Integrating Renewable Energy into the Electrical Grid, a TSO Perspective

Presented by Alberto Gil

RED ELÉCTRICA DE ESPAÑA

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System Operation:

- Operates the grid and 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):

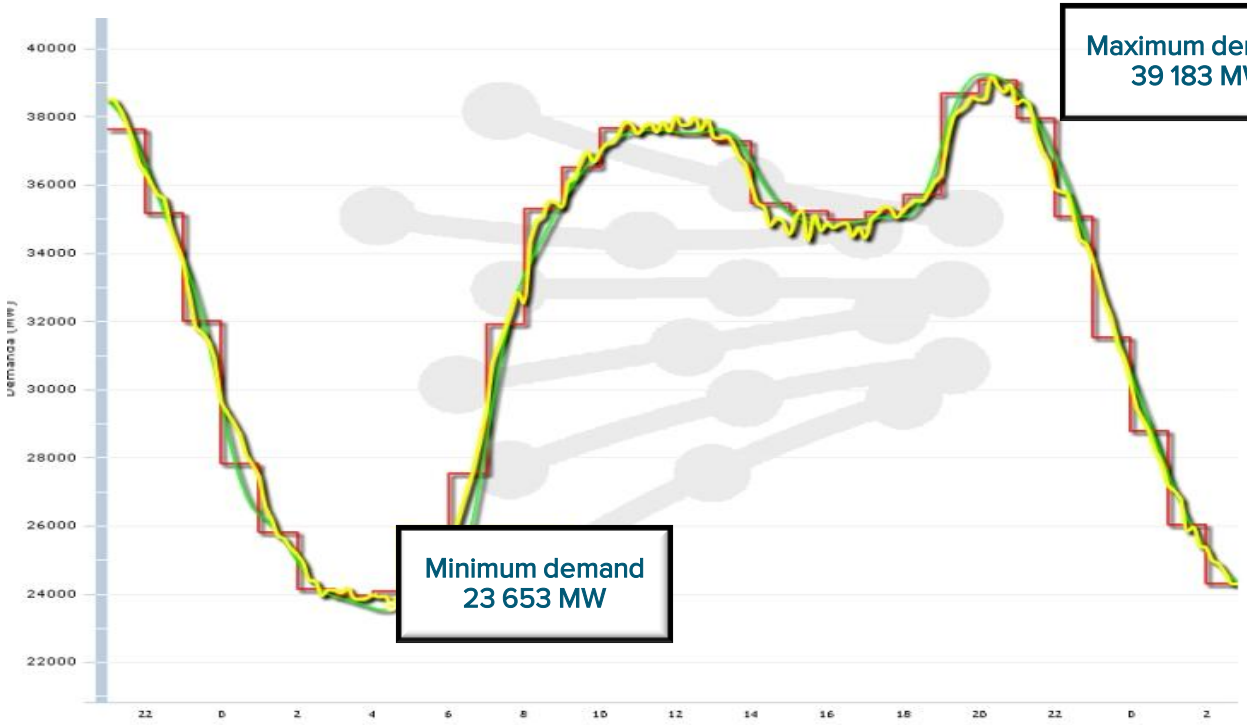
- *The development and the maintenance of the transmission facilities*
- *~ 41,000 km of lines and 78,000 MW of transforming capacity*

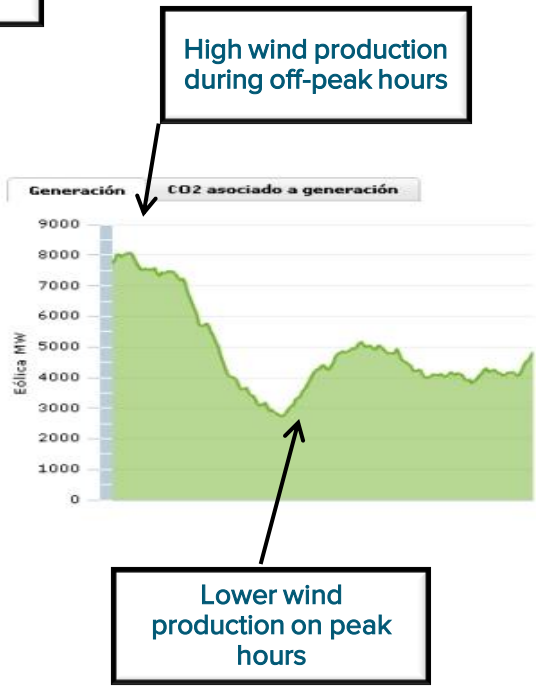
CEOCEL (Electrical Control Center)

CECOEL (Electrical Control Centre)

