



# **INTERNATIONAL SEMINAR ON LARGE SCALE BALANCING FROM NORWEGIAN HYDROPOWER**

The link between renewable energy in the future and  
storage needs – seen from Spain

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**POLITÉCNICA**

## Technical University of Madrid

- Founded in 1971
- Master and bachelor degrees in different engineering areas, architecture and sports science



## Civil Engineering School

- Founded in 1802
- Bachelor degrees in civil engineering and materials science
- Master degrees in civil engineering, civil engineering systems and structures, foundations and materials

## Department of Hydraulic and Energy Engineering (DICHE)

### Hydraulic engineering

Hydrology and water resources

Hydraulic structures

Physical and numerical modelling

Pipe networks

Dam safety

### Electrical engineering

Optimal operation and control of hydropower plants

Grid integration of renewable generation (wind, ocean)

### Thermal engineering

Energy efficiency in buildings

Geothermal energy

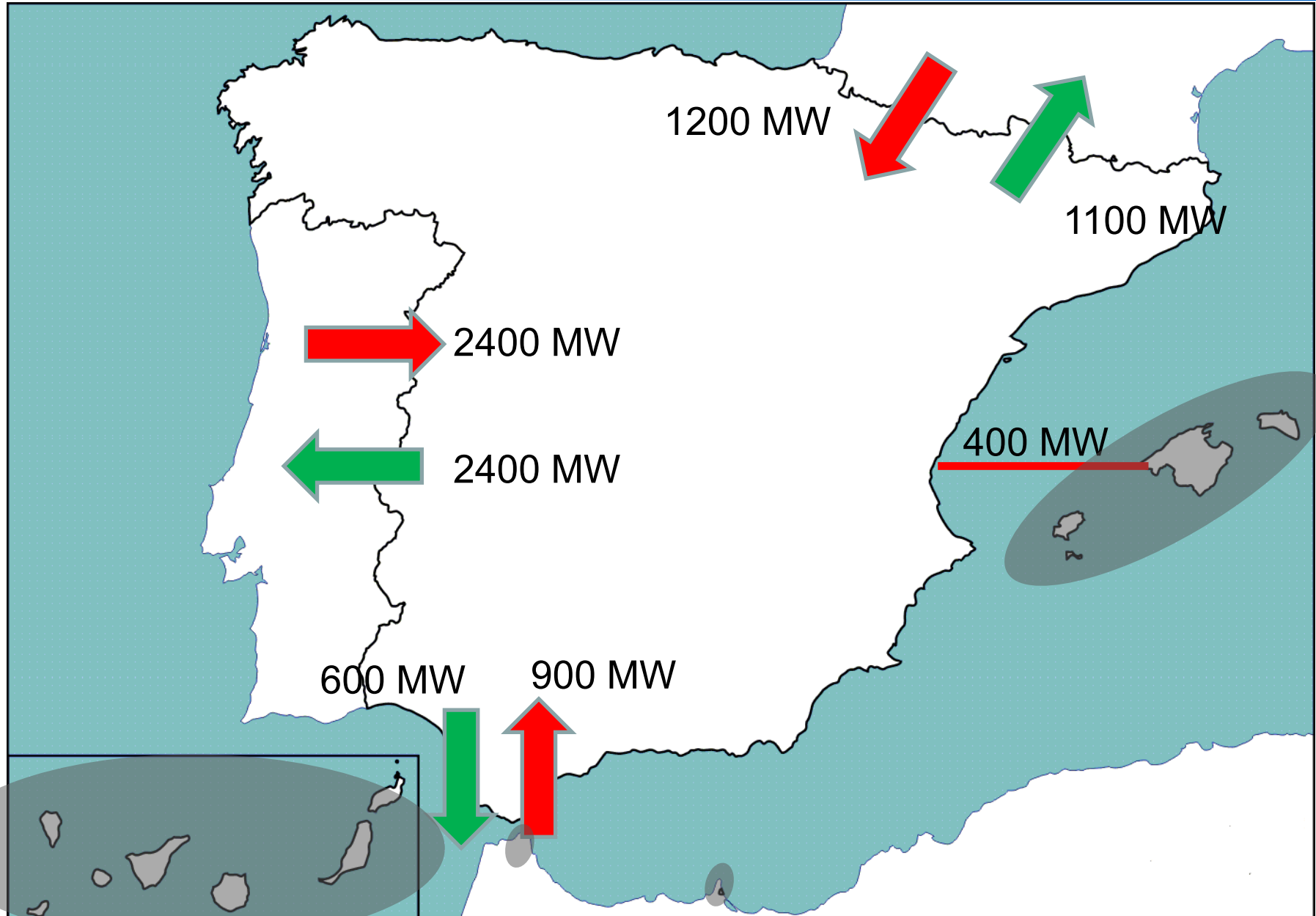
### Environmental radioactivity

Measurements in drinking water, soil, air and food

Radiation detectors and portal monitors



# 1. Spanish electric power system



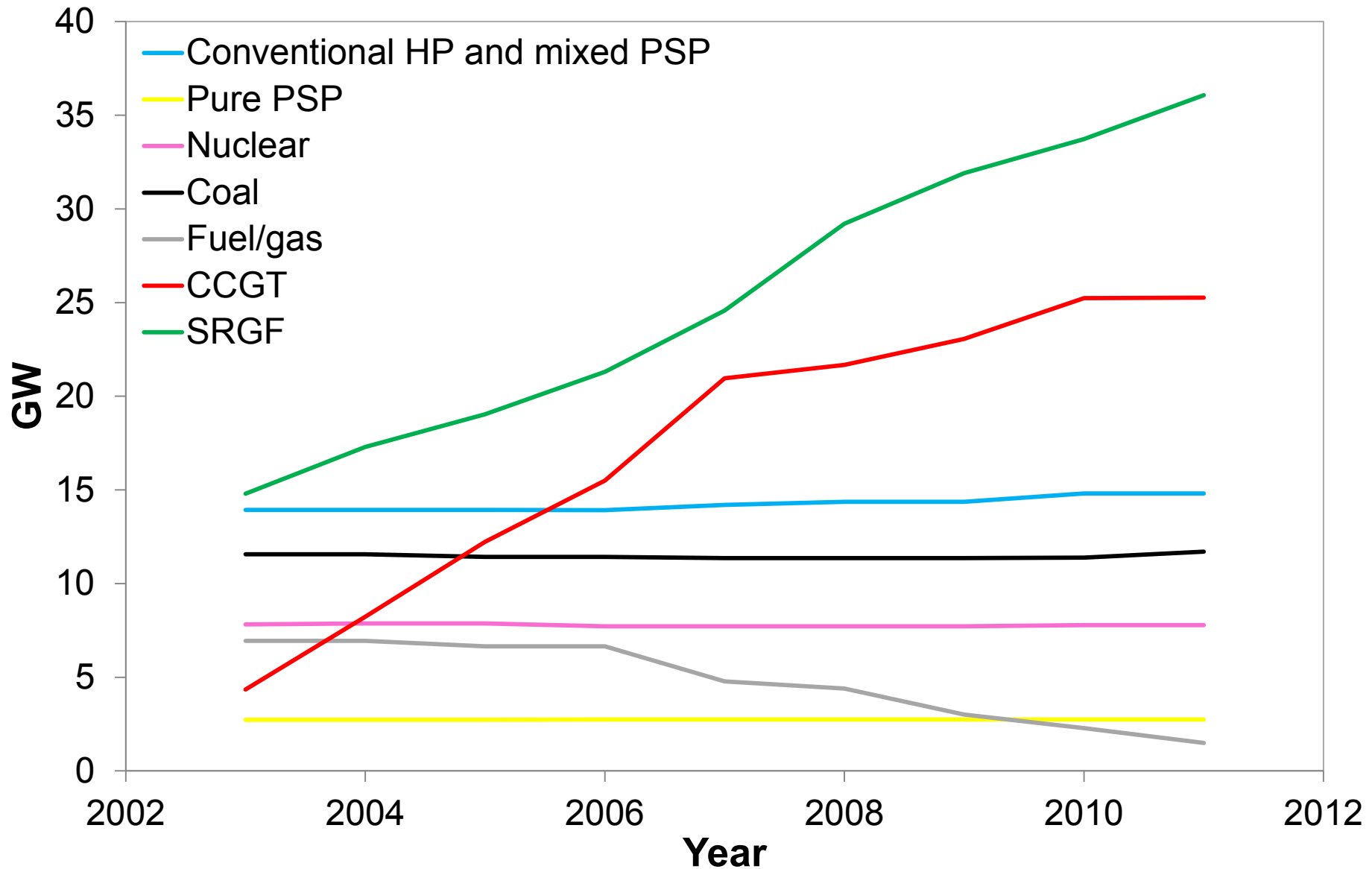
## Mainland Electric Power System (MEPS)

