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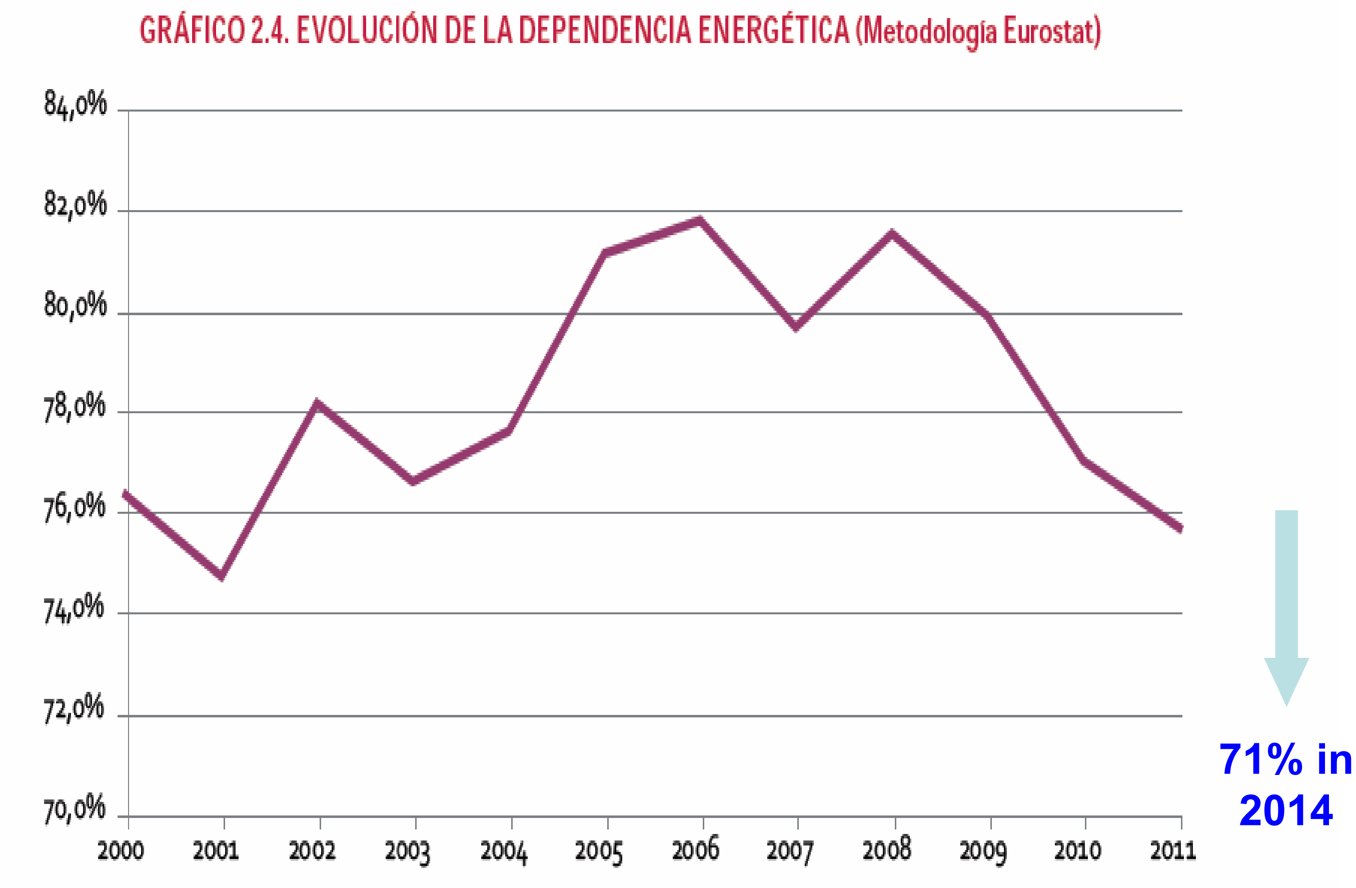
E.T.S. de Ingeniería Industrial
Universidad Politécnica de Cartagena (SPAIN)

EES-UETP Course: Demand Response in Deregulated Electricity Markets: Trends and Opportunities

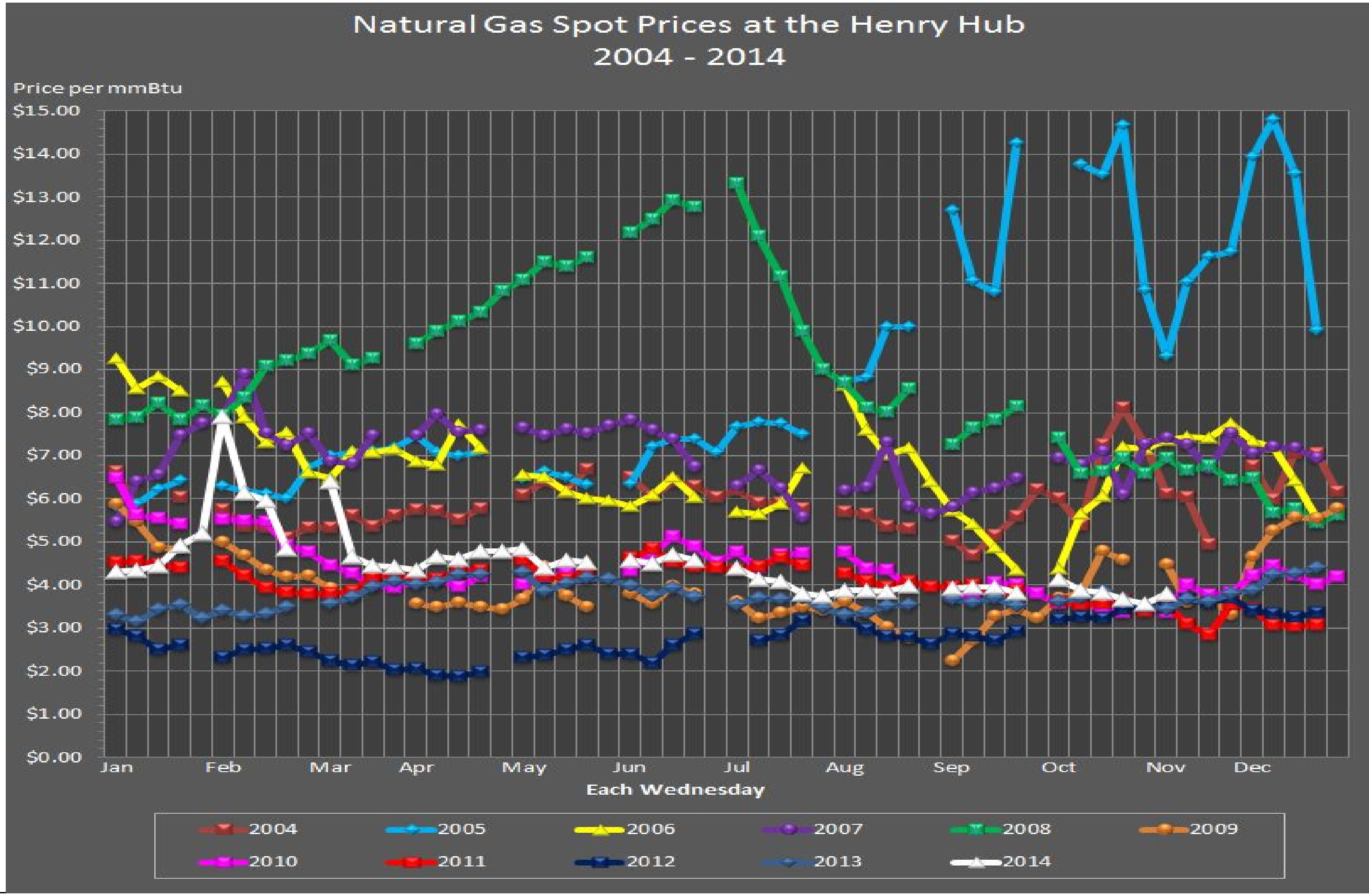
The Demand-Side perspective. Opportunities, barriers and New Markets for small/medium customers

A. Gabaldón, Nov. 2014

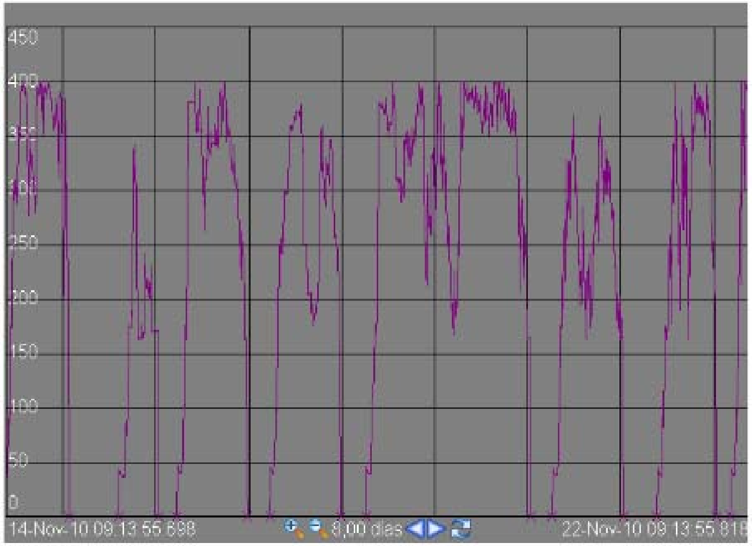
- **Problems of supply: energy dependence on foreign resources**
  - Energy dependence in Spain: trends (it falls slowly…the crisis?)
    - Figure source: Ministerio de Industria y Turismo, Spanish Goverment



- **Price volatility of primary resources. An example: Natural Gas Spot prices (EEUU)**
  - Forecasts are difficult: increasing of demand (emergent economies), political conflicts (Ukraine, Middle East, Libya,..)



- **Was the Planning Process in the medium and long term adequate?**
  - Status of certain generation technologies
  - For example,combined-cycle duty cycle of some units in Spain. Is it the right one for this power plants (4-6 hr/day)? No
    - Figure source: Gas Natural-Fenosa, Spain, 2012



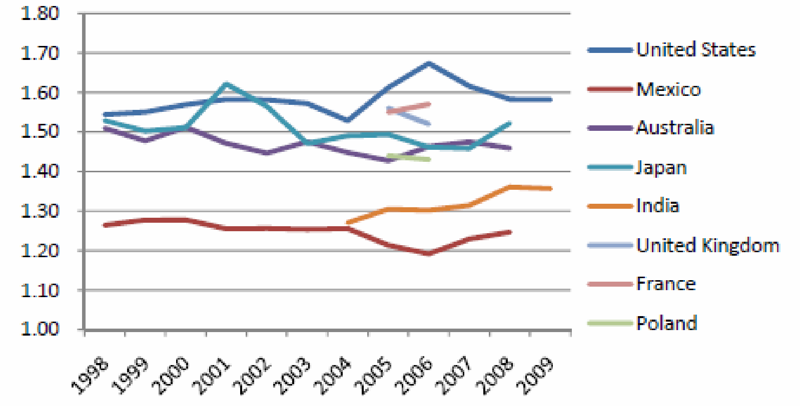
Weekly duty cycle

Daily duty cycle

- Costs of maintenance? Payback? ► Unit in “hibernation”

