Wind Energy in Spain

Néstor Aparicio Marín
Universitat Jaume I
Castelló de la Plana
Spain

UNSW, 24 November 2008

Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

1. Introduction

- Group of Electrical Engineering & Control

  Universitat Jaume I

  Castelló de la Plana

- Castelló has 570.5 MW of wind energy capacity

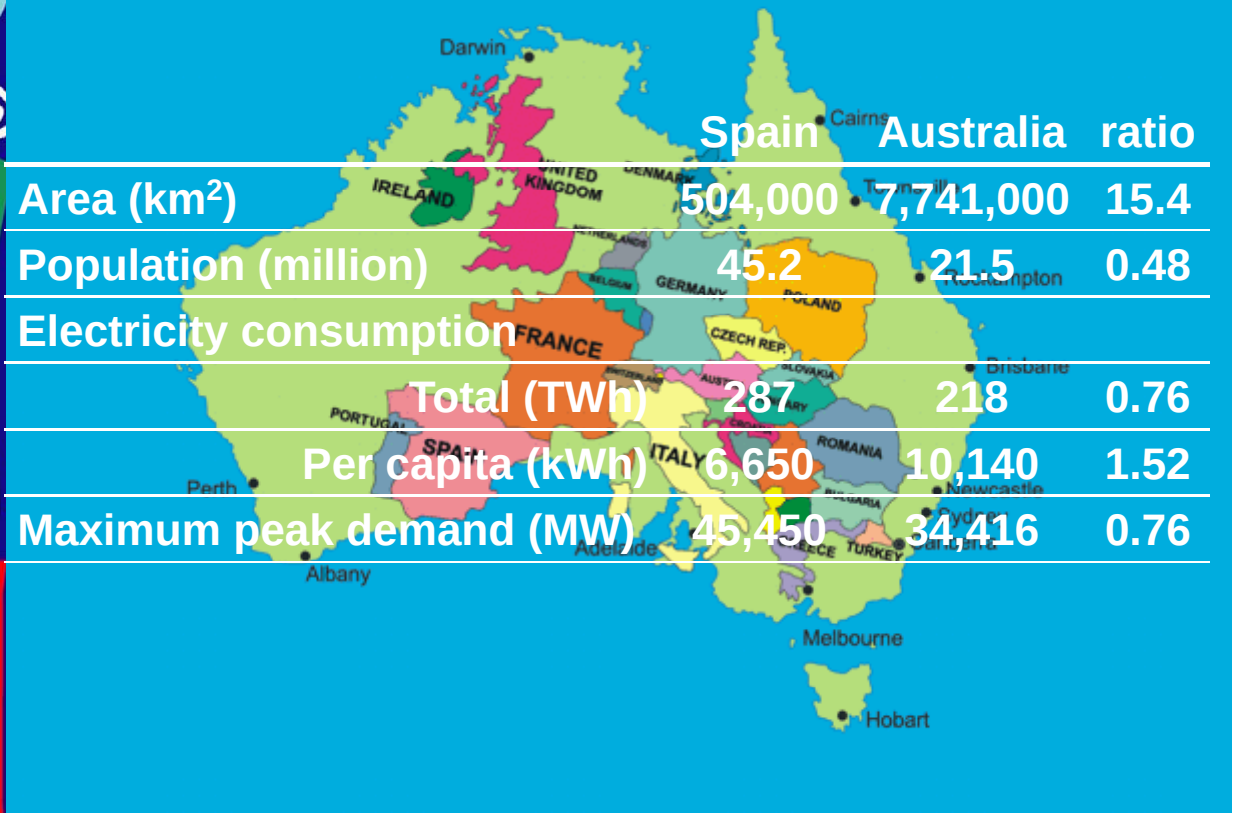
Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

2. Spain vs Australia

Note: You can find this picture here: http://www.ozdownunder.net/media/Europe_Aus.gif

2. Spain vs Australia



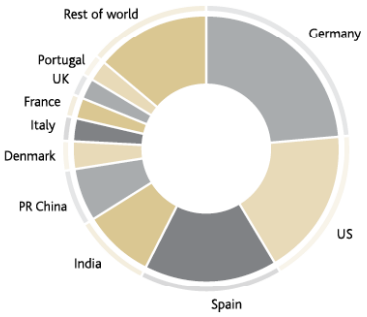
	Spain	Australia	ratio
Area (km^2)	504,000	7,741,000	15.4
Population (million)	45.2	21.5	0.48
Electricity consumption			
Total (TWh)	287	218	0.76
Per capita (kWh)	6,650	10,140	1.52
Maximum peak demand (MW)	45,450	34,416	0.76

Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

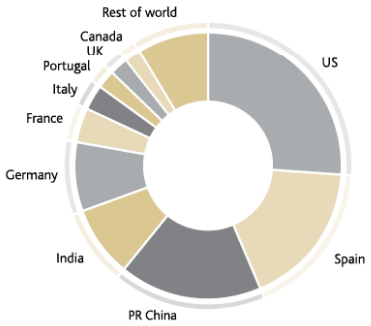
3. Capacity and generation

Top-10 total installed capacity



	MW	%
Germany	22,247	23.7
US	16,818	17.9
Spain	15,145	16.1
India	7,845	8.4
PR China	5,906	6.3
Denmark	3,125	3.3
Italy	2,726	2.9
France	2,454	2.6
UK	2,389	2.5
Portugal	2,150	2.3
Rest of world	13,060	13.9
Total top 10	**80,805**	**86.1**
Total	**93,864**	**100.0**

Top-10 new capacity

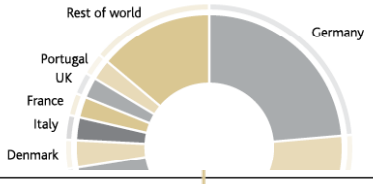


	MW	%
US	5,244	26.4
Spain	3,522	17.7
PR China	3,304	16.6
India	1,575	7.9
Germany	1,667	8.4
France	888	4.5
Italy	603	3.0
Portugal	434	2.2
UK	427	2.1
Canada	386	1.9
Rest of world	1,815	9.1
Total top 10	**18,050**	**90.9**
Total	**19,865**	**100.0**

Source: GWEC – Global Wind 2007 Report

3. Capacity and generation

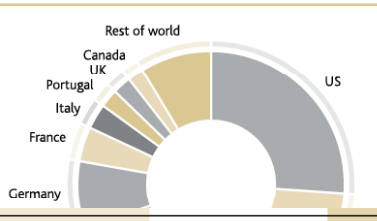
Top-10 total installed capacity



PACIFIC REGION	Australia	817	7	824
	New Zealand	171	151	322
	Pacific Islands	12	0	12
	Total	**1,000**	**158**	**1,158**

	MW	%
Germany	22,247	23.7
US	16,818	17.9
Spain	15,145	16.1
India	7,845	8.4
PR China	5,906	6.3
Denmark	3,125	3.3
Italy	2,726	2.9
France	2,454	2.6
UK	2,389	2.5
Portugal	2,150	2.3
Rest of world	13,060	13.9
Total top 10	**80,805**	**86.1**
Total	**93,864**	**100.0**

