Universidad Politécnica de Cartagena

Departament of Electrical Engineering

Doctoral Course on “Industrial Technologies”.

Subprogram “Neurotech, Control, Robotics and Energy Management”

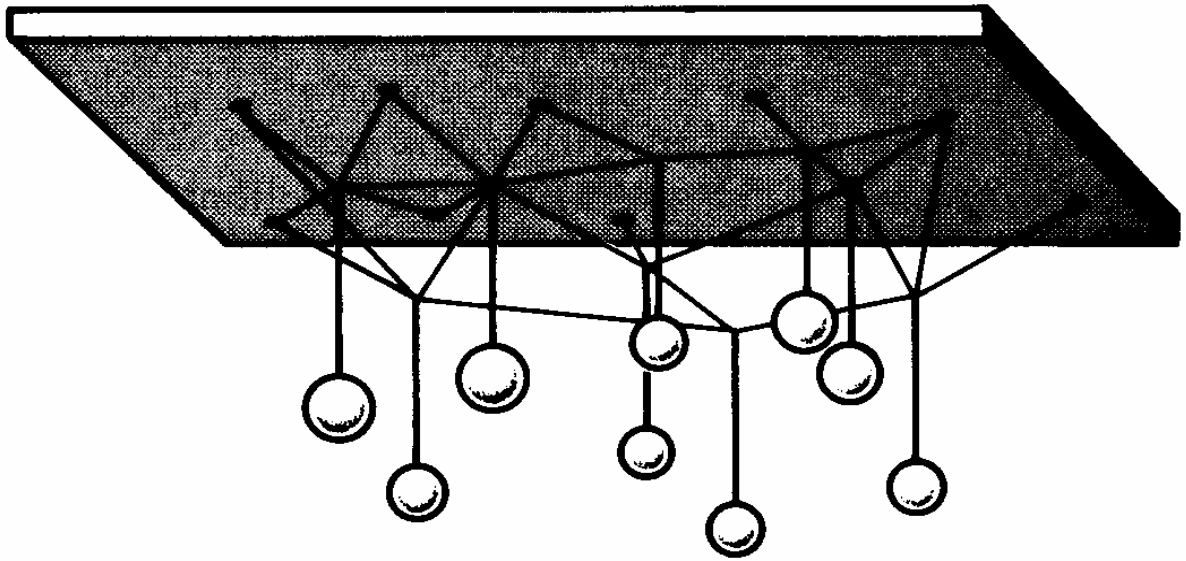
Analysis of Distributed Energy Resources: an Introduction to Demand Response

Cartagena, 2011

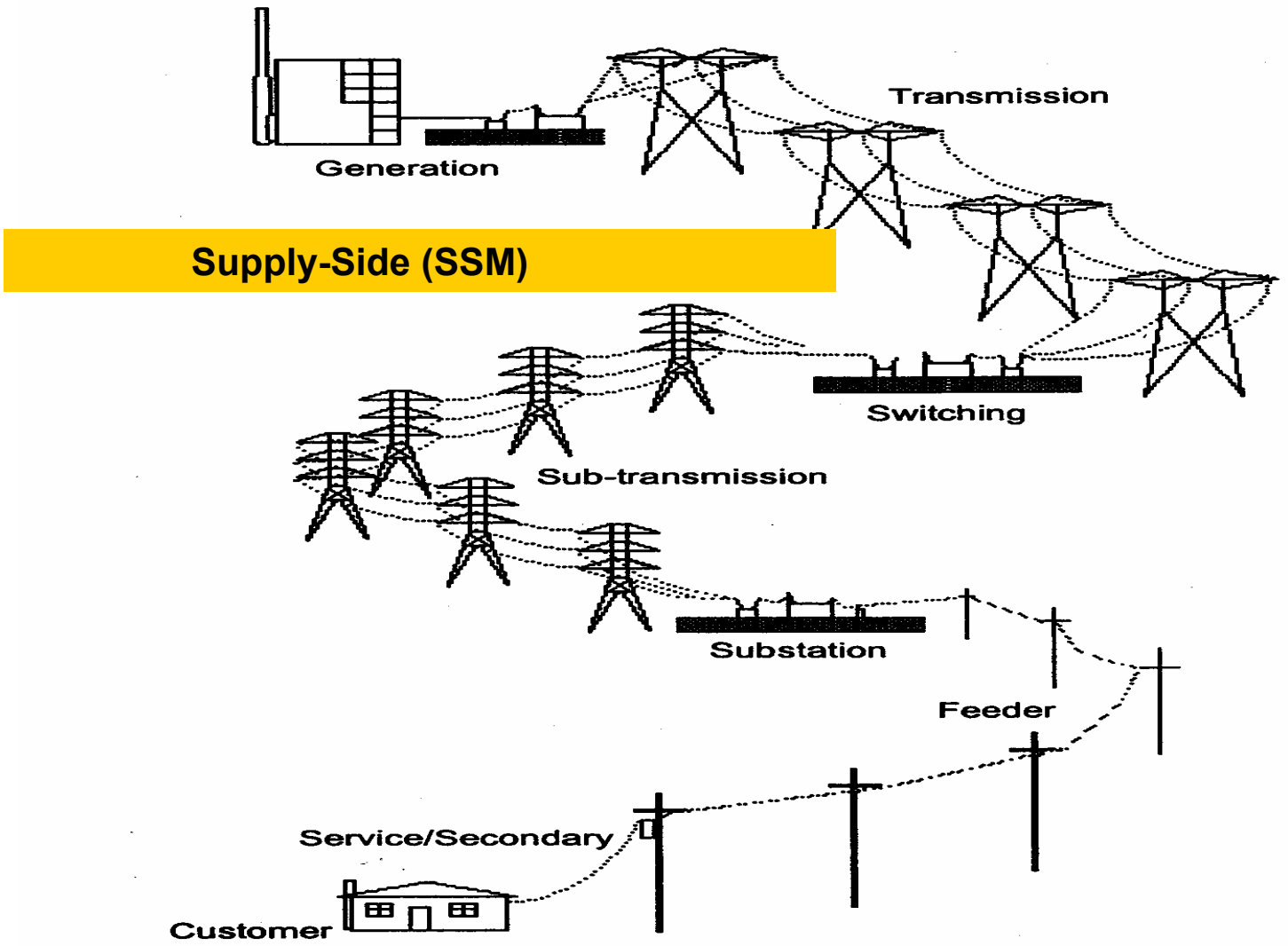
- Lesson 1
- Structure of Electrical Power Systems: An overview of some problems induced by the increase of demand.

