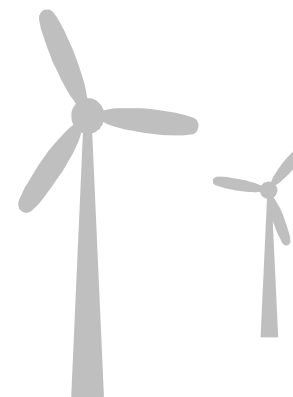




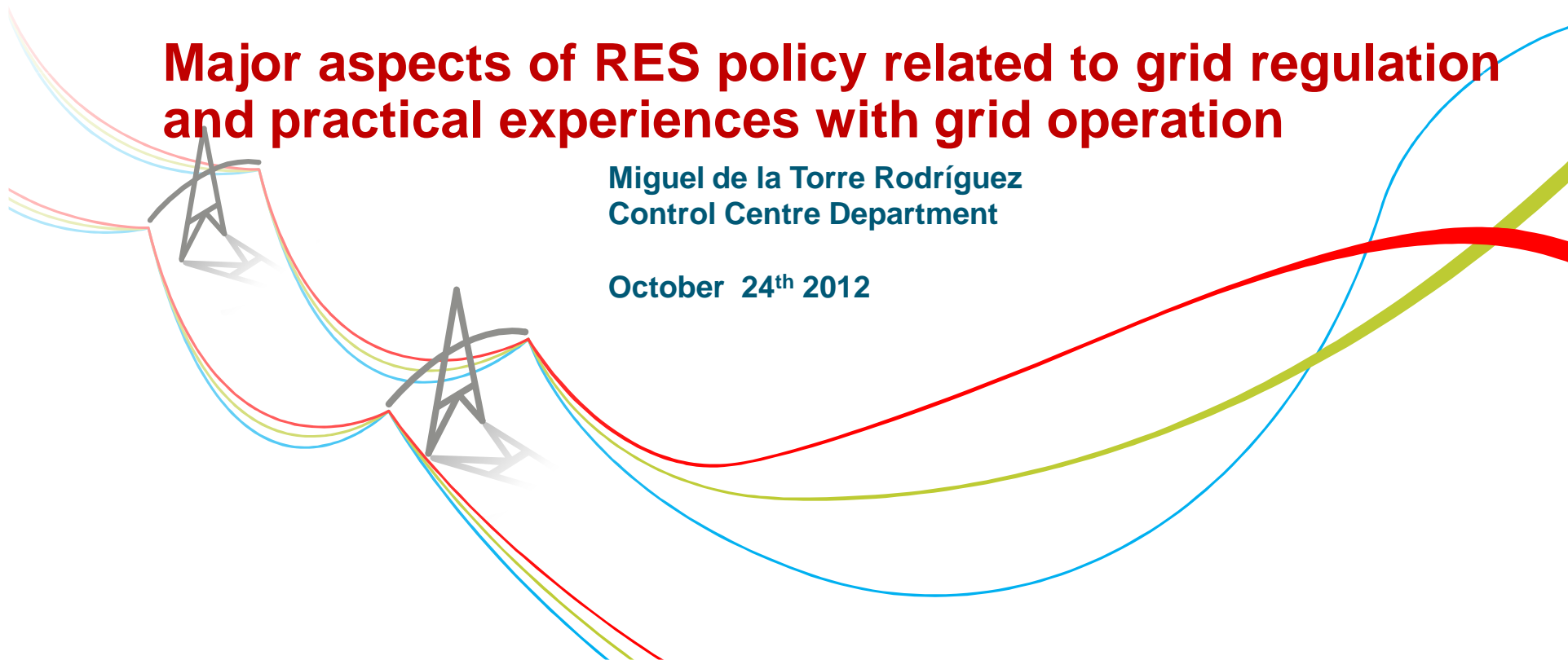
RED
ELÉCTRICA
DE ESPAÑA



Major aspects of RES policy related to grid regulation and practical experiences with grid operation

