GNOM

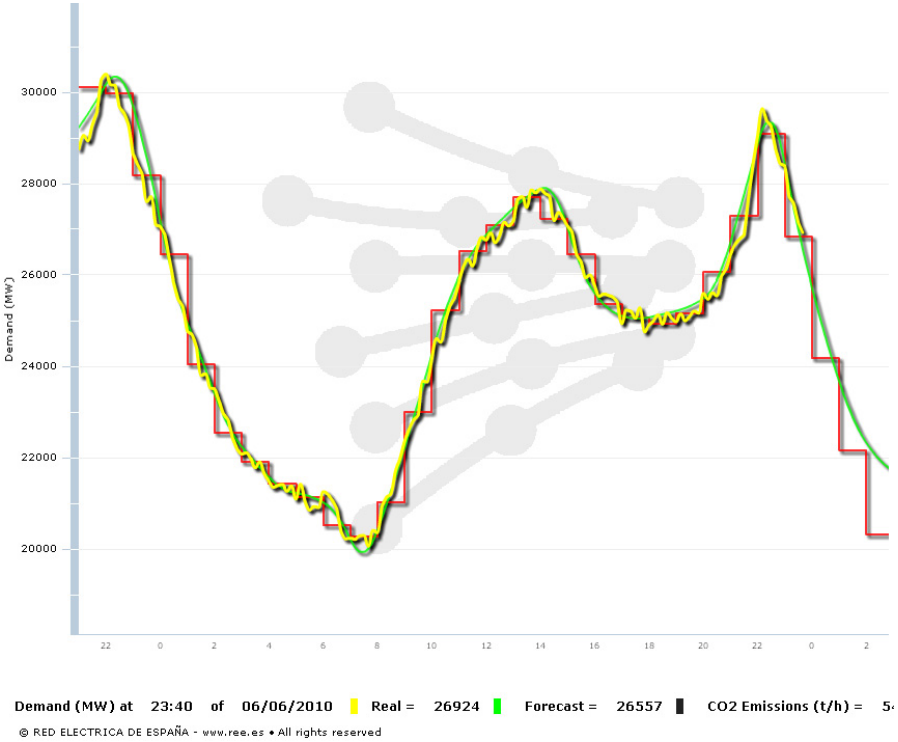
The GNOM research group

- **GNOM (Group on Numerical Optimization and Modeling)** is a research group made up by lecturers and post-graduate students of the departments of Statistics and Operations Research, and of Applied Mathematics I at the Universitat Politècnica de Catalunya (UPC), Barcelona.
- **GNOM** is a consolidated research group that is recognized and funded by the **Government of Catalonia** (SGR-2009-1122)**.**

- The group is working on both **numerical optimization** methods and **mathematical programming modeling** of any problem that can be solved through optimization, with special interest in energy and statistical data protection.

Energy

Optimal solutions for Power Systems and Electricity Market

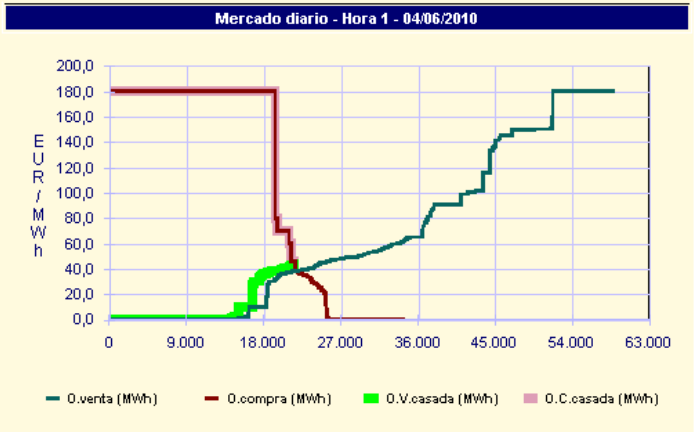


- For over two decades energy team of the GNOM group has been developing and applying advanced optimization procedures as well as mathematical modeling solutions to **Power Systems**.
- These publicy funded research and industrial projects have been consecutively carried out on a national and international level in concert with both the Spanish administration and with several European electric utilities.