Top-10 new capacity



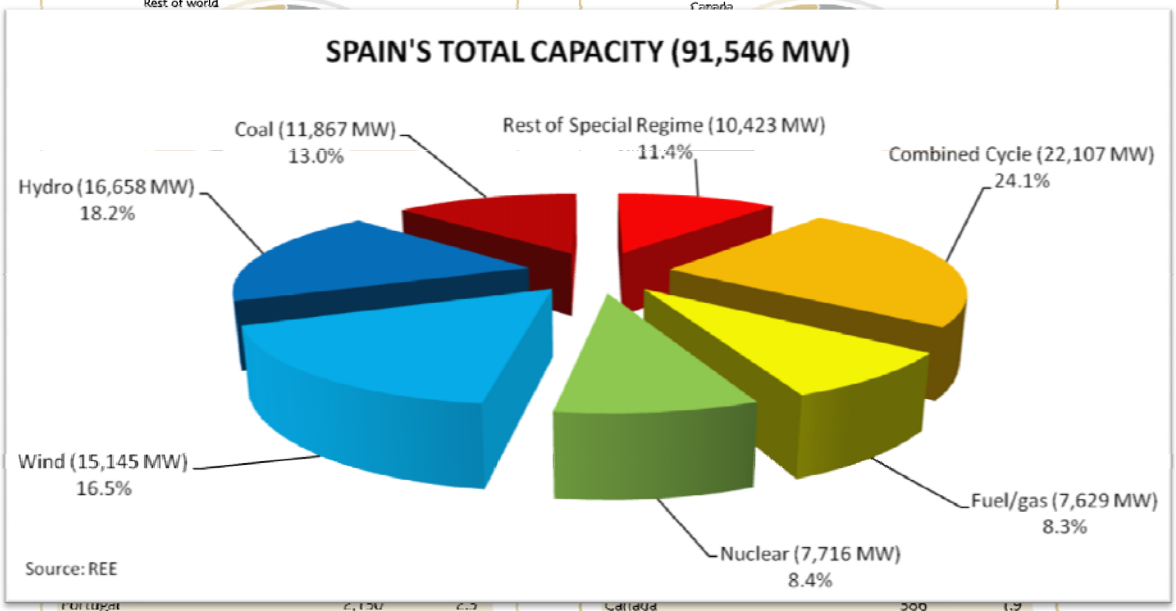
	MW	%
US	5,244	26.4
Spain	3,522	17.7
PR China	3,304	16.6
India	1,575	7.9
Germany	1,667	8.4
France	888	4.5
Italy	603	3.0
Portugal	434	2.2
UK	427	2.1
Canada	386	1.9
Rest of world	1,815	9.1
Total top 10	**18,050**	**90.9**
Total	**19,865**	**100.0**

Source: GWEC – Global Wind 2007 Report

3. Capacity and generation

Top-10 total installed capacity

Top-10 new capacity



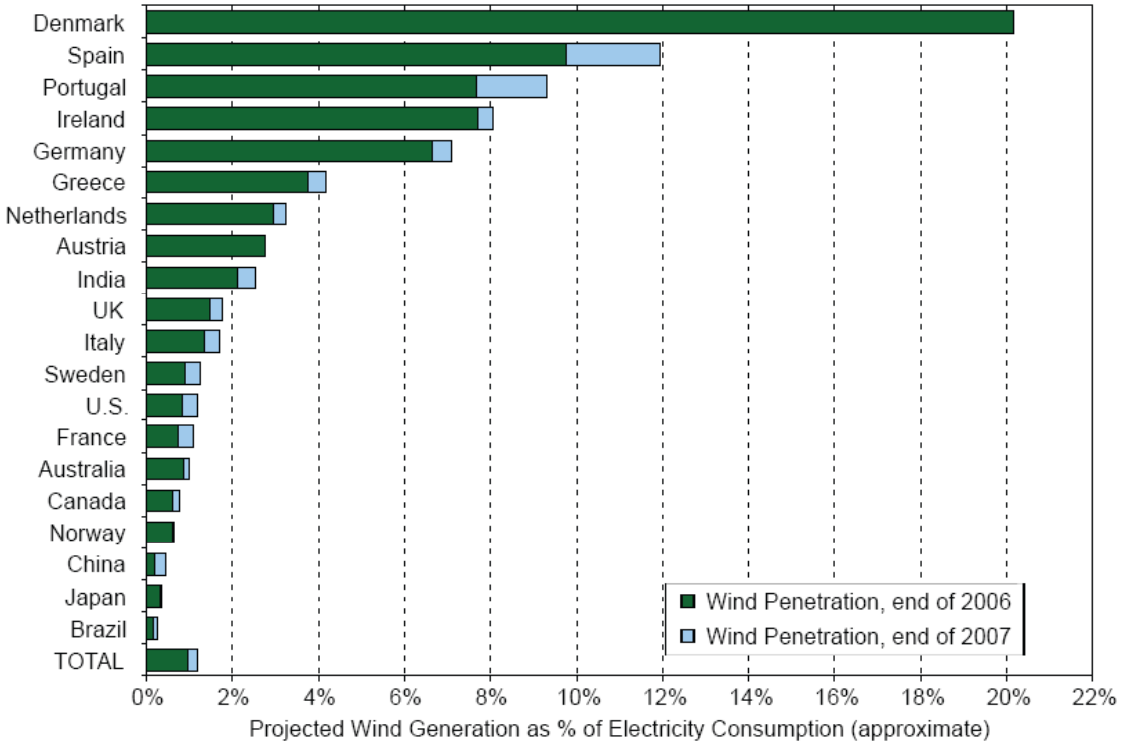
Rest of world	13,060	13.9
Total top 10	80,805	86.1
Total	93,864	100.0