Miguel de la Torre Rodríguez
Control Centre Department

October 24th 2012



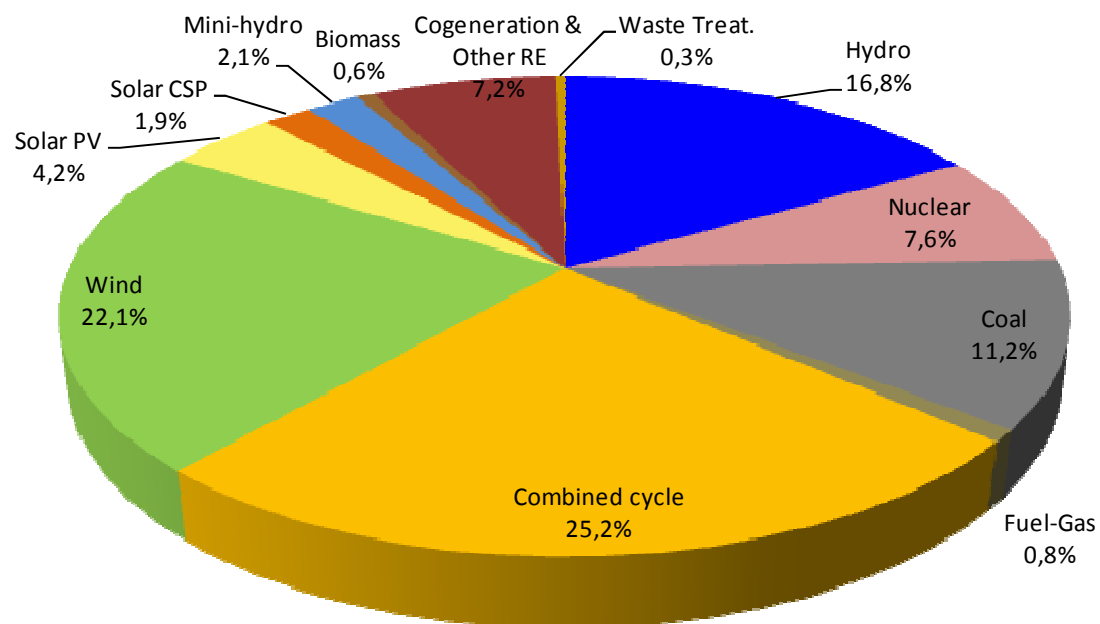


Índex

- Background
- Reasons for the occurrence of a technical limit
- Present limits and curtailment causes
- Influence of the international interconnections
- Increasing the limit of non-manageable renewable energy
- Limit of renewable energy in the future

Background (I)

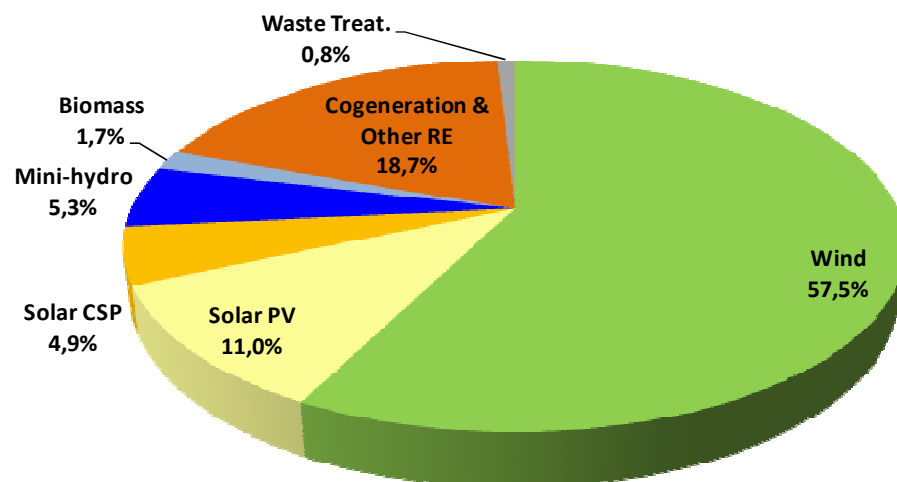
Installed capacity october 2012



| Technology | MW | % |
|--------------------------------|---------------|-------------|
| Combined cycles | 24.947 | 25,2 |
| Hydro-power | 16.657 | 16,8 |
| Coal | 11.085 | 11,2 |
| Nuclear | 7.505 | 7,6 |
| Fuel-Gas | 806 | 0,8 |
| Total (ordinary regime) | 61.000 | 61,5 |
| Wind | 21.943 | 22,2 |
| Cogeneration & Other RE | 7.132 | 7,2 |
| Solar PV | 4.183 | 4,2 |
| Special regime hydro | 2.034 | 2,1 |
| Solar CSP | 1.878 | 1,9 |
| Biomass | 639 | 0,6 |
| Waste treatment | 324 | 0,3 |
| Total (special regime) | 38.133 | 38,5 |
| Total | 99.133 | |

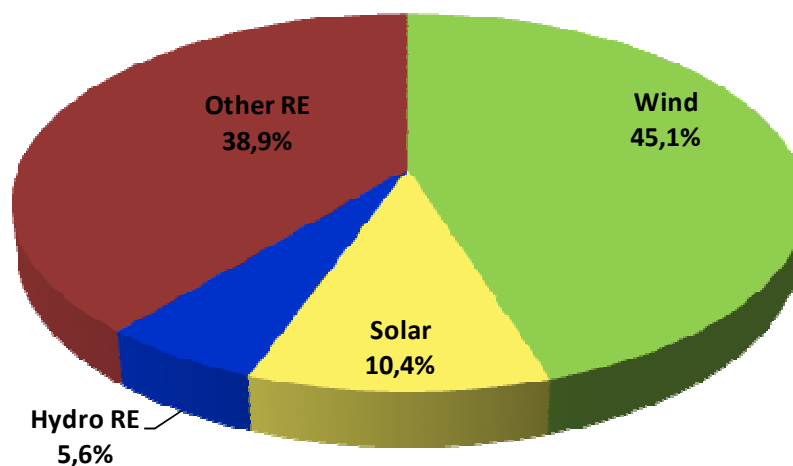
Background (II)