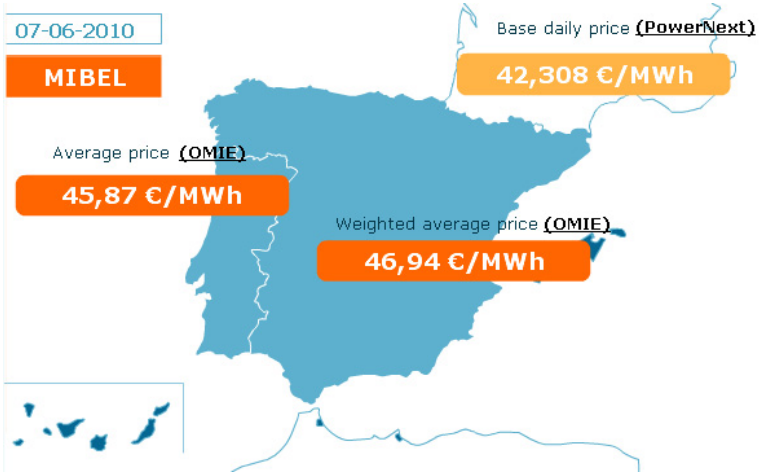
- The expertise of the GNOM group in **electricity market optimization** incorporates an especially **profund knowledge of the Iberian Electricity Market** (**MIBEL**).

Energy

Optimal solutions for Power Systems and Electricity Market



- The **short-term** focus (one day to one week) entiles the development of **stochastic programming models** for the joint **optimization of the generation bid** to the day-ahead, AGC (reserve) and intraday markets, which at all times takes into account futures and bilateral contracts, **greenhouse emission constraints and risk**.



- Over the **medium term** (a few-months to two-years) our procedures address the equilibrium planning of generation in pure pool or mixed markets with bilateral contracts, taking into account the impact of **wind power and photovoltaic generation**, as well as **emission caps**. Stochastic programming techniques are employed and constraints to limit the risk of profit loss are included.

Academic activity

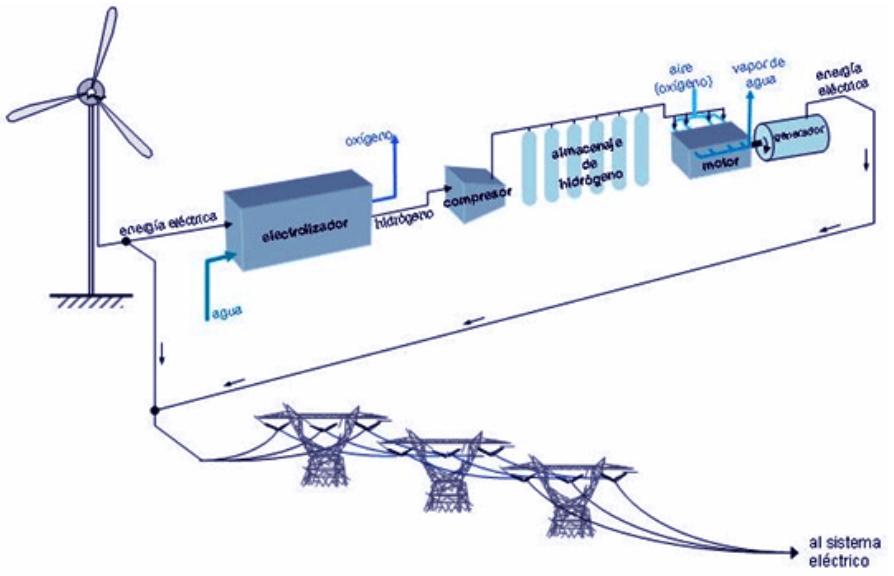
Master´s and degree courses, B.Sc., M.Sc. and PhD Thesis

- The lecturers of the **GNOM** group are especially motivated and involved in both fundamental and advanced courses on **optimization**, **probability** and **mathematical programming modeling**, as well as on the **optimization of energy systems**.
- **M.Sc. courses on energy systems optimization:**
  Electricity markets, Stochastic Programming, Modeling in Mathematical Programming, Large-Scale Optimization, Network Flows.

- **Recent B.Sc. and M.Sc. thesis on energy systems optimization :**
  - *Study and optimization of the sales bid on the (MIBEL)*.
  - *Optimal multi-market bid on the MIBEL*.
  - *Medium-term stochastic optimal schedulling of the electric generation in an oligopolistic market*.

