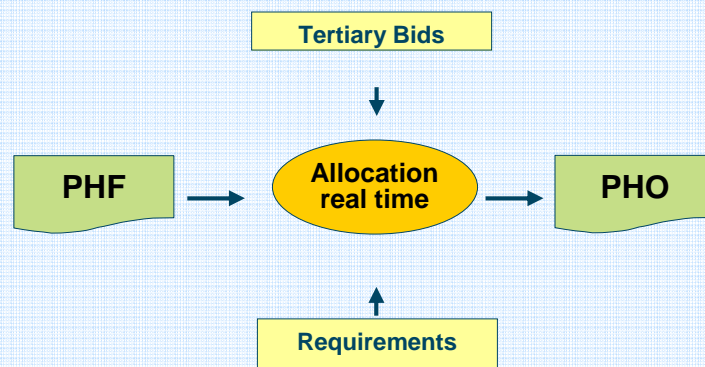
## General

- Bids:
  - Obligation to offer available power
  - Bids are sent at 23:00 the day before and can be updated till 25 min before the beginning of the hour
- Allocation:
  - Economic merit order. Constraints must not happen
  - 15 min before the beginning of the programming hour and, if necessary in the programming hour

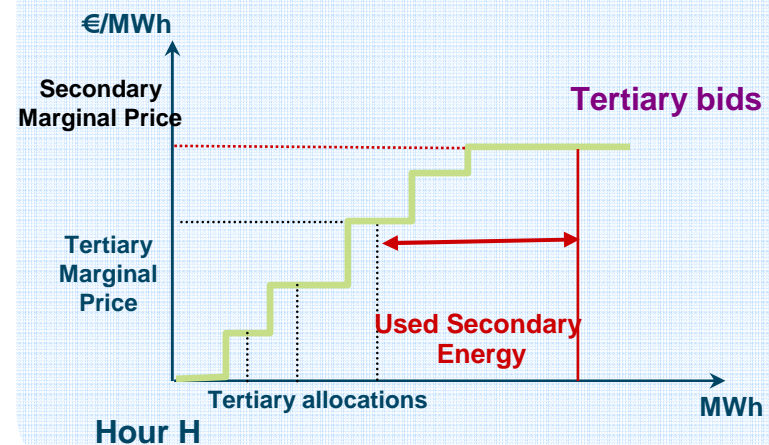
## Provider remuneration and overcost

- Service remuneration price:
  - Marginal price of allocated bids each hour
- Overcost:
  - Service overcost paid by generation and demand units which deviate from their programmes

## Process



## Tertiary Allocation



# Deviation management: Face foreseen deviations maintained during several hours

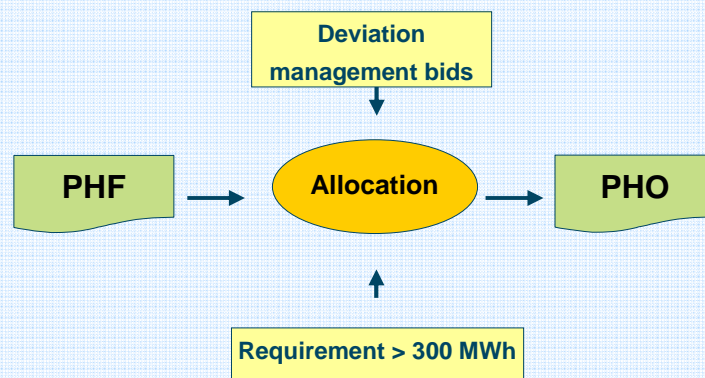
## General

- Process subsequent to the intraday market sessions to balance big differences ( $\geq 300$  MWh) between scheduled generation and forecasted demand
- Foreseen deviations: unavailabilities or justified changes communicated from generation
- It covers the period between Intraday market sessions
- Offers: Optional to Generation and pumping units authorized
- Allocation:
  - Economic merit order

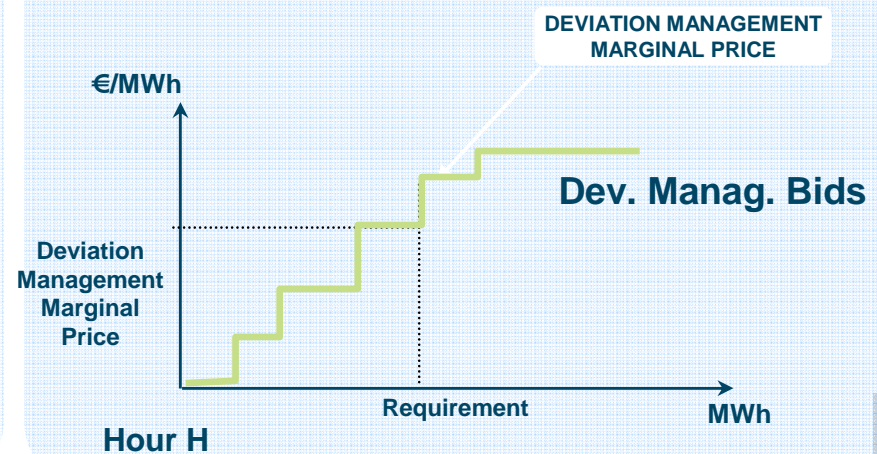
## Provider retribution and over cost

- Service remuneration:
  - Hourly Marginal Price
- Overcost :
  - Paid by generation and demand units which deviate from their programmes

## Process



## Deviation Management allocation



# Payment of Technical Services

TECHNICAL CONSTRAINTS  
SECONDARY RESERVE

**Final demand depending on the metered energy**  
(excepting pumping units and exports)

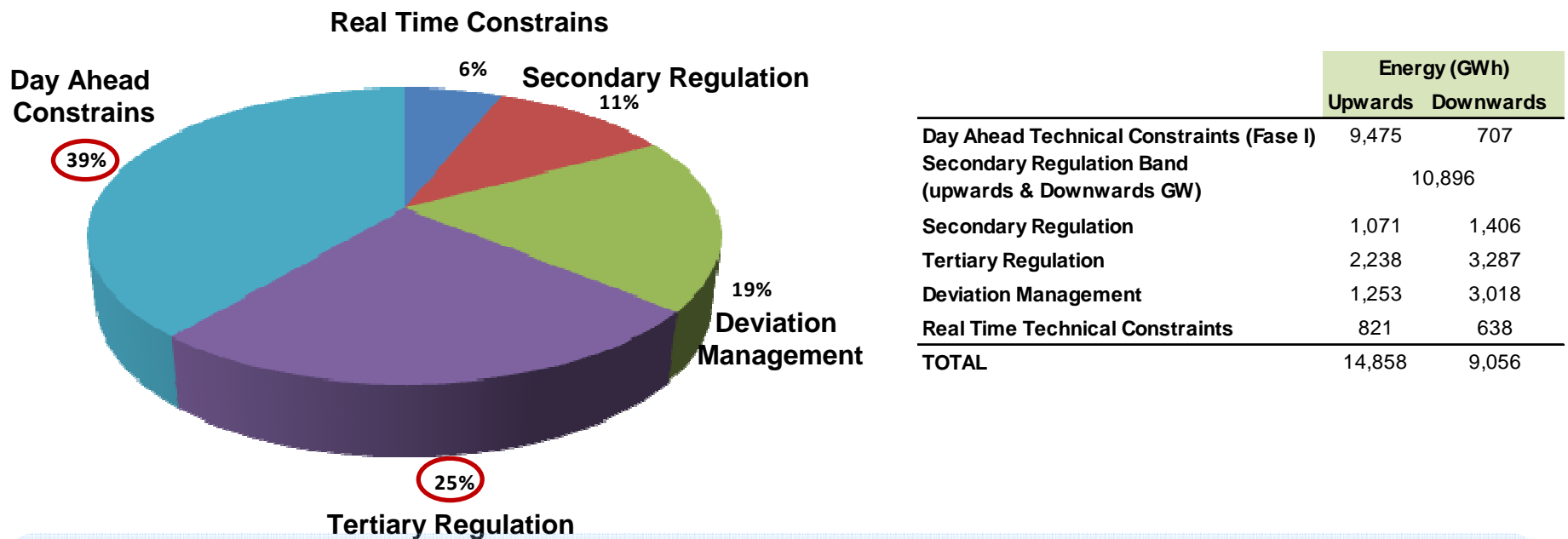
SECONDARY ENERGY  
TERTIARY ENERGY  
DEVIATION MANAGEMENT

### Units which deviate from their programs

	IN FAVOUR OF THE SYSTEM	IN OPOSITION TO THE SYSTEM
<p><b>UPWARD UNBALANCES</b> (less consumption, more generation)</p>	<p><b>Receive DMP</b></p>	<p>Receive minimum of:</p> <ul style="list-style-type: none"> <li>• DMP</li> <li>• Average price of DOWNWARD energy used (SR + TR + DM)</li> </ul>
<p><b>DOWNWARD UNBALANCES</b> (more consumption, less generation)</p>	<p><b>Pay DMP</b></p>	<p>Pay Maximum of:</p> <ul style="list-style-type: none"> <li>• DMP</li> <li>• Average price of UPWARD energy used (SR + TR + DM)</li> </ul>

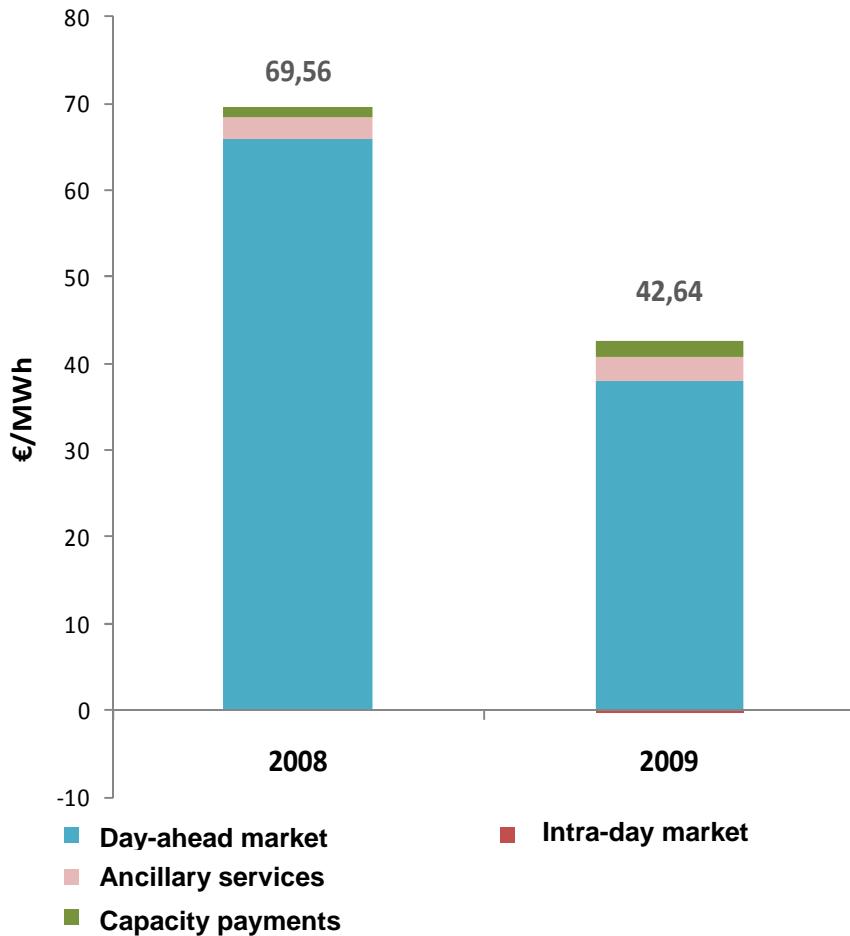
**Deficits and surpluses are paid by final demand proportionally to metered energy (excepting pumping units and exports)**