Installed Power Special Regime



| Tecnología | MW | % |
|-----------------------------|---------------|------|
| Wind | 21.943 | 57,5 |
| Cogeneration &Other RE | 7.132 | 18,7 |
| Solar PV | 4.183 | 11,0 |
| Special regime hydro | 2.034 | 5,3 |
| Solar CSP | 1.878 | 4,9 |
| Biomass | 639 | 1,7 |
| Waste treatment | 324 | 0,8 |
| Total Special Regime | 38.133 | |

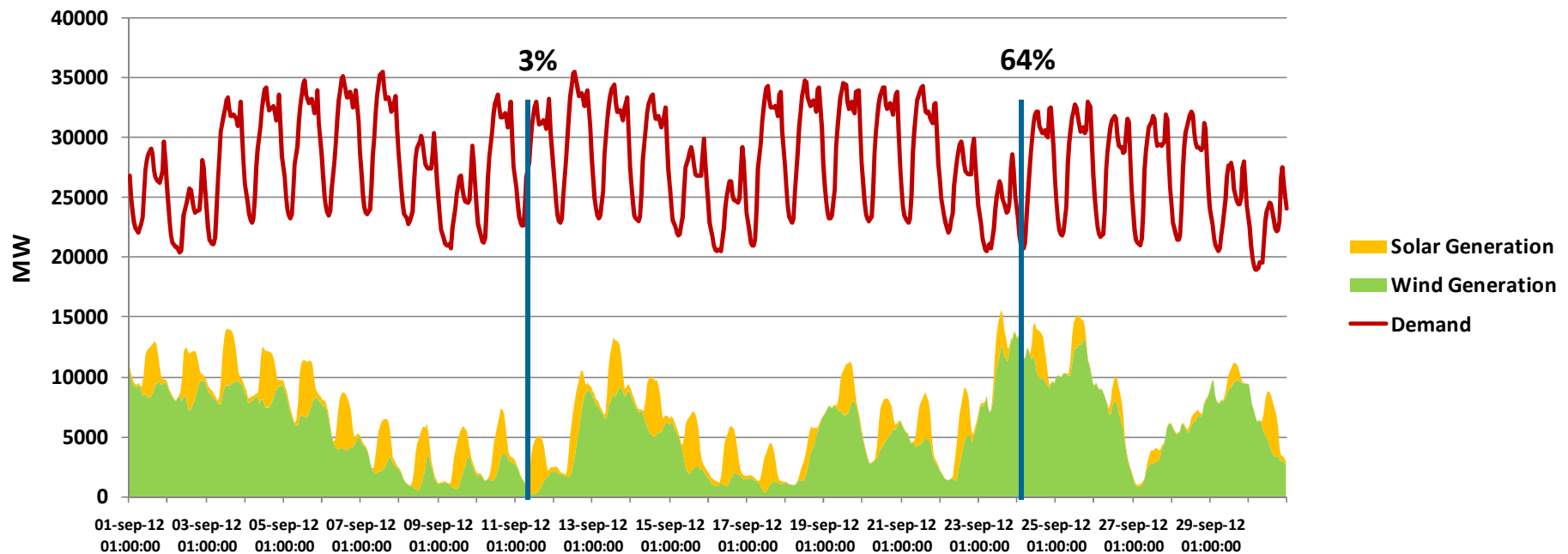
Energy produced in 2011



| Technology | GWh | % |
|-----------------------------|---------------|------|
| Wind | 41.661 | 47,7 |
| Solar | 9.598 | 7,4 |
| Hydro RE | 5.155 | 7,2 |
| Other RE | 35.939 | 38,5 |
| Total Special Regime | 92.353 | |

Background (III)

Characteristics of RES Generation

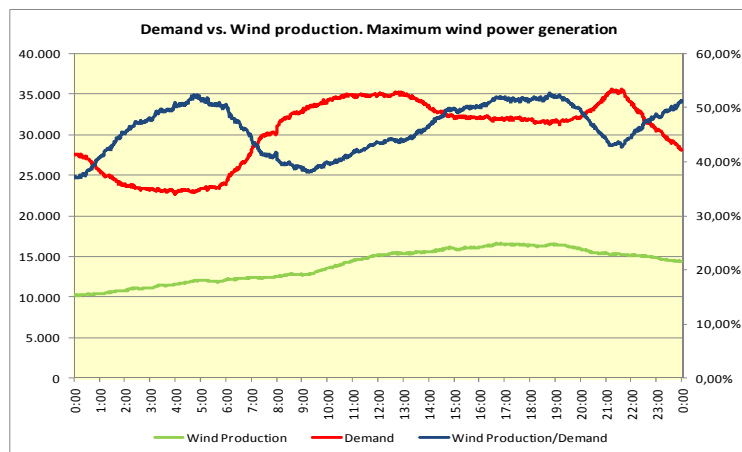
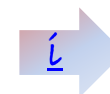