- **Electrical energy is a valuable form of energy, because it provides:**
  - Accuracy
  - Ease of process control
  - Friendly use
  - Environmental Benefits
  - Availability: various primary sources at reasonable costs
  - Efficiency: the best performance in transport and energy end-use electricity are obtained
  - It is versatile, easily converted into other forms of E
  - Involves 35 to 50% of the total energy consumed in the decade 2000-2010
- **Problems:**
  - The continuous increase of energy (and specifically power) consumption
  - There is no possibility of storage (in large amounts)

- **Mechanical analogy of Electrical Systems (Eldgerd, 1981)**
  - It is necessary to keep a balance in every instant (low storage capacity)
    Generation = Demand + Losses
  - With a certain level of quality and reliability of supply!



Power System Structure (four levels)



Characteristics of different levels

- Each level provides power to the next level
- The voltage and transport capacity decrease to Demand Side
- Each level has many more elements than the previous (DS)
- The net capacity increases to the user level
- The reliability decreases in the customer side (DS)
  - Example: small EPS (source Willis)

Level of System	Voltage kV	Number of Units	Avg. Cap. MVA	Total Cap MVA
Transmission	345, 138	12	150	1,400
Sub-transmission	138, 69	25	65	1,525
Substations	138/23.9, 69/13.8	45	44	1,980
Feeders	23.9, 13.8	227	11	2,497
Service Trans.	.12, .24	60,000	.05	3,000
Secondary/Service	.12, .24	250,000	.014	3,500
Customer	.12	250,000	.005	1,250

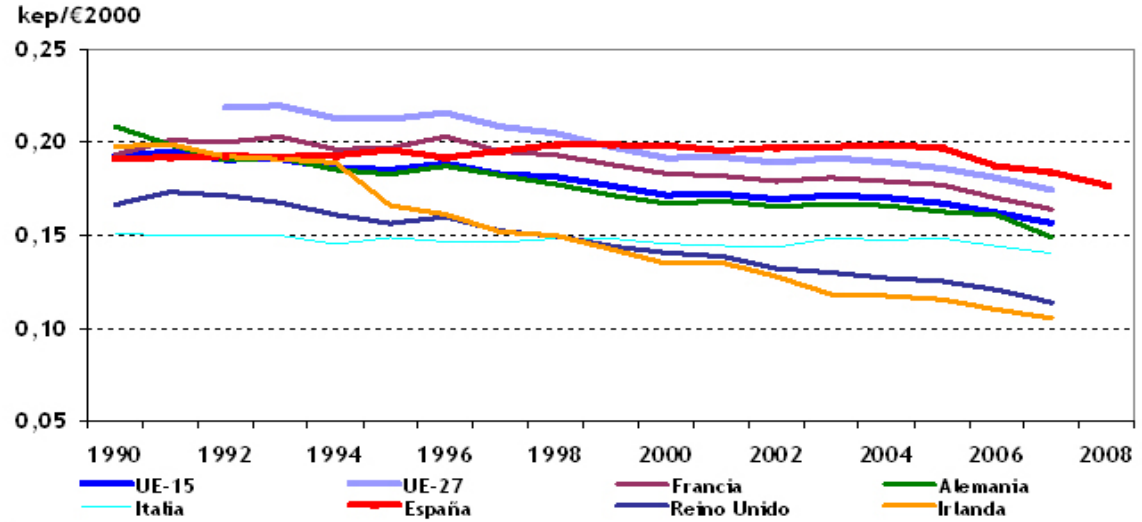
- **Costs of T & D levels (I): the addition of new resources in Supply is very expensive (an accurate forecast of demand is needed)**
  - Design, construction and operation cost.
  - Equipment and appliances have two types of costs: Capital, equipment, land (ROW), construction, assembly, installation and commissioning
  - Operation: labor and equipment to keep the system in operating conditions
  - Taxes, and losses in the system
  - Let us recall some cost ratios in each of the levels of the system