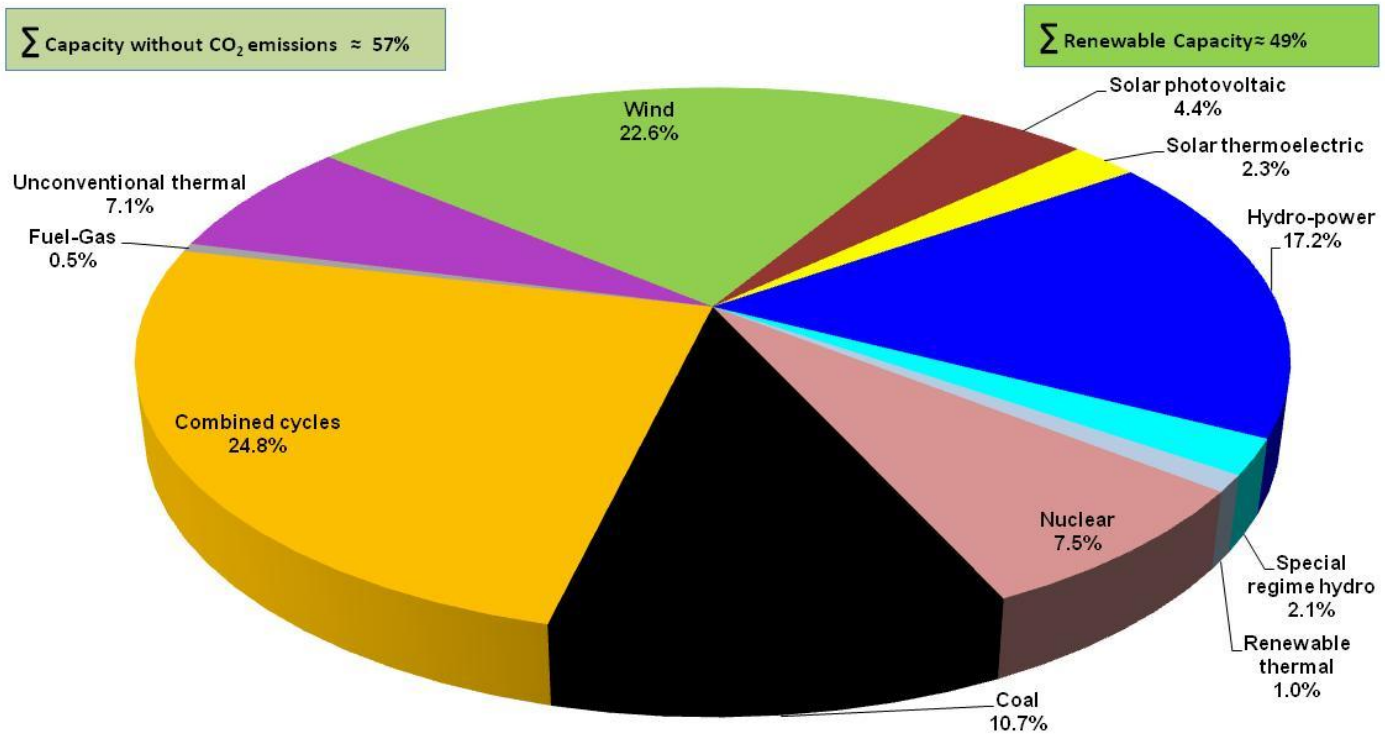
- **Control Centres' permanent availability**
- **Two Control Centres with symmetrical backup capability**
- **Redundancy of computer equipment, telecommunication and electrical supply in each Control Centre**

CECOEL (Demand Coverage)





CECOEL: Installed Generation Capacity September 2015 - 100 GW



CECOEL (Real-time data)

- Every telemetry is linked point to point

EMS System

- Observability: 47 000 analog and 223 000 digital telemetries updated in less than 12 s
- Controlability: 40 000 remote control signals

More than 2.5 billion data values every day

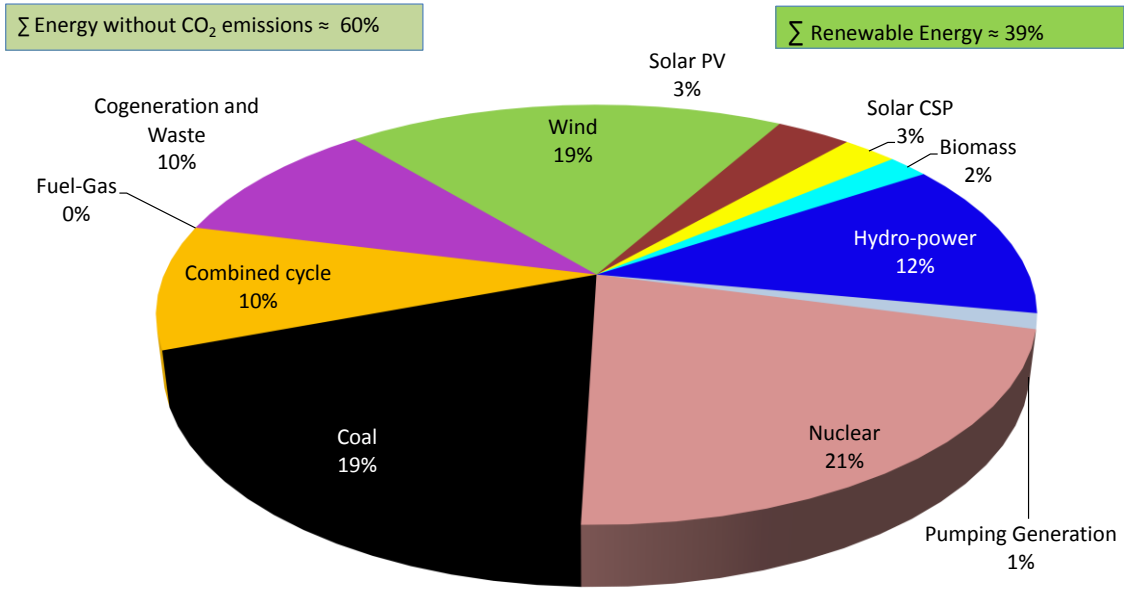
- *23.000 telemetries available for retrieving using PI System*

CECRE (Control Center for Renewable Energies)

CECRE: Control Center for Renewable Energies)