Optimization of a Wind-Hydrogen system

The Gas Natural's Sotavento experimental project

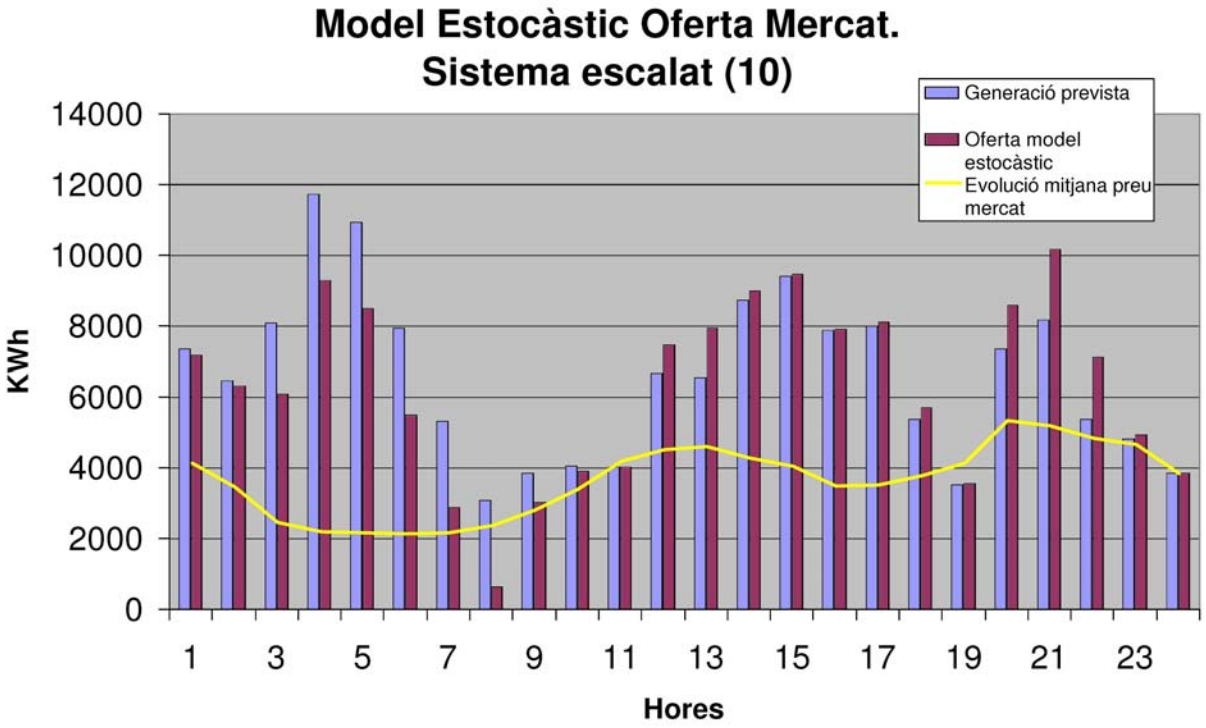


- **Wind-hydrogen** system is composed by a **wind energy** conversion system and a hydrogen system consisting of an **electrolyzer**, a **compressor**, a **hydrogen storage**, and a **fuel cell integrated into an existing diesel generator**.
- **Hydrogen production enhances the application of wind energy** through the production of a fuel, which can be used locally to generate electricity during periods of low wind or peak demand, used for other local energy needs or transported to the more energy demanding markets

- **Problems related with the operation of the wind-hydrogen system in elec. markets**:
  1. **Optimal wind generation bid problem**: to find the optimal wind generation bid based both on the forecasted spot market prices and wind generation.
  2. **Optimal operation of the hydrogen plant**: to find the optimal control of the wind-hydrogen generator that minimizes the deviation of the current generation w.r.t. the generation bid submitted to the day-ahead market.