- **Transportation Level costs (some examples):**
  - Costs of electrical lines:
    - 66kV line, 50MVA: [0.7, 1] €/ kVA-km
    - 380kV line (duplex): [0.3, 0.5] €/ kVA-km
- **Substation costs, including:**
  - Land: purchase and preparation
  - Transmission and distribution terminals
  - Transformers
  - Overall cost [20-50] €/ kVA
- **Distribution Level costs:**
  - Overhead line: €5-15 / kW-km
  - Underground: €20-40 / kW-km
  - Maintenance costs (they are difficult to evaluate, i.e. lack of actual data): 3-12% of capital cost per year (estimated)

- **If the forecast of demand fails, then we face to …**
  - The cost to renew or extend the system's capability
  - The cost of lack of service
- **Solution: large margins in the capacity of the lines? ►Anticipating the growth in demand**
- **Example: 20 kV line. 6MVA or 15MVA?**
  - Cost Option 1: Rated power 6MVA: €10 / kW-km
  - Cost Option 2: Rated power: 15MVA line: €8 / kW-km
  - Cost to extend line (option 1) (+9 MVA): €25/ kW-km, because we need …
    - Working in voltage?
    - Install new conductors?
    - New poles?
  - In many cases the system components are built with a significant margin (50%) to supply future needs (decades)
- **Are there alternatives to apply large margins into the Supply-Side? Yes, of course**

Supply problems: demand behavior in Spain (EU)

In Spain, the intensity of energy use (i.e. GDP / demand) slightly increased in XXI century

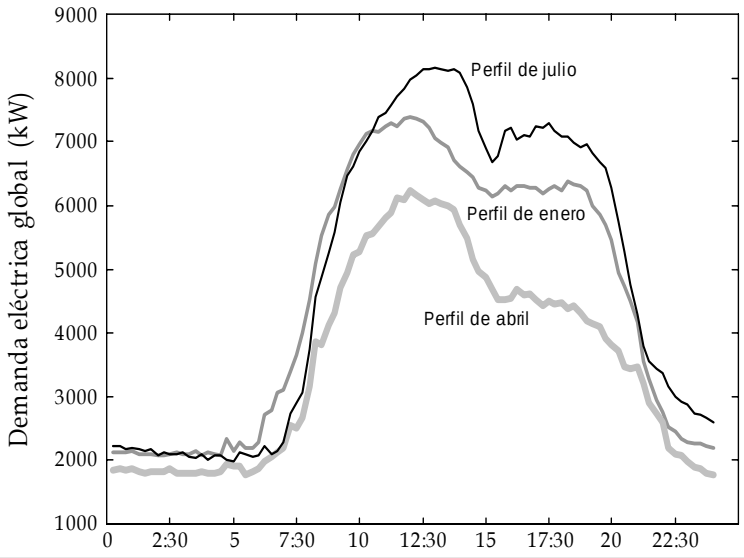


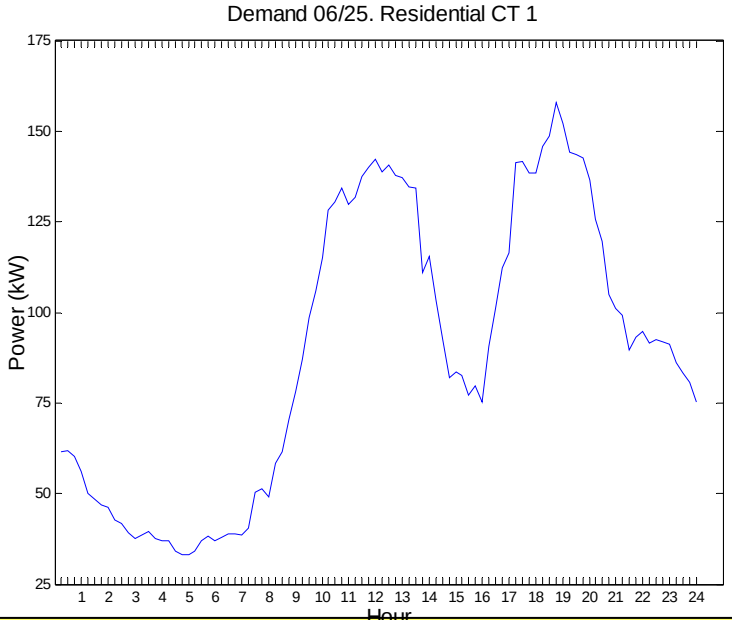
Fuente: EnR/IDAE

Nota: Los datos de *Intensidad Primaria* para España se han calculado a partir de las cifras de Producto Interior Bruto publicadas por el INE a precios constantes de 2000 y de acuerdo con el nuevo Sistema Europeo de Cuentas. Según esto, los valores del PIB han sido actualizados en noviembre de 2009.