Rest of world	1,815	9.1
Total top 10	18,050	90.9
Total	19,865	100.0

Source: GWEC – Global Wind 2007 Report

3. Capacity and generation

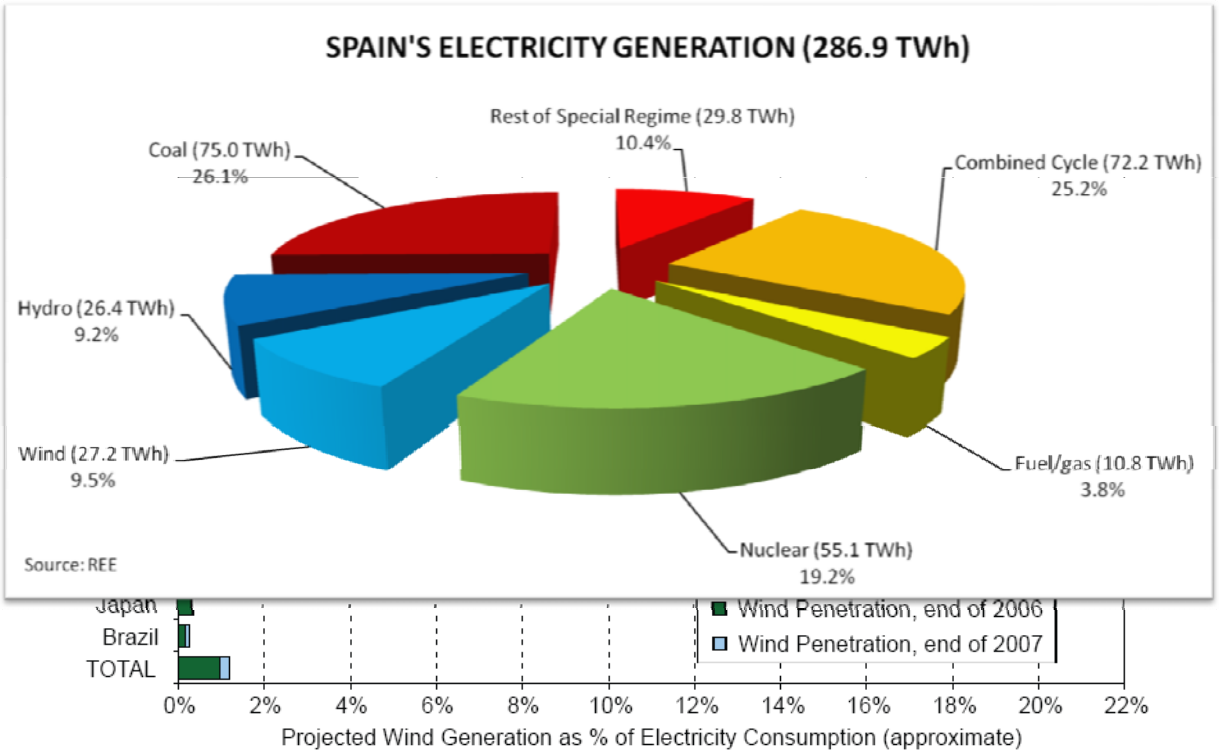
Approximate Wind Power Penetration



Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere.

3. Capacity and generation

Approximate Wind Power Penetration



Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere.

Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

4. Reasons for the Spanish success

- The growth in Europe started in the early 90's in Denmark followed by Germany:
  - Denmark: ecological conscience of the government at this time but also a clear interest in supporting the national industry
  - Germany: the arrival of the green party to the federal government
  - Both countries followed similar development: small owners of small installations embedded in distribution networks, and easy application procedures
- However in Spain…

4. Reasons for the Spanish success

- …is considered as a profitable financial investment
  - Big wind farms (distributed generation?)
  - Big companies and industries involved
  - Project finance
- Favourable legal framework
  - Electric Power Act 54/1997
    - Royal Decree 2818/1998: Defines a feed-in tariff mechanism for Special Regime Generators (RE and CHP)
    - Royal Decree 436/2004: Incentives to take part in the market
    - Royal Decree 661/2007: Lower tariffs with a cap and a floor

4. Reasons for the Spanish success

- Royal Decree 2818/1998
  - Feed-in tariff:

    The total electricity produced in the life-time of the wind farms must be purchased by the utilities at a fixed price of:

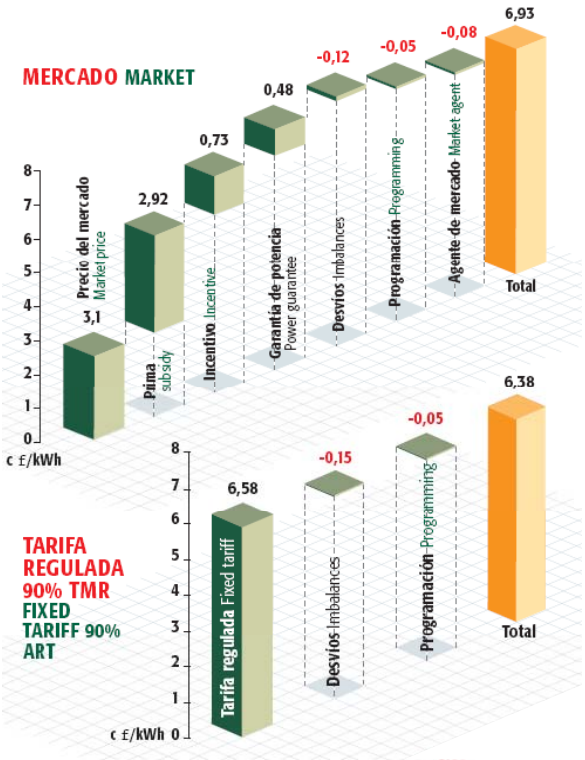
    Average price of the electricity + Subsidy

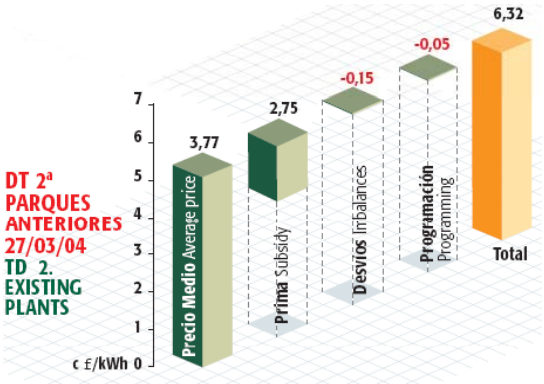
    (Both components calculated by the government)