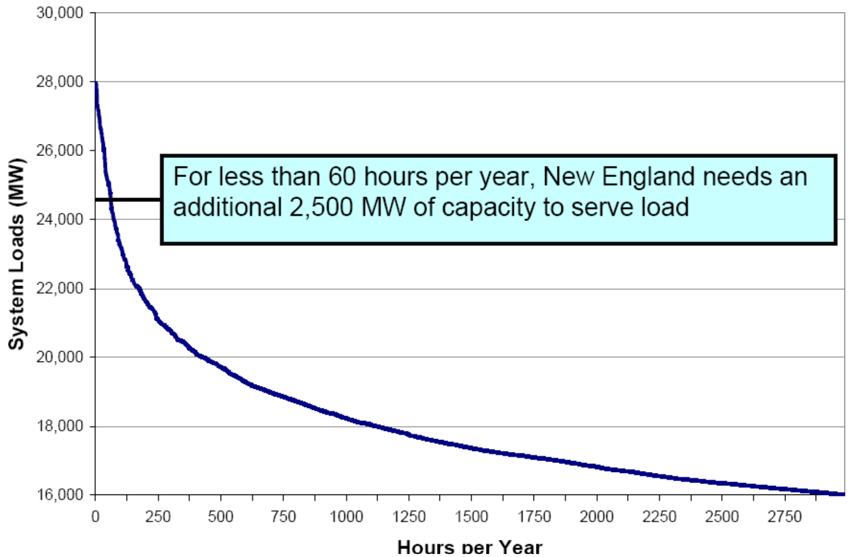
The use of Power Systems: capacity utilization (I)

- Load factors (LF) used in power system planning (60-65% or less, see ISO-NE data), capacity factors (CF).
  - **Figure source:** International Energy Agency, 2011



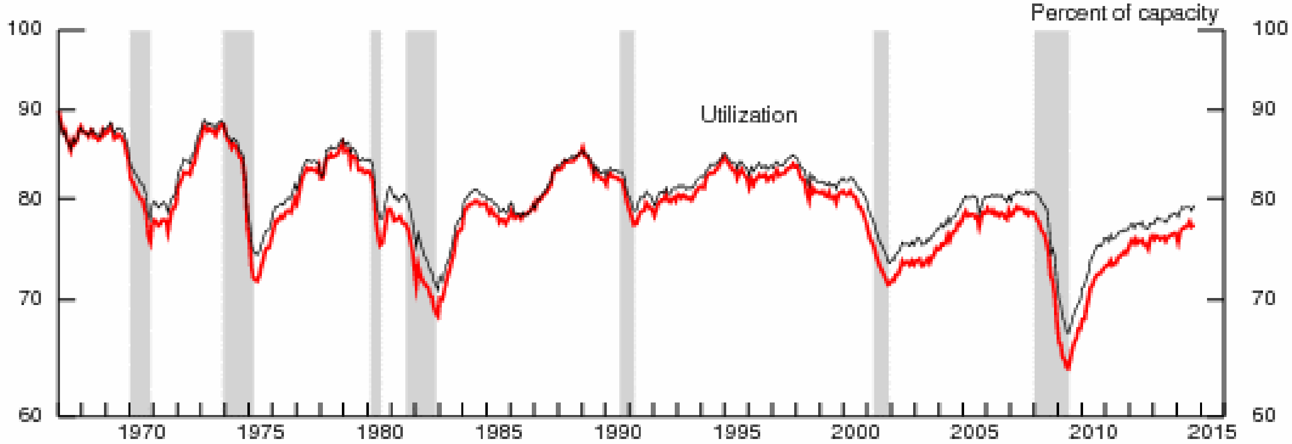
$$CF = \frac{Peak}{Average} = \frac{1}{LF}$$

- This is the same idea shown by cumulative load curves



- **The use of Power System infrastructures: capacity utilization in other strategic segments (II)**
  - Transportation: eg Air Berlin 85% (88% on August 2013), DB Schenker (North Rail Express Freight, 95%)

  - Industry sectors: overall and manufacturing
    - Figure source US Federal Reserve, October 2014



- **Please, smile before discussing more serious issues**
  - **Figure source: J.M. Nieto, ABC, October 2014**
- **Energy is a great concern but … only for engineers? The social welfare and sustainability are in question.**

- **Small demand segments: Residential Demand Response (RDR)**

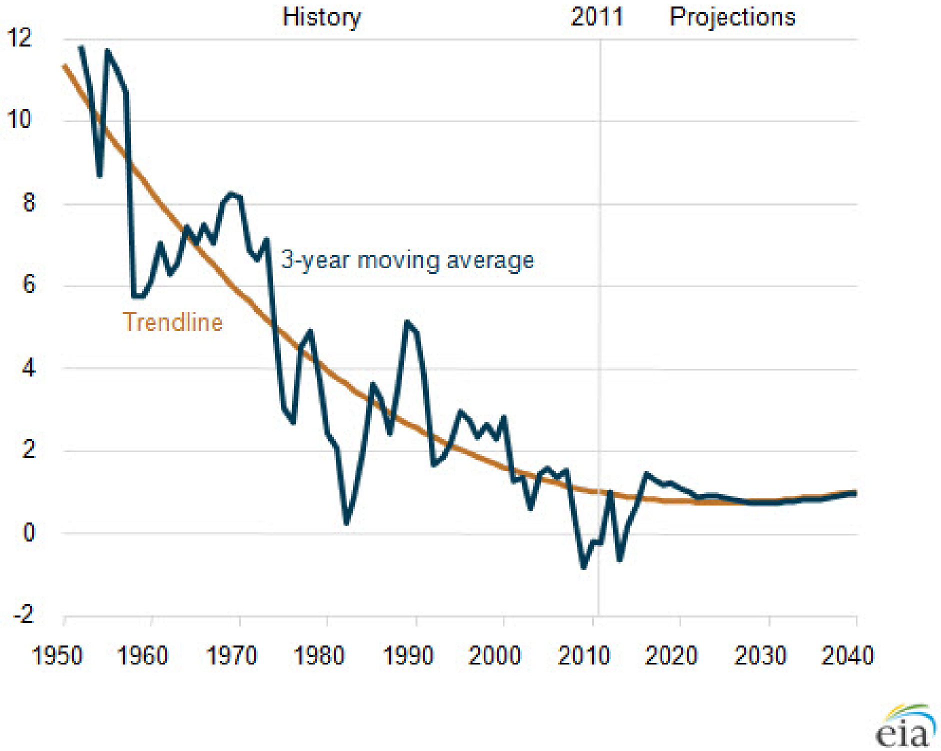
- **Why is the residential DR (RDR) so important for markets and Power Systems?**
- **Five arguments should be considered in the near future:**
  - 1) Residential segments are an important part of total energy consumption (and in the demand of electricity, of course)
  - 2) Residential demand for electricity will grow (according to forecasts for the period 2040-2050)
  - 3) Residential end-uses explain a high percent of system's peak-loads.
  - 4) Residential DR remains unexplored and/or is considered uncontrollable in many countries.
  - 5) Residential DR is important to get political energy objectives in EU (…and in other developed countries)

Some forecast about the growth of demand

- Figure source: Energy Information Agency, 2013, USA

- Growth is restrained, but continues despite economic crisis.
- Demand Response should grow in interest in the near future

Figure 75. U.S. electricity demand growth, 1950-2040 (percent, 3-year moving average)



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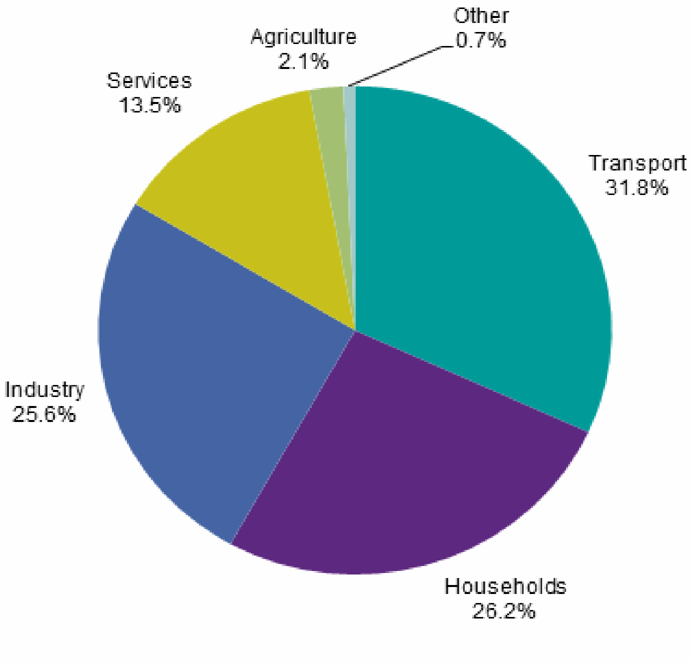
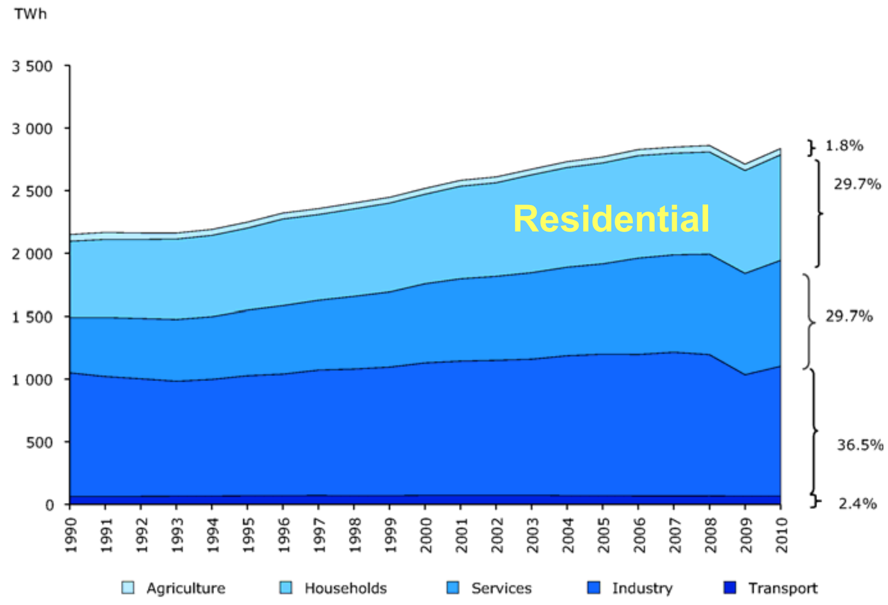
- **Segments of Demand (overall and electricity demand)**
  - Final energy consumption, EU-28, 2012 (% of total, based on tons of oil equivalent).
    - **Figure source: EUROSTAT, EC, 2012 & European Environment Agency, Jan. 2013)**