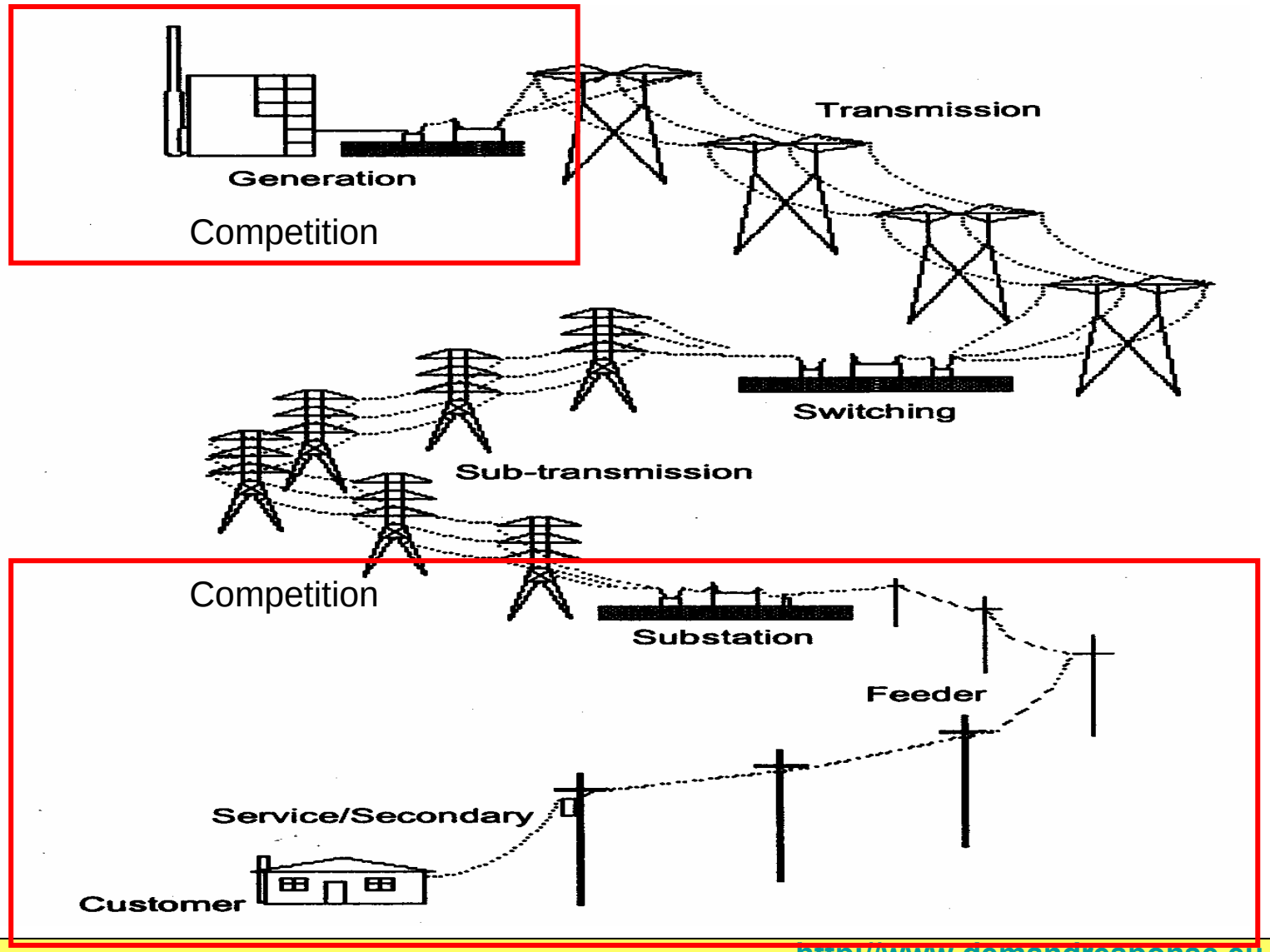
Problem of the last years:
Peak power increases by 40% and demand by 30%
Installed generation increases at a lower ratio: from 58 to 63GW in 2002 (8.6% ↑)
Hint: *we are less efficient in energy use*

- **Low load factors (LF): both daily and annual**
  - LF = average demand / peak demand
  - It may be in the range of 0.5-0.6 (exception France). The trend is to decrease from 1990 to 2010 (see New England ISO, USA).
  - Demand peaks define the generation capacity and power lines in our power systems (i.e. future costs).
  - Peak grows more than energy (we should pay attention to both variables).
  - Two examples of customer loads (university and residential)