Optimization of a Wind-Hydrogen system

Results for the optimal wind generation bid problem



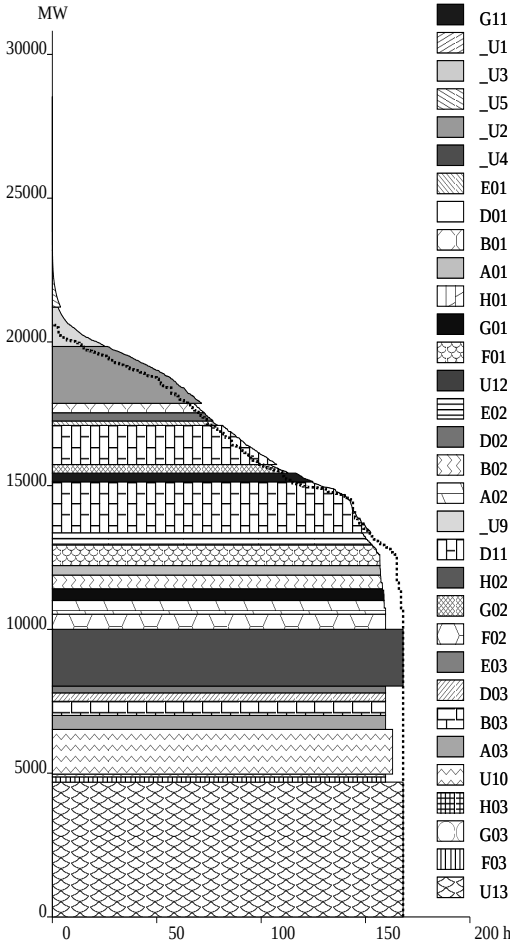
- The solution provides the **optimal wind generation bid to the day-ahead market** in such a way the expected incomes are maximized, for a given set of scenarios of both the **spot market prices** and **wind generation.**

Medium term power planning

Evaluation of the impact of renewable energies

- **Medium-term** electric power planning is a **stochastic optimization** problem. Its **time scope** is **one** (or two) **year**(s), which is **subdivided into shorter time periods** (monthly, bimonthly, ...)
- It has to be solved for (optimum) new plant planning, (optimum) fuel acquisition for the **yearly budget**, and (optimum) medium- and short-term operation.
- It is **stochastic because** load is uncertain, the generating units may have random outages (whose probability is assumed to be known), and water inflow in reservoirs and renewables' availability are also stochastic.
- Fortunately, we have the **convolution method** to combine the load duration with unit outages, the **Bloom and Gallant formulation** forsatisfying the load-matching and other constraints, and the **stochastic programming** techniques (scenarios).
- The most reasonable way of evaluating the **impact of renewable energies** is through **medium term planning**.
- The increase of **risk of profit loss** due to the use of renewables can be **also evaluated**.
- Medium term planning can also be used to find the **equilibrium solution in electricity markets** (Nikaido-Isoda algorithm).