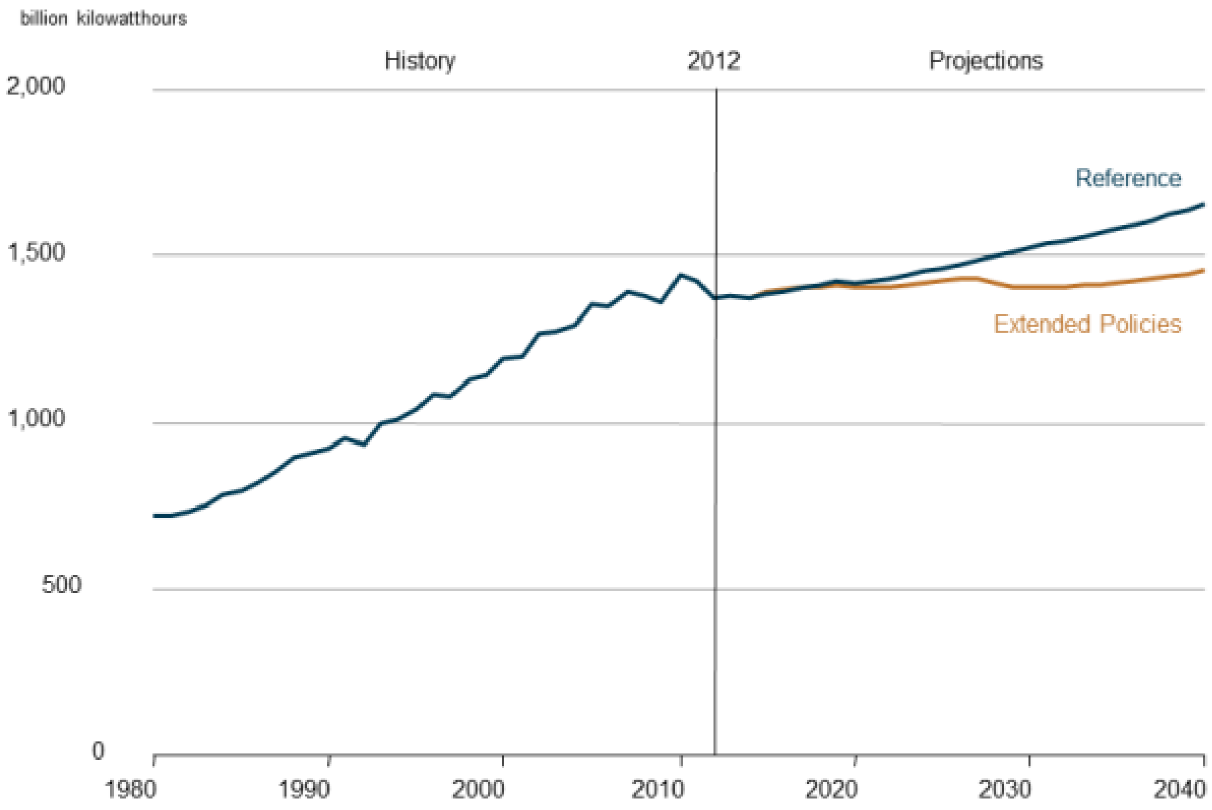
Overall demand



End-use of electricity

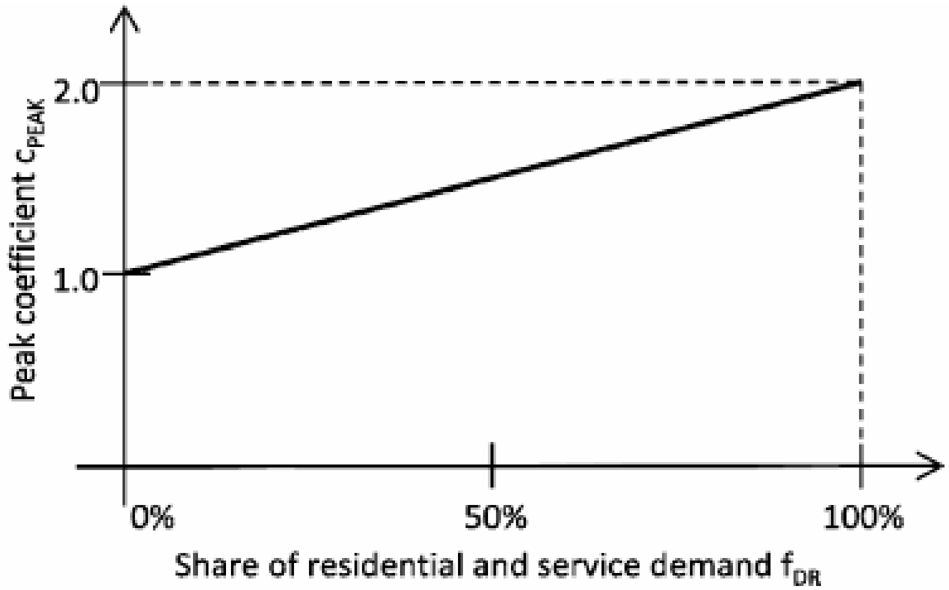
2) Residential demand for electricity is growing

- **Electricity, in USA, is the only fuel for which demand increases in the Residential sector from 2012 to 2040.**
  - Figure source: “Annual Energy Outlook”, EIA, USA, 2014



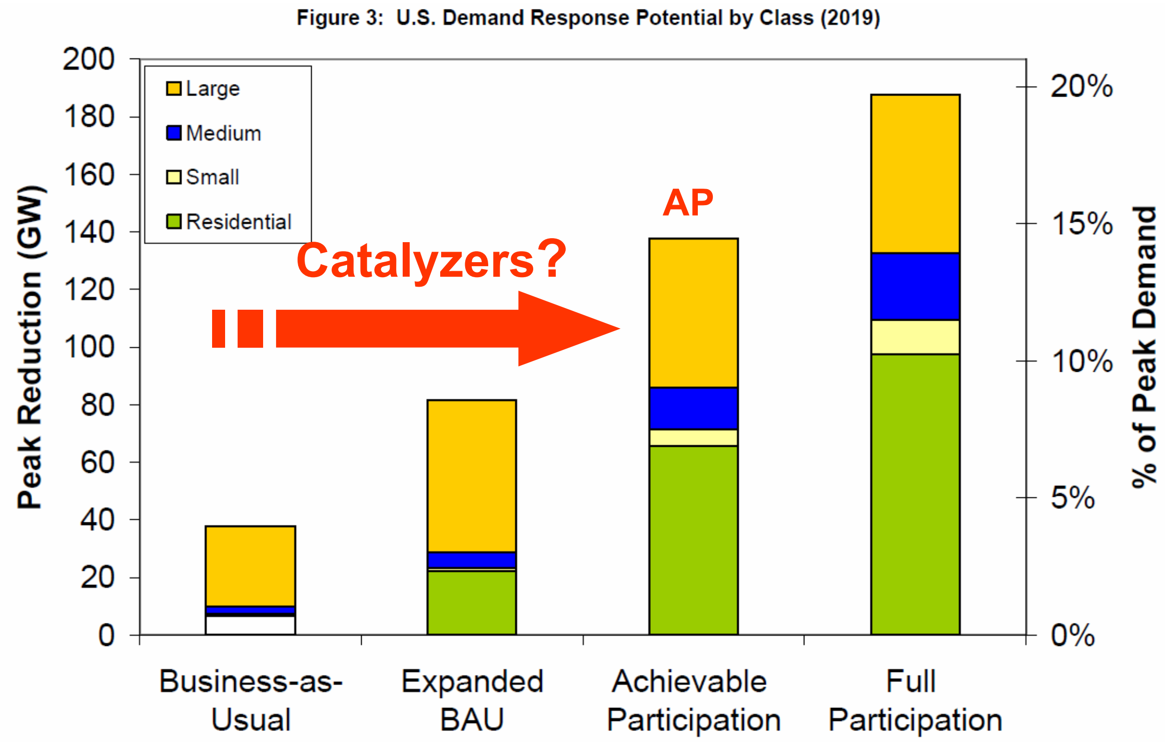
3) Residential end-uses explain a high percent of system's peak-loads

- **Peak Coefficient (Load Factor):** A growing fraction of residential and service demand is expected to increase the peak coefficient… the problem grows (the use of capacity)
  - **Residential end-uses account for up to 60% of peak load in some USA systems.**
    - **Figure source:** Impact of Smart Grid Technologies on Peak Load to 2050. International Energy Agency, 2011



4) Residential DR remains unexplored in many countries …

- **For example in the USA:** While in 2009 RDR provided only roughly 17 percent of DR potential, in the AP scenario they could provide over 45% of the potential impacts
  - Figure source: “A National Assessment of DR” FERC, USA, 2009



- **Navigant Research Forecasts: horizon 2023 (3Q/2014)**
  - RDR revenue will grow from $330 million to $2300 million
  - EU and Asia Pacific DRD markets will reach US market volume

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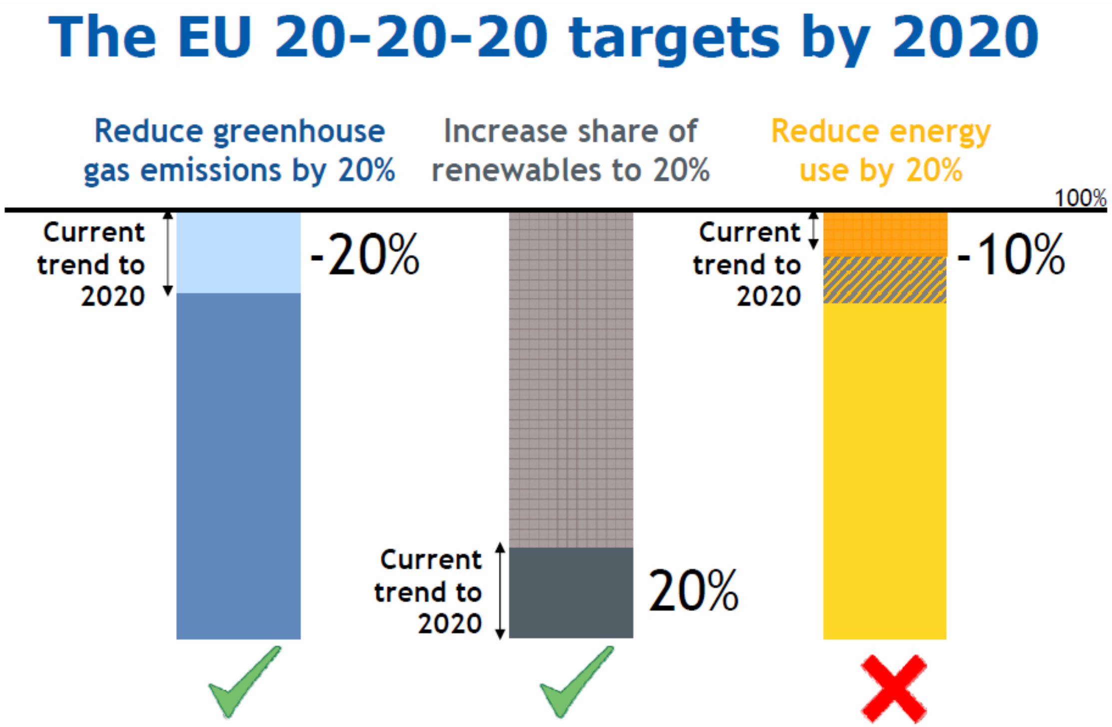
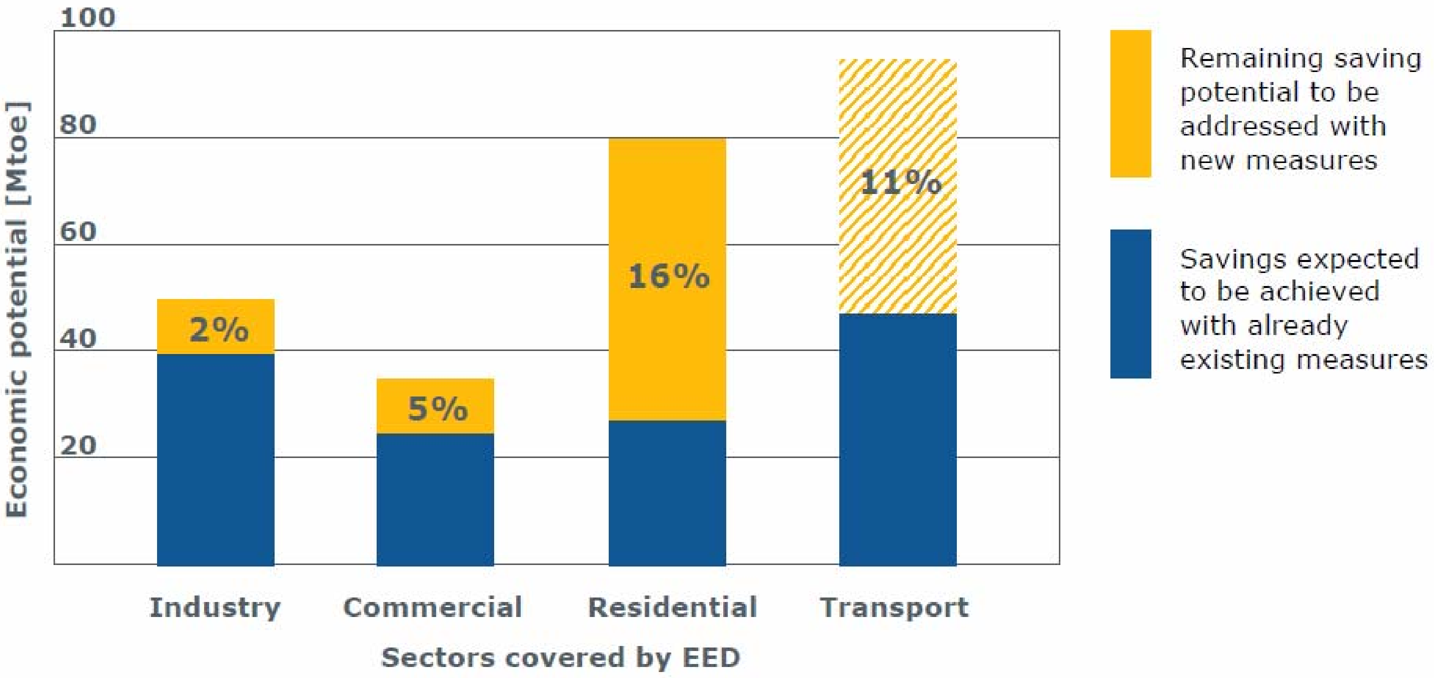
5) Residential DR might be important to get energy objectives in EU-28