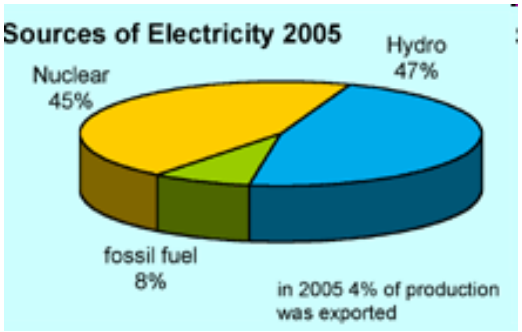




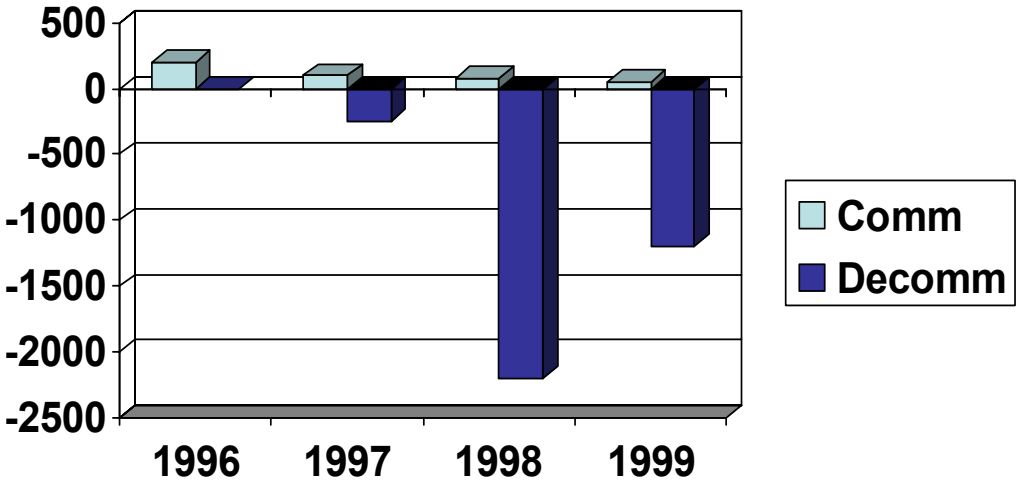
Activities in Power Systems (energy markets)



- **Effects of De-regulation (energy markets)**
- **Prices: actually have been falling as a result of liberalization.**
- **But there are other "effects" of liberalization:**
  - Generation plant closure: an example is Sweden (2000mW lost 1998 + 600MW nuclear plant).
  - "New plants? Low planned generation capacity. In 2006 change in nuclear policy.



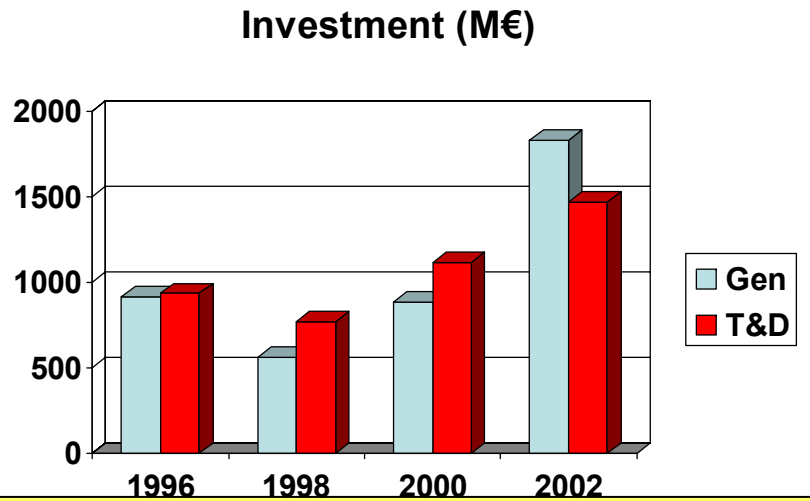
Change in Generation Resources Sweden (MW)



Another example. Spanish market situation (1996-2002). Deregulation in 1997 .. Sometimes traditional businesses were not very profitable ...