## Annual energy managed at ancillary services markets: 2009 (I)



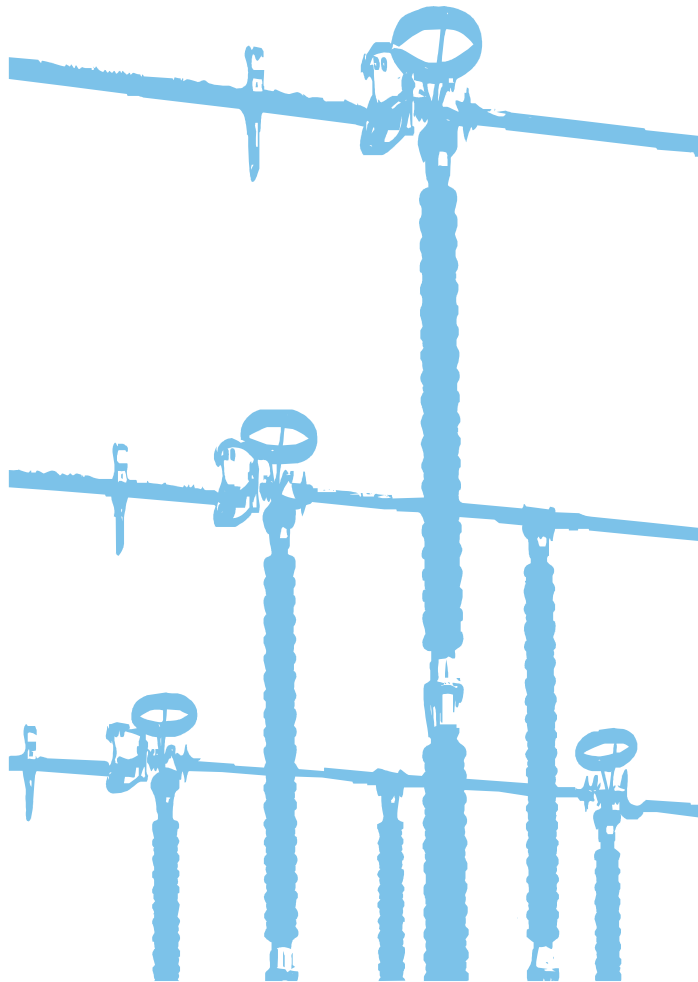
- The total amount of energy management at ancillary services during 2009 was 22.501 GWh, that means the 8,95% of the total energy supplied (251.305 GWh).
- Day-Ahead Technical Constraints solution process (39%) and Tertiary Regulation (25%) were the ancillary services that manage more amount of energy.

## Final electricity price (€/MWh)



€/MWh	2008	2009	2009%	%2009/2008
<b>Day-ahead market</b>	65.91	38.06	89.3%	↓ -42.3%
<b>Intra-day market</b>	0.00	-0.02	0.0%	-
<b>Ancillary services</b>	2.60	2.69	6.3%	↑ 3.5%
<b>Capacity payments</b>	1.05	1.91	4.5%	↑ 81.9%
<b>FINAL PRICE</b>	69.56	42.64		↓ -38.7%

Ancillary services				
€/MWh	2008	2009	2009%	%2009/2008
<b>Technical constraints</b>	1.55	1.84	58.4%	↑ 10.8%
<b>Secondary regulation band</b>	0.81	0.56	20.8%	↓ -30.9%
<b>Deviation management</b>	0.36	0.43	16.0%	↑ 19.4%
<b>Deviation surplus</b>	-0.23	-0.14	-5.2%	↓ -39.1%
<b>TOTAL</b>	2.60	2.69		↑ 3.5%



Brief review of Spanish Ancillary services scheme

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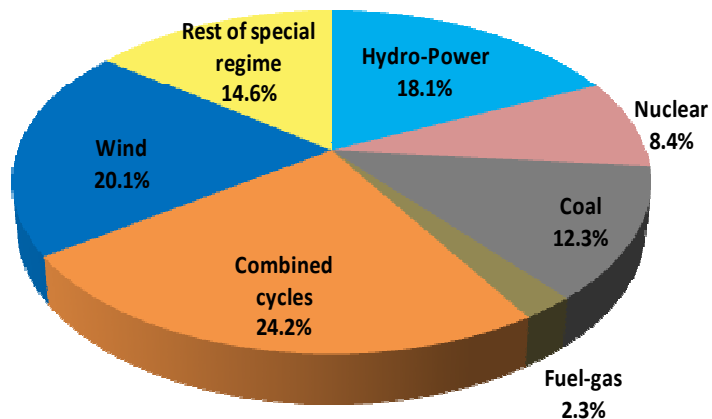
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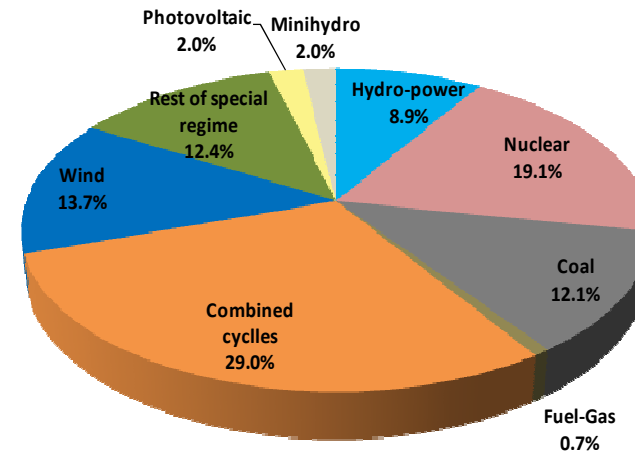


# Installed capacity and demand supply 2009

Installed capacity February 2010



Demand supply 2009

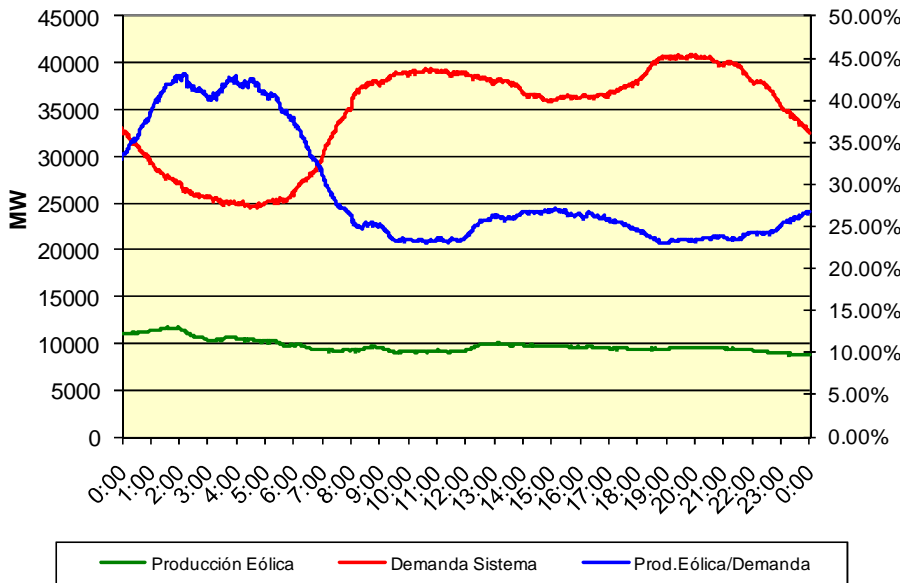


Technology	MW	%
Hydro-power	16.657	18,1
Nuclear	7.716	8,4
Coal	11.359	12,3
Fuel-Gas	2.087	2,3
Combined cycles	22.243	24,1
<b>Total (ordinary regime)</b>	<b>60.872</b>	<b>65,3</b>
Wind power generation	18.458	20,1
Rest of special regime	13.471	14,6
<b>Total (special regime)</b>	<b>31.861</b>	<b>34,7</b>
<b>Total</b>	<b>91.991</b>	