- **The goals and tools of DR and Energy Efficiency are complementaries**
- **The policies (at the energy level in EU-28) have not worked very well and objectives are not being achieved**
  - … considering that we are in a period of economic crisis since 2008
    - Figure source: Directorate General for Energy, EC, 2013

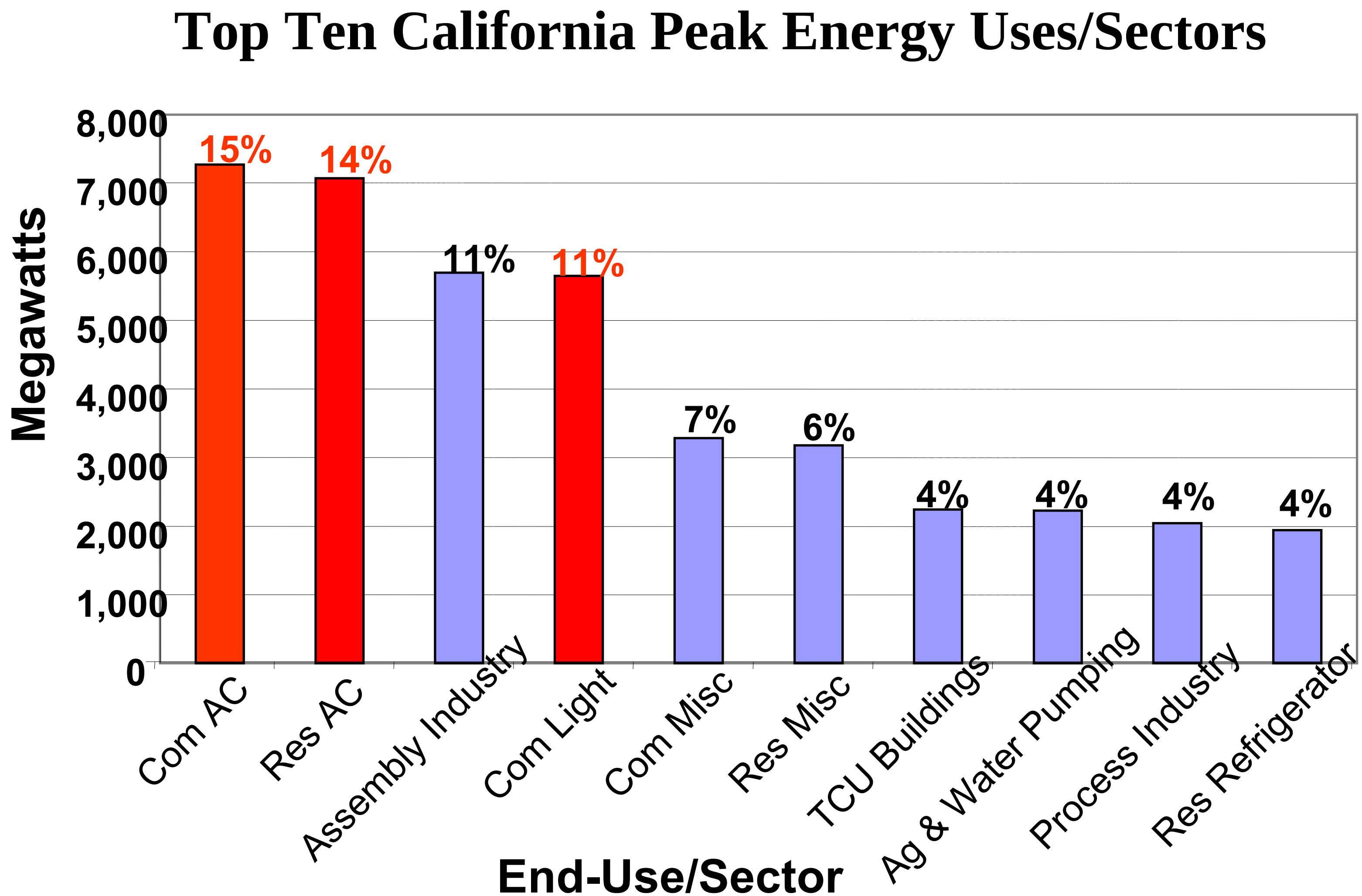


- **Segments covered by EC Energy Ef. Directive (EED)**
  - Energy Efficiency in Residential Segments must be taken into consideration jointly with RDR
    - Figure source: Directorate-General for Energy, EC)



These reasons explain why small/medium customers have been considered of interest

- Figure source: California (CEC& LBNL), USA, 2003



- **RDR possibilities: a market overview**

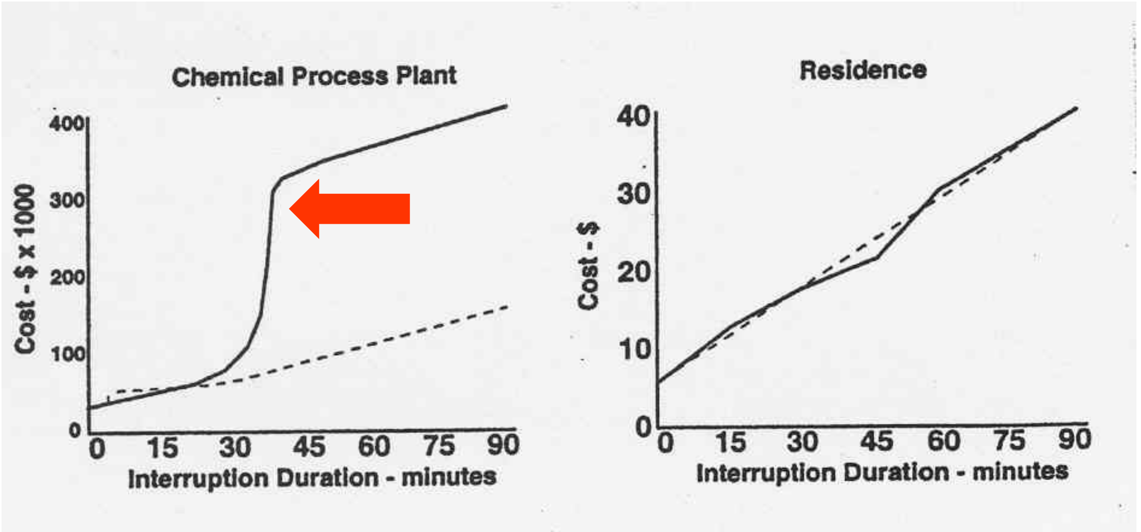
- **Potential customers look for some attributes in a DR program:**
  - Attractiveness of payment and incentives:
    - Large enough to make it economically worthwhile
    - Simple and certain enough so that the user can accurately forecast the benefits of participation
    - And with a reasonable cost to maintain the capability to participate
  - Appropriate level of complexity
    - DR program´s operational complexity must fit the users´ level of sophistication
  - Ability to supply the resource requested
    - Emergency/standby programs: help reduce demand peak during an event (a day or more in advance). Calls: only a few times per year
    - Price response: flexibility to curtail or change load based on wholesale prices.
    - Ancillary services: flexibility to provide regulation and reserve services. Notice: 30 min or less. Calls are more frequent but whit brief curtailment periods

To be considered: Customer Interruption Costs

- Example: Cost per average kW. Source: Ernest Orlando LBNL Report 2132, 2009

Interruption Cost ($/kW)	Momentary	30 min	1 hr	4 hr	8 hr
Medium and Large C&I	8	11.3	15.3	52.5	85
Small C&I	133	198	282	1195	2368
Residential	1.4	1.8	2.2	4.9	6.9