Year	Generation	Distribution
1997	8,1	5,3
1999	6,6	4,5
2002	6,6	5,1

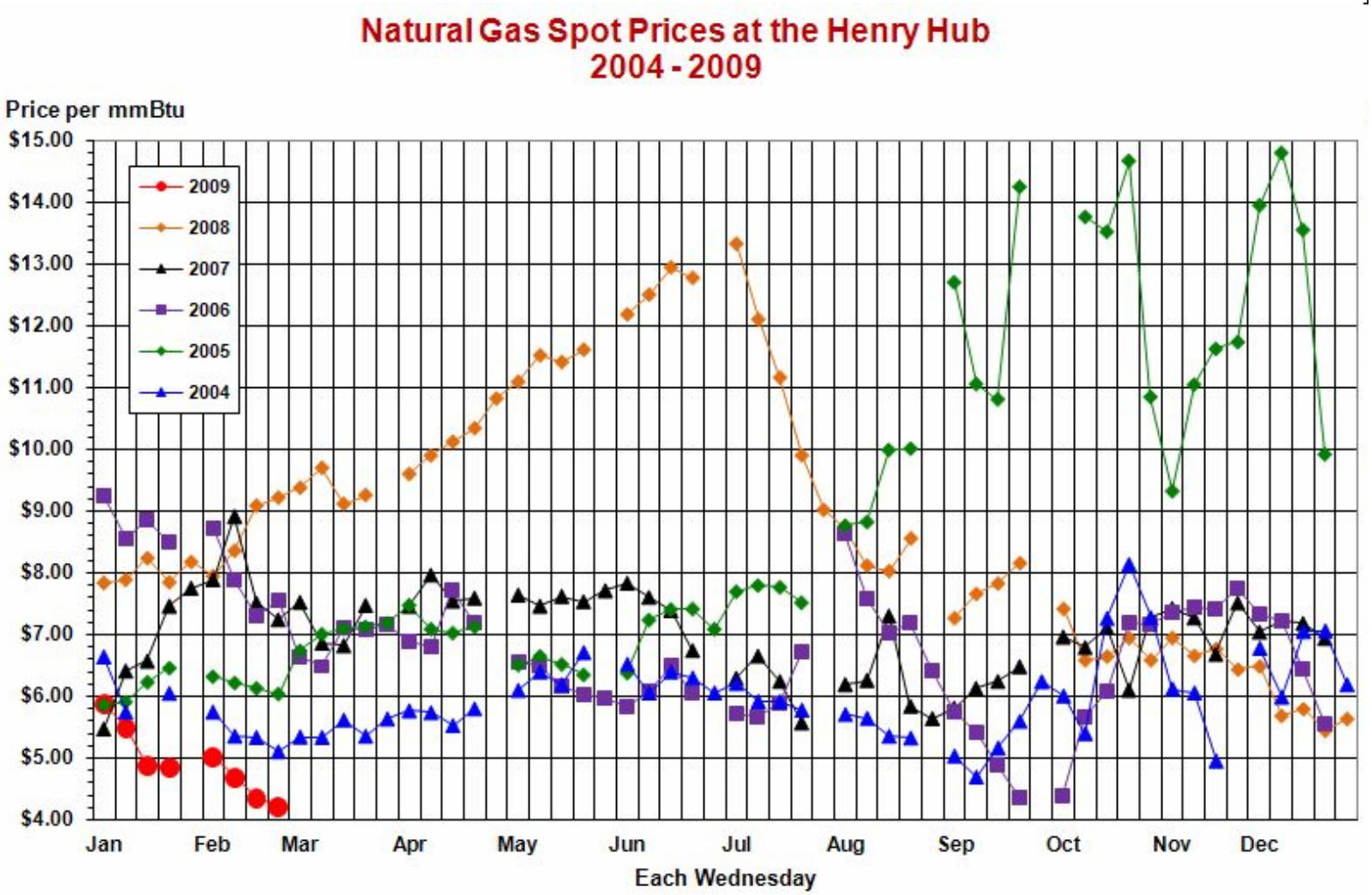
So, the investment was scarce



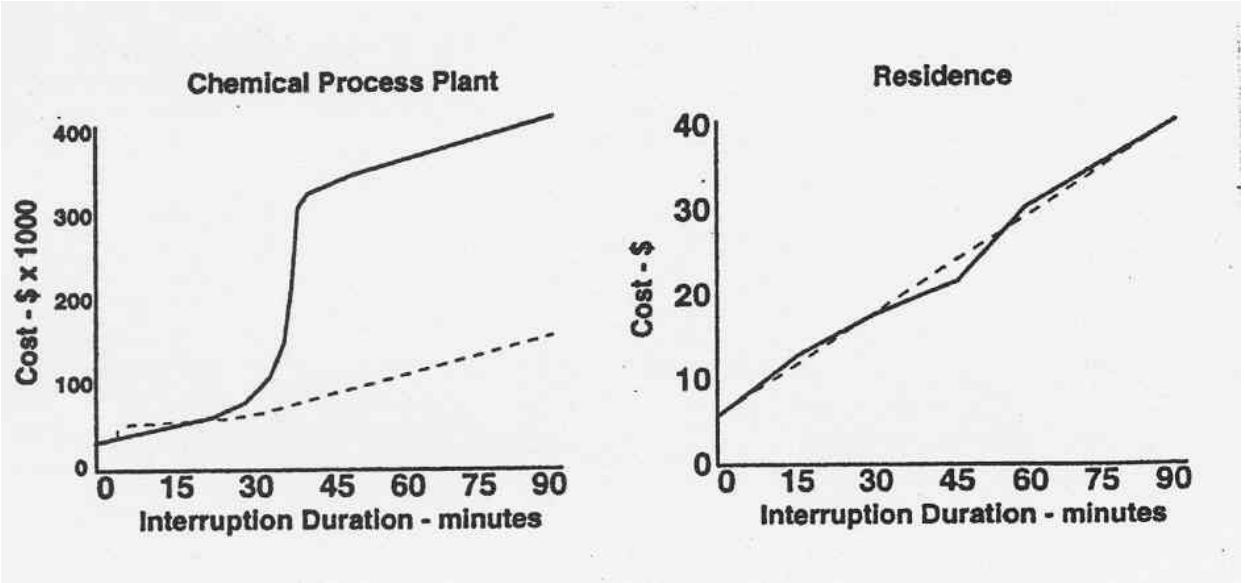
- **What is the cost of conventional generation?**
  - Many plants are technically outdated
- **Example of cost uncertainty: Combined cycle plants**
  - They have a high efficiency (at least 20-30% more than conventional thermal unit)
  - The deregulated market has led to the construction of such plants (USA, EU,…)
  - That is nice: Lower emissions to the environment
  - 60% less than a coal plant (CO2)
  - Problems: Many of them were planned to a market cost less than $ 3 / MMBtu. The problem is that the price is above $5 / MMBtu (in some years, over $8/MMBtu)
- **There may be a long term solution**
  - Need to reduce dependence on natural gas, using it for other smartest purposes (GD, CHP)