- Since January 1<sup>st</sup>, 1998, the Spanish Electricity Market is deregulated
- Since January 1<sup>st</sup>, 2007, the Spanish and Portuguese electricity markets merged into the Iberian Electricity Market (MIBEL)
- MIBEL is organized around a short-term wholesale pool-based market where every day generating companies, consumers and energy services companies submit bids for selling or buying energy for the next 24 h
  - ***Day-ahead market***
- Additionally, 6 pool-based *intraday or balancing markets* are celebrated everyday
- There exist several markets for load-frequency regulation (**reserve markets**), real-time balancing and voltage control

## Mainland Electric Power System (MEPS)

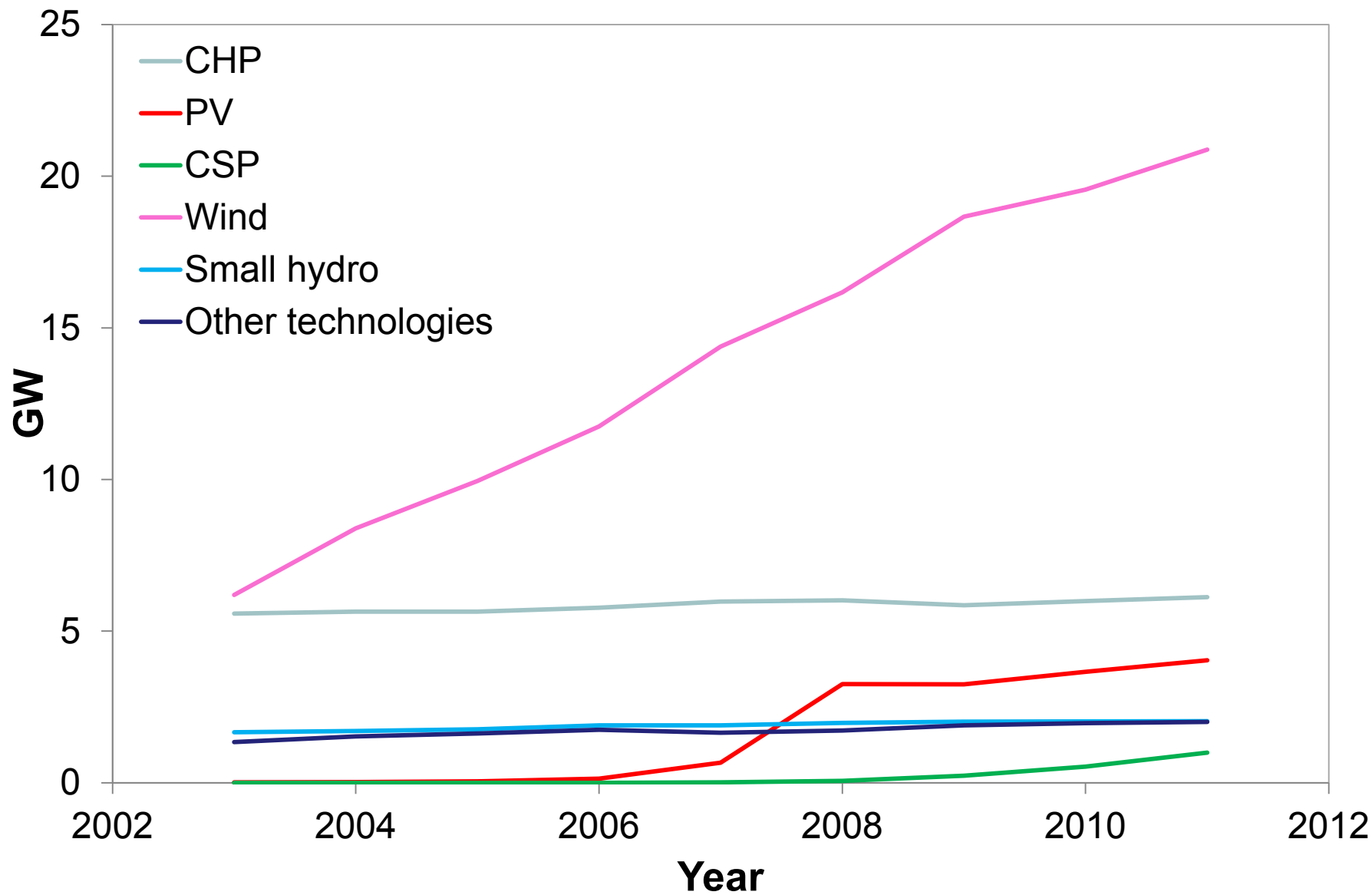
- Two different power production regimes are considered in the MIBEL framework → *Ordinary and special regimes*
- Generation facilities within the special regime are those with an installed **capacity lower or equal than 50 MW** and using combined heat and power, **renewable energies** and different types of residues, among others
- The rest of generation facilities belongs to the ordinary regime
- Special regime generation facilities (SRGF) have\* certain economic advantages → **feed-in tariff / premium**
- Ordinary regime generation facilities (ORGF) are forced to participate in the day-ahead electricity market for selling energy