+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

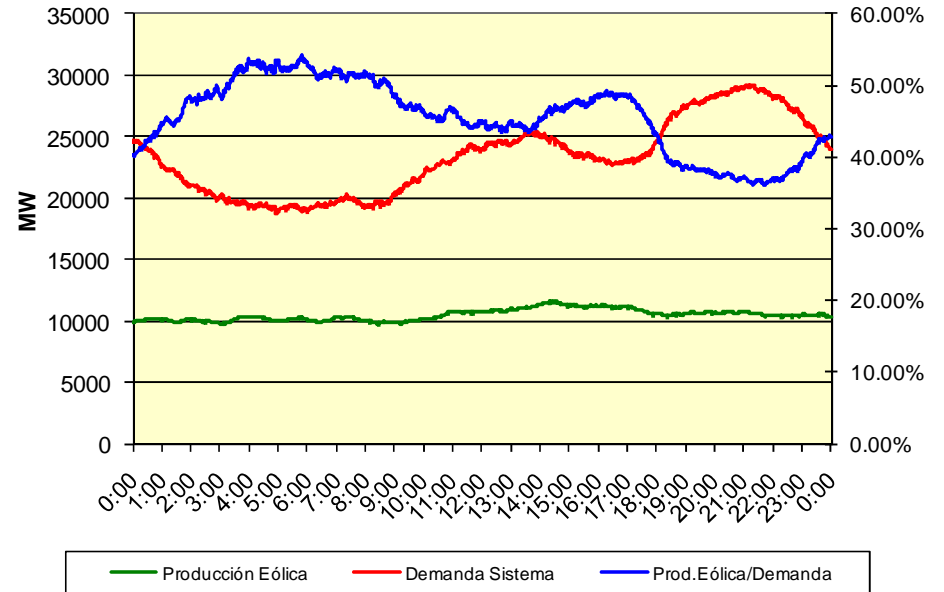
# Wind energy production records

**MAXIMUM PRODUCTION**



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

**DEMAND vs. WIND PRODUCTION**

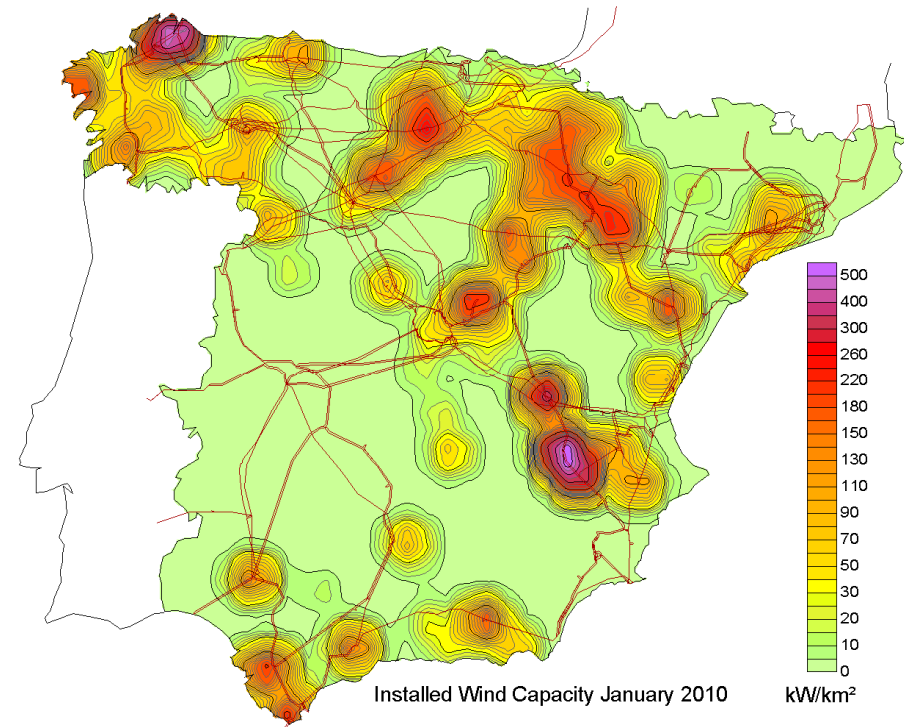
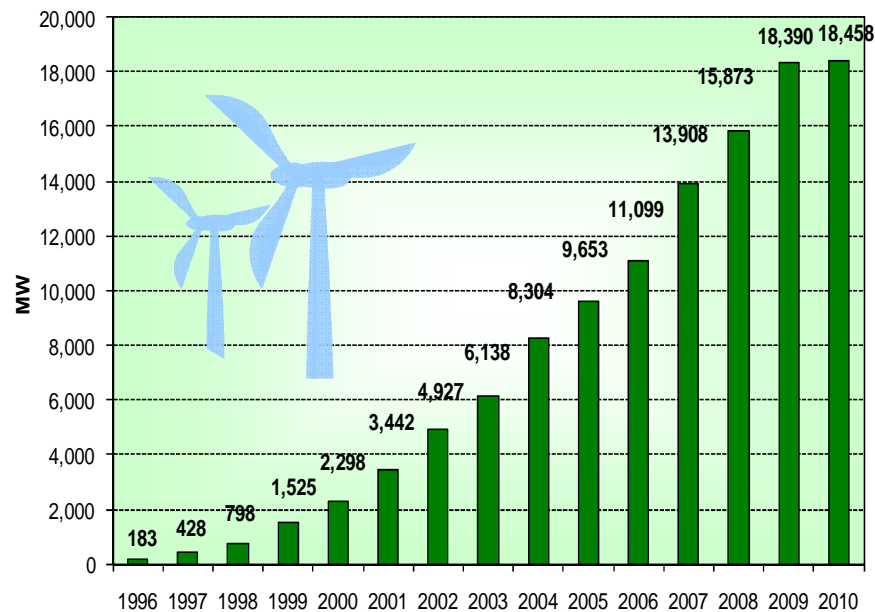


- m **Maximum coverage: 54% of demand coverage by wind energy (08/11/09).**
- m **Minimum coverage: less than < 1% of the demand (27/08/09).**



# Wind power capacity: Present and evolution

Installed Wind power generation evolution 1996-2010

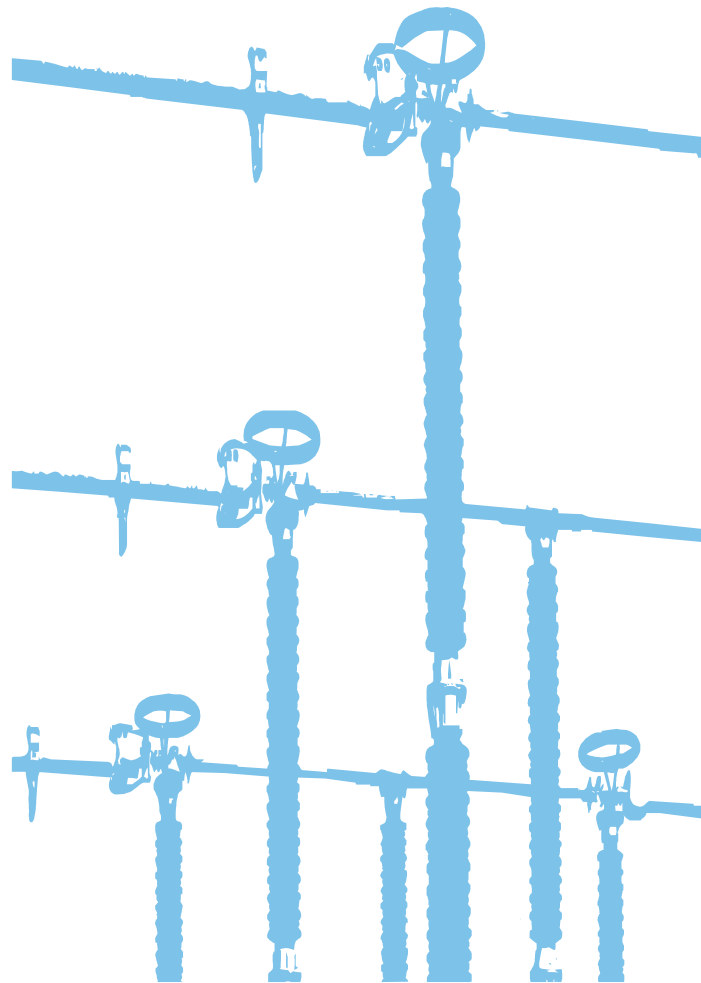


## Installed Capacity Expected for 2016:

- 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).



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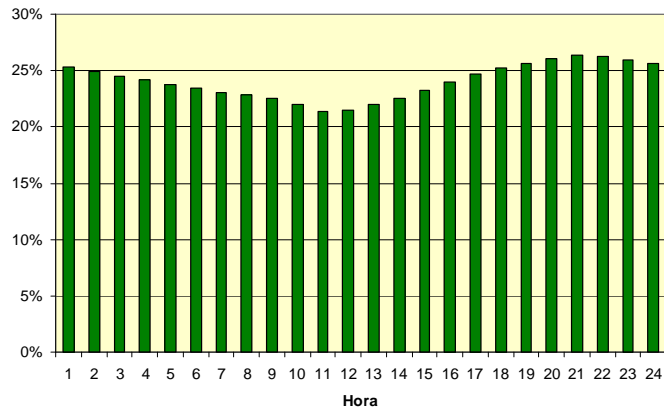
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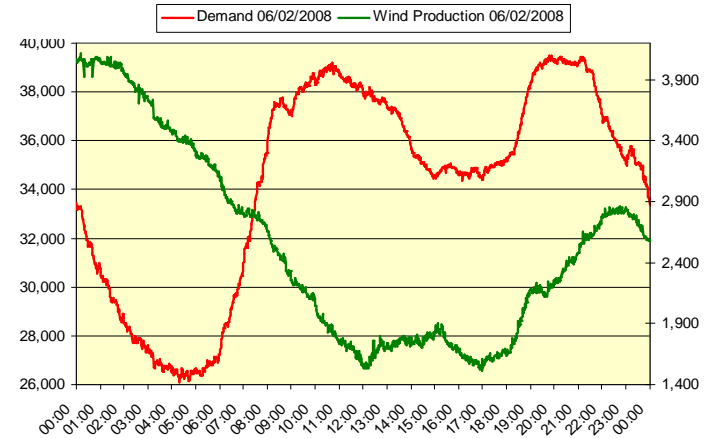
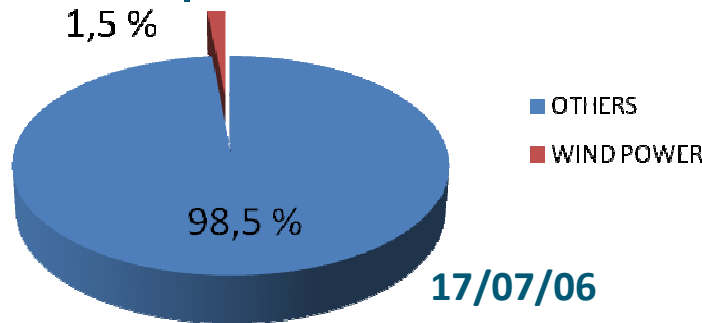


# Production not correlated with consumption

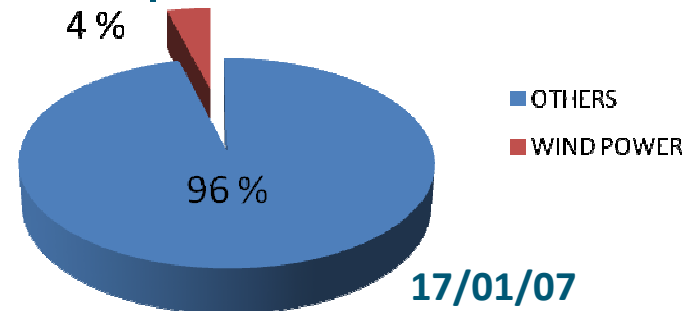
HOURLY WIND PRODUCTION DISTRIBUTION (2008)



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



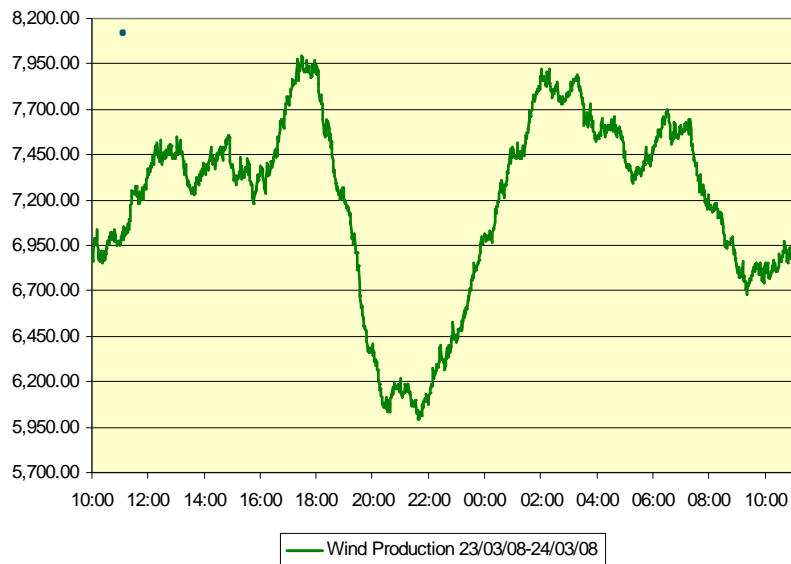
**Demand supply: winter maximum demand Max. peak load = 45.450 MW**



- q Downward ramps in wind production in the mornings often increase morning ramps of conventional generation.
- q Wind production differs sometimes from demand requirements, specially in summer.