- Variability depending on primary resource.
- RES don't follow needs of demand/consumers.
- Back-up dispatchable generation must be ready to compensate fluctuations of demand and RES generation.
- Some times very little net demand/'space' for dispatchable generation. 5

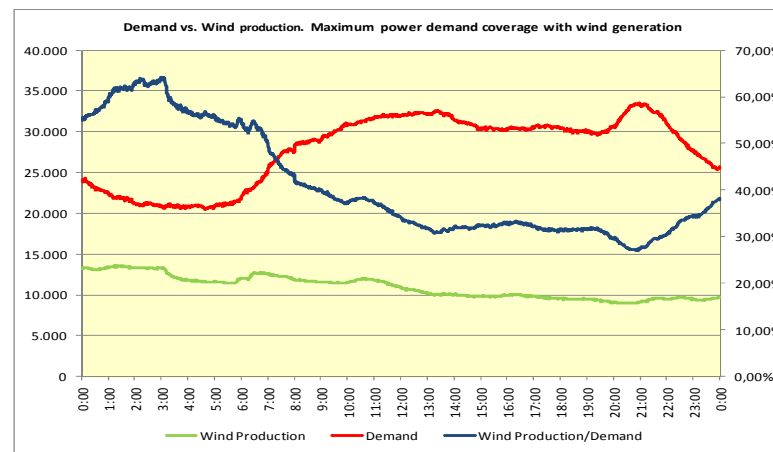
Background (IV)

Wind Production Records

| Wind Energy Generation | Tuesday 09/11/10 | Sunday 06/11/11 | Monday 16/04/12 | Wednesday 18/04/12 | Thursday 19/04/12 | Monday |
|-------------------------|---------------------|--------------------|--------------------|-----------------------|----------------------|------------------|
| Power (MW) | 14.962 | | | 16.636 | | |
| Hourly energy (MWh) | 14.752 | | | 16.455 | | |
| Daily energy (MWh) | 315.258 | | | 334.850 | | |
| Demand coverage | 54,3 % 3:35 h | 59,6 % 2:00 h | 60,4 % 3:48 h | | 61% 1.37 h | 64,25% 3.03 h |
| Monthly demand coverage | | 21,5 % Feb-12 | | | 27% Apr-12 | |



- Maximum: 16.636 MW (18/04/2012)
- Minimum last year: 85 MW (11:34 h, 11/09/2012)

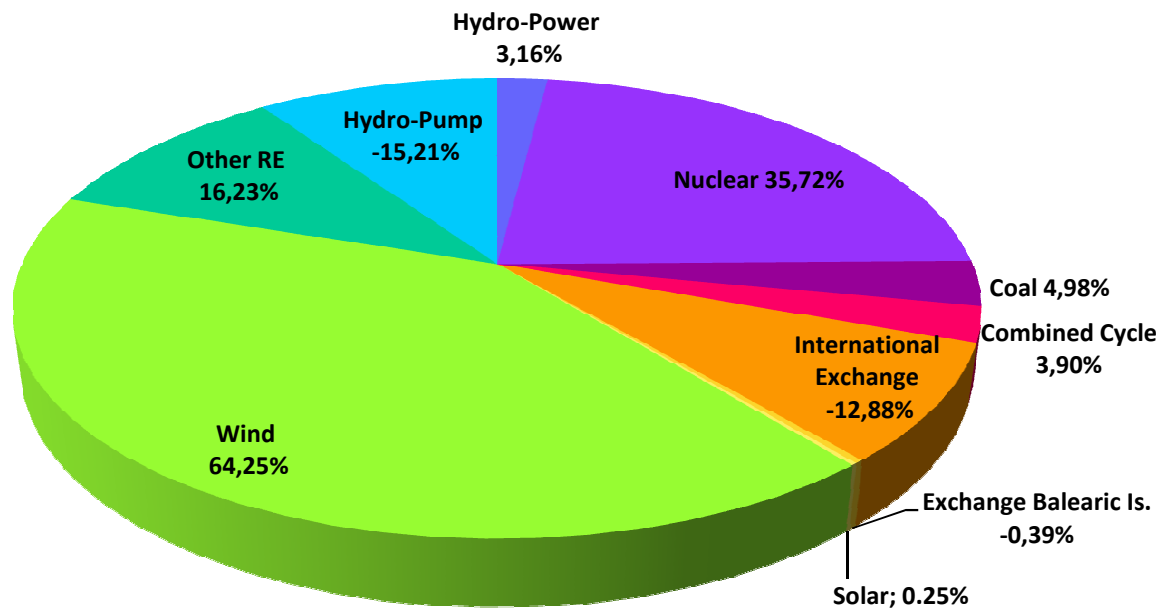


- Maximum: 64% of demand (24/09/2012 3:03 h)
- Wind production: 13.285 MW
- Demand: 20.677 MW
- Minimum < 1% of demand

Background (V)