4. Reasons for the Spanish success

- Royal Decree 436/2004

  Either adopt new regulation Or Continue with previous

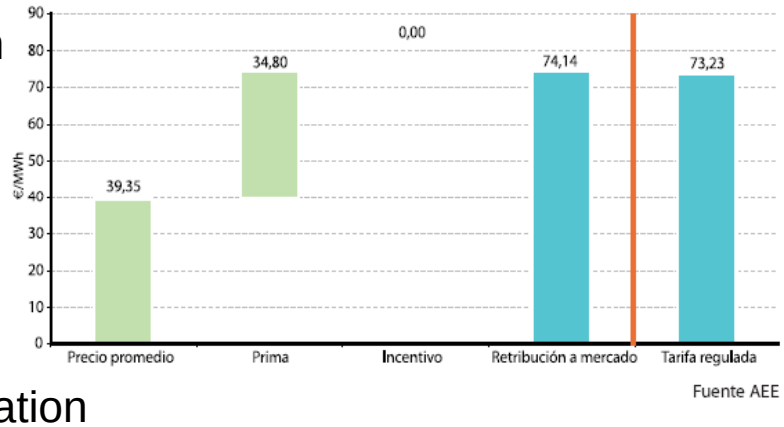




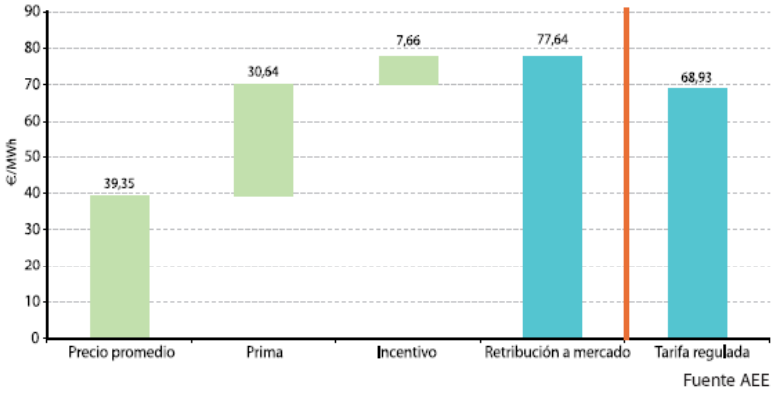
4. Reasons for the Spanish success

- Royal Decree 661/2007

New regulation

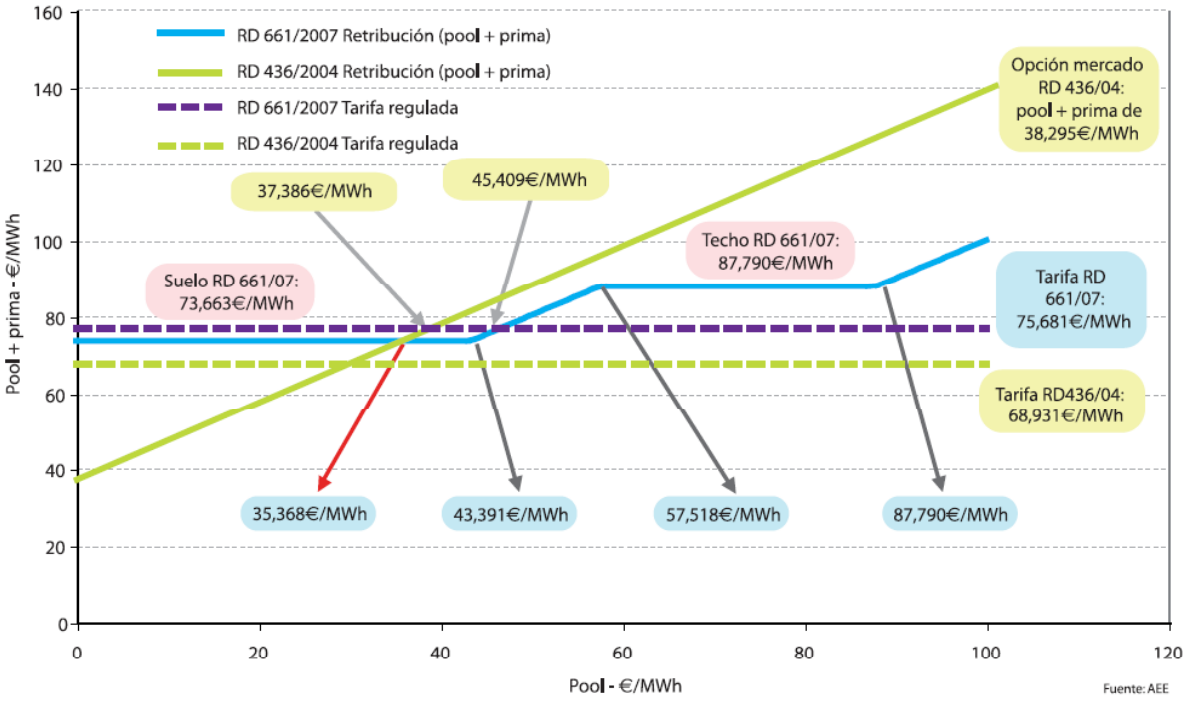


Previous regulation



4. Reasons for the Spanish success

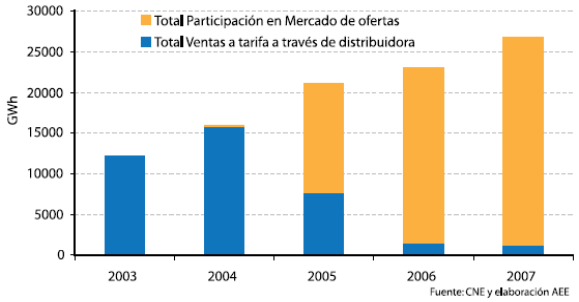
- Royal Decree 661/2007



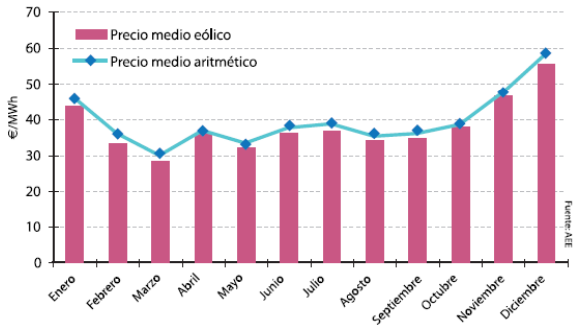
(*) Prices will increase yearly: CPI – 0.25 till 2012 and CPI – 0.50 since then