# 1. Spanish electric power system



Installed capacity evolution in MEPS

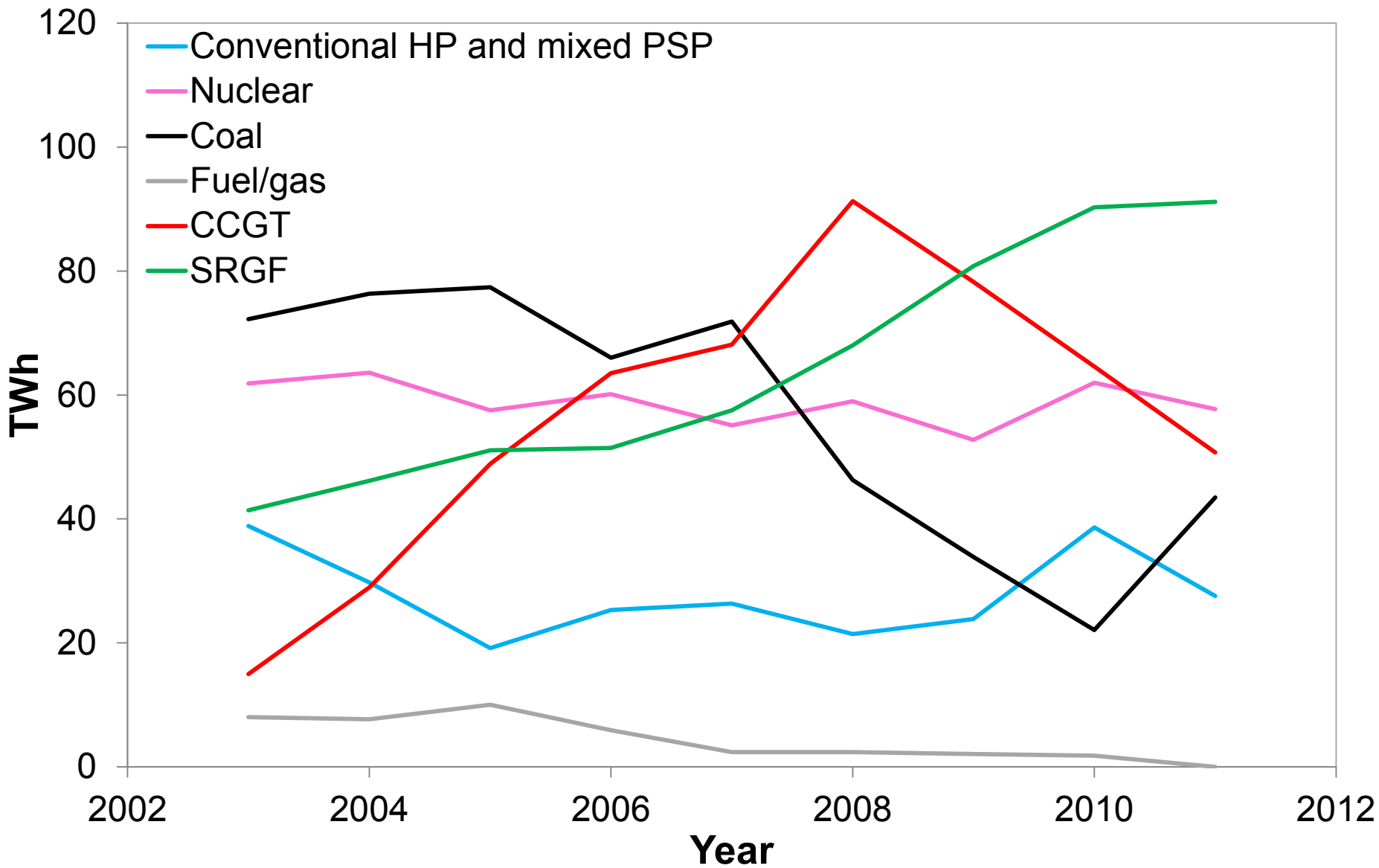
# 1. Spanish electric power system



SRGF Installed capacity in MEPS

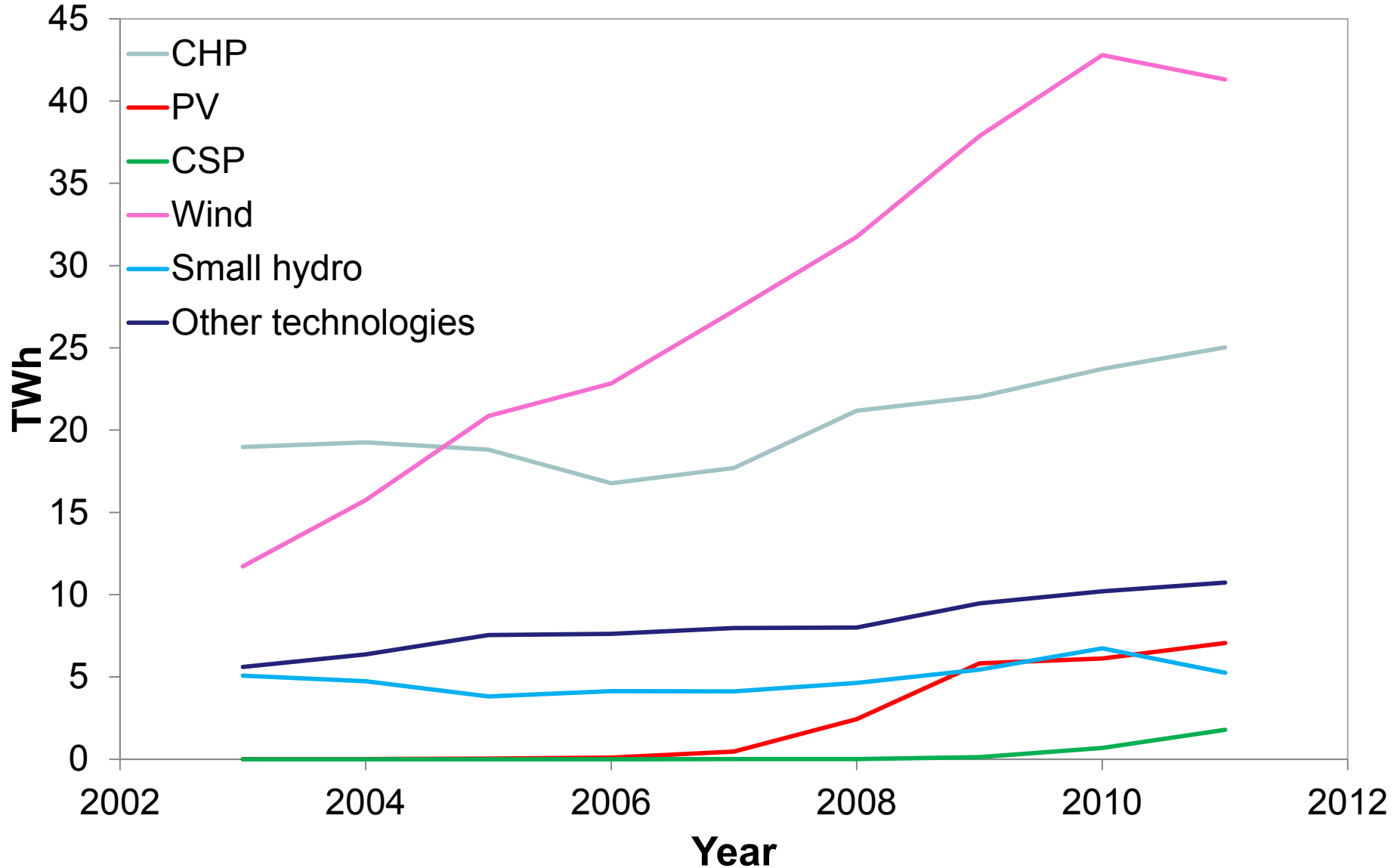


# 1. Spanish electric power system



Demand supply evolution in MEPS

# 1. Spanish electric power system

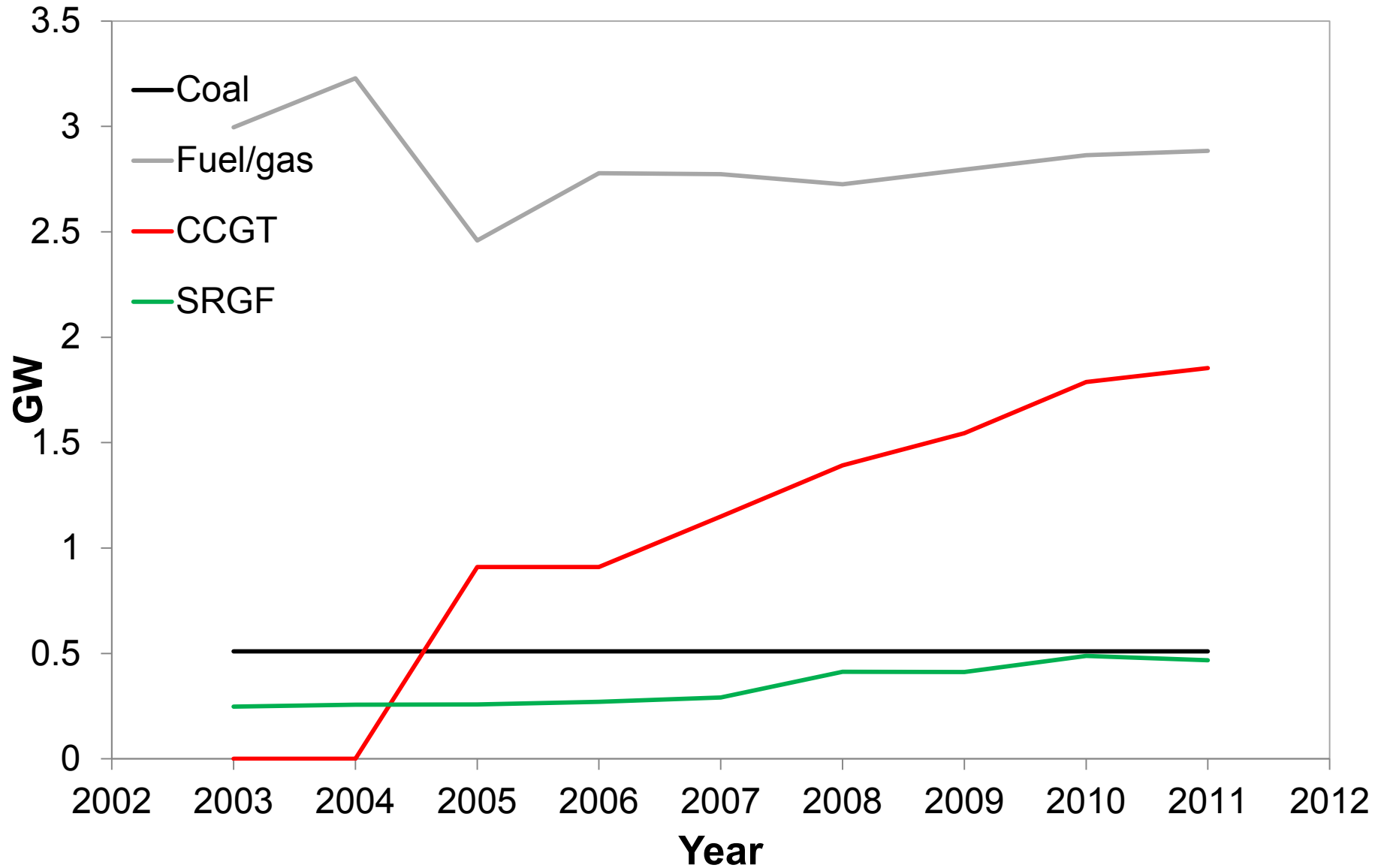


Contribution of SRGF to demand supply in MEPS

## Extrapeninsular electric power systems (EEPS)

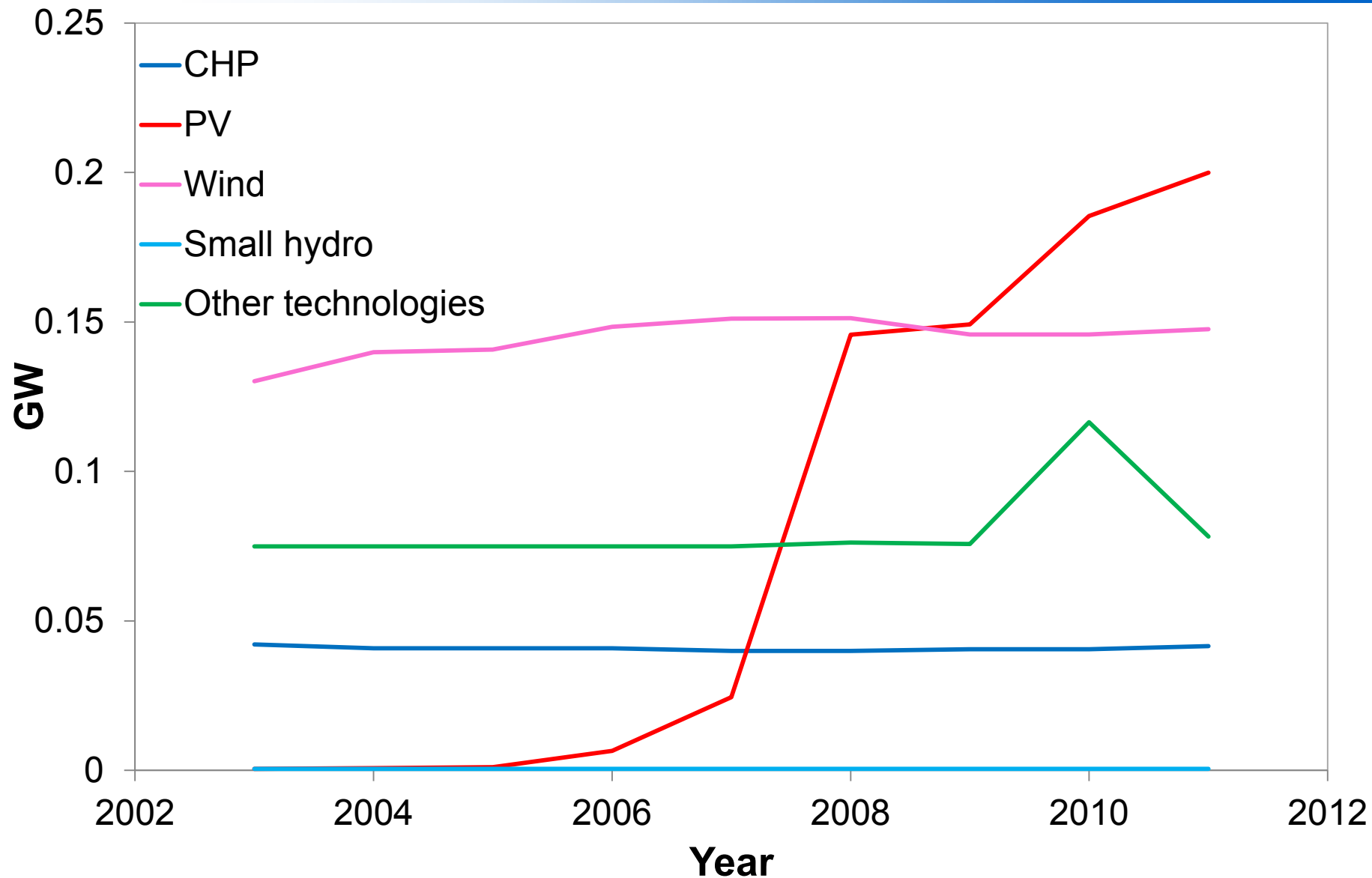
- Power production remuneration in the EEPS is regulated by the Spanish Ministry of Industry, Energy and Tourism
- There are 4 different EEPS: Canary and Balearic islands, Ceuta and Melilla
- In the Canary archipelago, 2 islands (Fuerteventura and Lanzarote) are electrically connected to each other
- In the Balearic archipelago, 2 islands (Formentera and Ibiza) are electrically connected to each other and 1 island (Mallorca) is connected to the MEPS
- The rest of islands are electrically isolated