- Willis: "Distributed Generation", Marcel-Dekker, 2001

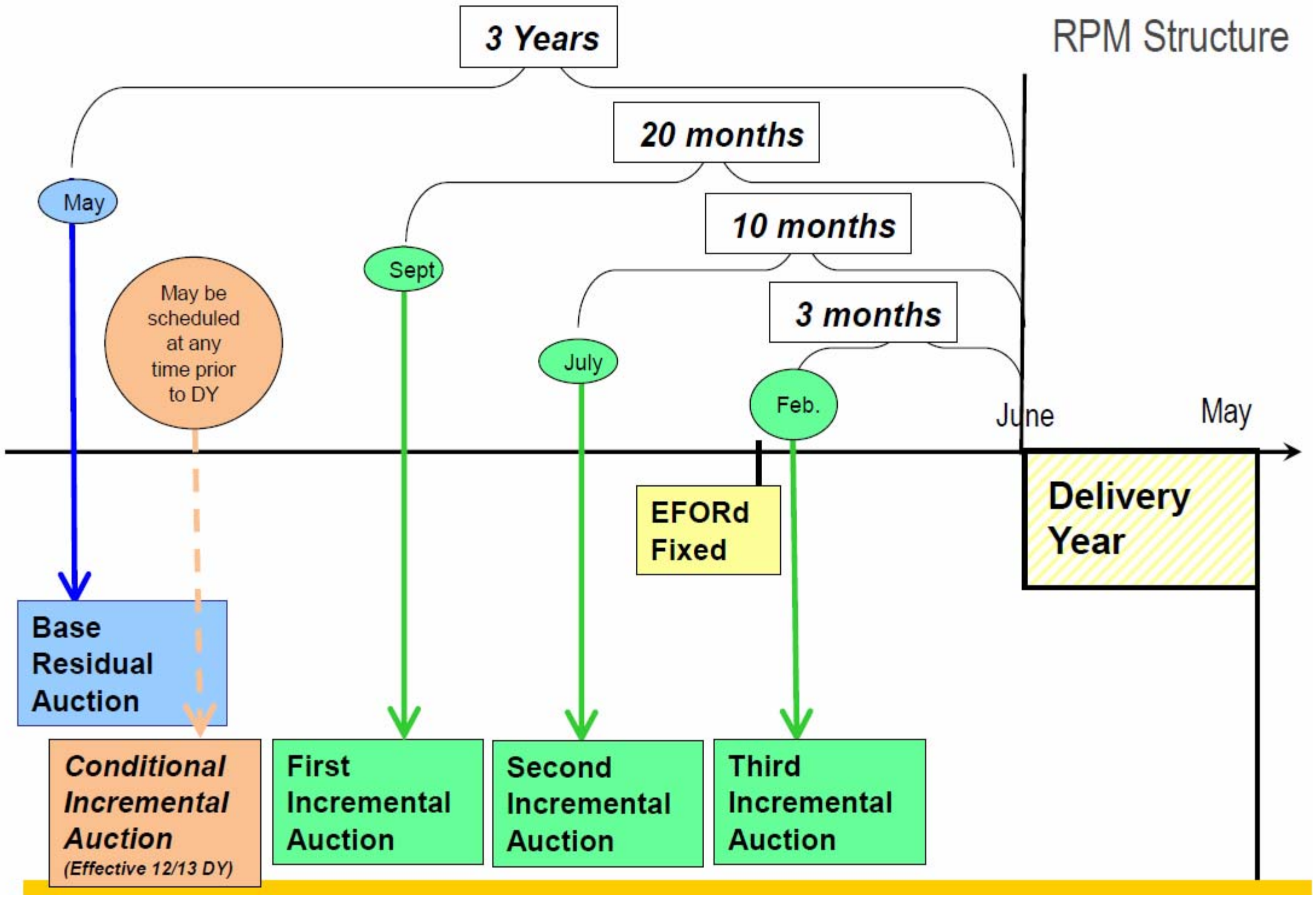


- **RDR potential in different markets/products**
  - At least some systems (worldwide level) allow the participation of demand or propose DR involvement in future regulations.
- **For instance:**
  - Capacity markets
    - Energy Efficiency
    - Demand Response availability
  - Emergency/standby
    - Direct Load Control (DLC)
    - Customer-controlled load shutdown of some appliances
    - Customer-controlled modification of temperature set-points or lighting control
  - Energy Markets: price response
    - Customer/aggregator load shutdown/rescheduling
  - Ancillary Services

- **Usually, resources in capacity markets are:**
  - Generation Resources
  - *Energy Efficiency Resources*
  - *Demand Resources*
  - Transmission Upgrades
- **Theoretically an open market (in the USA), with a minimum level of demand 100kW**
  - Achieved through aggregators: that is not a problem
- **For energy efficiency resources, "does not meet definition…" (DoE Webminar, PJM, 2012)**
  - *"Switching an appliance or process from electric to gas…"*
- **Why? Thermal Energy Storage (TES) is efficient from energy and economic points of view. Let us consider some examples**

Capacity markets (time frame)

- Reliability Price Market (RPM), Forward Capacity (FCM).
  - Figure source: PJM ISO, EEUU



Dual fuel loads (I)

- **Dual/Hybrid loads: electric + (gas or fuel)**
  - A lot of manufacturers: Daikin, Carrier, Goodman
- **What is the advantage of Hybrid Loads?**
  - The efficiency of heat pumps falls sharply when outdoor temperatures are under 0ºC
  - Solutions:
    - Auxiliary Resistors: a “peak” problem (Athens experiment, USA)
    - They usually add a condensing gas boiler
- **An example (auxiliary resistors)**

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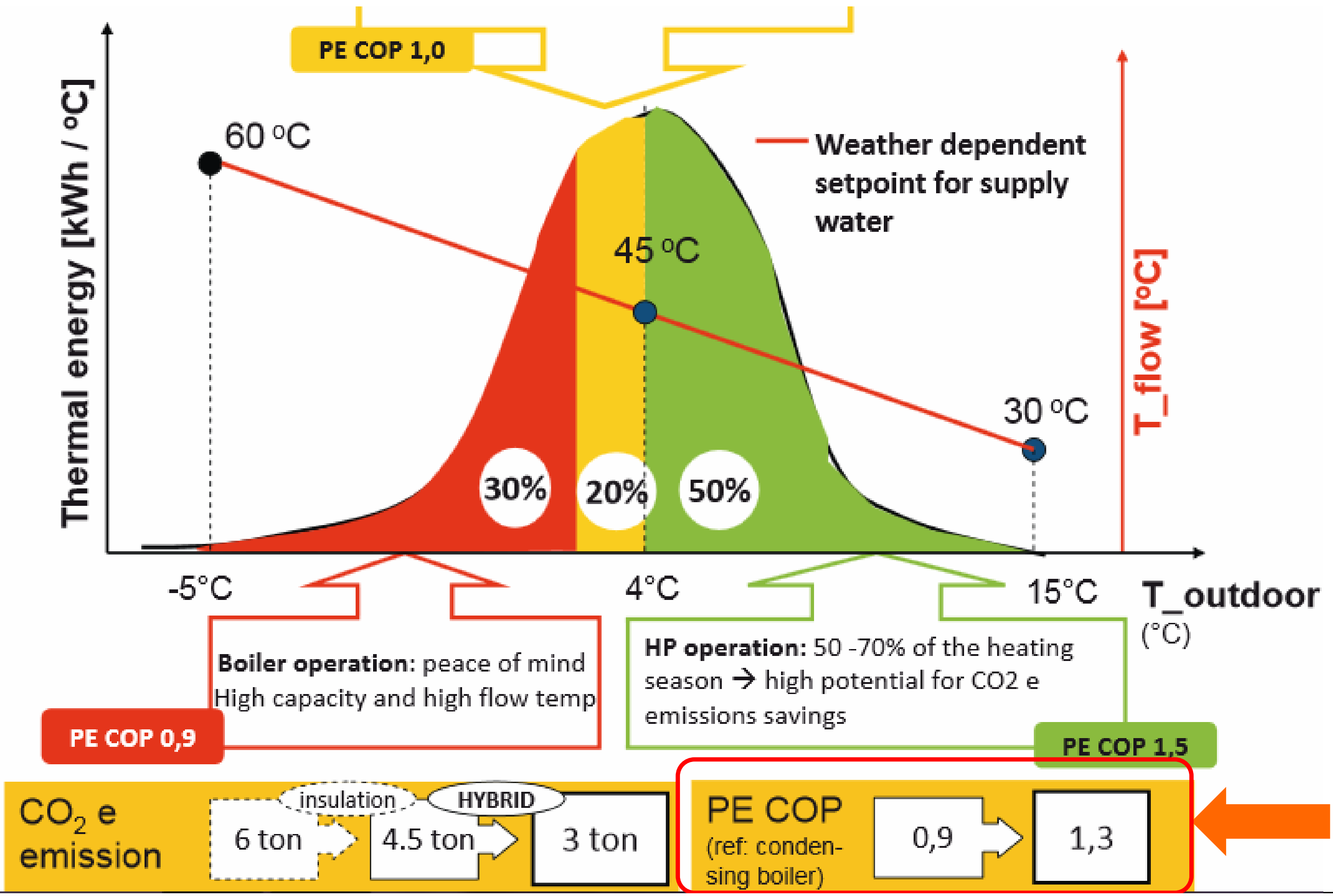
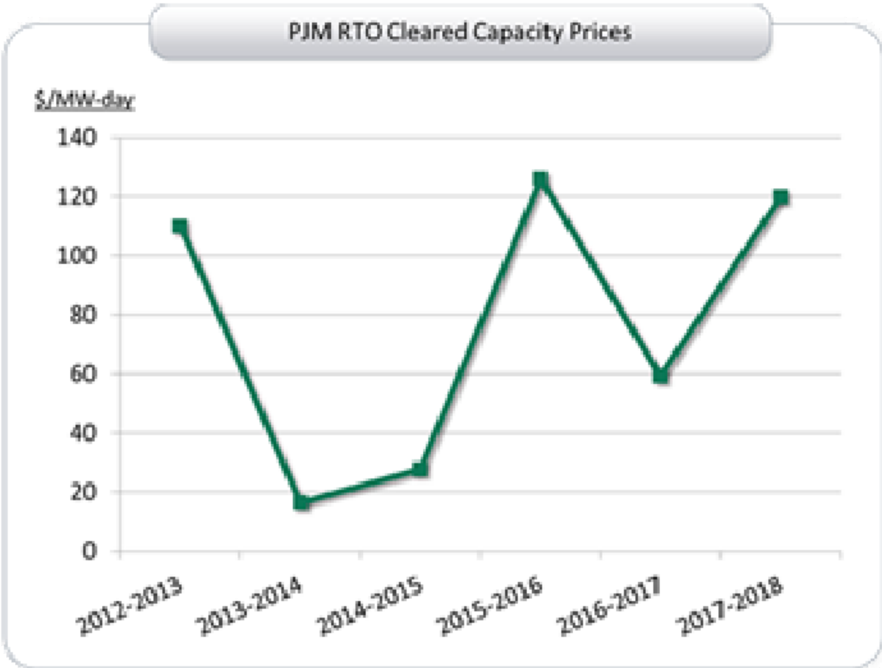
- **Distribution of space heating energy depending of outdoor temperature (eg London, UK)**
  - Figure source: Daikin, REHVA journal, March 2013
- Gain in efficiency: from 0,9 to 1,3 (this is efficiency!!!)



- **Cost of an Hybrid System**
  - Price premium of the hybrid heat pump: from €1000 to €2500 (depending on sq. meters and kind of house/flat)
  - Lifetime expectancy: 15 years
- **Revenues**
  - Price of energy (gas vs. electricity)
  - Capacity markets: from $36 to $60/kW-year



Example: Energy Efficiency in lighting

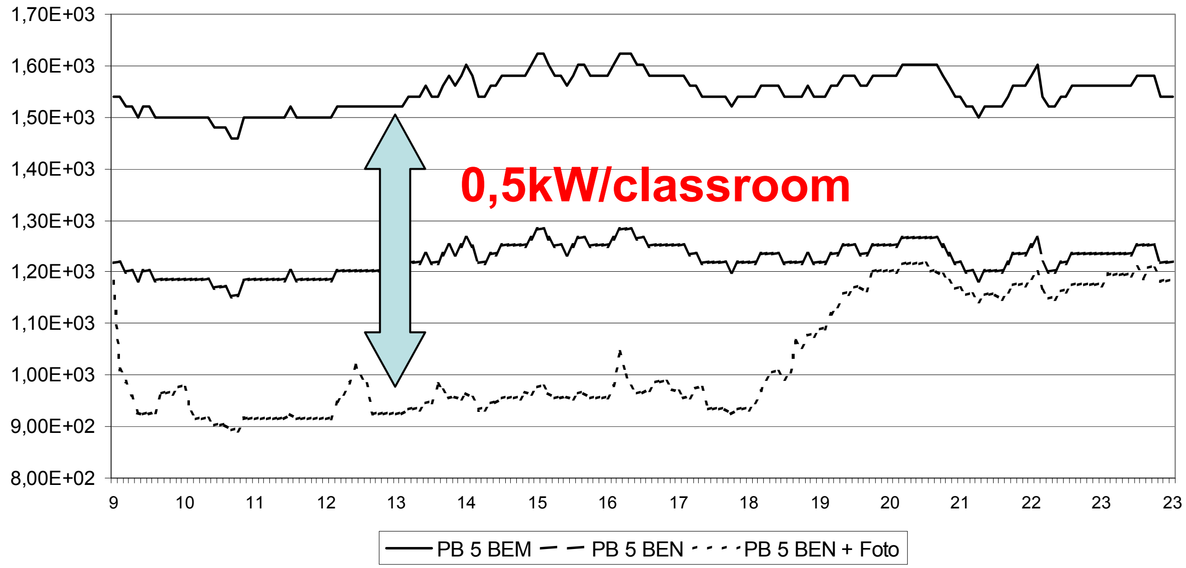
- Figure Source: Greenlight initiative, ETSII de Cartagena (SPAIN) www.demandresponse.eu