CECRE: Structure of the accumulated net generation 2015

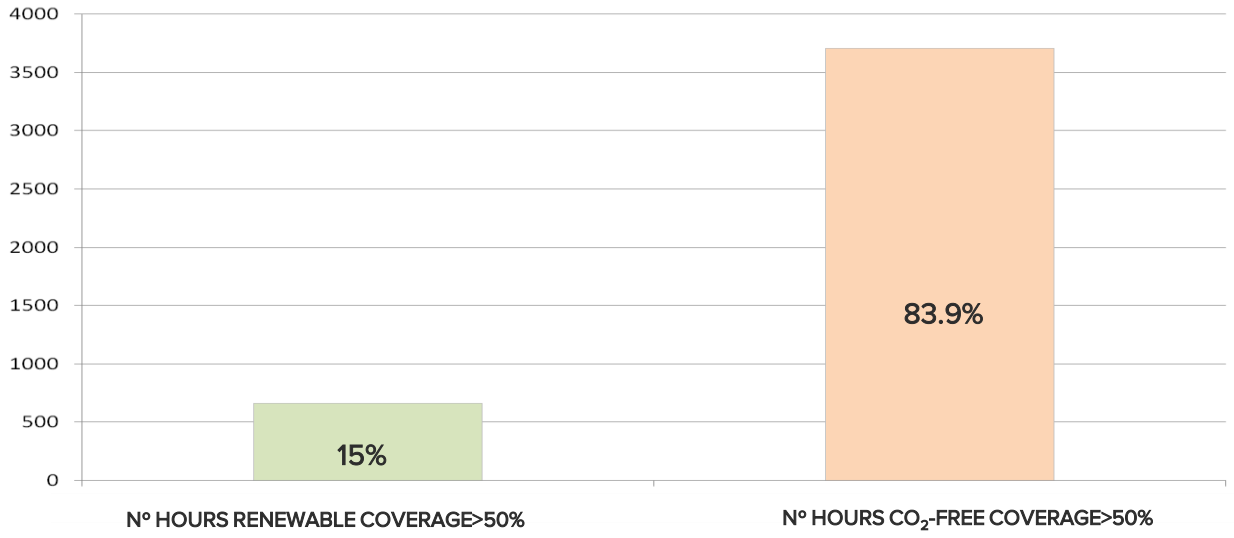
	GWh
Wind	33.585
Solar PV	5.725
Solar CSP	4.185
Biomass	3.171
Hydro-power	21.169
Pumping Generation	2.063
Nuclear	37.043
Coal	32.728
Combined cycle	16.656
Fuel-Gas	0
Cogeneration and Waste	17.345
GENERATION	173.670



(*) Provisional data-January .. August 2015

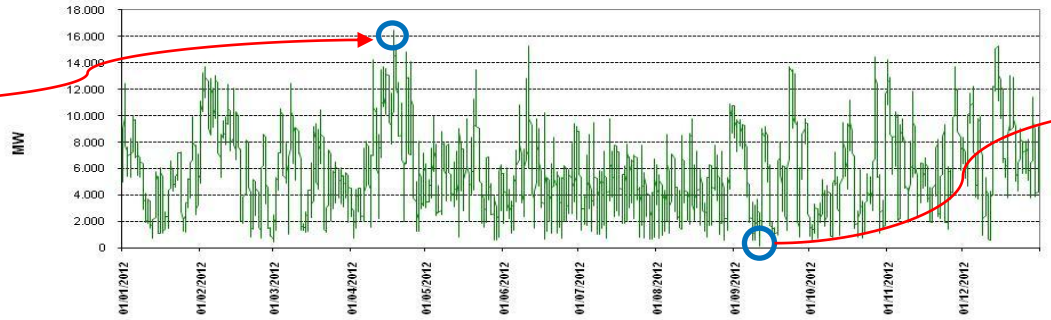
CECRE: RENEWABLE DEMAND COVERAGE

Hours with renewable and co2-free demand coverage over 50% (2013)

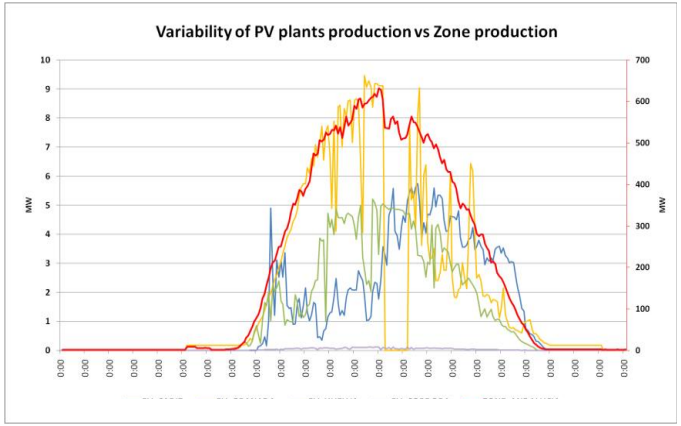


CECRE: Variability

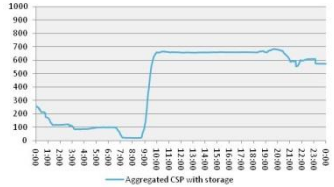
Maximum coverage 64%



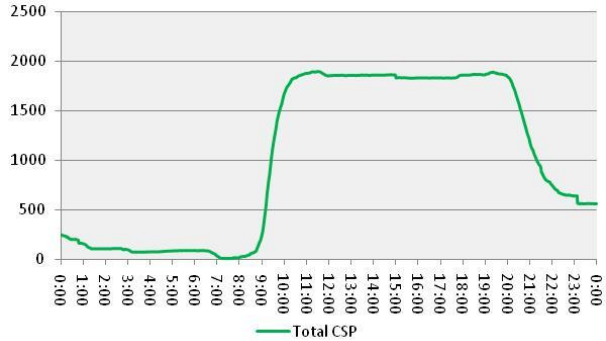
Minimum coverage <1%



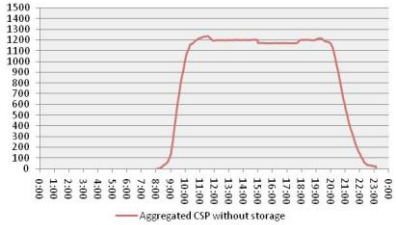
CECRE: Outcome of CS Plants depending on technology