Maximum contribution of wind generation to demand coverage

- 24/09/2012 at 3:03 h: 64,25% of wind production



| Technology | MW | % |
|------------------------|---------------|--------|
| Wind | 13.285 | 64,25 |
| Nuclear | 7.385 | 35,72 |
| Other RE | 3.355 | 16,23 |
| Coal | 1.029 | 4,98 |
| Combined Cycle | 807 | 3,90 |
| Hydro | 653 | 3,16 |
| Solar | 52 | 0,25 |
| Fuel-Gas | 0 | 0,00 |
| Exchange Balearic Is. | -80 | -0,39 |
| International Exchange | -2.664 | -12,88 |
| Hydro Pump | -3.145 | -15,21 |
| Total | 20.677 | |



Reasons for the occurrence of a technical limit (I)

In order to ensure the electrical supply, the Operator System needs the generation units to supply enough:

- Inertia
- Load-Frequency Control
- Voltage regulation
- Load following capability
- Robustness to disturbances
- Firmness in power injection



Reasons for the occurrence of a technical limit (II)

- Even a technology that met all technical requirements above would be limited by the demand of the system and the export capacity.
- But in general, to different degrees, neither the wind farms nor photovoltaic plants satisfy the above requirements satisfactorily.
- That implies that other technologies have to be present in the generation mix to provide permanently the electrical system of these features and services.
- If other technologies have to be present, the net demand/“space” left for non-manageable renewable energies (wind + solar) is less than the theoretical “demand + export capacity”.

Reasons for the occurrence of a technical limit (III)

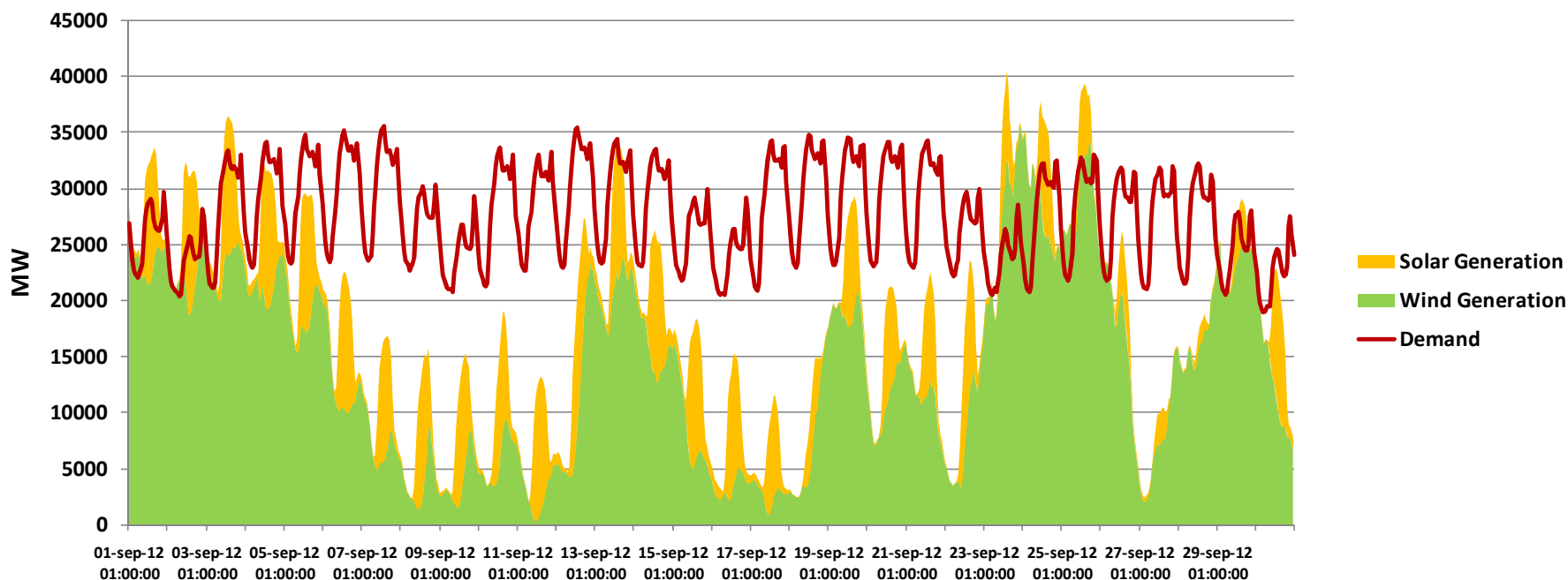
Non manageable renewable energy

- **Non-manageable Generation definition (RD 661/2007):**
 - Primary energy source is neither controllable nor storable. Production control implies primary energy spilling.
 - The firmness of the forecast of future production is not enough to be considered as a program.
- **Production depending on available primary energy source.**
- **Connection without having into account the needs of the system.**
- **Necessity of additional reserve in the system.**
- **No participation in the balance mechanism of the system.**
- **Uncertainties associates with their production.**

Reasons for the occurrence of a technical limit (IV)

System balancing

- Presently, with 22 GW of wind and 6.1 GW of solar variable RES represent 19.3% of the total energy produced.
- If wind and solar were to supply 50% of the demand with the same proportion as today:
 - The Spanish system would need 57 GW of wind and 16 GW of solar.
 - 11% of the time wind and solar production would be greater than the demand.