WIND POWER GENERATION IN THE MEDIUM TERM
The load duration curve LDC

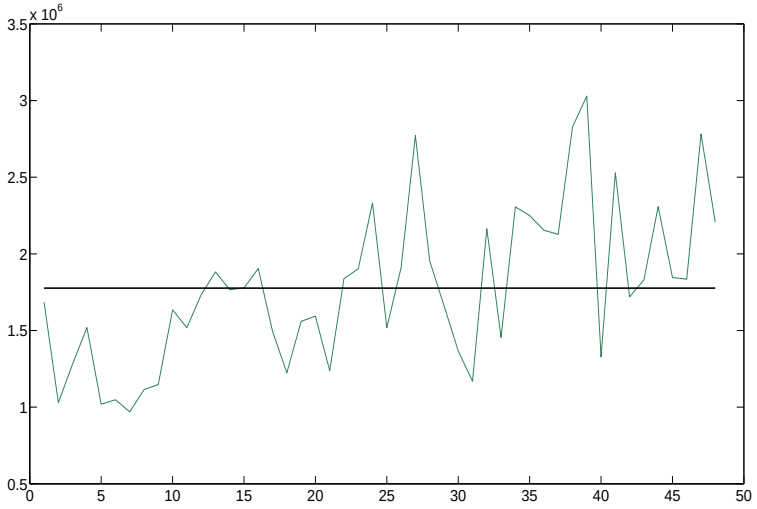


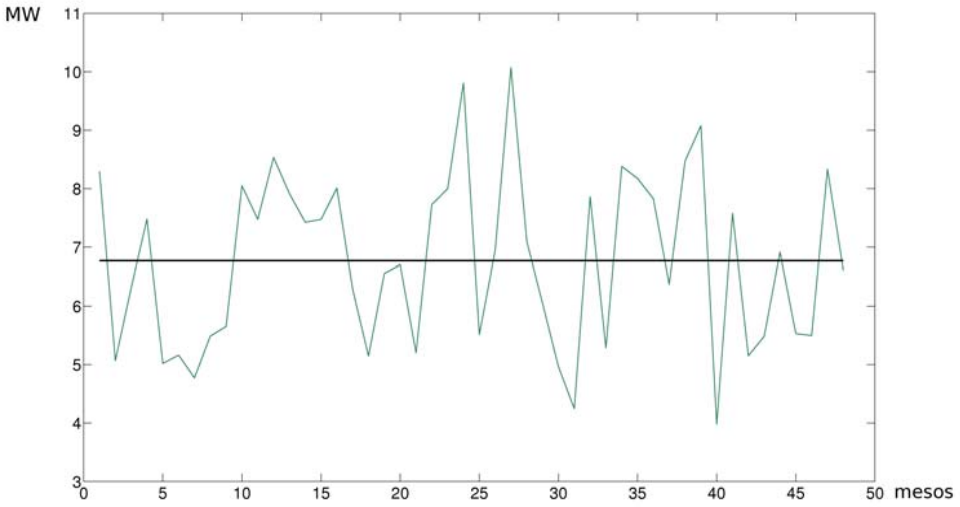
- The **generation duration curve GDC** is obtained from the **load duration curve LDC**. It provides expected generations of future periods
- The LDC must be predicted for every future period considered (into which the medium-term horizon is subdivided)
- The **Bloom & Gallant** formulation has expected generations as variables and expresses the matching of LDCs by expected generations through **linear inequality constraints**
- Every generation unit is represented by a ***power capacity*** and a ***failure probability***
- The power planning can be optimized

WIND POWER GENERATION SCENARIOS

Wind power series for scenario generation

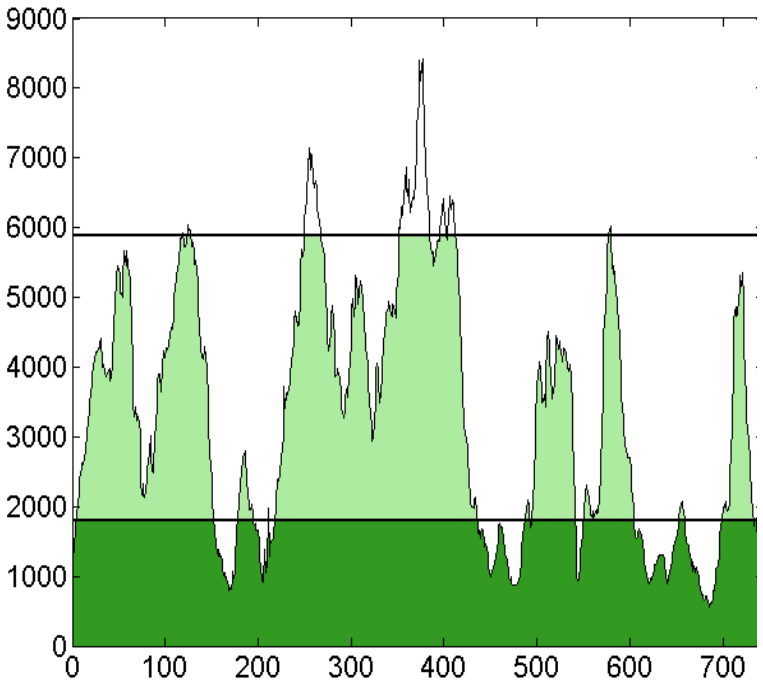
- **Scenario generation** is a necessary task. Historical records of wind power generation must be employed.
- The **increasing capacity** of the installed wind power farms must be taken into account
- **Scenario generation** and **scenario reduction** techniques must be employed so that the resulting problems have a reasonable size