# 1. Spanish electric power system



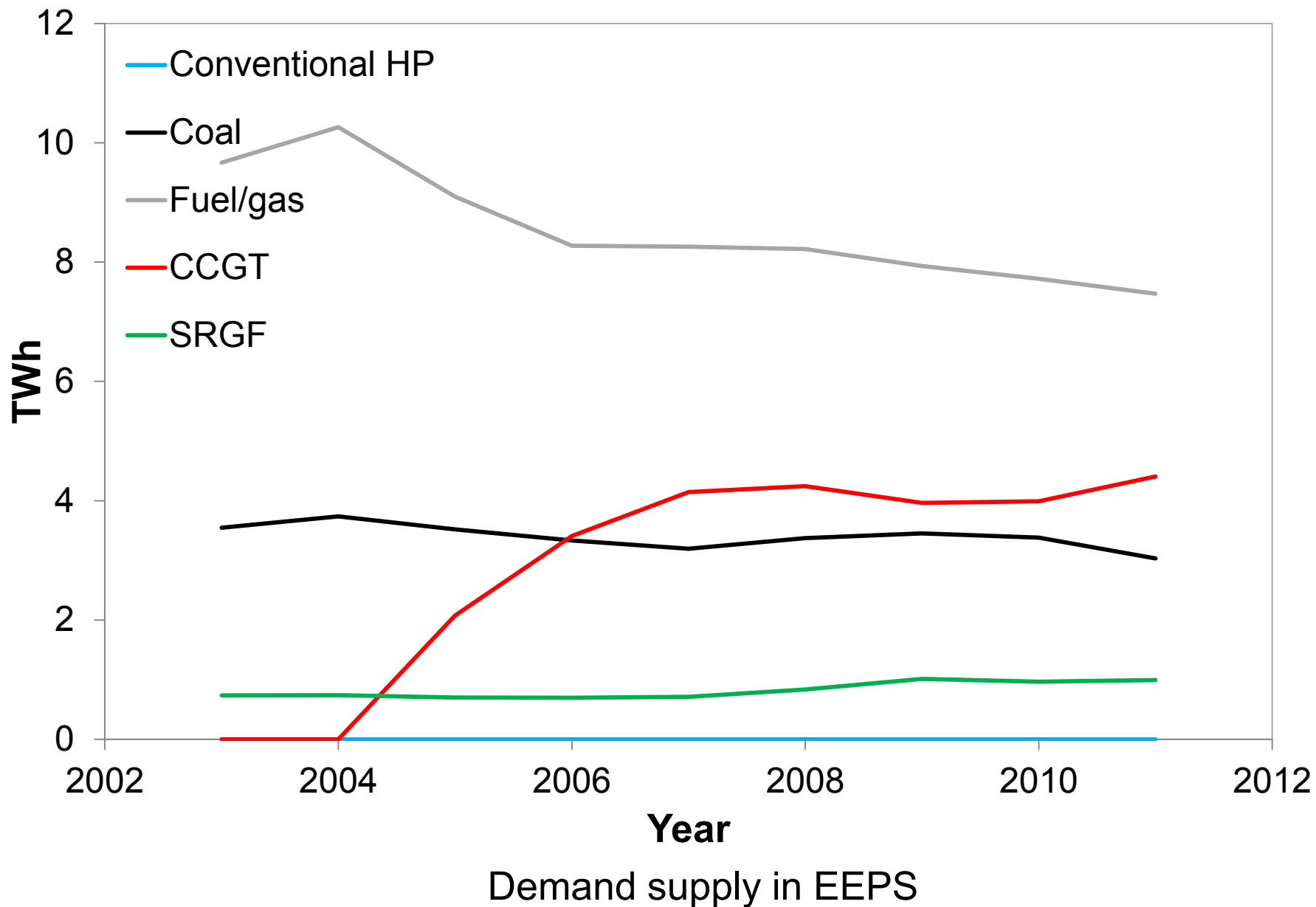
Installed capacity evolution in EEPS

# 1. Spanish electric power system

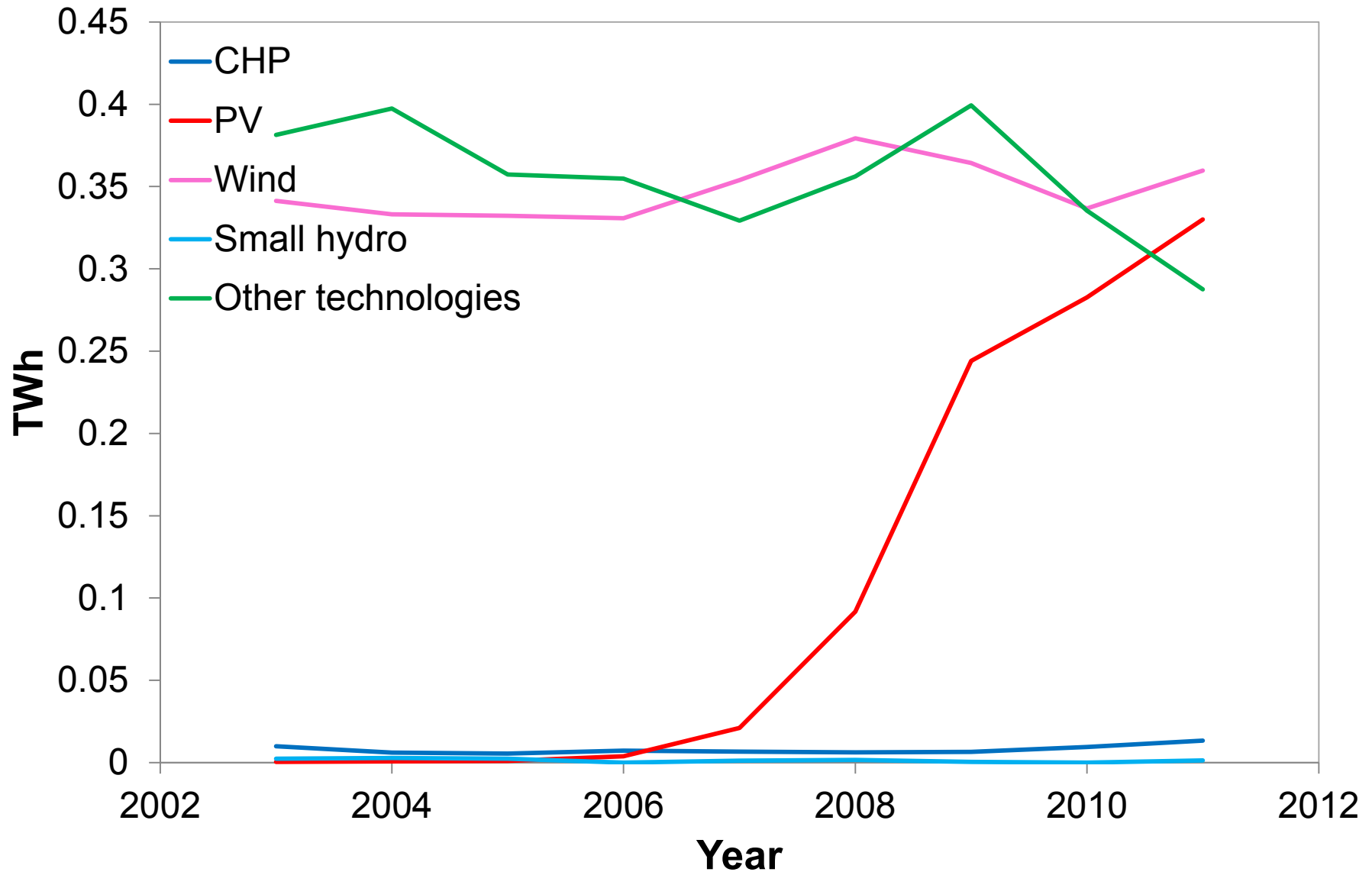


SRGF Installed capacity in EEPS

# 1. Spanish electric power system



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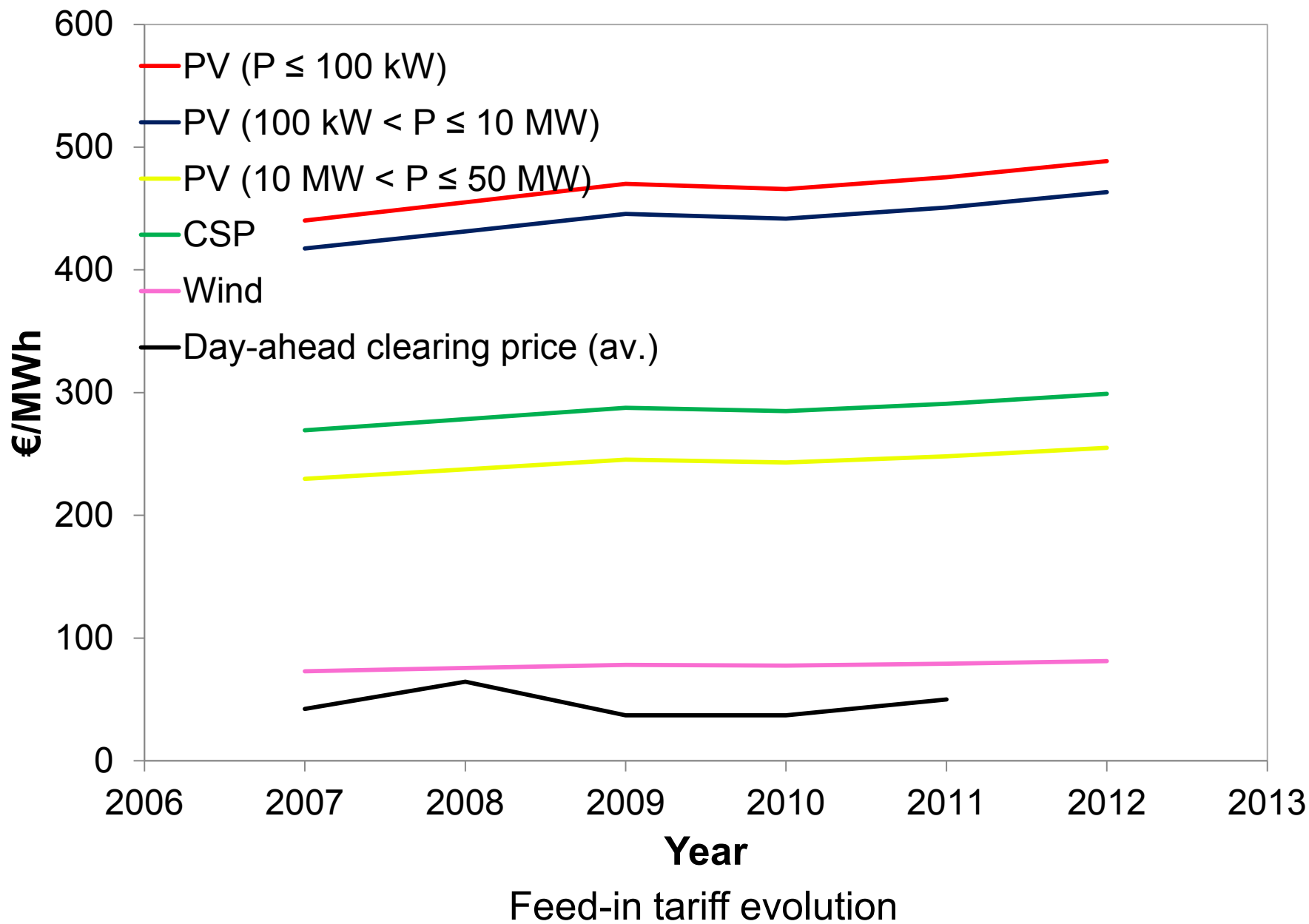
Contribution of SGRF to demand supply evolution in EEPS