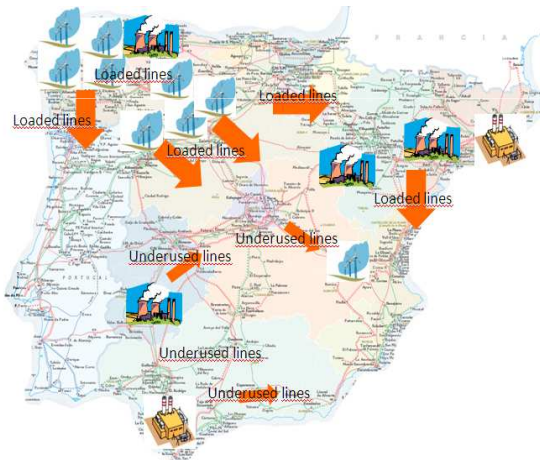


Reasons for the occurrence of a technical limit (V)

Low capacity factors

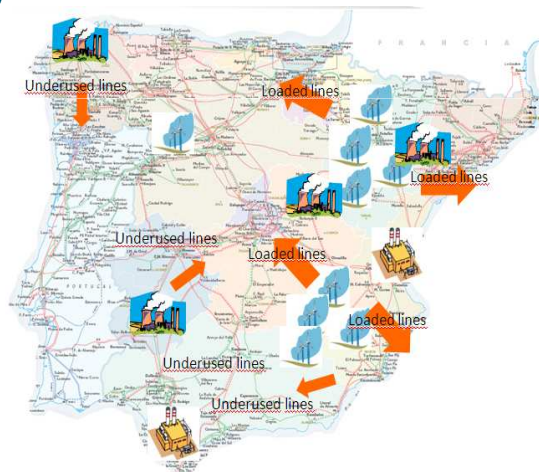
- Low capacity factor (low produced energy per MW installed).
- Higher need for transmission lines than conventional per unit energy.

November 3rd 2011



Heavy flows from the North-West to the center and East. Low hydro and CC.

November 6th 2011



Heavy flows from the East to the center and North. Low hydro and CC.

November 7th 2011



Heavy flows from the East and South-West to the center and South. High hydro and CC.

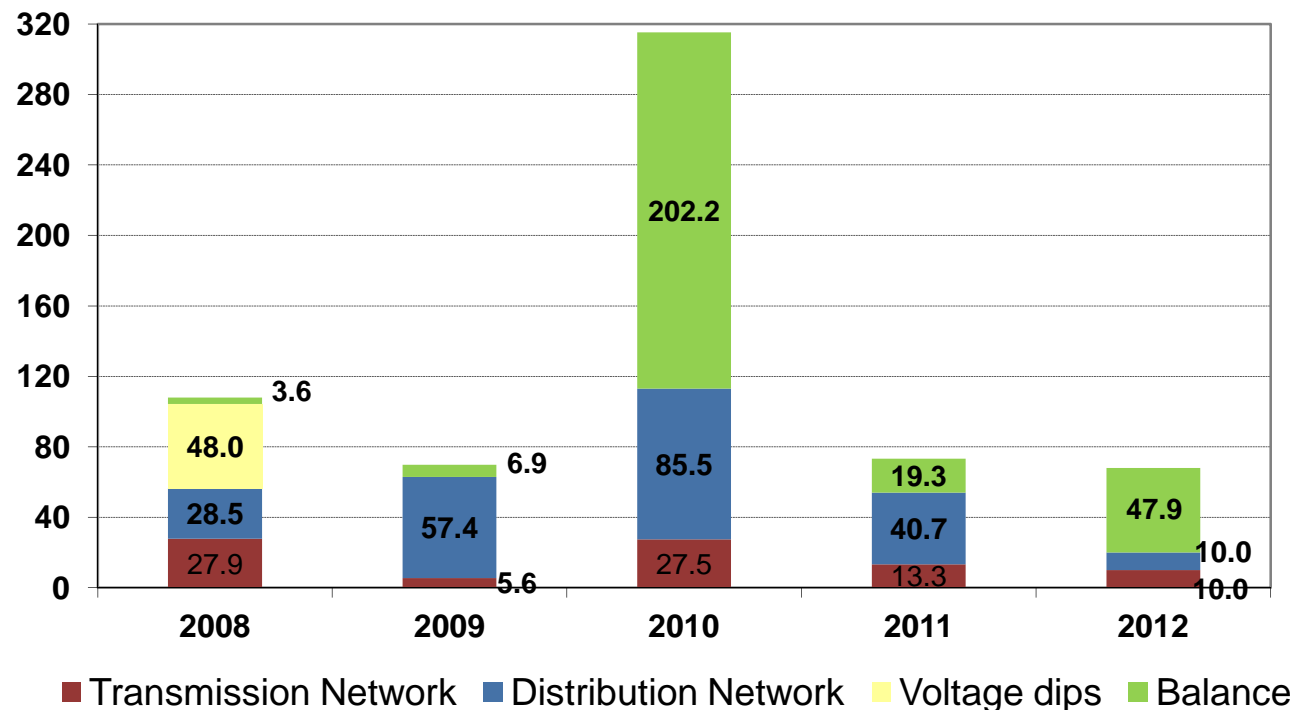


Present limits and curtailment causes (I)