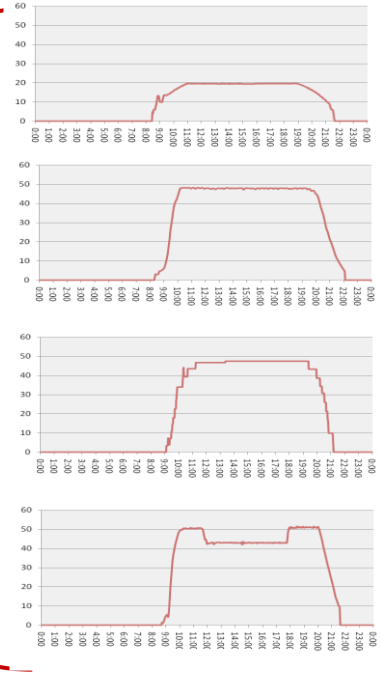


Aggregated outcome power from CSP with storage

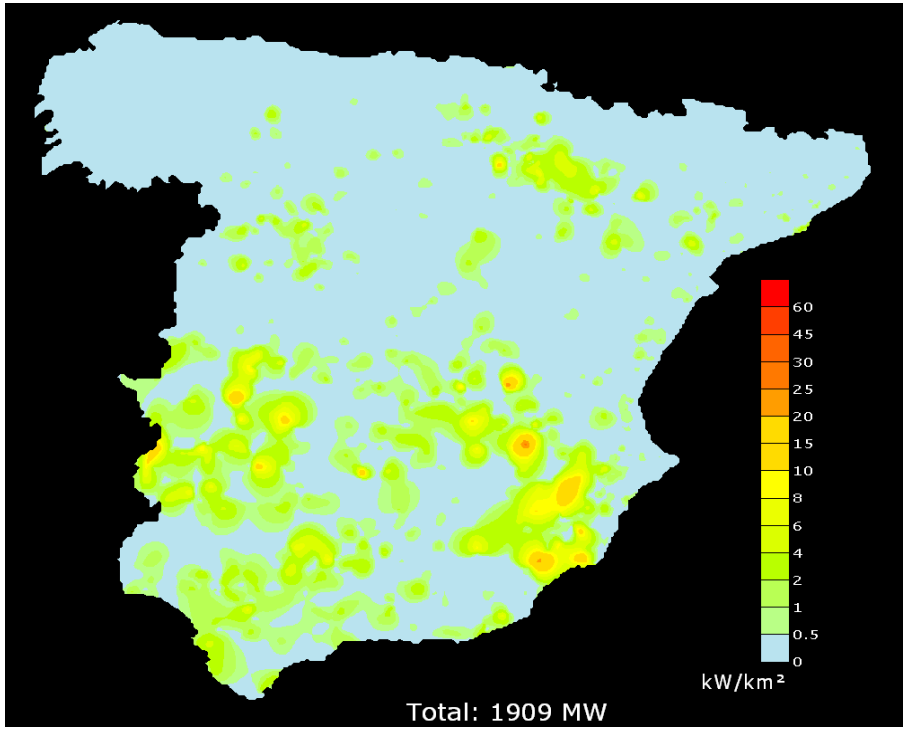


Aggregated outcome power from CSP without storage



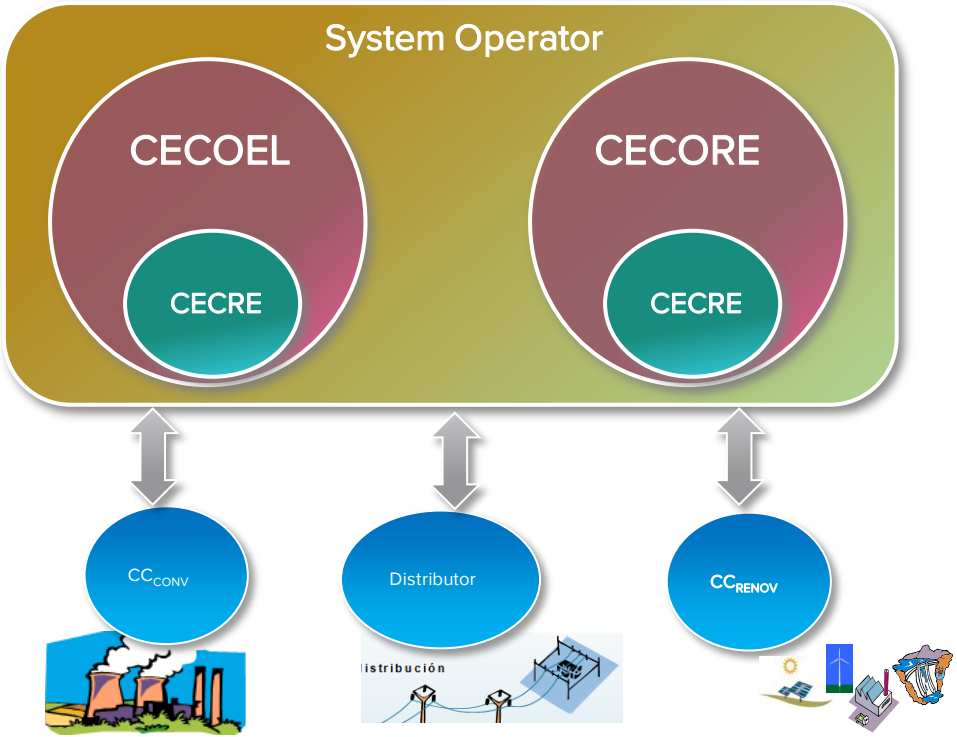


CECRE: Observability



Real-time Photovoltaic Generation

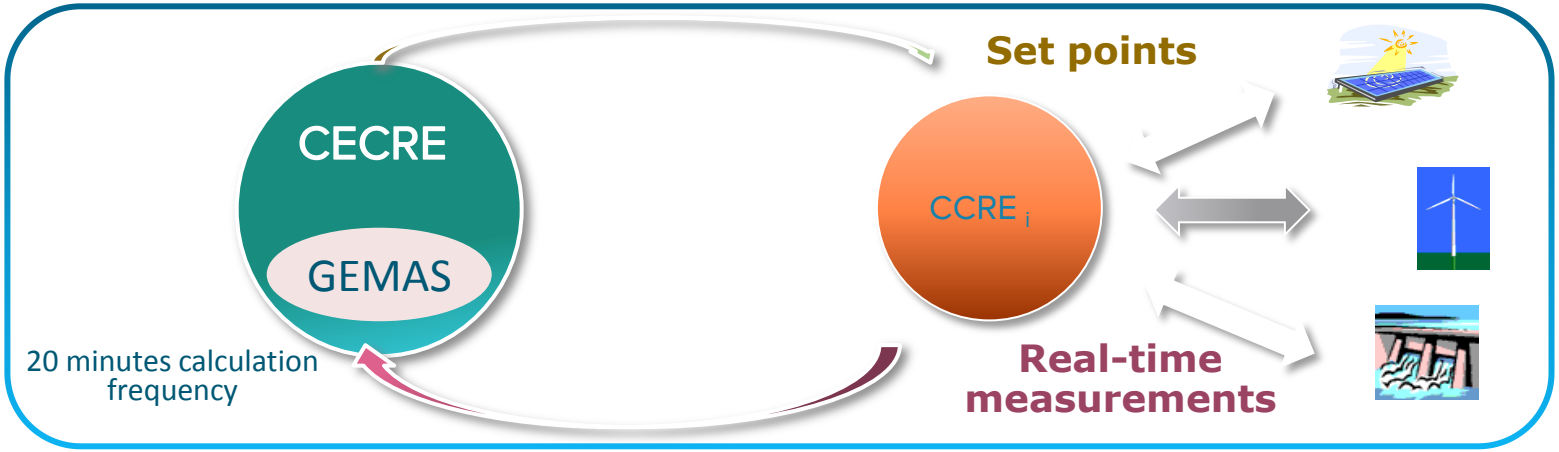
CECRE: Control Center for Renewable Energies



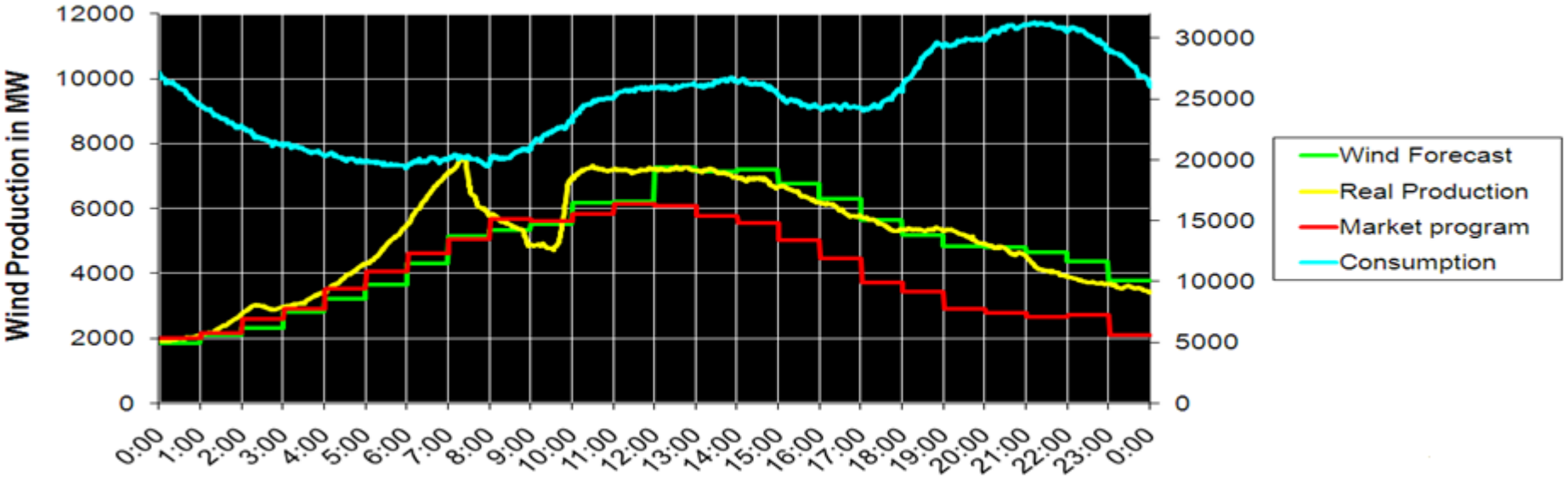