Natural Gas Prices (source: Henry Hub, USA)

- As always fall short of forecasts!

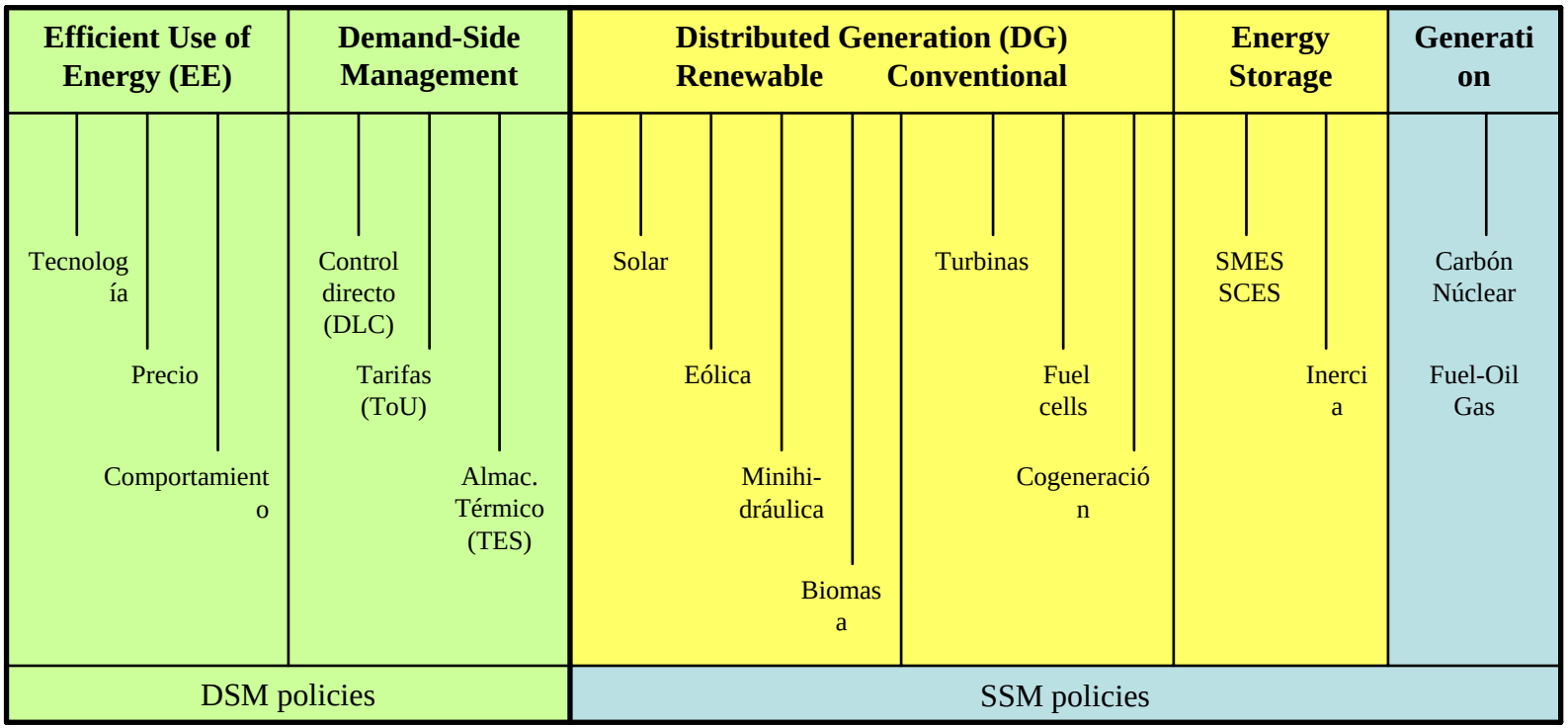


- **We should consider: users need different levels of quality and reliability**
  - Reliability standards are very high in Power (99.9%)
  - What do they mean? No service 10 hours a year
  - The "lack" of reliability may have a high cost to the user:
    - Loss of data (computers)
    - Loss of production (pottery, chemical)
  - A conventional electrical system can not have 100% reliability. Other possibilities? Yes (source: Willis et al.)