4. Reasons for the Spanish success

- Royal Decree 661/2007
  - 90% of the wind capacity is bidding in the market…

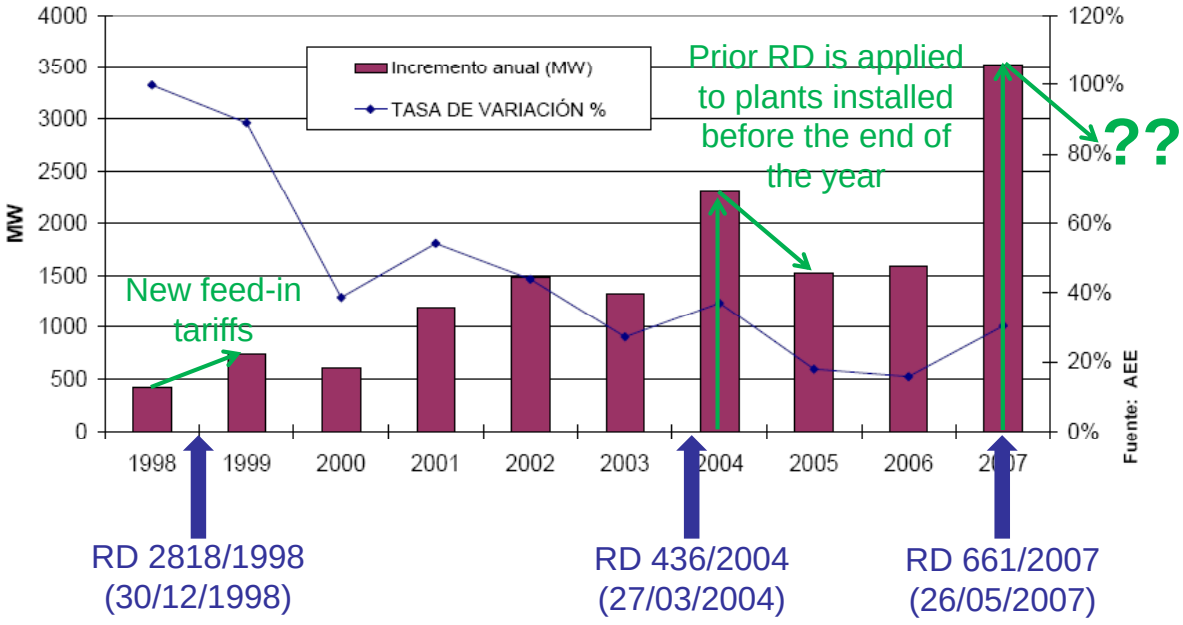


...the price has decreased



4. Reasons for the Spanish success

- Effect of Royal Decrees announcement in installed capacity per year

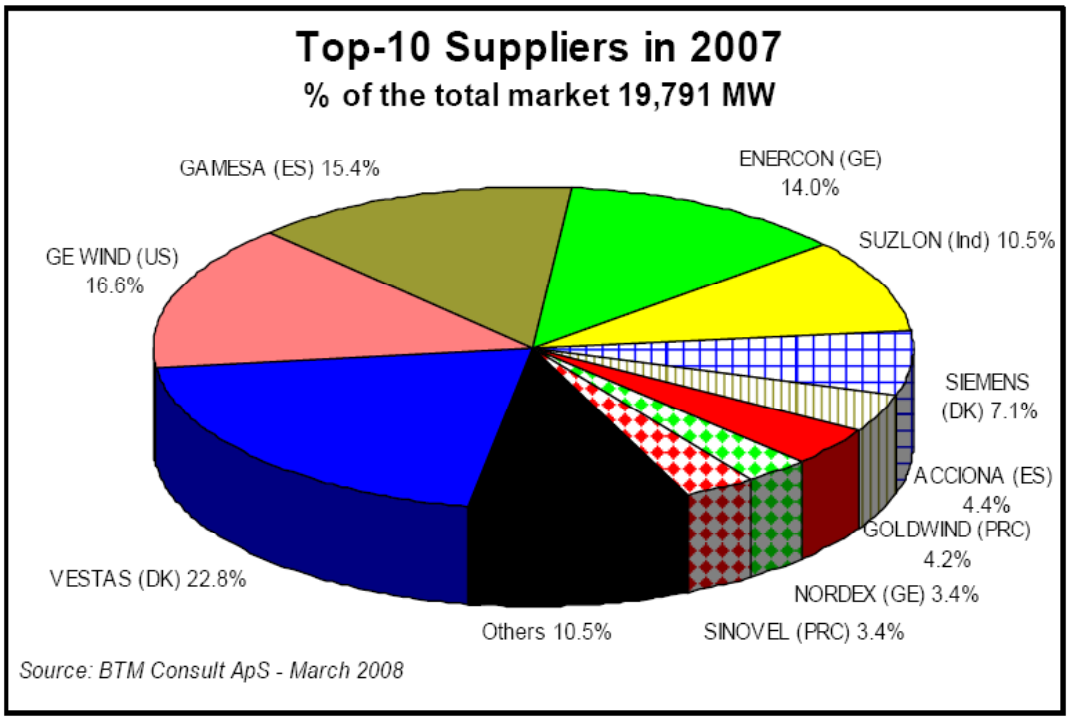


Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

5. Benefits of the Spanish success

- Two top-10 manufacturers



5. Benefits of the Spanish success

Gamesa

- G52-850 kW
- G58-850 kW
- G80-2.0 MW
- G87-2.0 MW
- G90-2.0 MW

Made by Gamesa

- AE-52-800 kW
- AE-56-800 kW
- AE-59-800 kW
- AE-61-1320 kW

acciona Energía

- AW-70/1500
- AW-77/1500
- AW-82/1500
- AW-100/3000
- AW-109/3000
- AW-116/3000

ecotècnia
your best partnership

M TORRES

50% of the production is exported

5. Benefits of the Spanish success

- The world's biggest wind farm owner

IBERDROLA RENOVABLES

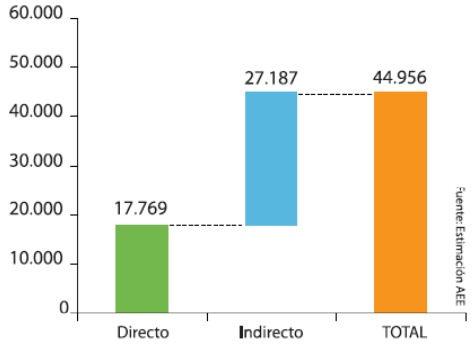
Country	Wind Farms	Capacity (MW)
Spain	155	4382
USA	27	1983
UK	21	531
Greece	16	217
France	17	166
Poland	3	128
Germany	9	63
Portugal	3	56
Brazil	2	49
Mexico	1	31
TOTAL	**254**	**7606**

acciona Energía

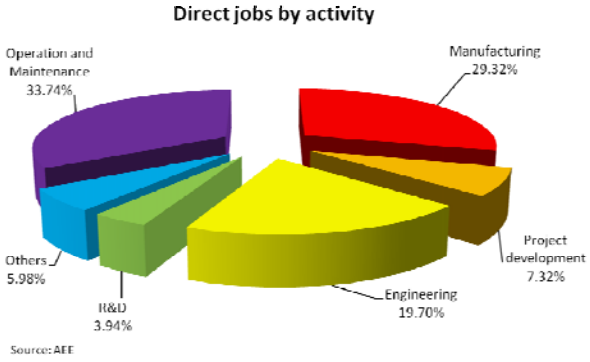
Country	Wind Farms	Capacity (MW)
Spain	106	2492
USA	3	192
Germany	15	140
Australia	2	96
Italy	2	71
Canada	3	58
Greece	2	37
Portugal	1	26
India	1	13
Hungary	1	11
South Korea	1	3
TOTAL	**137**	**3139**

5. Benefits of the Spanish success

- Employments in 2007



  - Direct jobs distributed in many different activities

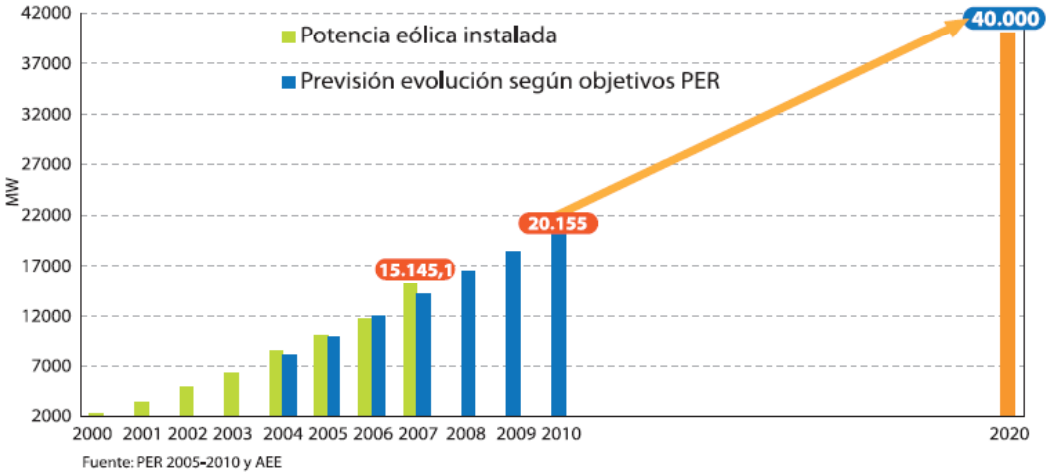


Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

6. Main challenges and limitations

- Objectives
  - The Plan de Energías Renovables (PER) set a target of 20.155 MW by 2010
  - The Spanish Wind Energy Association (AEE) estimates 40,000 MW of onshore and 5,000 MW of offshore by 2020