- **3 000 generation installations**
- **37 generation control centers**
- **350 distribution operators**
- **Communication is needed in case of emergency, outages or maintenance**

CECRE: Controllability

SECURITY ANALYSIS USING A REAL-TIME WIND SCENARIO



CECRE: Controllability



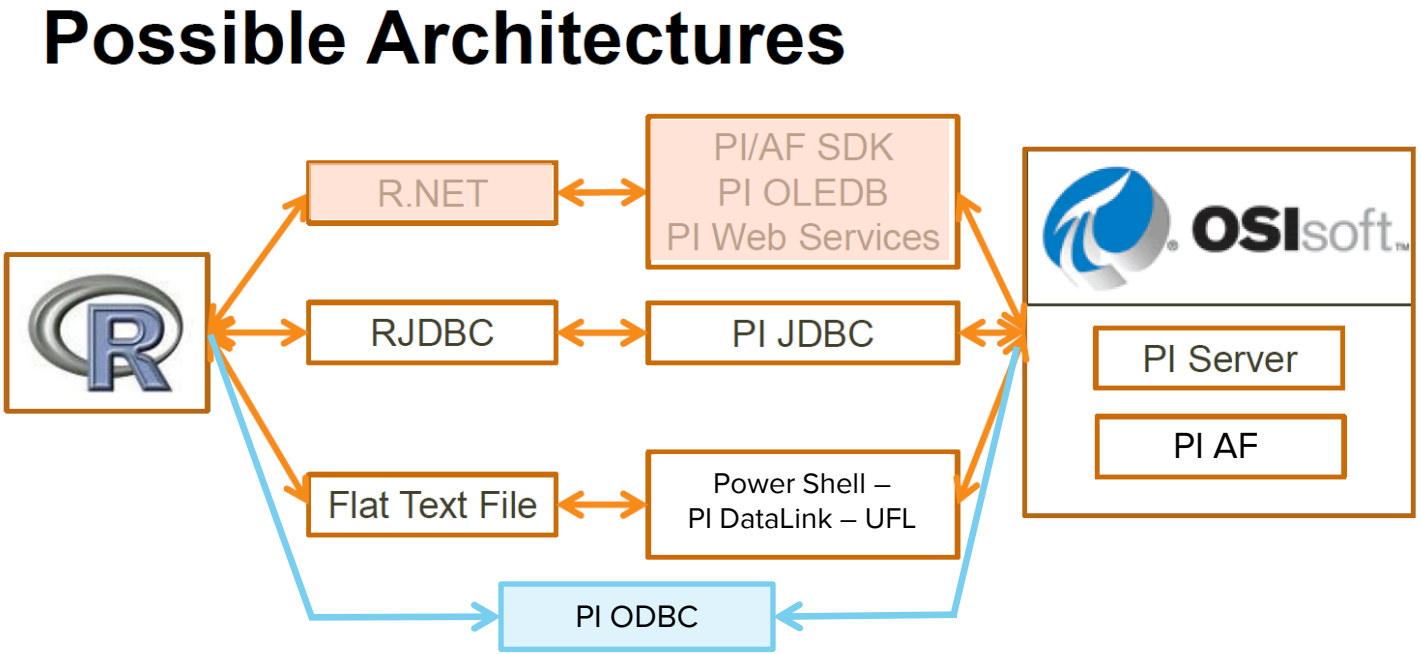
Operational data analysis combining the PI System and R