Concept: Integrated Resource Planning (IRP)

- First time proposed by F. Schweppe (1989)
- Use all the resources available. It's a great lesson and example: to avoid technically unfounded prejudices (nuclear, renewables, DSM, …)
- IRP portfolio

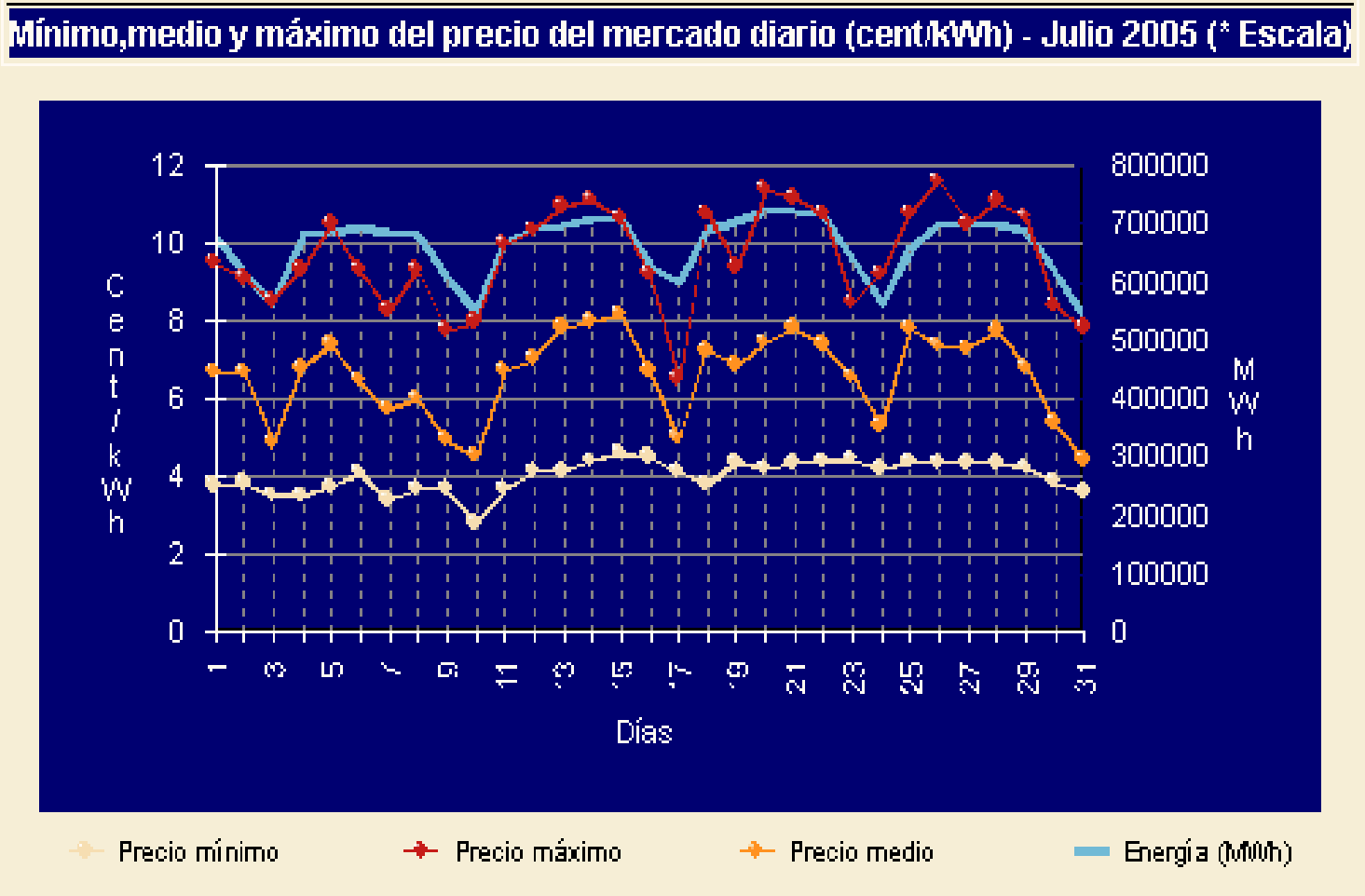


- **How can the user manage their energy costs? Through the participation in energy markets (there are barriers!)**
  - By itself (large users)
  - Through "demand aggregators“ (a nice idea)
  - Market prices are very interesting, different possibilities in terms of: demand elasticity and pattern change

Day/Months/ Years	Day ahead	Day	Real Time
Supply contracts **Bilateral contracts** **Capacity markets**	**Energy markets** **Reserve markets**	**Network constraints** **Real Time**	**Ancillary Services**

Examples of prices: energy markets (Spain)

- Daily prices/ month: there are changes (i.e. opportunities to manage and reduce costs)



- **Are there any solutions apart from traditional SSM and “renewables”?**
- **Of course, they exist: the “Demand-Side portfolio" (DSM traditional, Demand Response)**
  - They can compete with the increased expansion and operation costs
  - We mean:
    - Demand management (DSM)
    - Distributed Generation (DG)
    - Demand-Side Bidding (DSB)
    - And **Demand Response (DR)**
  - Resources: Distributed Energy Resources (DER) including Demand Resources (DERD)