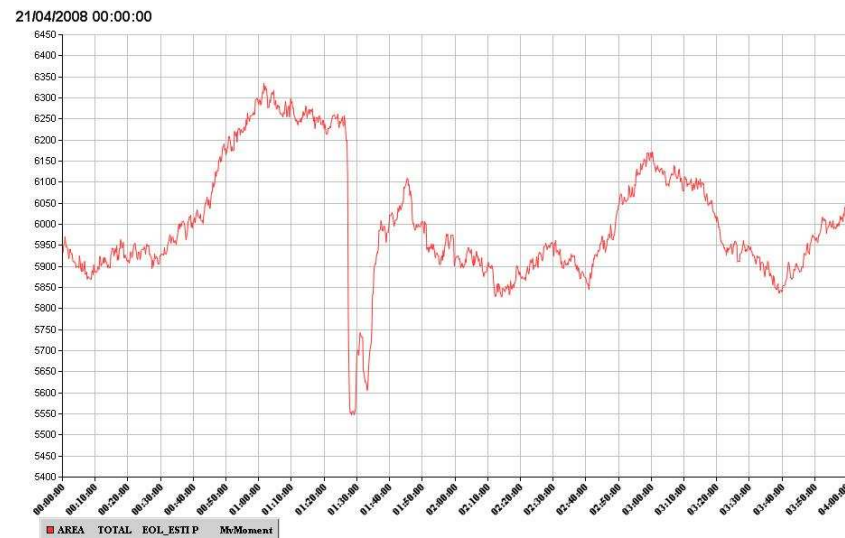
# Wind turbines technology

## Wind generation tripping due due to their over-speed protection



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

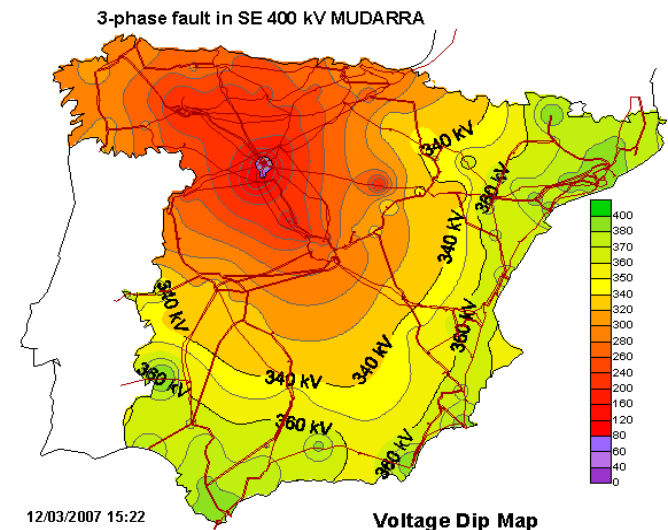
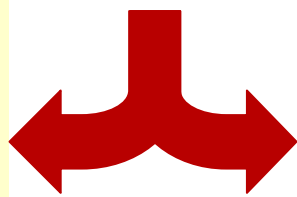
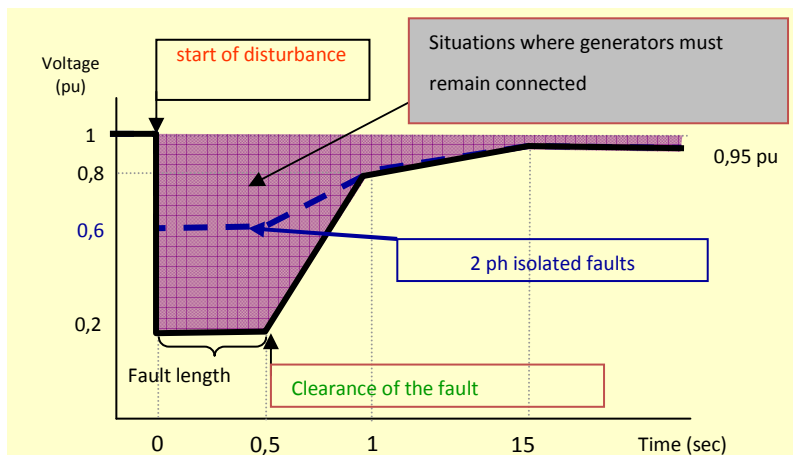
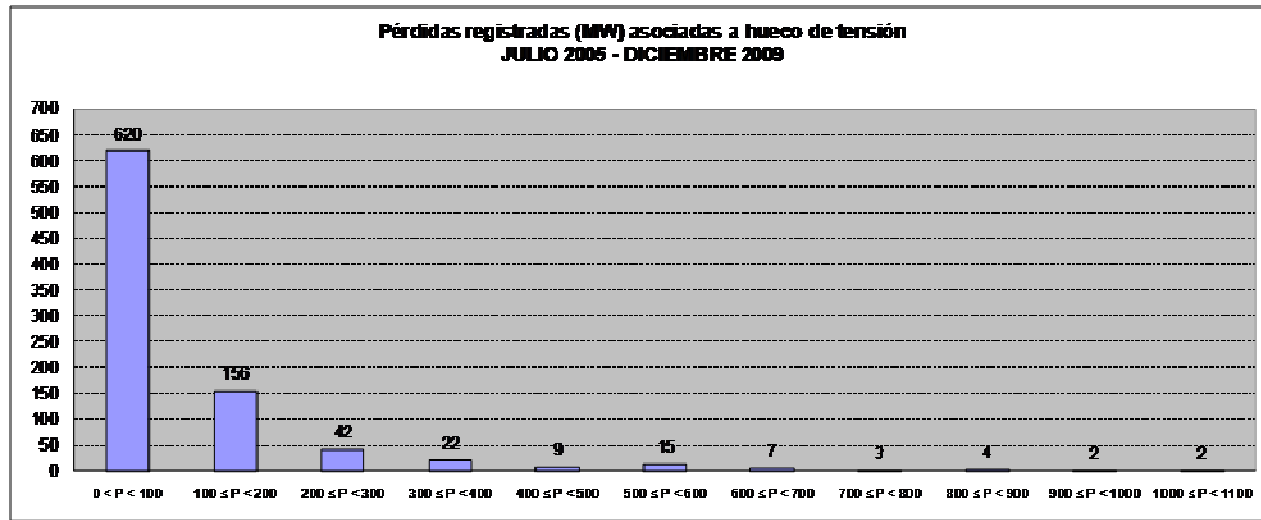
## Wind generation tripping due to voltage dips



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

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

# Observation of wind generation trips



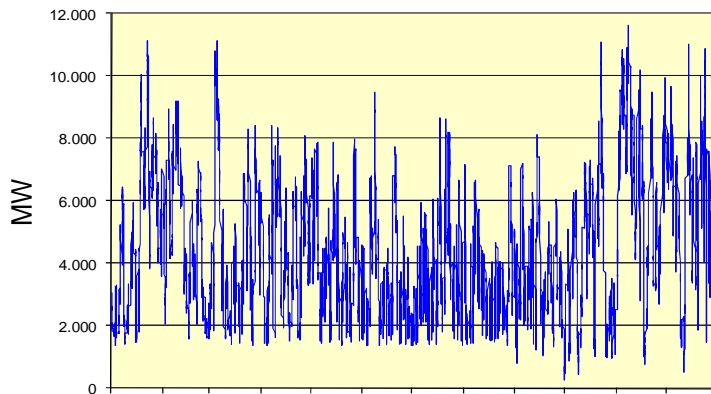
New "grid code". Operational Procedure 12.3