Data analysis combining the PI System and R Programming

- R is a free software programming language and software environment for statistical computing and graphics.
- The R language is widely used among statisticians and data miners for developing statistical software and data analysis.
  - Effective data handling
  - A suite of operators for arrays and matrices
  - Graphical facilities for data analysis and display
  - A well-developed, simple and effective programming language

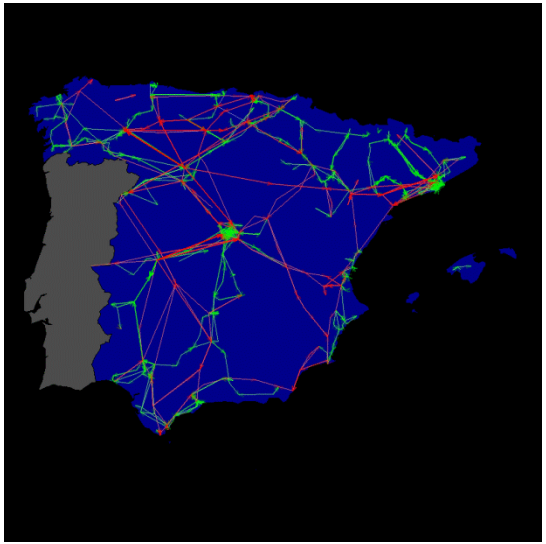
Data analysis combining the PI System and R Programming

Combining the PI System with R

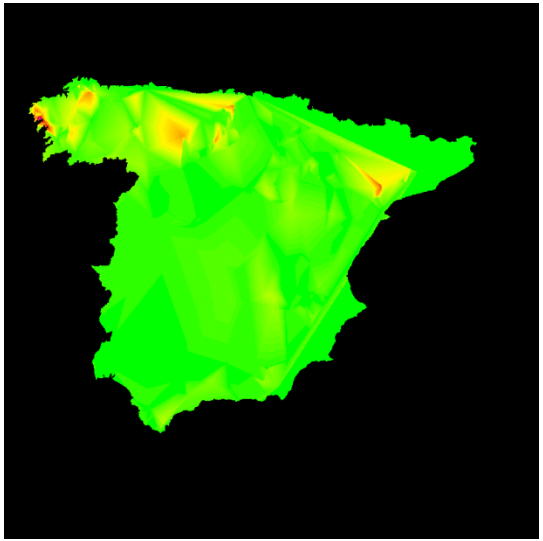


Data analysis combining the PI System and R Programming

- Monitoring Electrical variables and Power Generation in real-time



- **Real-time Power flows in the Transmission Grid**



- **Real-time Wind Power Generation**

contornos_eolica_2014-06-23.gif

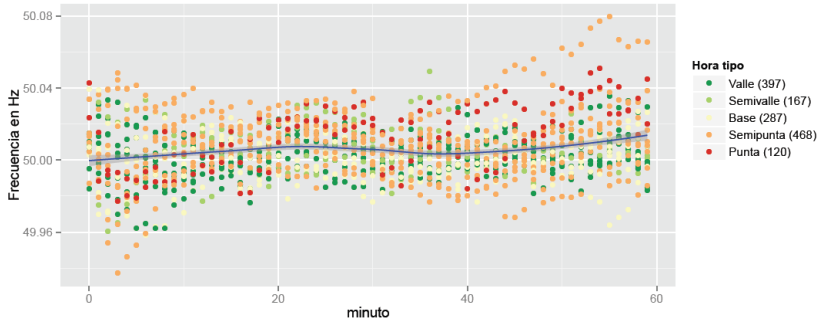
R Packages required:

- Rmaps.r
- Ggmaps.r
- Akima.r

Data analysis combining the PI System and R Programming

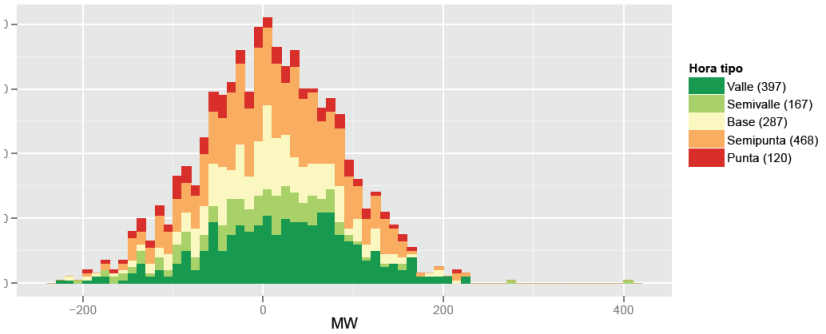
- Historical Analysis of Electrical Variables