## 2. Facts and figures about RE and PS in Spain

- In 2005, the deficit of the electric power sector reached 3811 M€
- In 2009, the Spanish TSO (REE) stated that no additional capacity would be necessary until 2014 and warned that the rate of growth of RE would cause power curtailments
- In 2009, the Spanish Energy Secretariat estimated that the installation of the already registered RE installations could cause an extra cost of 6 M€
- An increase of 15000 MW in wind power and of 4000 MW in PS was established as an objective in the Renewable Energy Plan (PER) 2011-2020
- An increase of 850 MW in wind power was established as an objective for the Canary islands in the Canary Energy Plan (PECAN); an increase of 299 MW in PS was established as an objective for the Canary islands in the Electricity and Gas Sectorial Planning 2008-2016



## 2. Facts and figures about RE and PS in Spain



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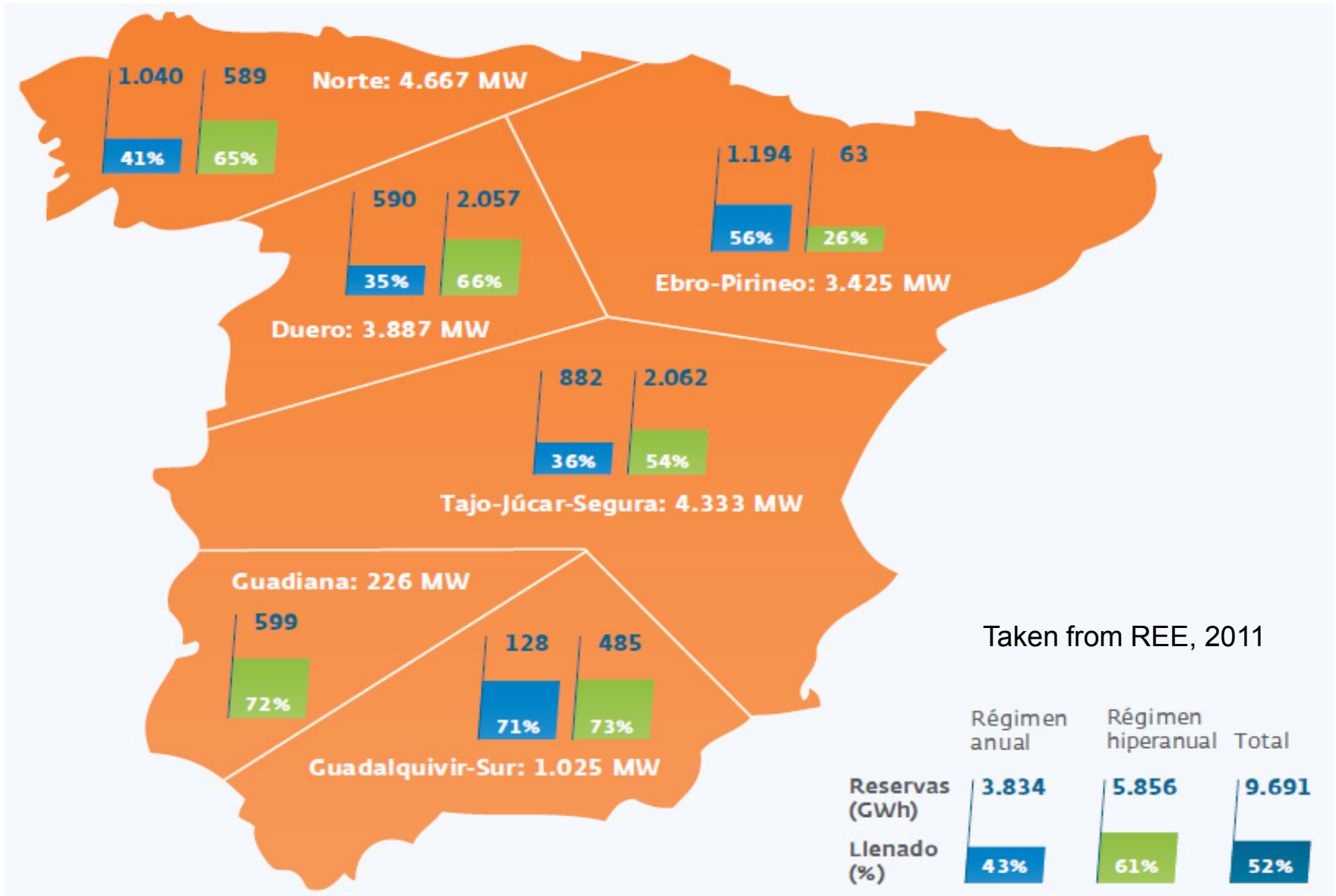
- In January 27<sup>th</sup>, 2012, **all economic incentives** (feed-in tariffs, premiums, etc.) **for new RE installations were suppressed** by the Royal Decree Law 1/2012
- In February, 2012, the National Energy Commission carried out a **public consultation process about potential regulatory changes** in the Spanish electric power system
- Many important regulatory changes are **currently being discussed**

### **UNCERTAINTIES**

- Different taxes for each generation technology, including RE
- Subsidies for national coal
- Compensatory measurements for underused CCGT