Real Time Risk Assesment

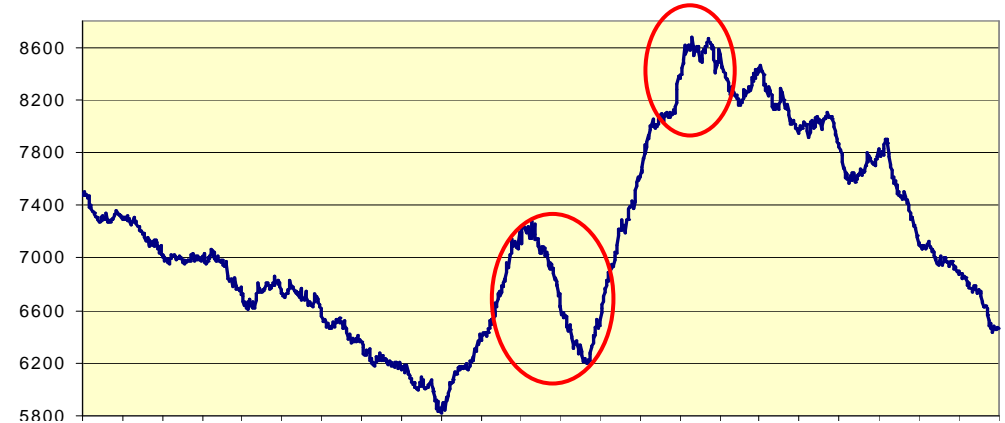
# Wind production variability

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

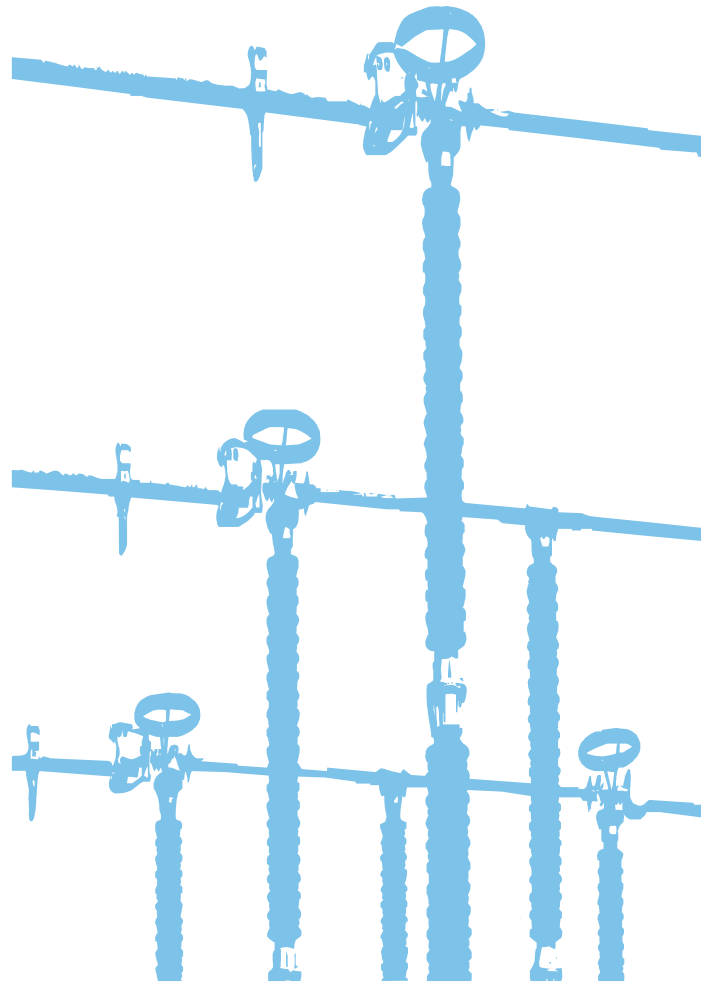
WIND PRODUCTION DURING A YEAR



WIND PRODUCTION VARIABILITY



- q At present wind downward/upward ramps may reach  $\pm 1500$  MWh.
- q 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.
- q Larger forecast errors imply more provision of reserves increasing system costs.



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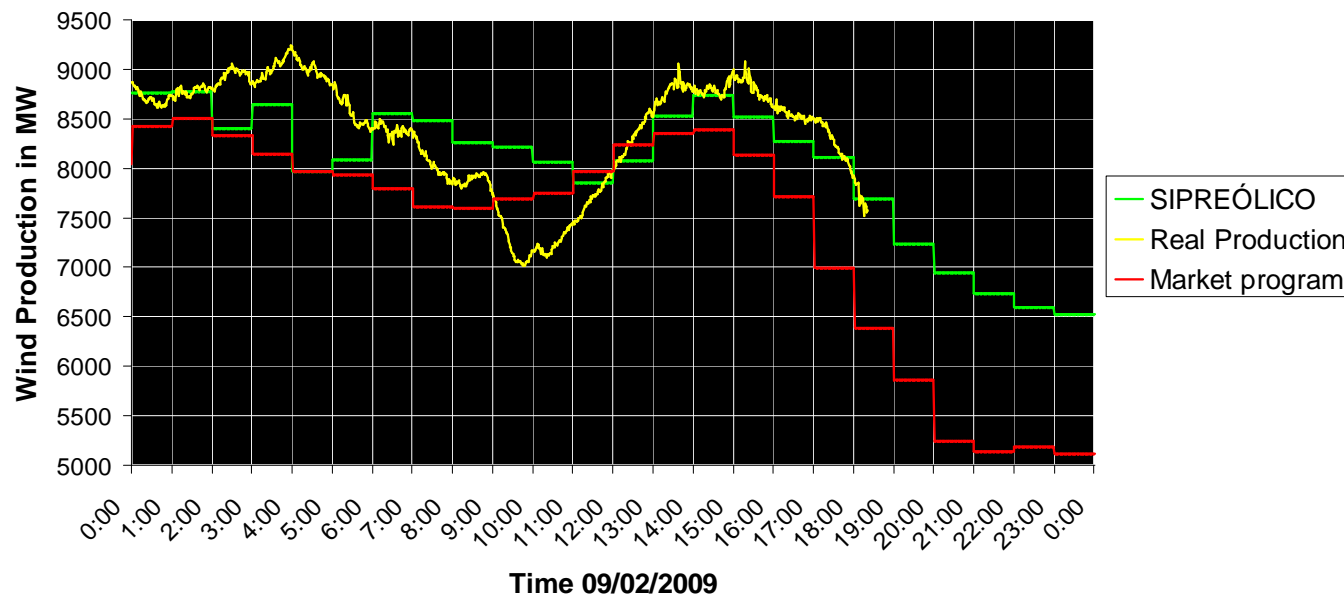
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# Wind forecasts available to the CECRE

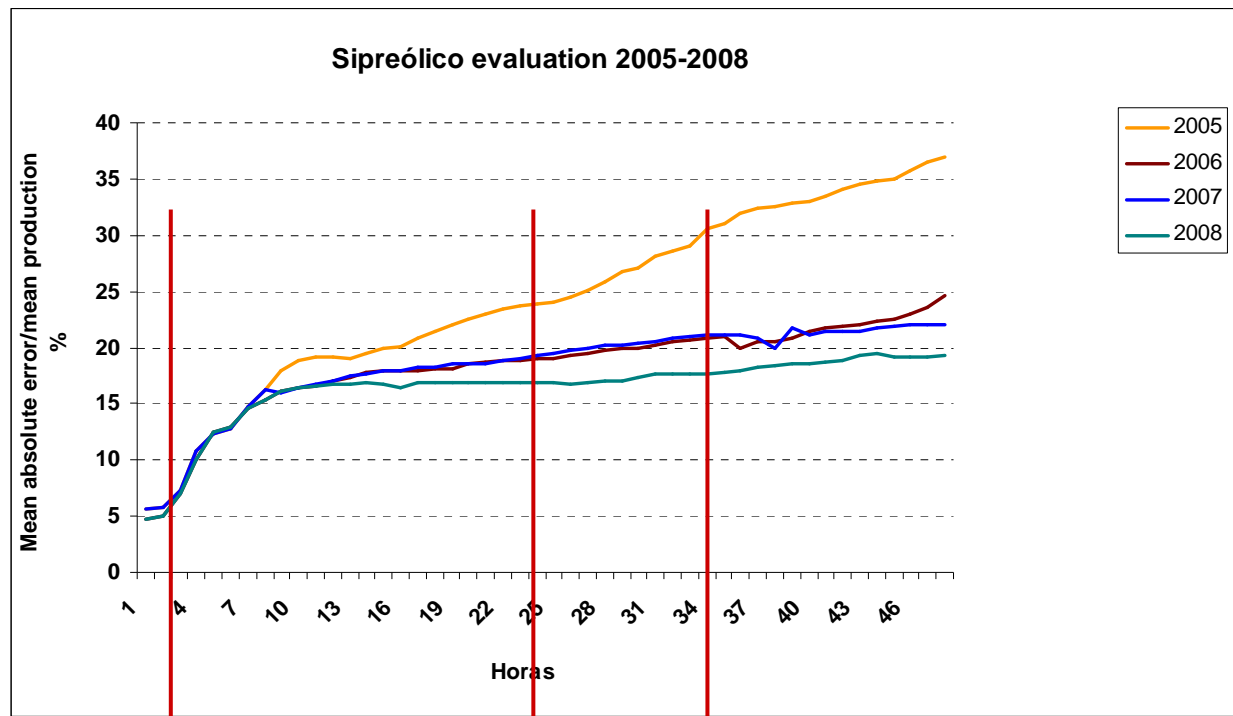
- q In order to size reserves and to check the instantaneous need for manageable generation wind forecast becomes crucial for system balancing.
- q REE has an internal forecast of all wind parks: SIPREÓLICO
- Total hourly forecast for next 10 days (update 1 hour).
- Hourly forecasts for next 48 hours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



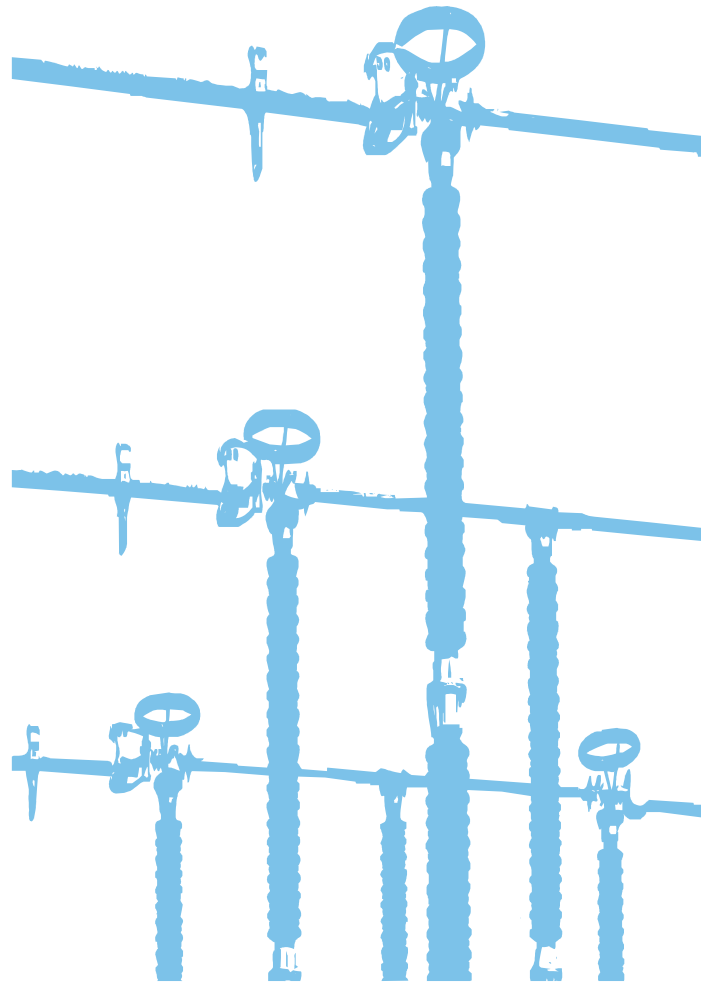


# Hourly forecasts error based on production for the next 48 hours

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



- q 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.