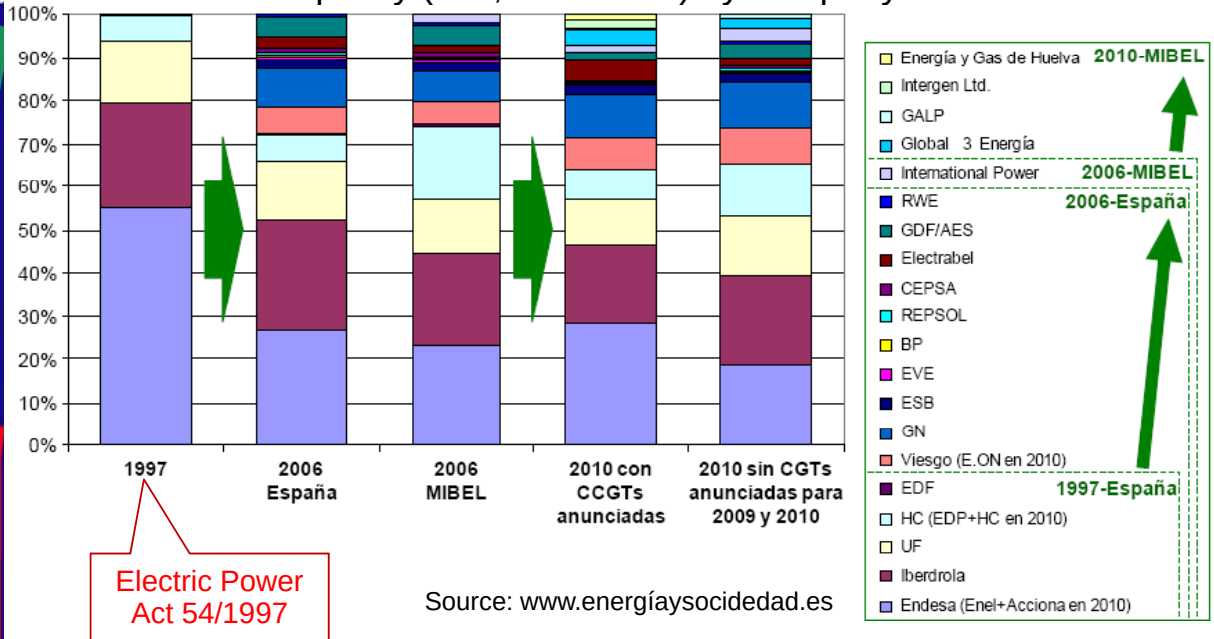


6. Main challenges and limitations

- Inefficient electricity market
  - 1 hour spot market
  - Two utilities have market power

endesa IBERDROLA

Thermal capacity (fuel, coal & CC) by company



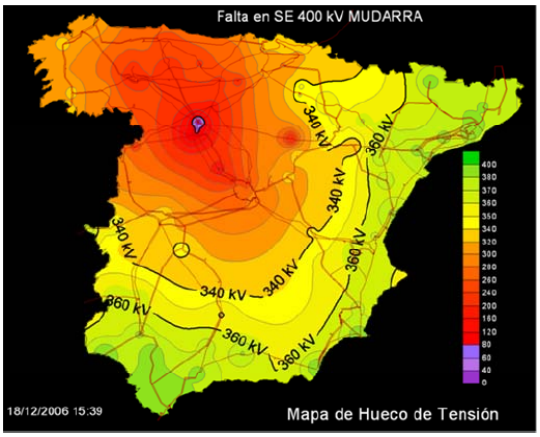
Electric Power Act 54/1997

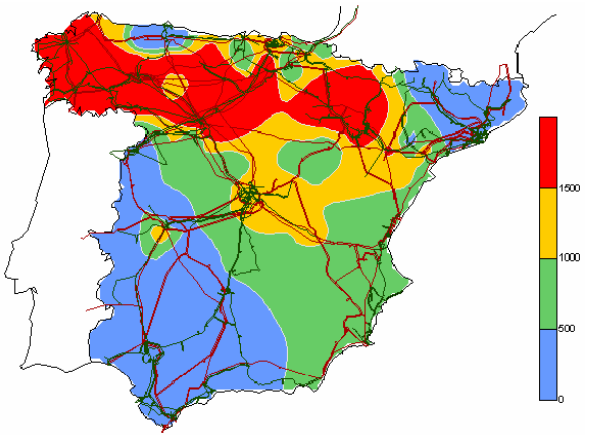
Source: www.energíaysocidedad.es

6. Main challenges and limitations

- Low voltage ride-through
  - DFIG is the dominant technology in Spain and it is very sensitive to voltage dips

Short-circuit ⇒ Voltage dip ⇒ Trip of wind farms



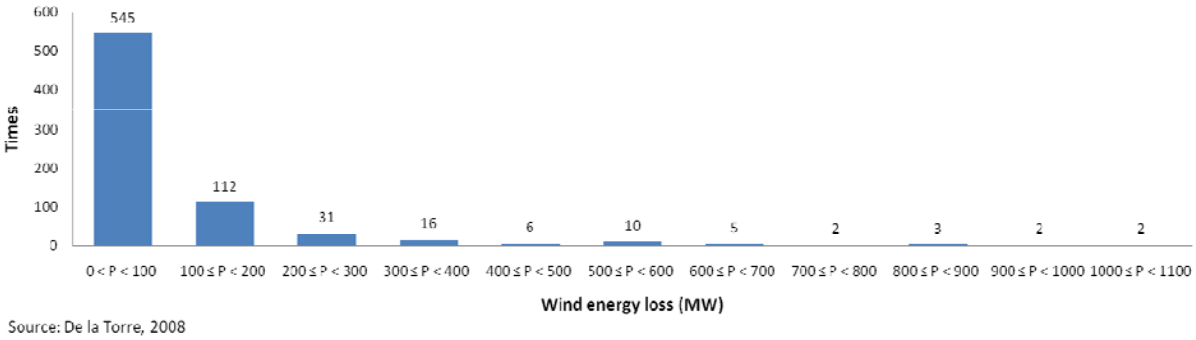


4,866 MW (32.1%) with a voltage dip of 0.90 pu

5,195 MW (34.3%) with a voltage dip of 0.85 pu

6. Main challenges and limitations

- Low voltage ride-through
  - All the sudden trippings associated with voltage dips has been recorded in a database since January 2005 by the Spanish TSO (REE)



Source: De la Torre, 2008

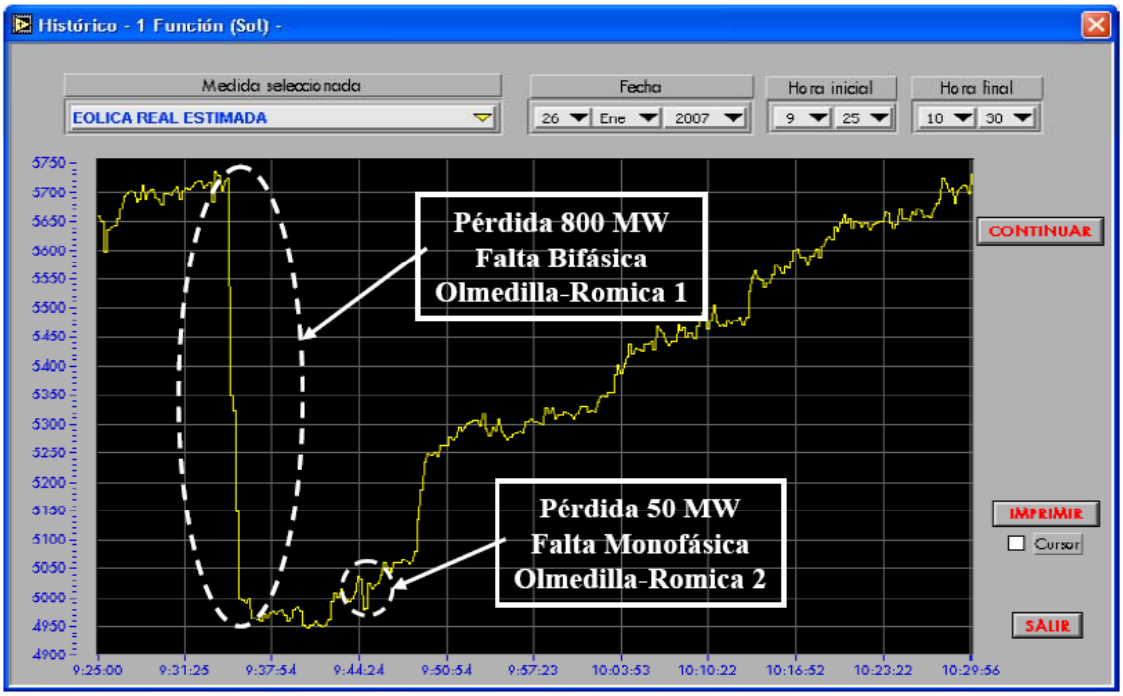
  - The largest wind energy loss was around 1,100 MW out of 3,200 MW being produced at the time