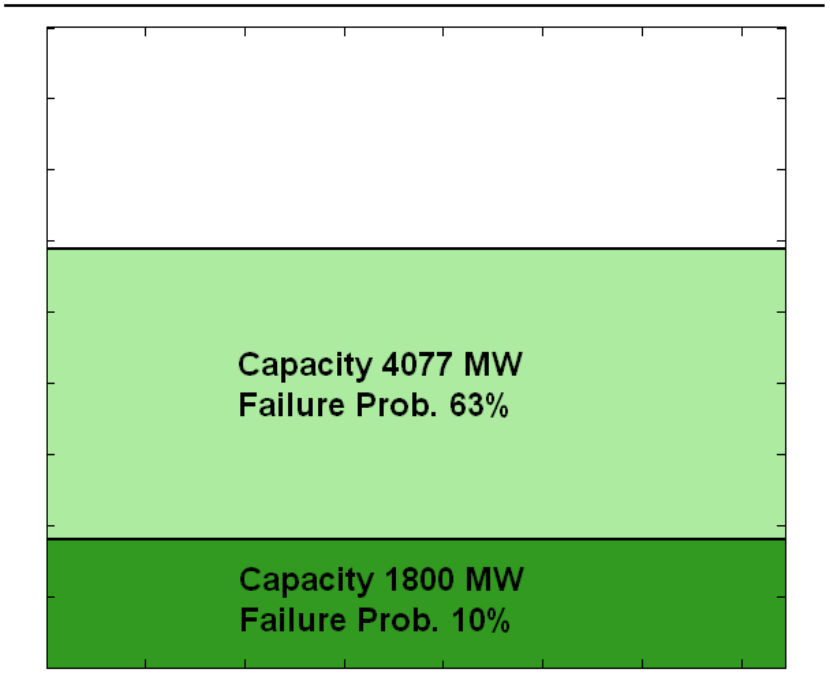




WIND POWER GENERATION IN THE MEDIUM TERM
The *two-unit* generation model

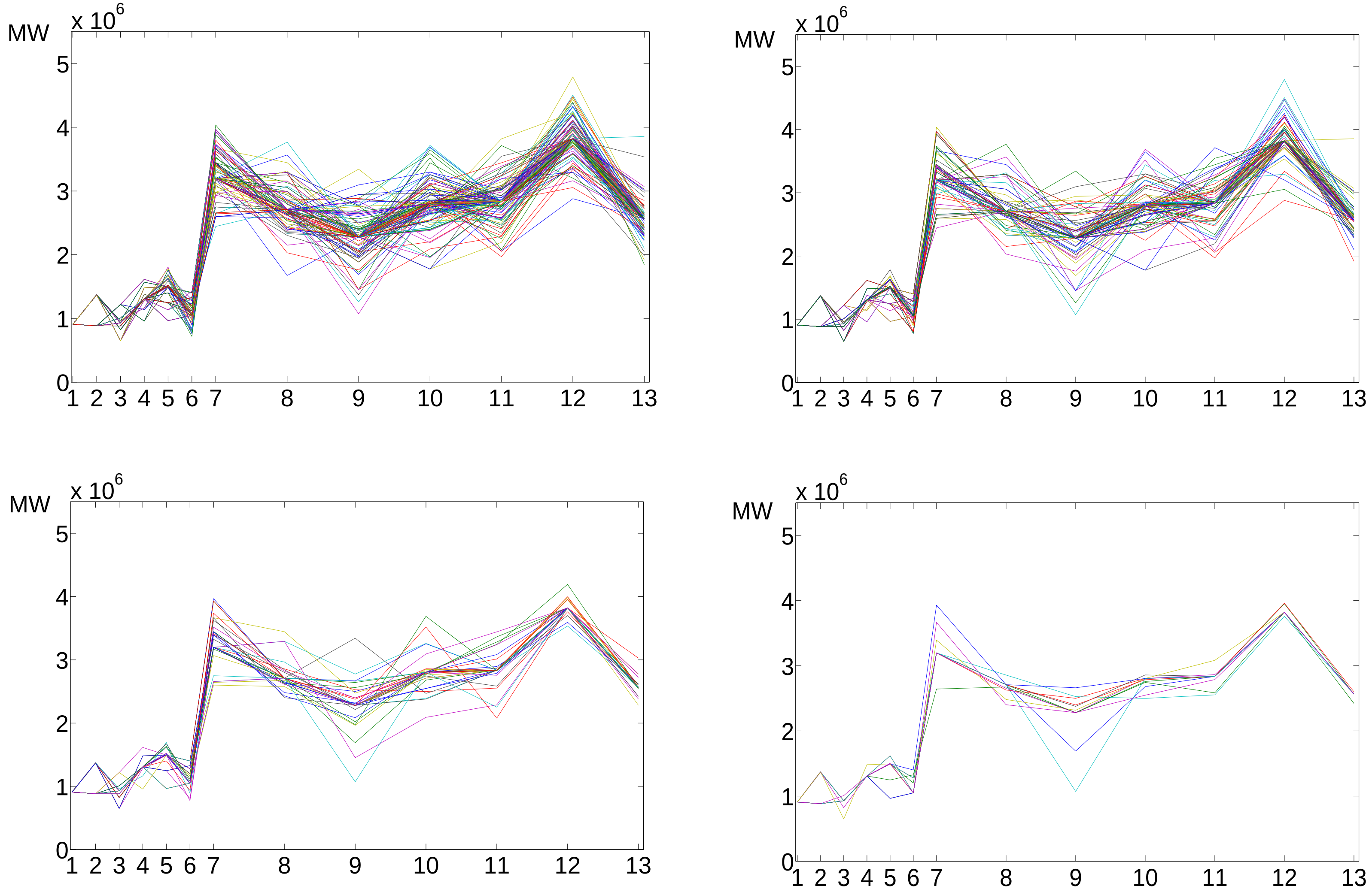
- From the wind power series corresponding to a given time period (e.g. June) we deduce the **two-unit model** that represents its wind-power generation
- Two pseudo units represent all the significant wind power: the **base unit** and the **crest unit**
- In scenario generation the scenario tree nodes are based on **base unit capacity** (fixed failure 10%) and **crest unit failure** (fixed crest capacity)