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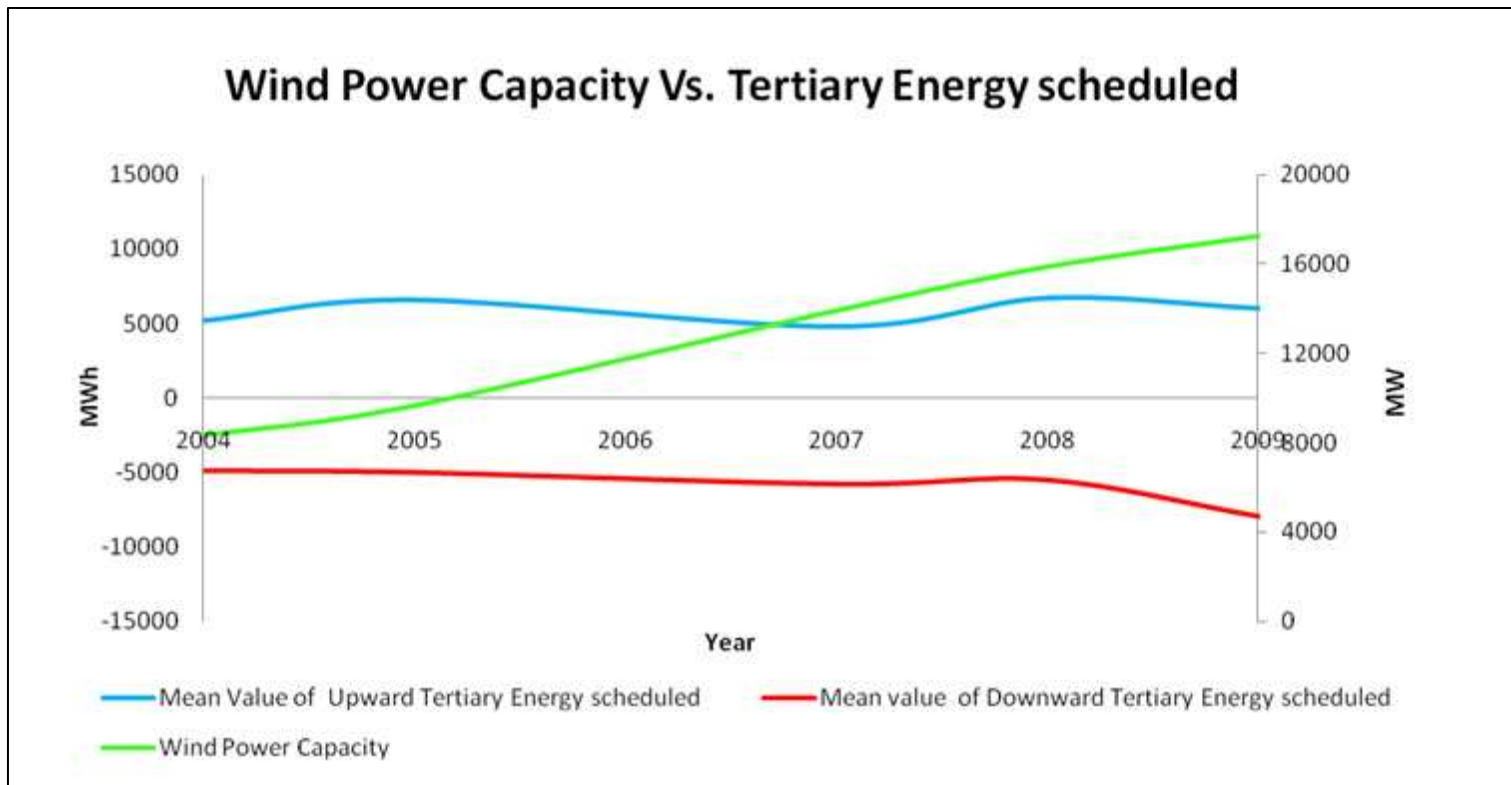


# System balancing services

Type	Definition	Influence of Wind Power on Reserve
<b>Primary Regulation</b>	Action of speed regulators from generator units responding to changes in system frequency (<30 s to 15 minutes)	<b>Currently a very low and decreasing impact</b> due to nowadays very few RES generation without fault-ride capability (and less expected in the future)
<b>Secondary Regulation</b>	Automatic and hierarchical control that faces changes in system frequency and power deviations with respect to France-Spain exchange program. ( $\leq 100$ s to 15 minutes)	Nowadays, no need to contract further reserve bands.
<b>Tertiary Regulation</b>	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.
<b>Slow reserve</b>	Running reserves of connected thermal units (30 min. 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

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

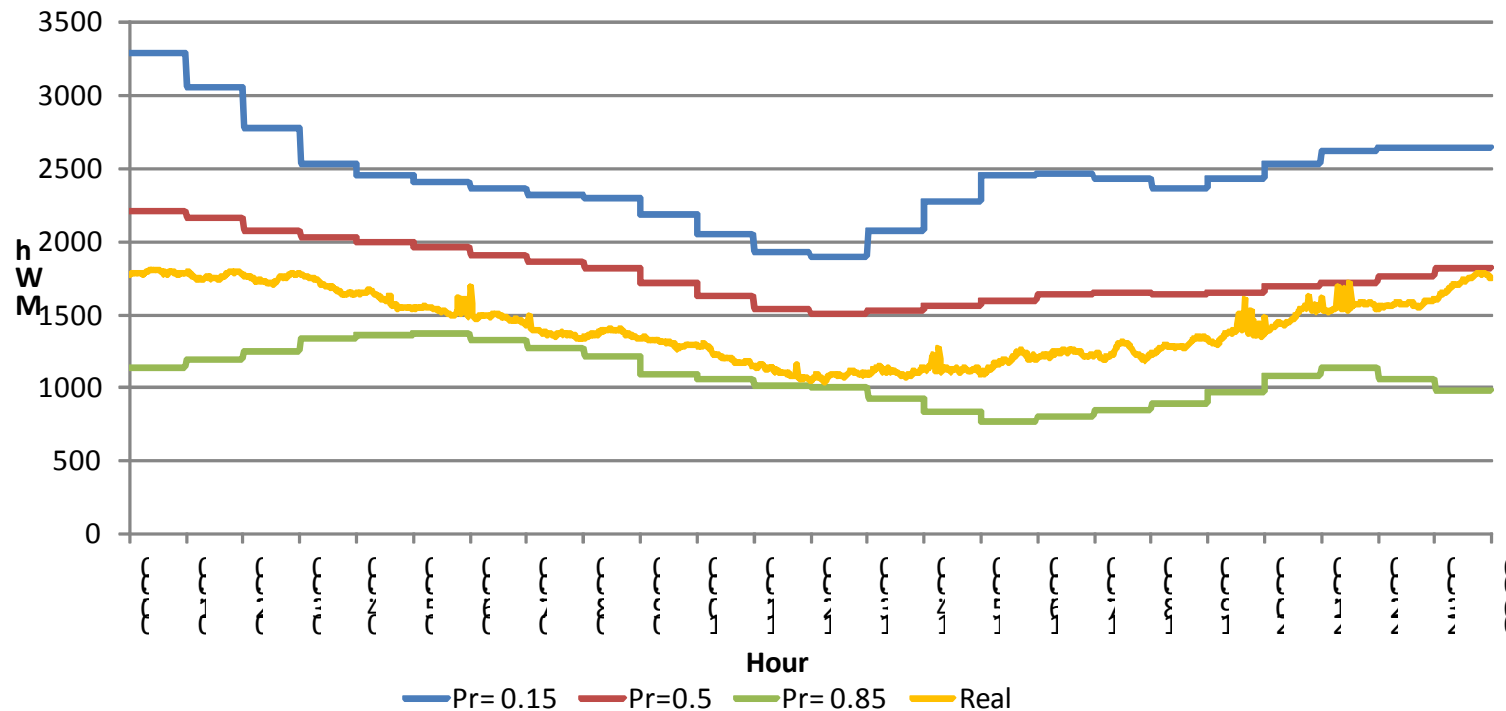


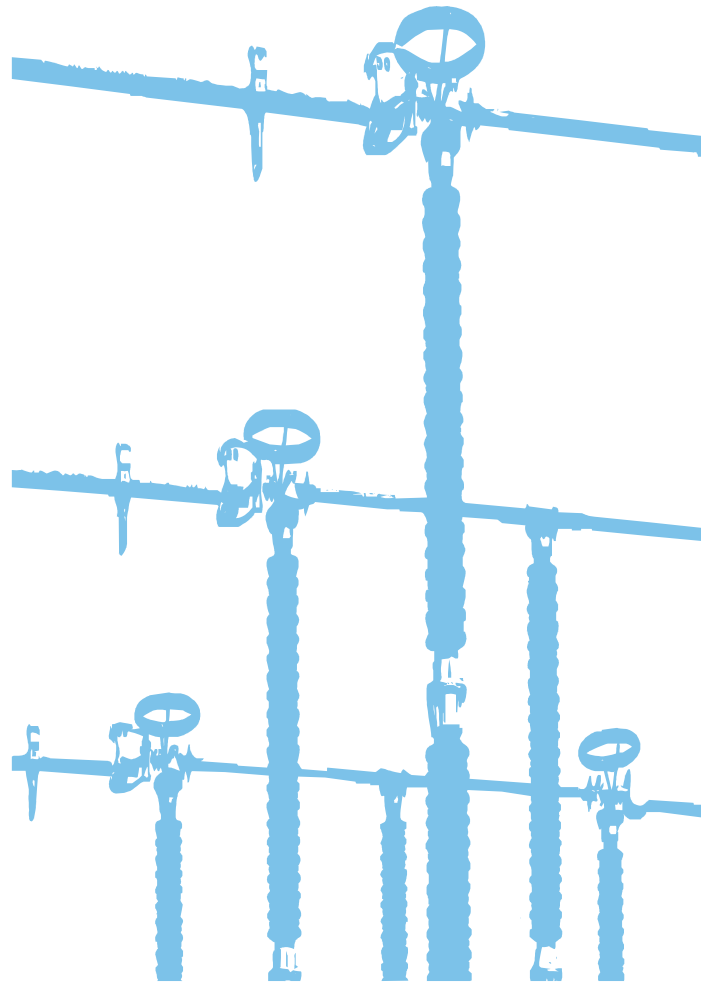
# Running reserves scheduled

## Wind forecast use for reserve evaluation in D-1

- q 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.
- q Probabilistic wind forecast: confidence intervals used for both upward and downward reserves
- q If reserves are not sufficient more thermal plants must be connected to the grid.

Wind forecast with different confidence intervals





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# Real time actions to restore running reserves

q 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 the grid (face peaks & deliver ancillary services)

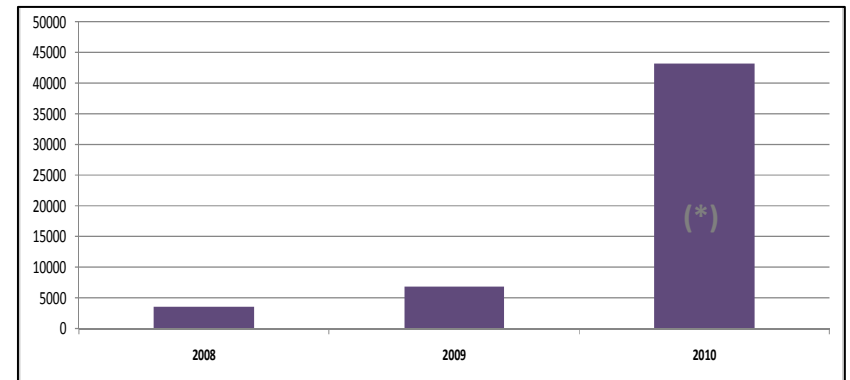
q In the case of running out of:

- 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 a last resort, may issue maximum wind production nodal instructions.