Frequency Analysis



- Distribution of frequency values with 1-minute sampled

Area Control Error (ACE) Analysis



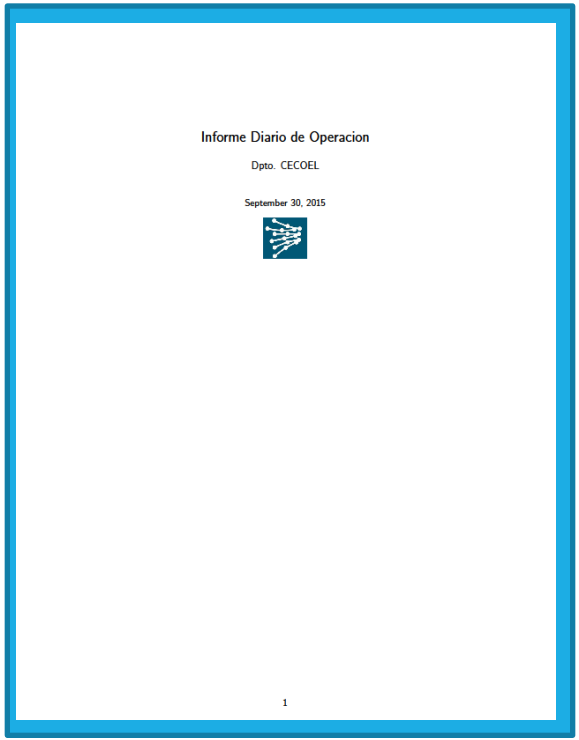
- Daily Distribution of the Area Control Error (ACE)

R Packages required:

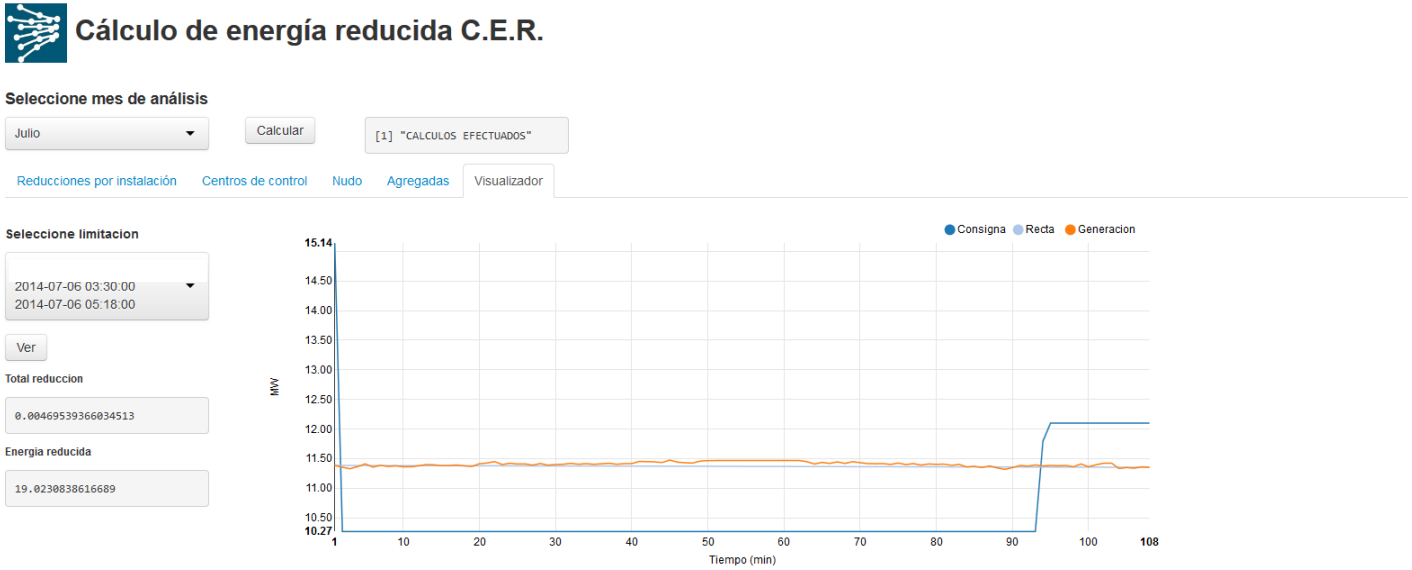
- GGplot

Data analysis combining the PI System and R Programming

- Automatic report generation



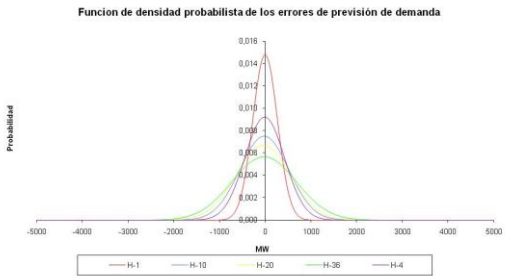
Data analysis combining the PI System and R Programming

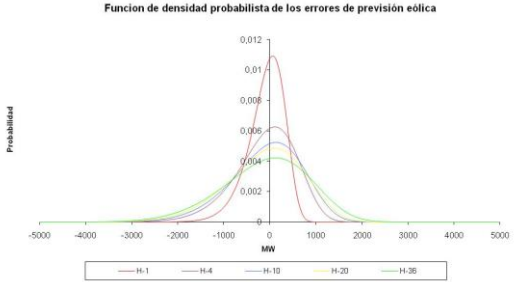


- **Renewable Energy Curtailment analysis application using the PI System, R and Shiny**

Data analysis combining the PI System and R Programming

- Calculation of the required amount of reserve using a probabilistic methodology