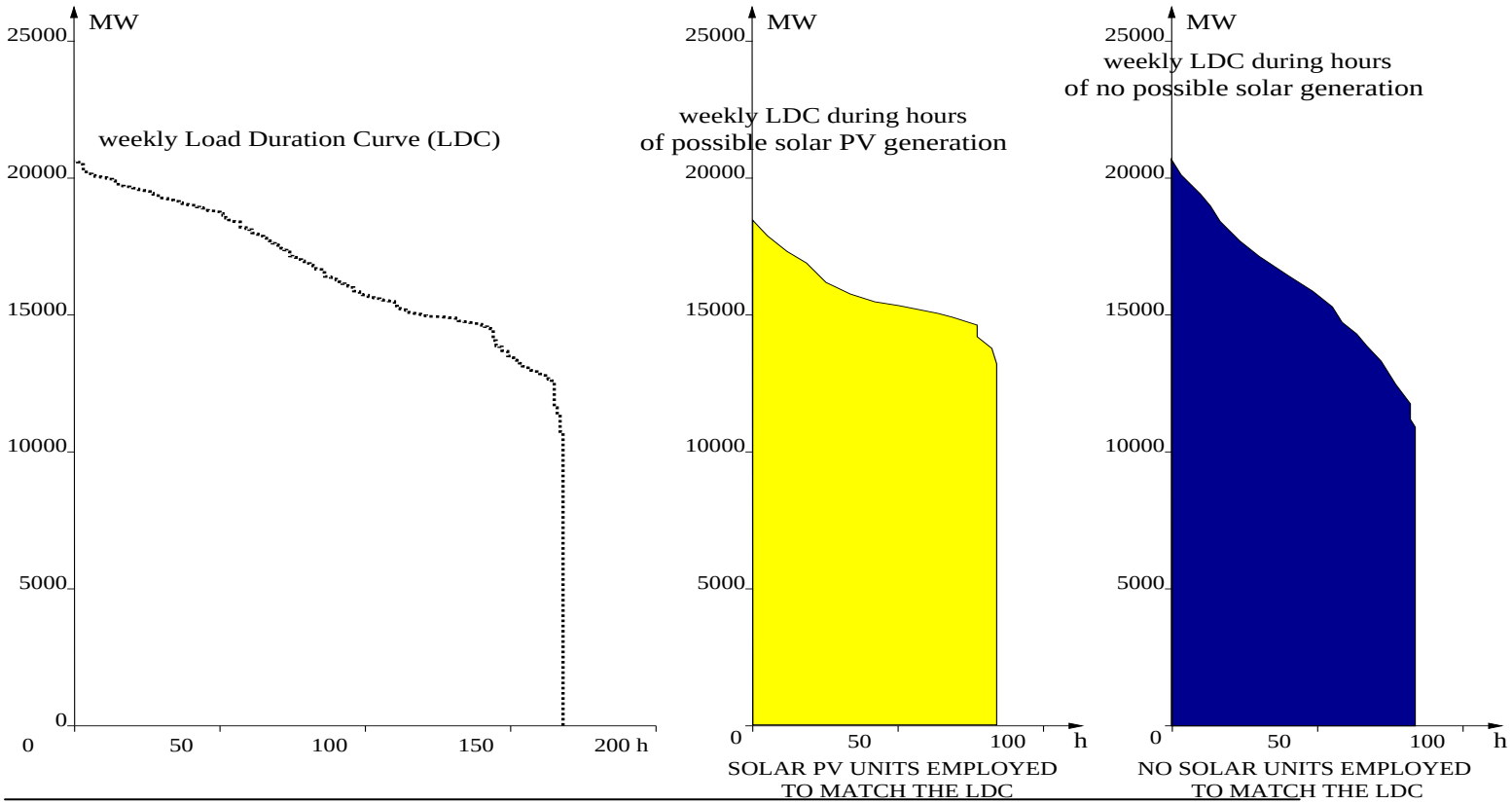
WIND POWER GENERATION SCENARIOS

Solution using Stochastic Programming

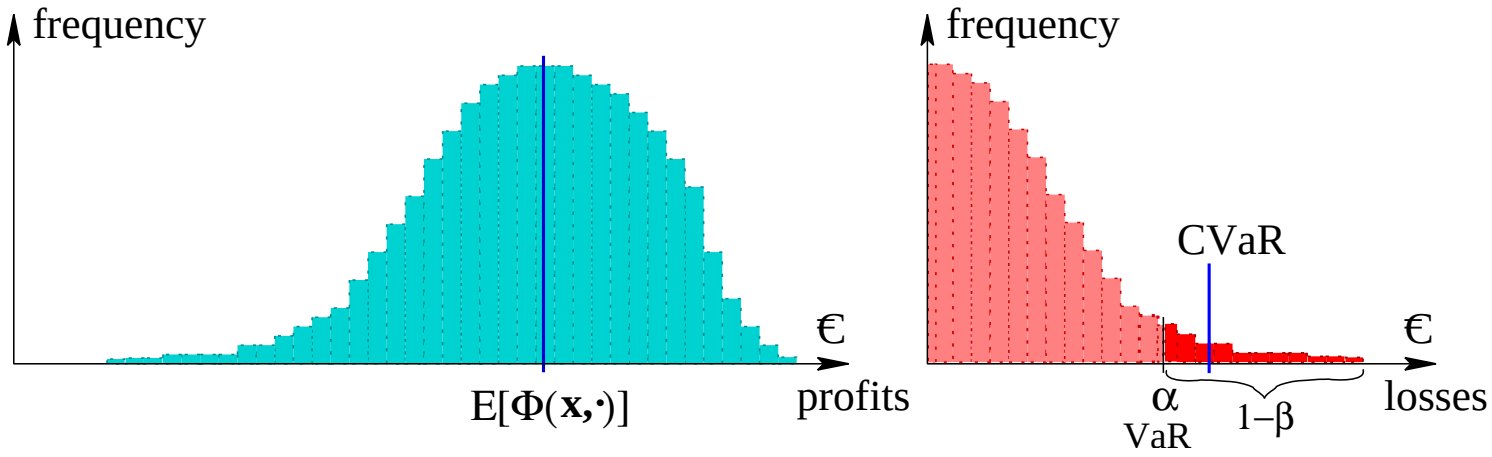


SOLAR PV POWER GENERATION IN THE MEDIUM TERM
The split load duration curve (LDC)

- A **two-unit model**, similar to that of wind power, is also employed to represent **solar PV power generation**
- Period **must be split into two**: one with **daylight hours** and the other with **no sun hours**. Solar PV units **only generate in the daylight subperiod**



SOLUTION FOR EACH MEDIUM TERM SCENARIO
Risk of Profit loss



- The stochastic programming solution provides the value of the **profit for each scenario** of the scenario tree with its **associate probability**.
- A profit-frequency plot can be set up, and through it, a **measure of risk (CVaR)** of profit loss can be stablished (for each player in the electricity market).
- The impact of the **renewable energies employed** is an **increase of profits** but it can be also evaluated in terms of the **increase in risk of profit loss**.
- **Medium term planning** provides a **sound methodology** to evaluate the **real impact** of the use of renewable and other types of **energy sources**.

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GRÀCIES PER LA SEVA ATENCIÓ

http://gnom.upc.edu/

KIC Meeting, Barcelona, June 7, 2010