Induction lamps

- Energy savings: 50%. Offer in capacity markets: 30kW
- Costs: 16*16 165W induction lamp (250€/lamp)
- Benefit: capacity payments + Eª savings + O&M
- Energy efficient due to energy savings

Dimming ballasts in fluorescent lamps (daylight)

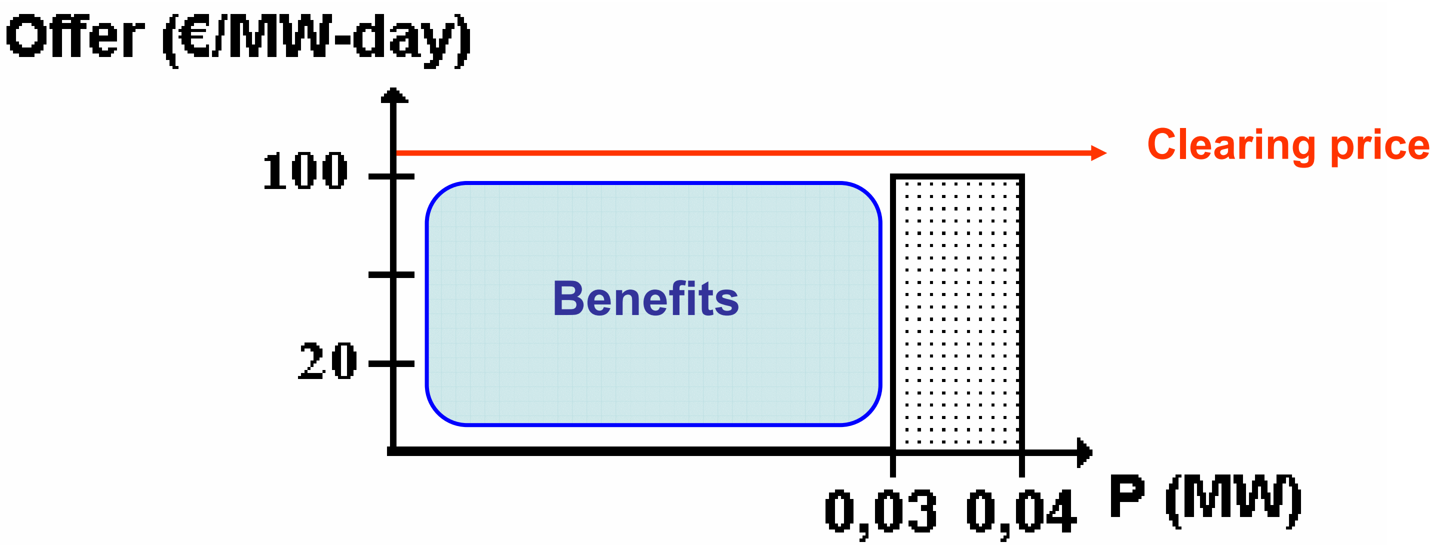
- It is not cost-effective due to labor replacement costs: change of ballast, the installation of control circuits, photosensors,,,,



- Service: 10hr/yr*22days/month*10month/yr = 2200hr/yr

- **Classroom (PB5) demand: ~ 1kW**
  - 1/3 of tubes with electronic ballast and 2/3 with dimmable
- **Costs:**
  - Dimmable ballasts: €450
  - Labor (new circuits): €150
  - Control eq,: €150
- **Availability factor (daylight contribution)**
  - Winter: 0,5; Spring/Autum:1; Summer: 2
- **Energy reduction (average price €0,18/kWh)**
  - ≈ €90/yr. Payback >7,5 years
- **With Capacity revenues**
  - 0,25-0,5kW/classroom*3years*€40/yr ►€40-€75
- **Externalities**
  - Technology allows control of DR for other markets

- **Offer curve (Capacity markets)**
  - Induction: 30kW (€0/MWh-day)
  - Fluorescent: 10kW (€100/MWh,day)
- **In other buildings, similar auctions to reach 0,1MW (min.)**



- **Conclusion: Induction benefits "haul" other technologies (i,e. En. Efficiency technologies helps DR involvement)**

- **Emergency/standby**

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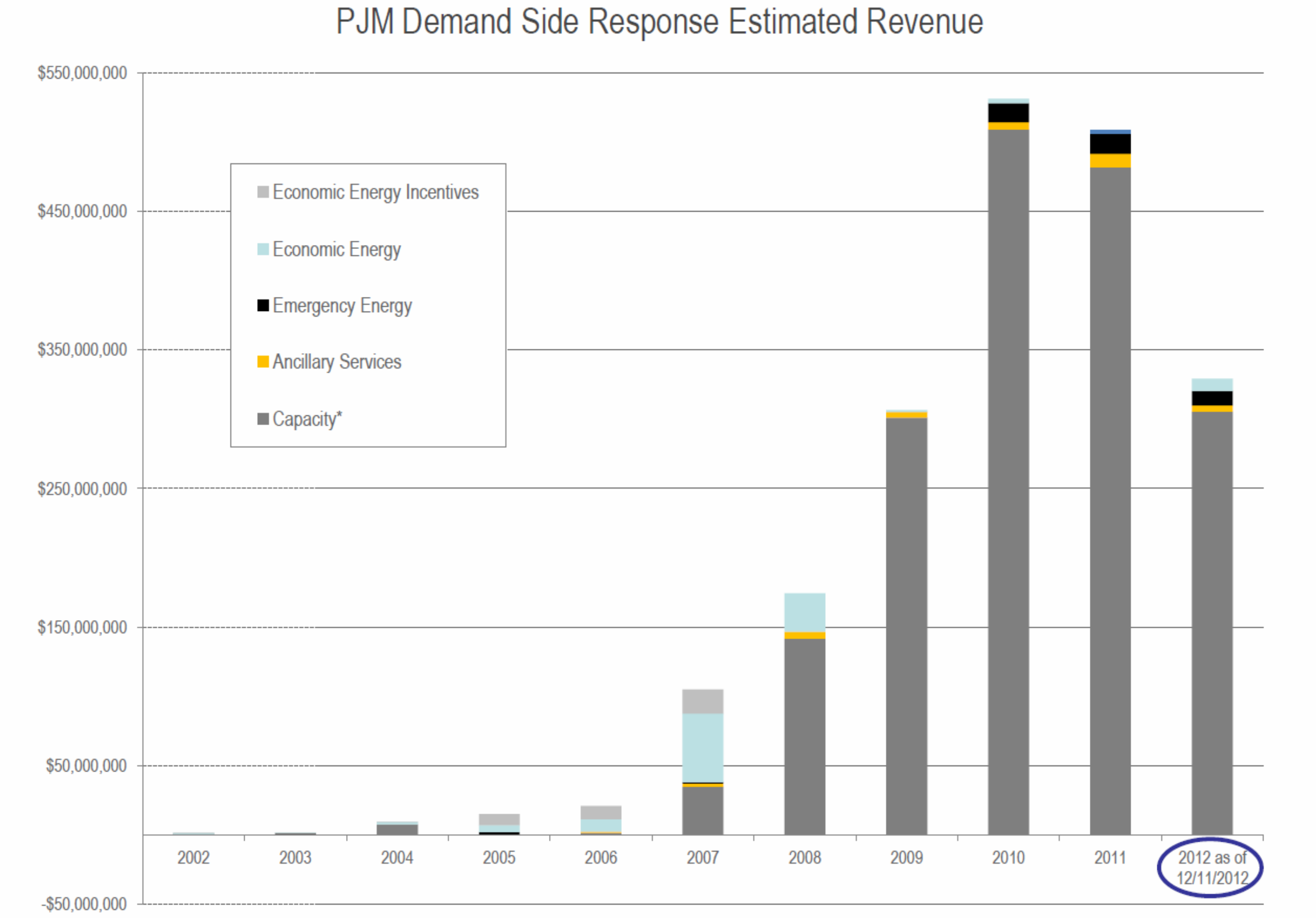
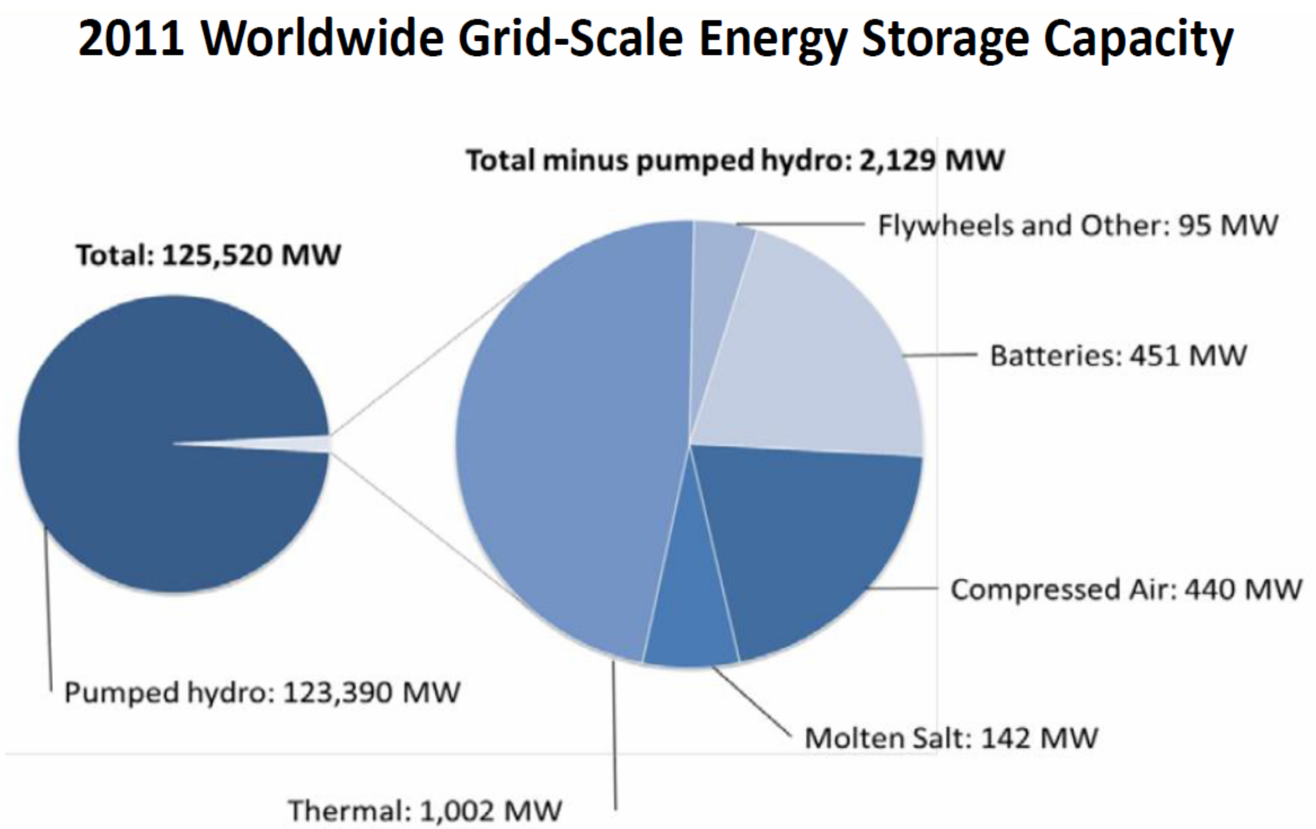
- **Emergency DR represents 87% of demand reduction capabilities in USA (NERC 2012, State of reliability)**
    - Figure source: PJM (ISO), USA, 2013
  - 87% of DR capabilities across the USA regions (also in revenues)



*Capacity Net Revenue inclusive of Capacity Credits and Charges.