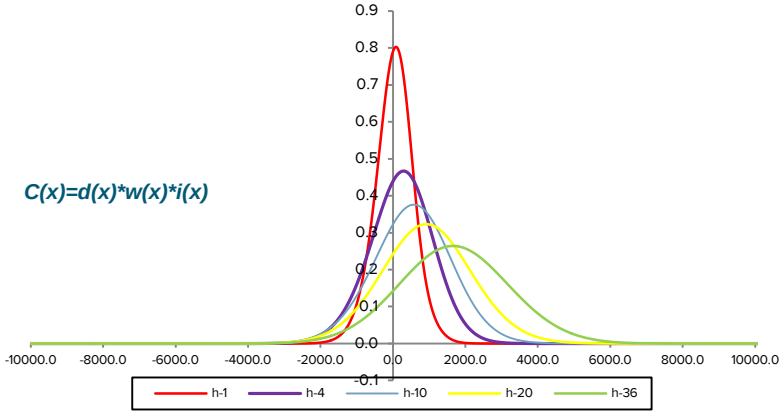
Certain amount of reserve in the system is necessary in order to face:

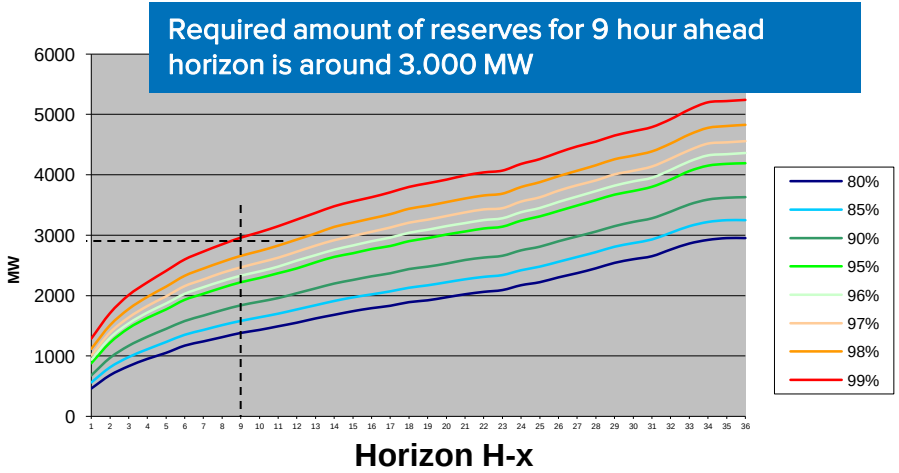
- Demand forecast errors
- Renewable forecast errors
- Non availability generation units

Required level of reserve can be obtain by the "sum" (convolution) of these 3 "uncertainties" (probabilistic density functions)

Data analysis combining the PI System and R Programming

- Calculation of the required amount of reserve using a probabilistic methodology
  - Using the PI Data Archive to get historical demand and renewable generation records in order to calculate these errors.
  - Using R is to fit these errors to standard probabilistic density functions (Gaussian, Weibull) and perform Montecarlo simulation.





Conclusions and Next Steps

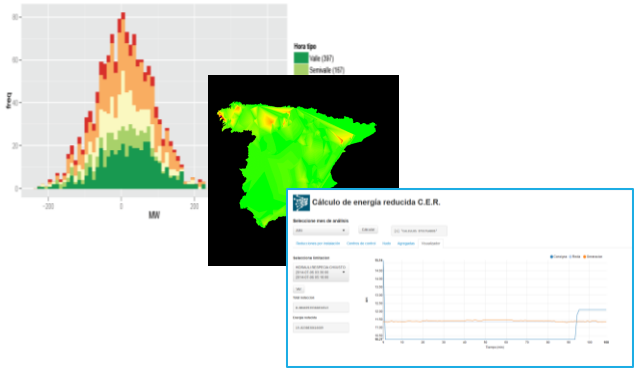
Conclusions and Next Steps

- Real-time data awareness: 2.5 billion telemetries every day.
- PI System is a powerful tool for:
  - Retrieving both real time and historical data values.
  - Monitoring at the electrical control center.
  - Advanced data processing: PI System supports standard programming languages.
- Combining the PI System and R programming allows more powerful way to analyze data

Conclusions and Next Steps

- Future steps using PI DataLink & R approach:
  - Implementing more efficient architectures to link PI DataLink and R (R.net /PI WebServices) in order to speed up even more retrieving and data analysis.
  - Implementing this approach to other existing analysis tools used in the control centre.
  - Development new tools for System Operation using this approach (voltage control, processing structural information of both conventional and renewable generation).

Big Data Analytics and Real-time Data Awareness at CECRE



Business Challenge

- Management and analysis of big data for Electrical System Operation.

Solution

- Implementing PI DataLink, for easy data handling.
- Combining PI DataLink with R programming for complex statistical analysis of large amount of data.

Results and Benefits

- Better operational tools for System Operation analysis.
- Alternative real-time graphical representation.

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Contact Information

Alberto Gil

algil@ree.es

Electrical Engineer

Red Eléctrica de España

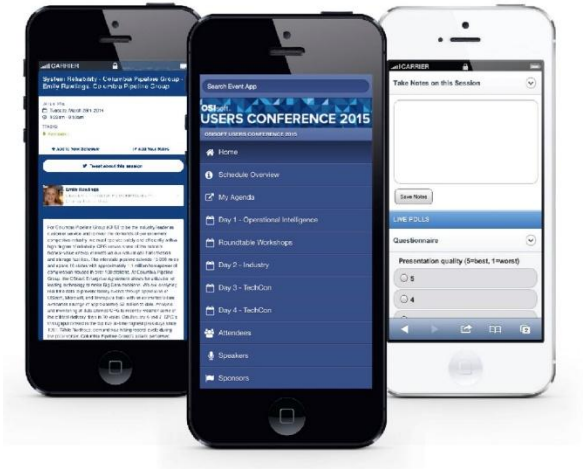
Questions

Please wait for the **microphone** before asking your questions

State your
name & company

Please don't forget to…

Complete the Online Survey for this session



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감사합니다

谢谢

Danke

Gracias

Merci

Thank You

ありがとう

Спасибо

Obrigado