    (10,500 MW installed capacity)

6. Main challenges and limitations

- Low voltage ride-through

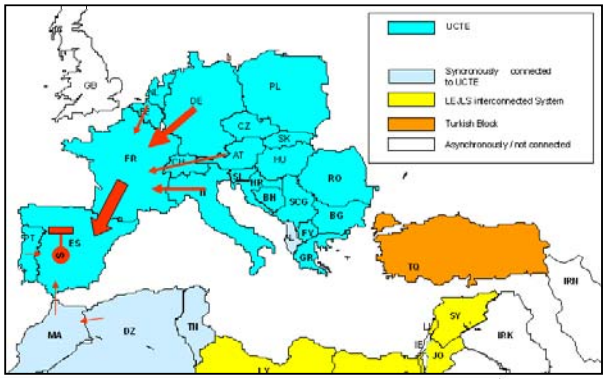
  Two-phase short-circuit in a 400 kV line the 27 January 2007

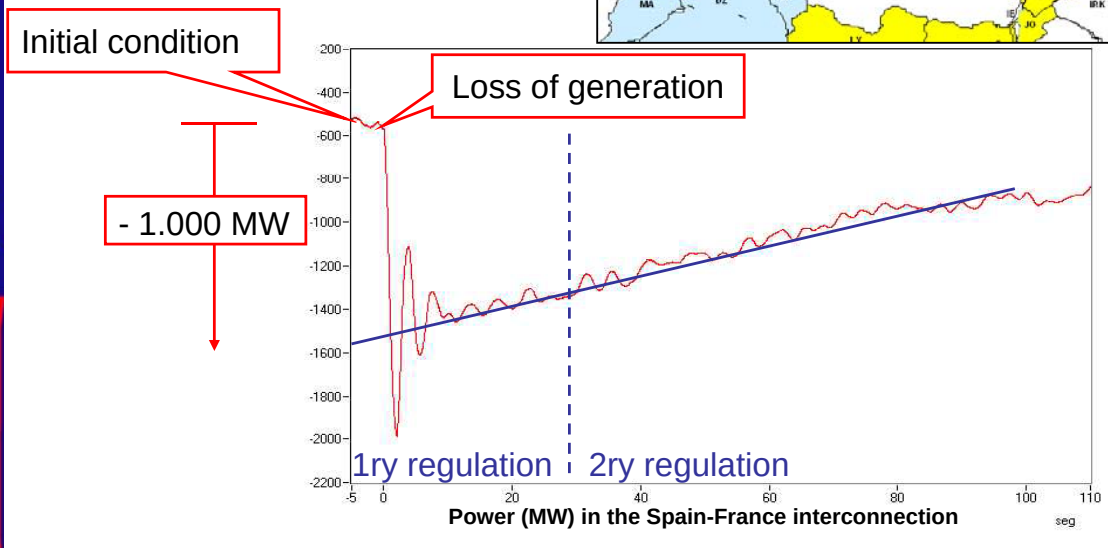


6. Main challenges and limitations

When there is a loss in generation the whole UCTE system supports the Spanish system

However…





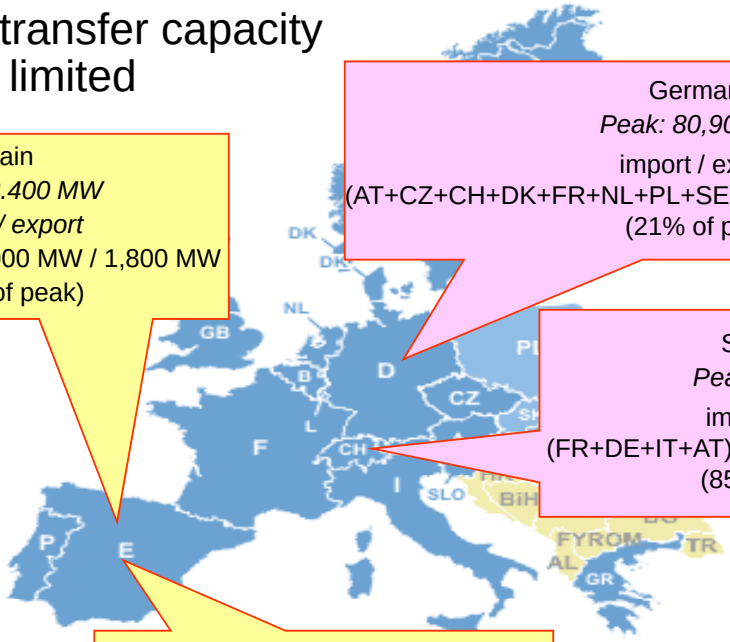
6. Main challenges and limitations

… the transfer capacity is very limited

Germany
Peak: 80,900 MW
import / export
(AT+CZ+CH+DK+FR+NL+PL+SE) = 17,000 MW / 14,950 MW
(21% of peak)

Spain
Peak: 43.400 MW
import / export
(FR+PT+MO) = 3,000 MW / 1,800 MW
(6.9% of peak)

Switzerland
Peak: 9,700 MW
import / export
(FR+DE+IT+AT) = 8,260 MW / 11,390 MW
(85.1% of peak)

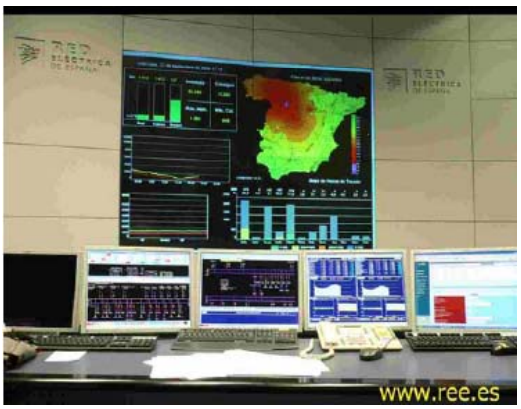


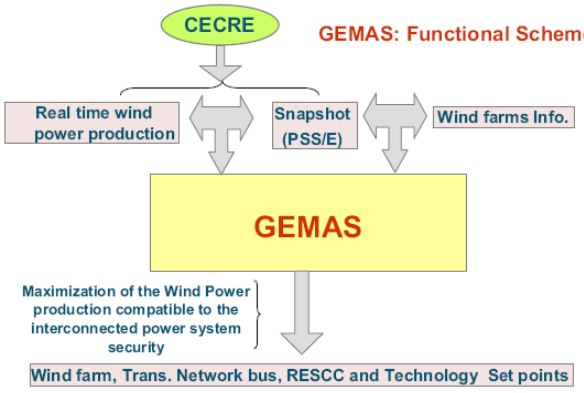
Iberian Peninsula (ES+PT)
Peak: 52.000 MW
import / export
(UCTE) (FR) = 1,400 MW / 500 MW
(2.7% of peak)

Source: REE

6. Main challenges and limitations

- Low voltage ride-through
  - In June 2006 REE launched the Control Centre for Special Regime (CECRE)