## 2. Facts and figures about RE and PS in Spain

### CERTAINTIES ON HP and PS

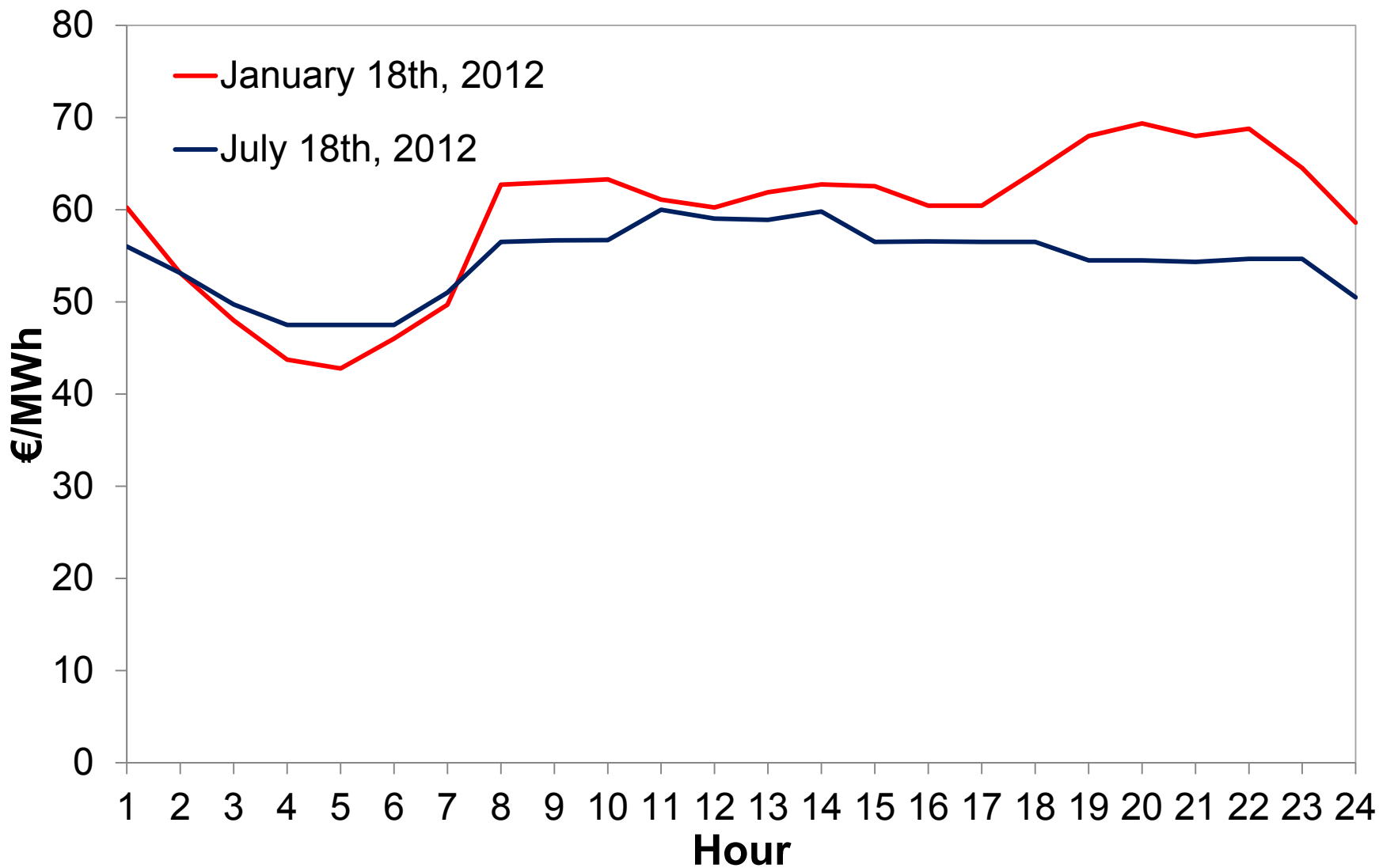


## 2. Facts and figures about RE and PS in Spain

### **CERTAINTIES ON HP and PS**

- At present, there are **23 PS power plants** in operation
- At least **5 PS projects** in the **MPS** and **6 in the Canary islands** are currently in the planning, draft design or construction phase
- Special importance is being given in the planning phase to analyzing different alternatives for providing **load-frequency regulation in pump mode**
  - Hydraulic short-circuit
  - Adjustable speed operation in pump mode
    - a) Synchronous machines + full frequency converter
    - b) Doubly fed asynchronous machine

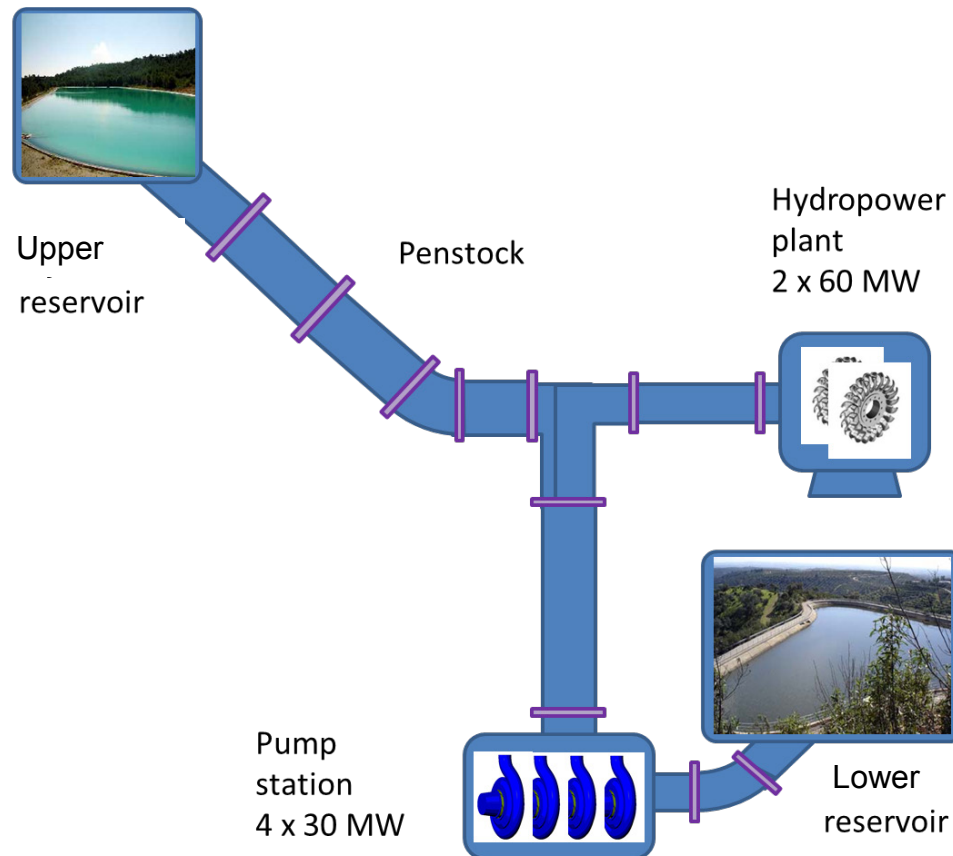
## 2. Facts and figures about RE and PS in Spain