- **Evacuation infeasibility in the Transmission Network**
- **Evacuation infeasibility in the Distribution Network**
- **Non-adequate behaviour of the units after an incident**
- **Load-generation balance infeasibility**

Present limits and curtailment causes (II)

Wind reductions (GWh)



- Presently very low level of curtailments. 0.18% of total available wind energy in 2011.

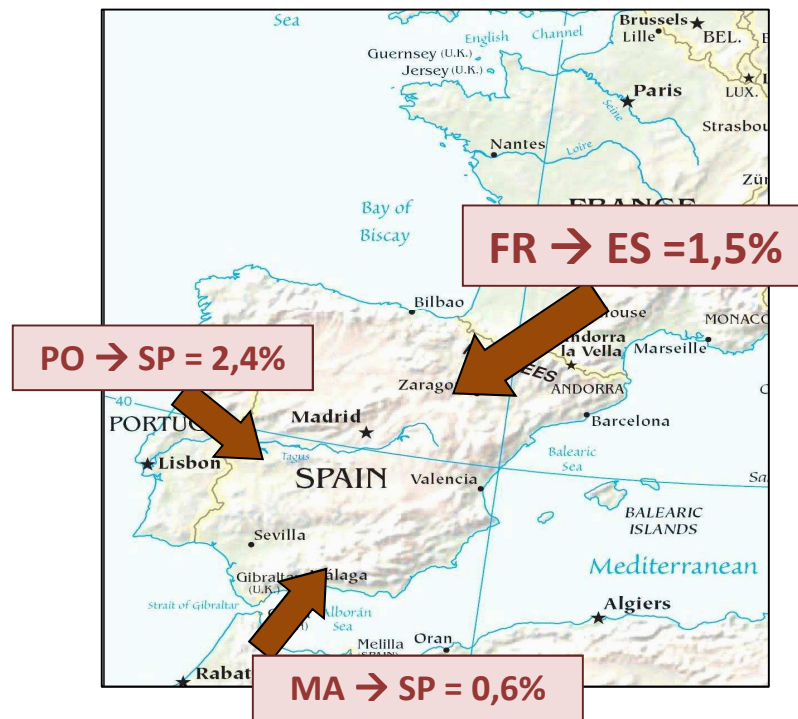
Influence of the international interconnections (I) Contribution to the mainland electrical system

- Support in case of load-generation unbalance.
- Provide stability and security to the system.

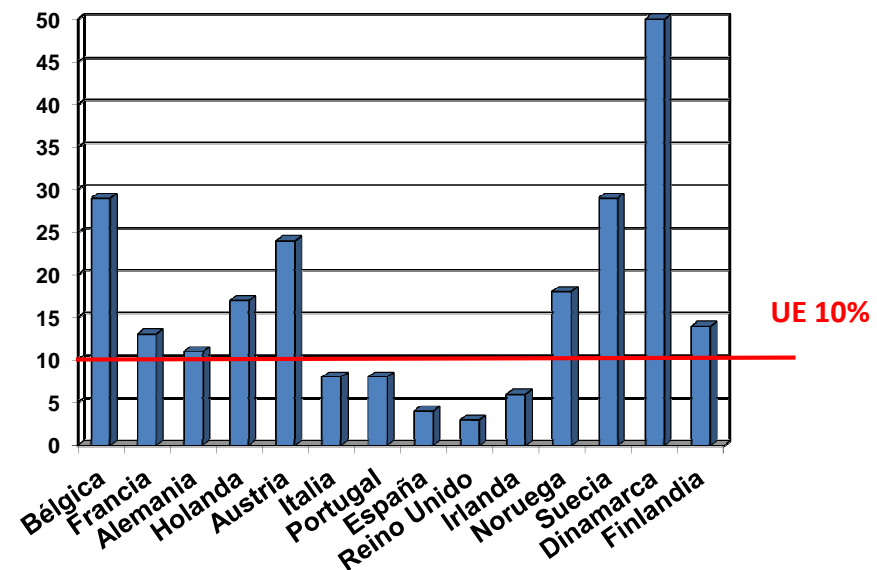


Influence of the international interconnections (II)

Spanish interconnections capacity



Interconnection capacity compared to installed capacity



Installed Power SPAIN ≈ 99 GW

- Limited interconnection capacity with France, security link with the European Interconnected system. In practice almost an “electrical island”.