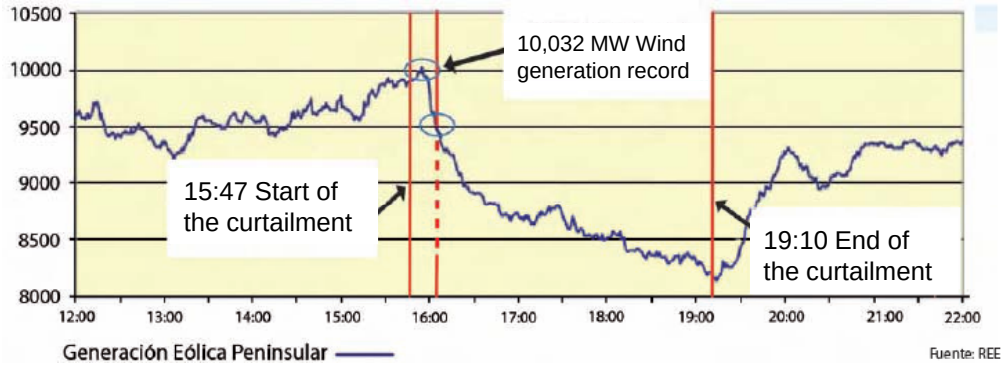




  - A new computer application (GEMAS) has been developed, which calculates the maximum wind energy production that can be successfully managed in the power system

6. Main challenges and limitations

- Low voltage ride-through
  - The first limitation imposed by GEMAS due to transient stability issues was in March 2008



  - Since then, limitations have been issued on seven occasions in order to safeguard the interconnection with France
  - GEMAS together with technological developments and new grid codes and have mainly solved the low voltage ride-through problems

6. Main challenges and limitations

- Frequency ride-through

  This is also a problem that wind generation has to face.

For example:

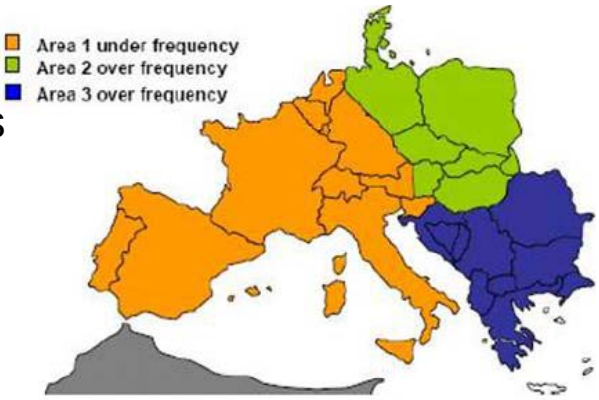
On 4 November 2006 a high-voltage line over the river Hase (Germany) was disconnected from the grid in order to allow the safe crossing of a boat

As it was a very cold night, other transmission lines were overloaded so the overcurrent protections tripped and a cascade effect caused a blackout in part of the German power system

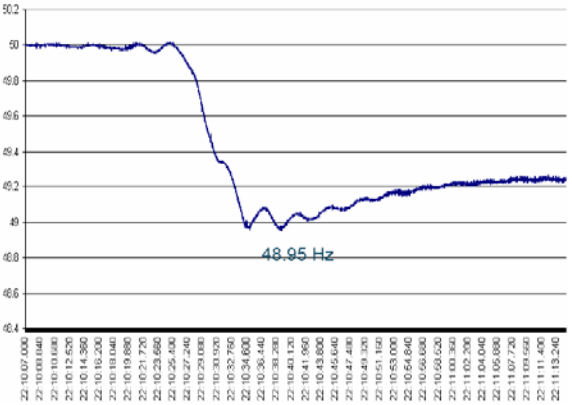
6. Main challenges and limitations

- Frequency ride-through

  Power-frequency oscillations that followed caused the UCTE system to split into three areas



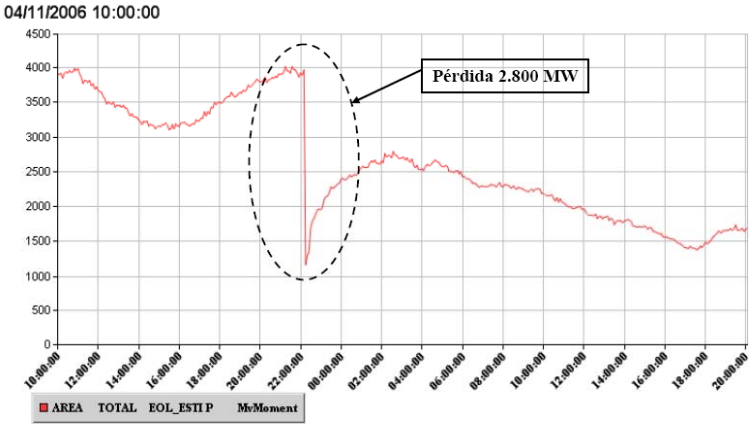
The frequency in western Europe decreased to 48.95 Hz



6. Main challenges and limitations

- Frequency ride-through

  2,800 MW of wind generation were disconnected from the grid in Spain (under frequency protections)



The frequency control system produced load shedding of 1,500 MW in Spain, 5,000 MW in France, 1,300 MW in Italy and 500 MW in Portugal

6. Main challenges and limitations

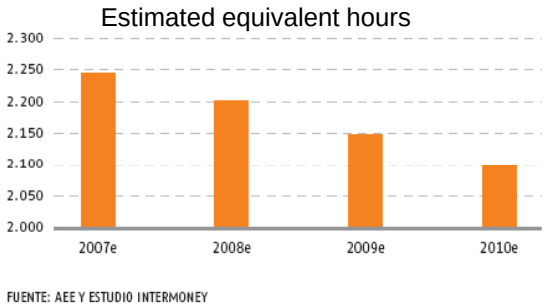
- Ancillary services
  - Frequency control
    - Additional reserves are required due to wind variability
    - While wind farms do not provide FCAS there will be certain moments when wind generation will be curtailed
    - Combined cycle power units are being shut down in real time in order to recover downward tertiary reserves
    - It is planned to increase the number of hydro-pump storage units. Today there are 4,800 MW installed
  - Voltage control
    - The sudden change in the reactive power generation causes abrupt changes in voltage that can cause wind farms to disconnect
    - Continuous voltage control with associated revenues should be considered

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

6. Main challenges and limitations

- Location of new installations
  - Onshore:
    - Difficult to find places with high winds



FUENTE: AEE Y ESTUDIO INTERMONEY

    - Parts of the transmission system are congested
  - Offshore:
    - Much higher capital and maintenance costs
    - The current expertise shows that the working conditions are even harsher than expected

Contents

1. Introduction
2. Spain vs Australia
3. Capacity and generation
4. Reasons for the Spanish success
5. Benefits of the Spanish success
6. Main limitations and challenges
7. Conclusions

7. Conclusions

- Spain is one of the world leaders in wind energy
- The main reason is a favourable legal framework making wind energy be considered as a profitable investment with a guaranteed economic return
- This development in Spain has been important for permitting the growth of national companies that are now world leaders
- Spain has to face important challenges in order to meet the target of 20 GW by 2010
  - Modify the electricity market arrangements to accommodate the characteristics of wind energy
  - Improve low voltage and frequency ride-through
  - Reinforce interconnections with the UCTE system
  - Reconsider ancillary services
  - Find new suitable locations for wind farms

Thank you for your attention

Any questions?

Néstor Aparicio Marín
aparicio@esid.uji.es
n.aparicio@unsw.edu.au