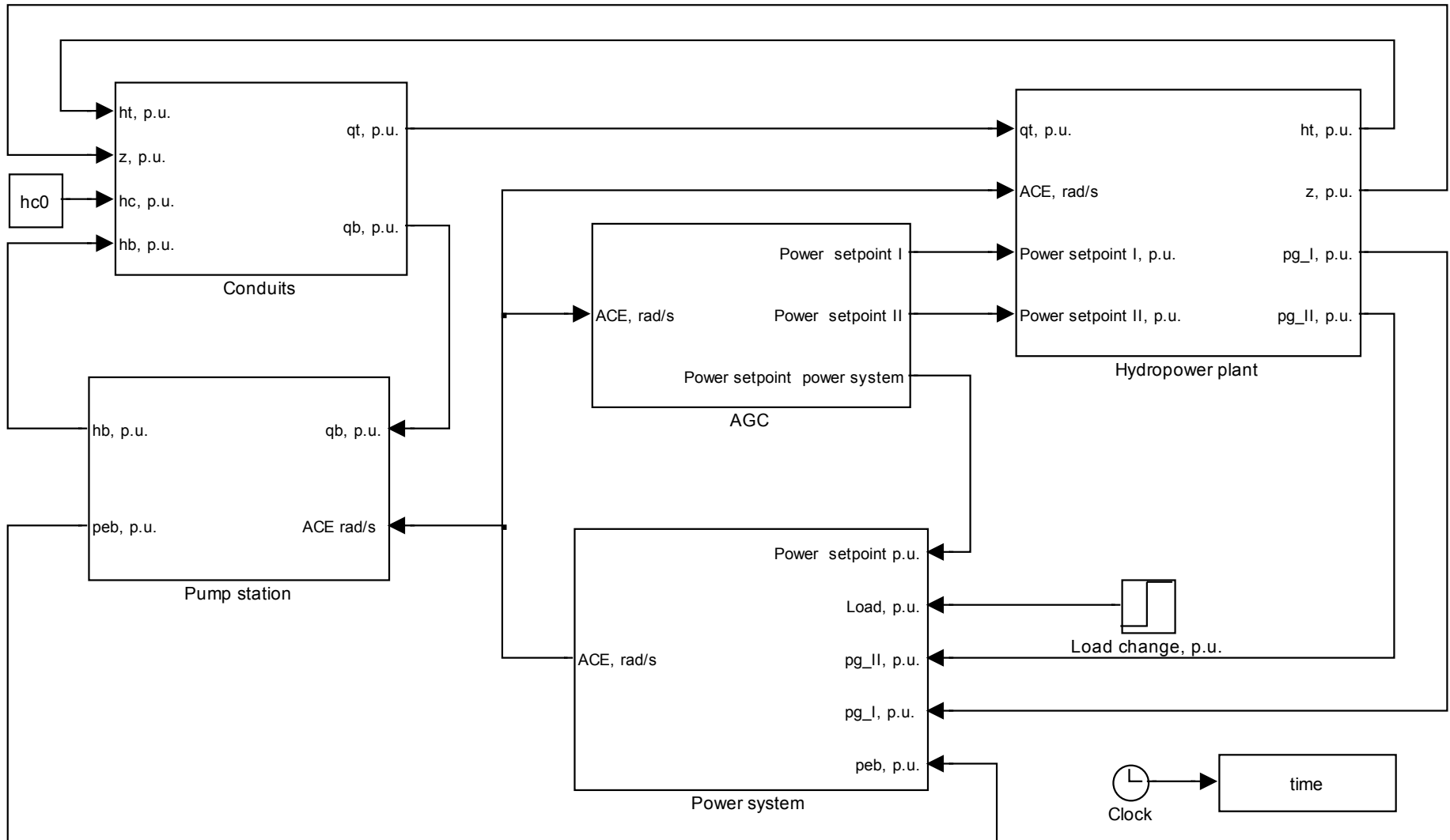
Pool prices

### 3. A hydraulic short-circuit PS power plant study

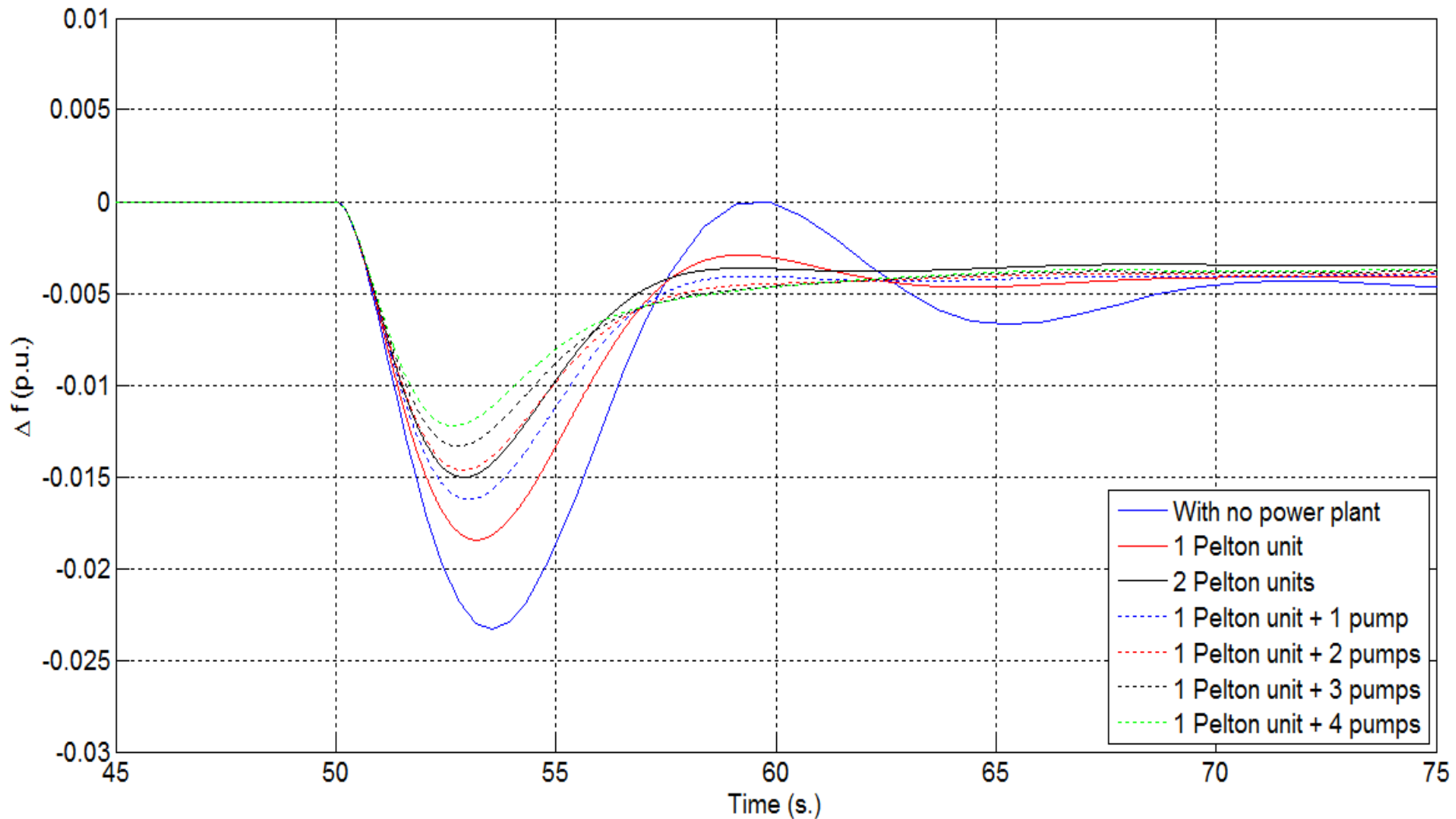
- The objective of the present study is to analyze the **dynamic response** of a hydraulic short-circuit pumped-storage power plant and to evaluate its **load-frequency regulation capability** in an isolated power system (Canary islands)



# 3. A hydraulic short-circuit PS power plant study



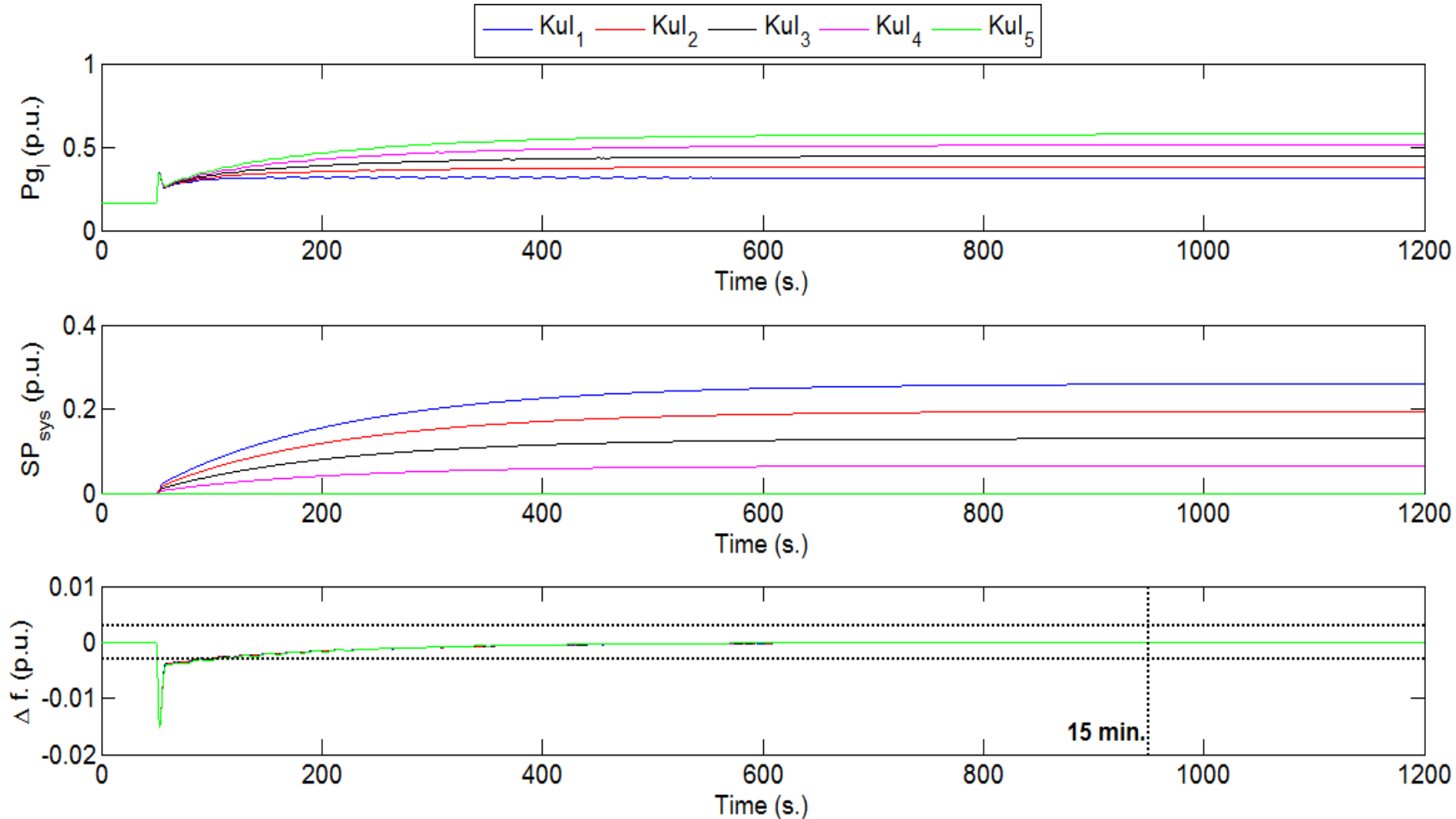
### 3. A hydraulic short-circuit PS power plant study



Frequency response under a sudden loss of a 50 MW generating unit



### 3. A hydraulic short-circuit PS power plant study



Electric power, system set point and frequency deviation after a sudden loss of a 50 MW generating unit, for different participation factors

### 3. A hydraulic short-circuit PS power plant study

- The hydro plant **meets the mandatory requirements for providing load-frequency regulation** either under the control of the AGC (*normal operation*), or by starting-up or shutting-down one Pelton or pump unit (*emergency operation*)
- **The hydraulic short-circuit scheme provides the power plant with a great flexibility for load-frequency regulation**

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Thank you very much for your attention

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