Number of maximum wind production nodal instructions:

- q 2 times in 2008
- q 14 times in 2009
- q 17 times in the two first months of 2010

Wind Energy reduced due to integration problems (MW)

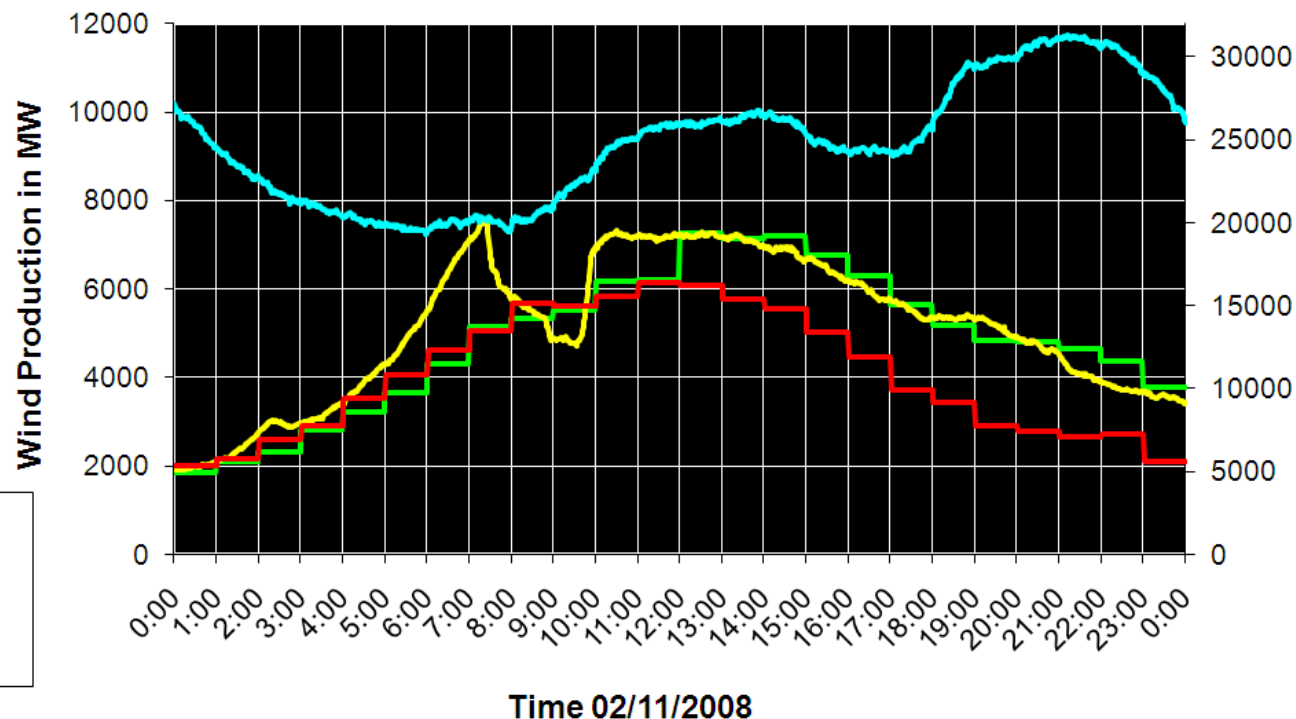


\* Datos provisionales a 31.01.10.

# Running out of downward reserve due to wind forecast errors

## Maximum wind production nodal instructions, November 2nd 2008 (I)

- q 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.
- q Increase in error from 5:00 to 7:00 h too fast to have time to shut down thermal plants.
- q 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.

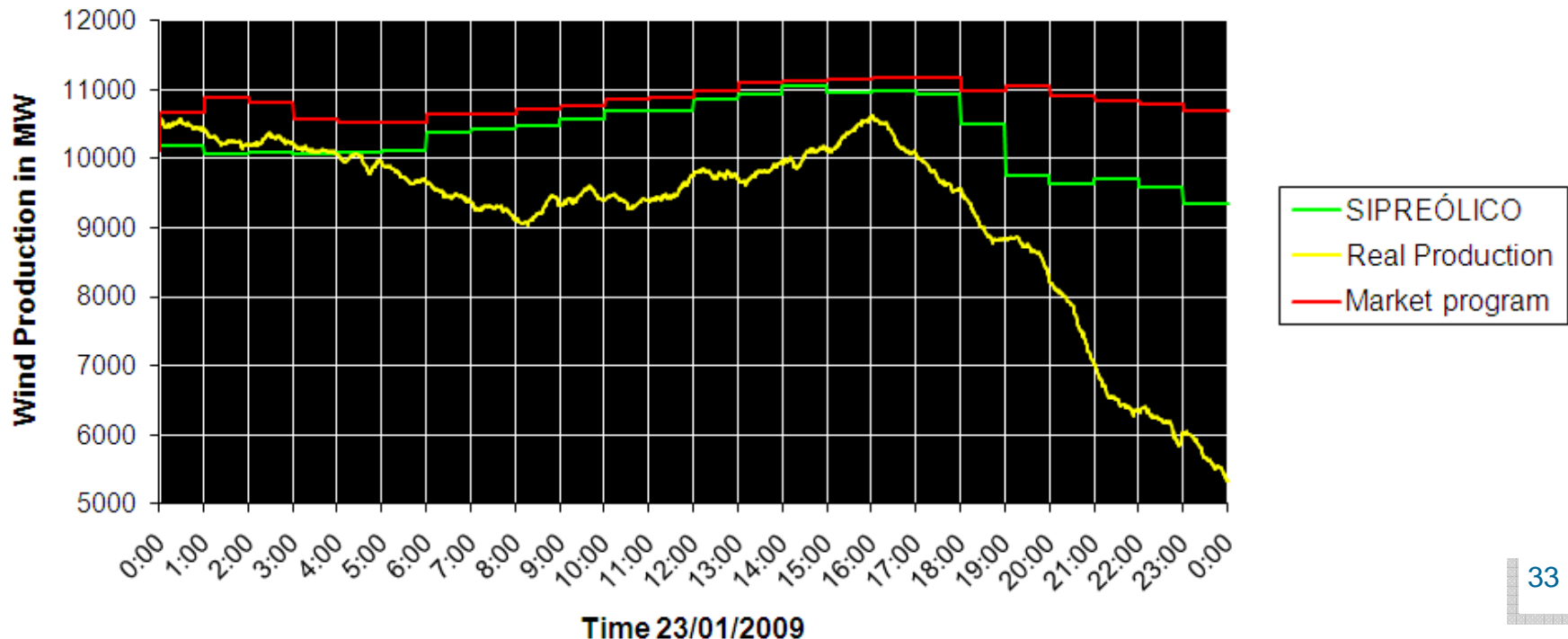


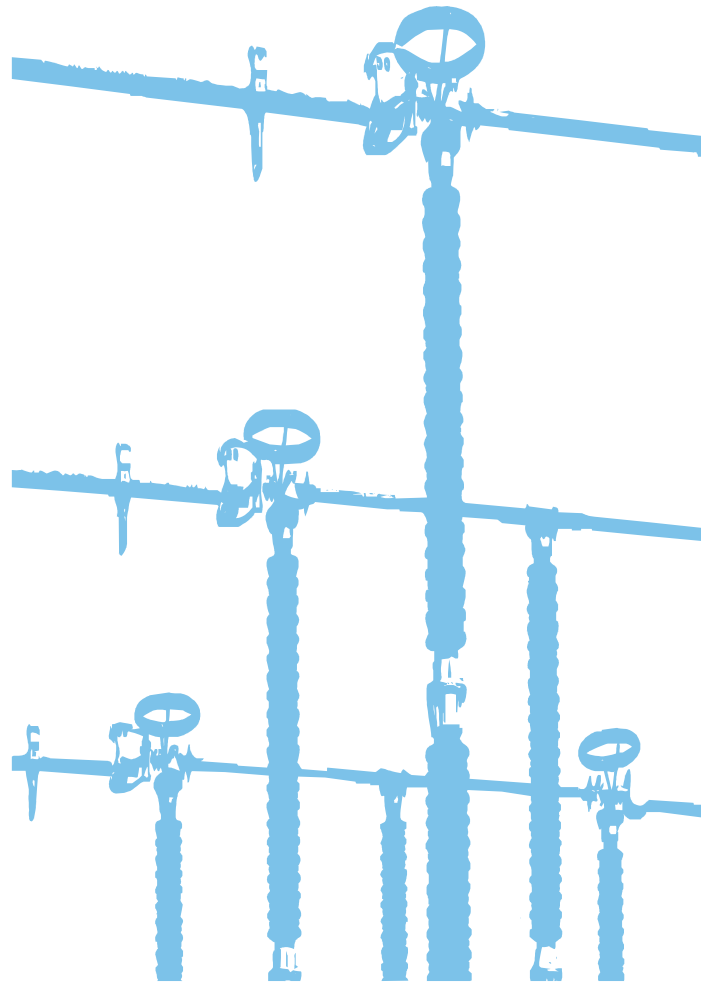


# Running out of upward reserve due to wind generation tripping

## Wind reduction instructions, January 23<sup>rd</sup> and 24<sup>th</sup> 2009

- q January 23<sup>rd</sup> and 24<sup>th</sup> 2009: The storm Klaus. Winds up to 220 km/h hit the Iberian peninsula.
- q Most turbines in the north of Spain shut down due to their over-speed protection.
- q 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.