- **Importance of different storage systems worldwide**
  - Figure source: DoE Energy Storage Report (2011)



⇒ **Heat/Cool storage**

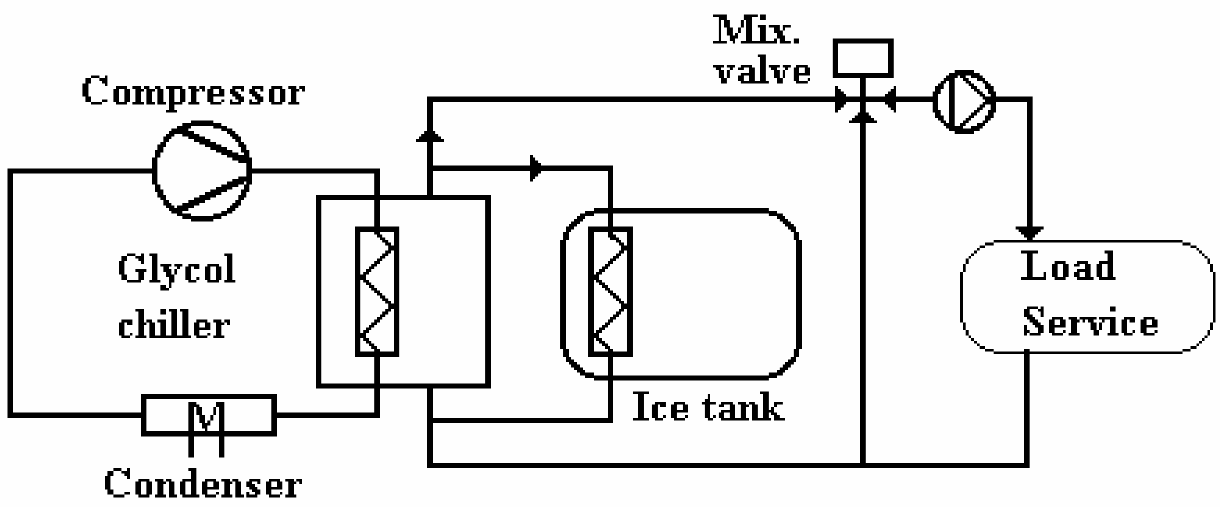
Systems for heat storage (I): partial and full storage

- Ceramic storage (Iron oxides). Density: 4000 kg/m3
- Weight: Full storage 70-300 kg; Partial storage: up to 30kg
- Joule effect. Efficiency <100%
- Hint! Take into account average time for response in our system (1h, 2h30,…)

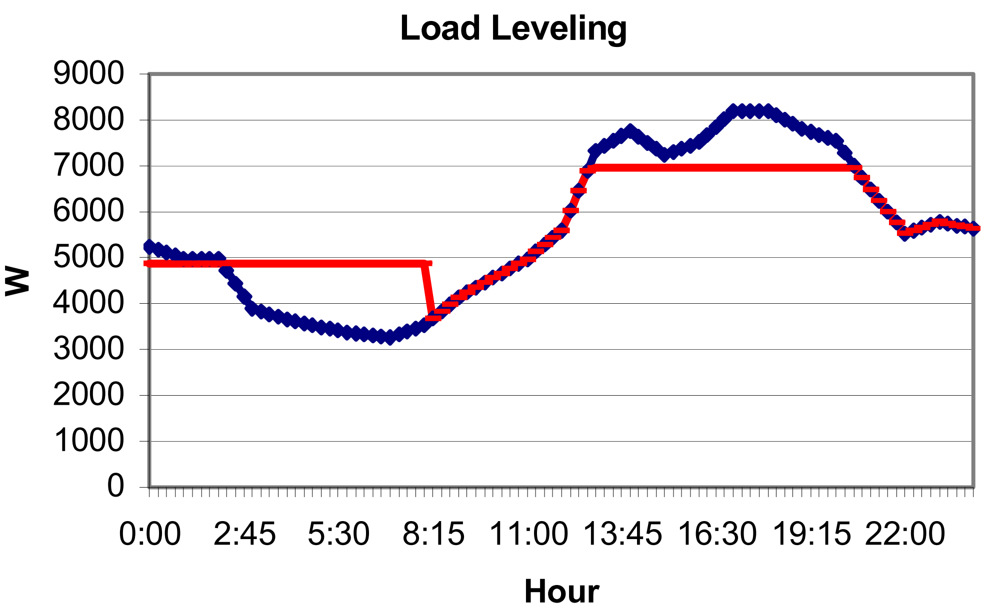
Haverland (UK) 1,8kWW-30kg-1h (500€)

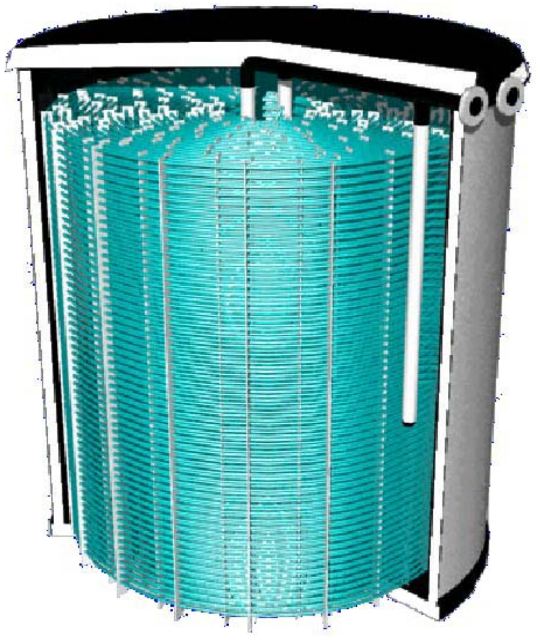
Gabarron (SP) 2kW-120kg-8h (700€)

- **Sistems for cold storage (II) (TES)**
  - Ice may store energy through:
    - Specific heat (water or ice) 42 kJ / kg
    - Heat of fusion (change of state): 335kJ / kg
  - Advantages:
    - The ice requires less storage space
    - The efficiency is better at night and the air to be used is cooler (►smaller sizes of pipes and fans, i.e. savings)
- **Manufacturer : Calmac Coorporation (Roofberg ®)**
  - Example: Cap. Storage ≥150kWk; Price: 35$/kWh



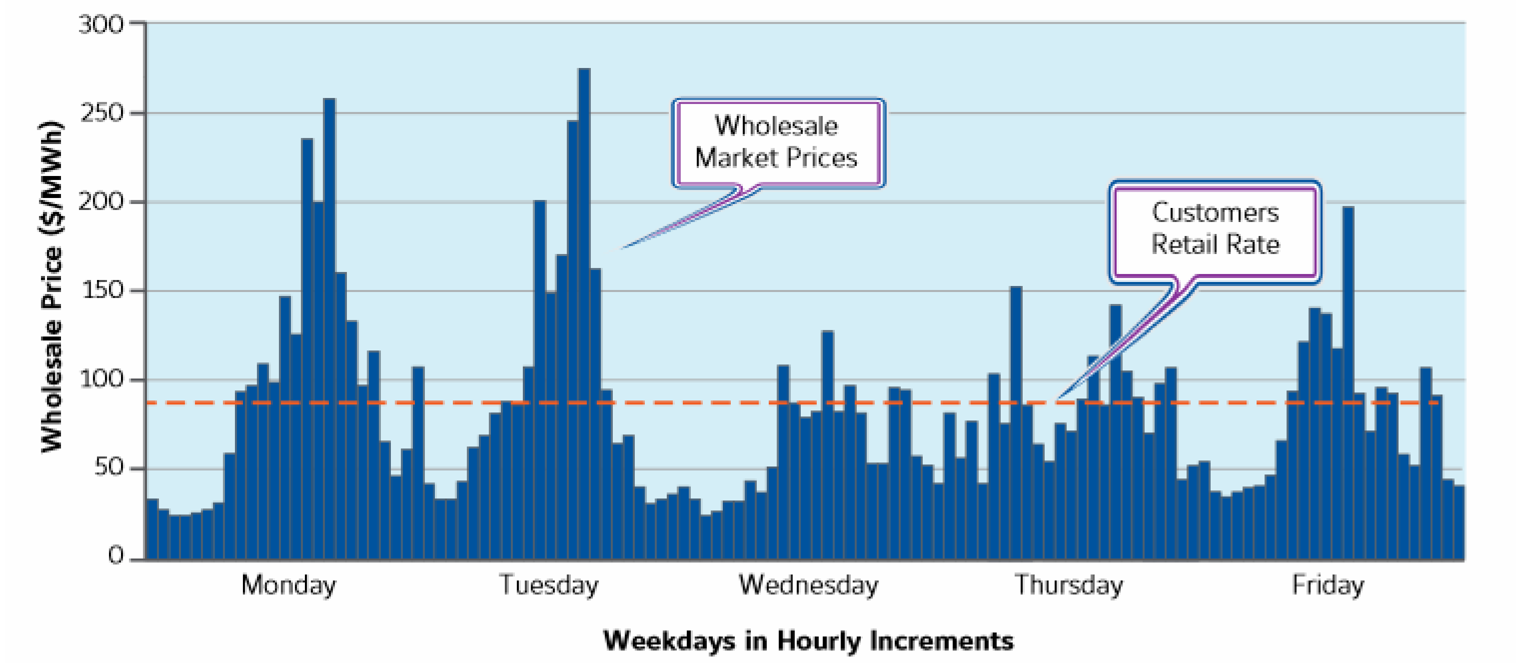
- **Is it efficient? And what about storage losses?**
  - Obviously storing → losses
- **Advantages:**
  - Operation at night (cooler, more efficient chiller)
  - Low nighttime electricity prices, RDR possibility
  - Lower losses in the electrical system
- **Residential example (tested by simulation in 2005):**
  - It was not cost effective (capital costs/energy savings)
  - And now? New sinergies: Revenues from Capacity Markets?





- **Price response for RDR**

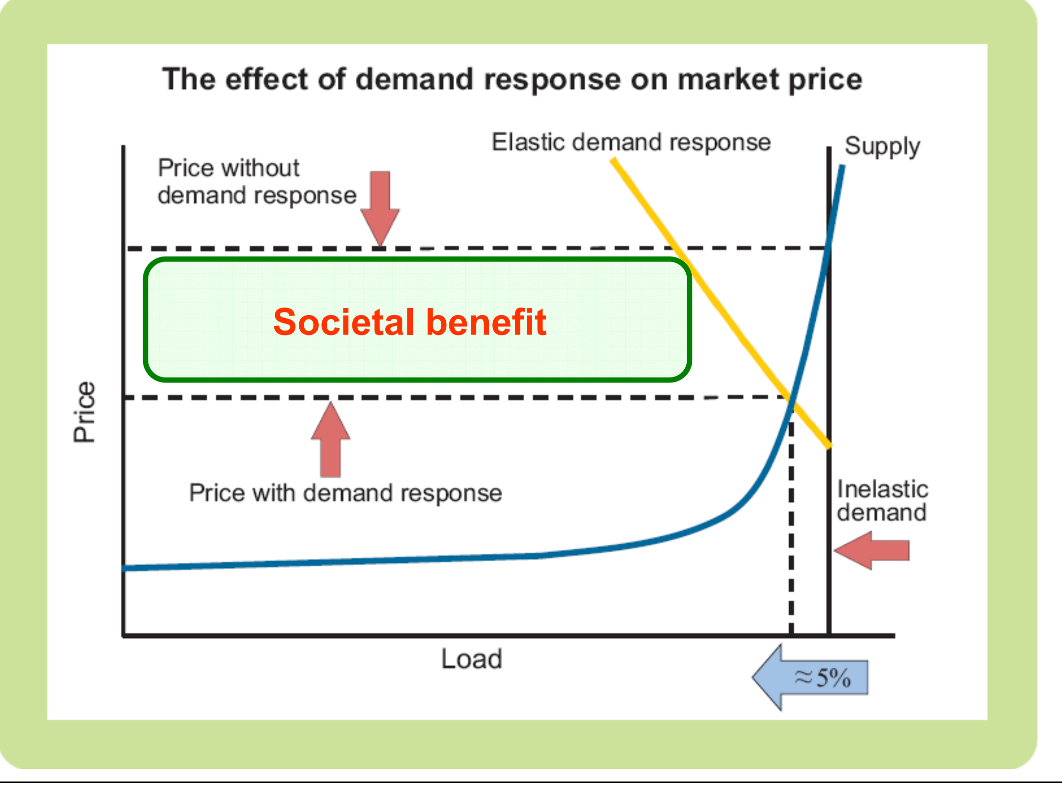
- **Energy markets show spikes in the wholesale price of electricity**
  - There is usually a complete disconnect between what customers pay for electricity and what it actually costs
    - **Figure source: Inst. for Building Efficiency, 2014**