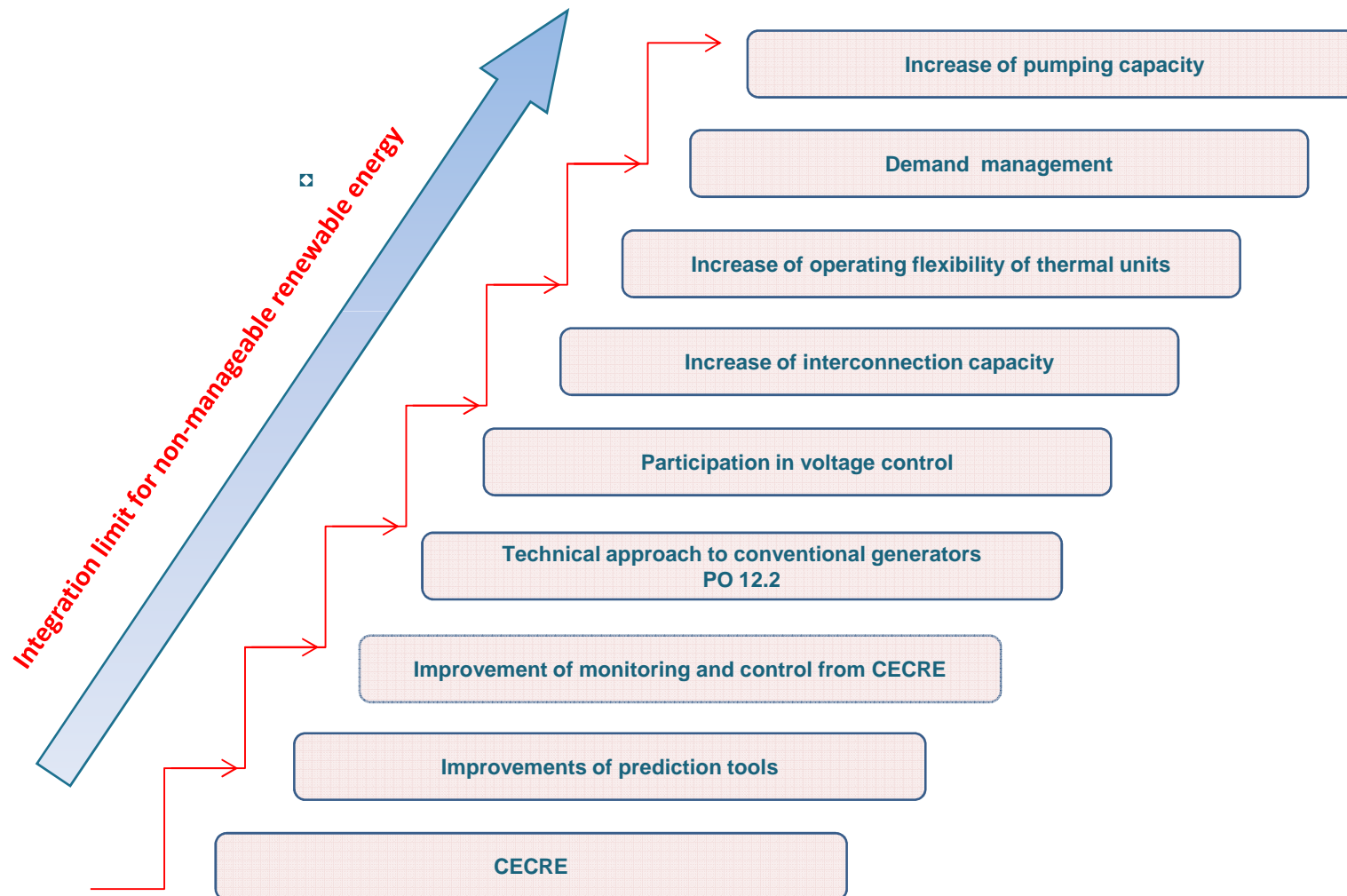
Influence of the international interconnections (III)

Next increase in the capacity with France

New interconnection line Spain-France: L-400 kV Baixas-Santa Llogaia.

- **Planned in 2014.**
- **Capacity: 2 x 1000 MW.**
- **HVDC VSC technology:**
 - Active and Reactive power permanently controlled, avoiding overloads.
 - Prevents from disturbances propagation.
 - Lower transmission losses.
 - Lower environmental impact.
 - Converter stations more complex.
 - Need of filters to limit generated harmonics.
 - Contribution to system security lower than AC technology.

Increasing the limit of non-manageable renewable energy (I)





Increasing the limit of non-manageable renewable energy (II)

- Theoretically, there is no limit in the installation (there will be limitation on the economic, environmental integration,...), but an excessive over-installation may generate operational risks.
- *There is a limit for penetration of renewable energy for a giving time.*
- **The limit is not unique:**

Penetration limit= f(demand and pumping at instant, demand for the next hours, network state, generation mix, interchange capacity, technological adaptation)

*Upper limit of penetration = Demand + Pumping +
Export – Nuclear power
– Regulating power units (Thermal + Hydraulic) –
Special Regime*

..... and it will be calculated by CECOEL/CECRE in real time.

Thanks for your attention!



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