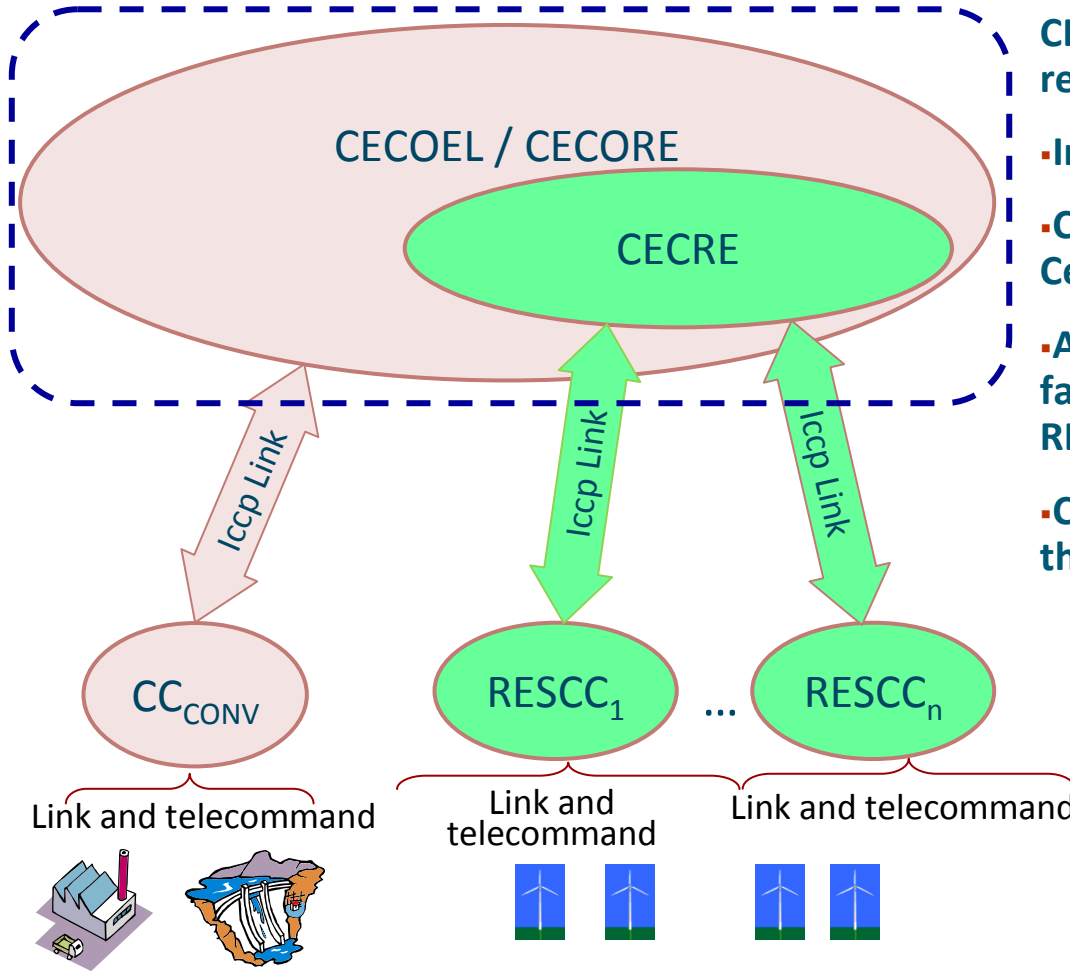


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- Conclusions





# CECRE: Functional Scheme



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:

- Minihydro
- Biomass
- Wind
- Industrial waste
- Urban waste
- Solar

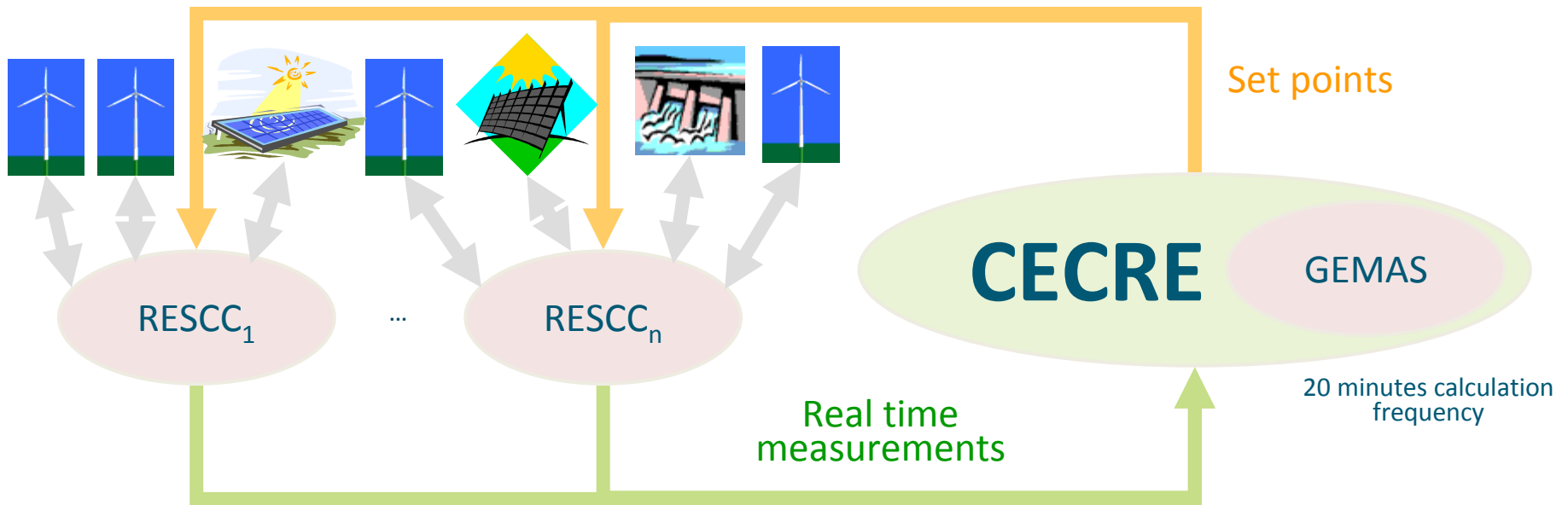
Non Renewable:

- Cogeneration
- Coal
- Fuel - Gas oil
- Refinery gas
- Natural gas

RESCC: Renewable Energy Source Control Centre  
 CC<sub>CONV</sub>: Control Centre for conventional generation

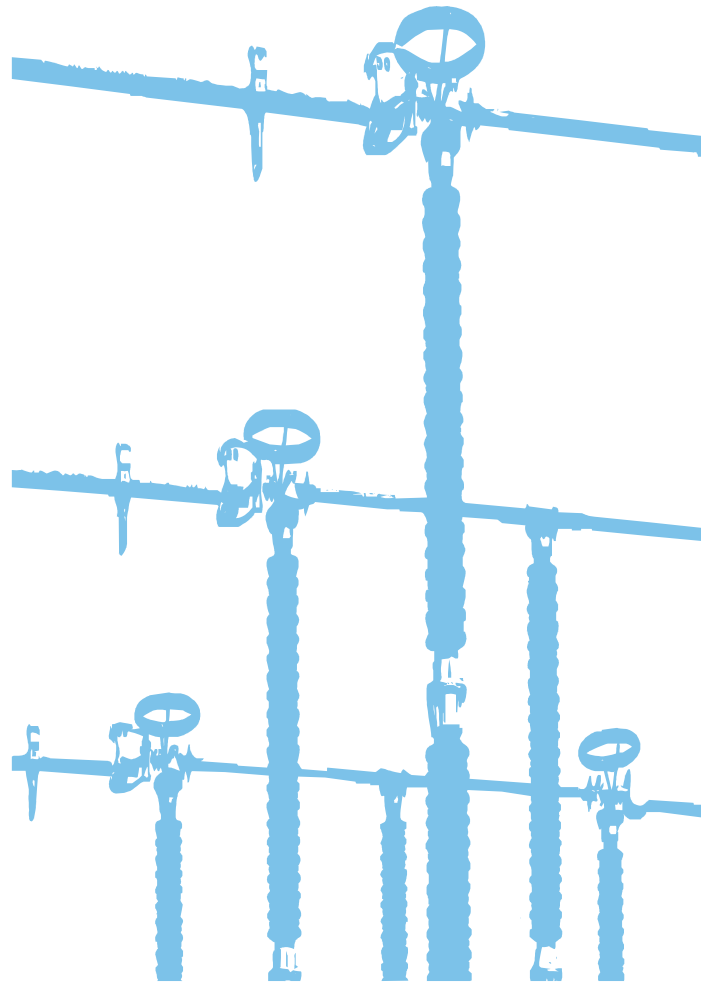
# Checking the security with the real-time wind scenario

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



- q 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.



- Brief review of Spanish Ancillary services scheme
- Renewable energy in Spain today
- Challenges integrating renewable energy nowadays
- Wind forecast and use in reserve calculation
- Influence of wind power on balancing reserves
- Real time actions to restore system reserves
- Control centre for renewable energies (CECRE)
- Challenges integrating renewable energy for tomorrow**
- Conclusions





## Facing the future (i)

- q **Challenges 2011: 20 000 MW wind installed capacity:**
  - m Balance in off-peak hours → downward reserve management is an issue
  - m Voltage dip tripping should no longer be a problem due to compliance with the grid code
  - m Active voltage control with set-points (instead of load factors keeping)
  
- q **Challenges beyond 2011: Up to 40 000 MW wind installed capacity. Safe integration will depend on several factors:**
  - m Need for wind generation to provide frequency control (primary reserve, inertia emulation,...).
  - m Increase of storage capability: more hydro-pump units
  - m Need of more flexible and fast thermal plants (open cycle gas turbine)
  - m Interaction between wind and solar production will be an issue
  - m Improvement of wind forecast tools
  - m More Flexible market mechanisms and regulatory measures

## Facing the future (ii): more flexible market mechanisms and regulatory measures

- q **Encourage flexible and fast conventional generation throughout adequate economic signals:**
  - q Open cycle gas turbines
  - q Household isolated operation of conventional units
  - q To encourage more pump storage units and other storage facilities
- q **Introduction of negative pricing (balancing markets/energy markets):**
  - q Adequate for manage deep off-peaks and high wind production
- q **Inter-TSO balancing actions:**
  - q Need of compatibility of ancillary services to exchange
  - q Need of compatibility of gate closures associated
  - q Usage of ATC
- q **Encourage RES to change from user towards providers of system services**

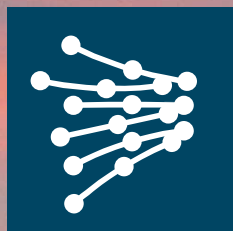




## Conclusions

- q **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.**
- q **Spanish RES control center (CECRE) has helped to reach a high penetration of special regime generation in the System making these technologies compatible with security of supply.**
- q **There is not a significant influence of the present wind capacity on primary, secondary or tertiary reserves.**
- q **Wind forecast has been improving in the last years, being now a basic tool for hot reserve evaluation. Its accuracy for time scopes from 24 to 32 hours in advance affect required levels of reserve and helps dispatching manageable generation to counteract wind fluctuations.**
- q **Some days , due to the lack of downward reserve wind energy reduction are unavoidable in order to keep system balance. Thanks to the CECRE curtailments take less time to be done so we could plan and place less stricter limitations increasing RES production and installation.**

Thank you for your attention!



# **RED ELÉCTRICA** DE ESPAÑA

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