Price response benefit: elasticity of demand

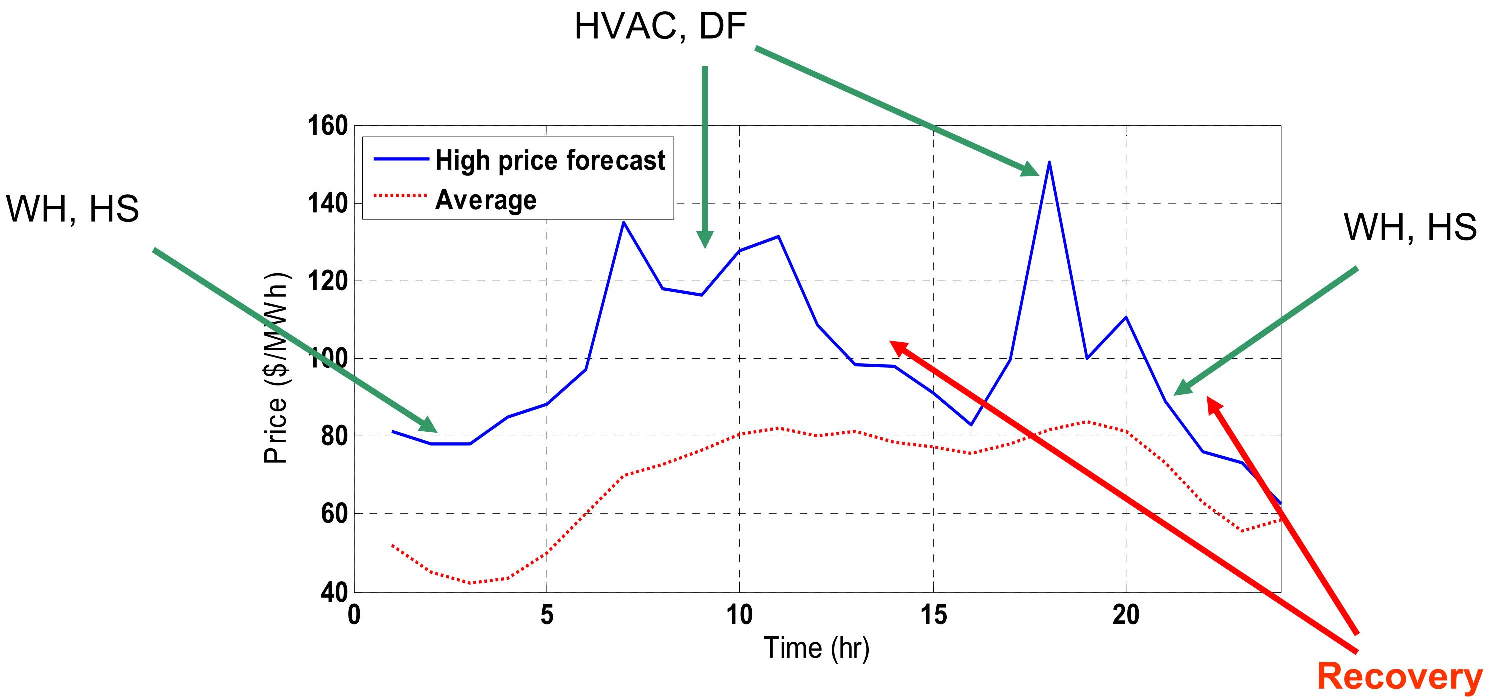
$$Elasticity = \frac{\Delta P / P}{\Delta D / D}$$

- ▲Elasticity
  - ▼Prices (for all segments of customers)
  - ▼The possibility to exert any class of power market
    - Figure source: “Demand Side Integration”, CIGRE WC6.09, 2011

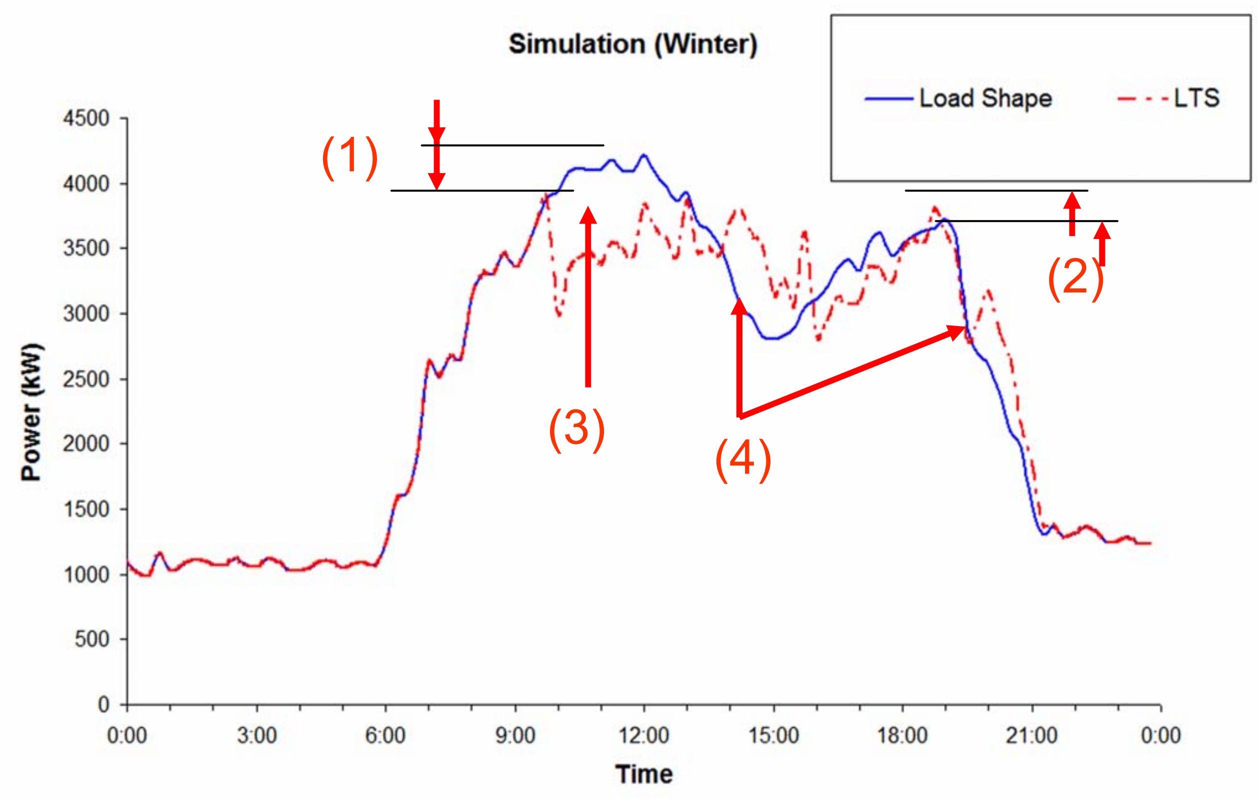


Some "trivial" considerations

- The customer should perform reduction offers when price forecasts show that a price spike is possible…
- They should choose the more appropriate loads (customer service and shed/rescheduling potential)
  - Loads (WH: water heater; HS: storage; DF: dual fuel)
  - **Figure source: www.demandresponse.eu**

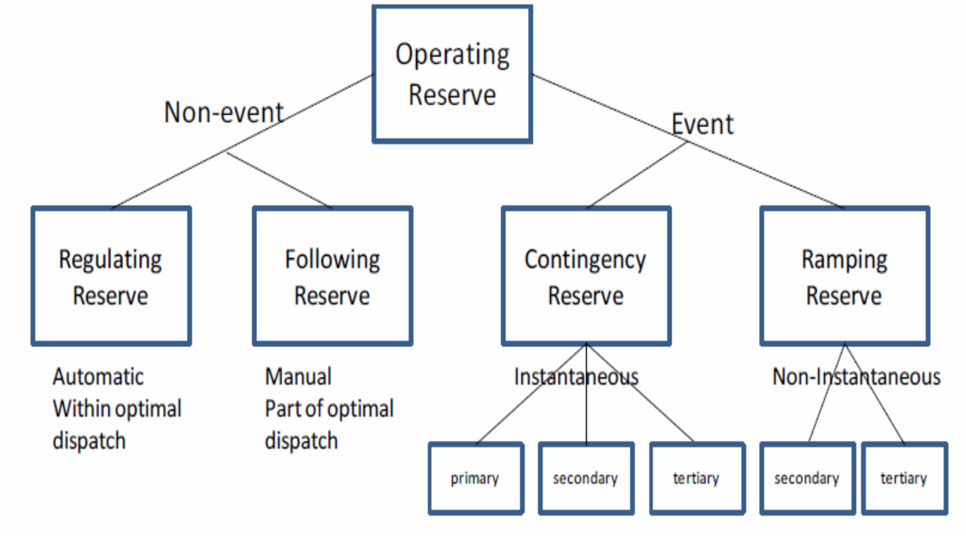


- **Evaluation of price response… Load models, please!**
  - Peak saving in kW (1)
  - Rebound effect (“cold load” recovery): in kW (2)
  - Energy reduction: kWh (3)
  - Energy to recover the “service” (Payback, Snapback) kWh (4)
    - **Figure source: www.demandresponse.eu**

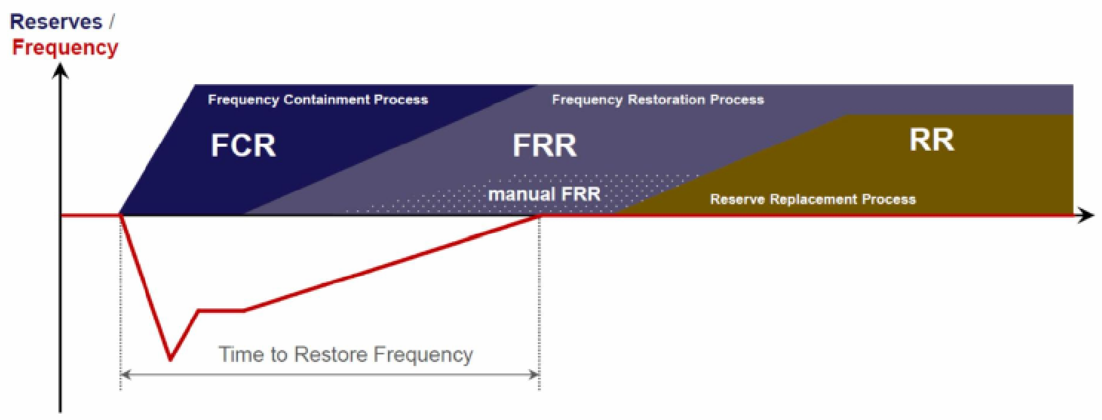


- **Ancillary Services**

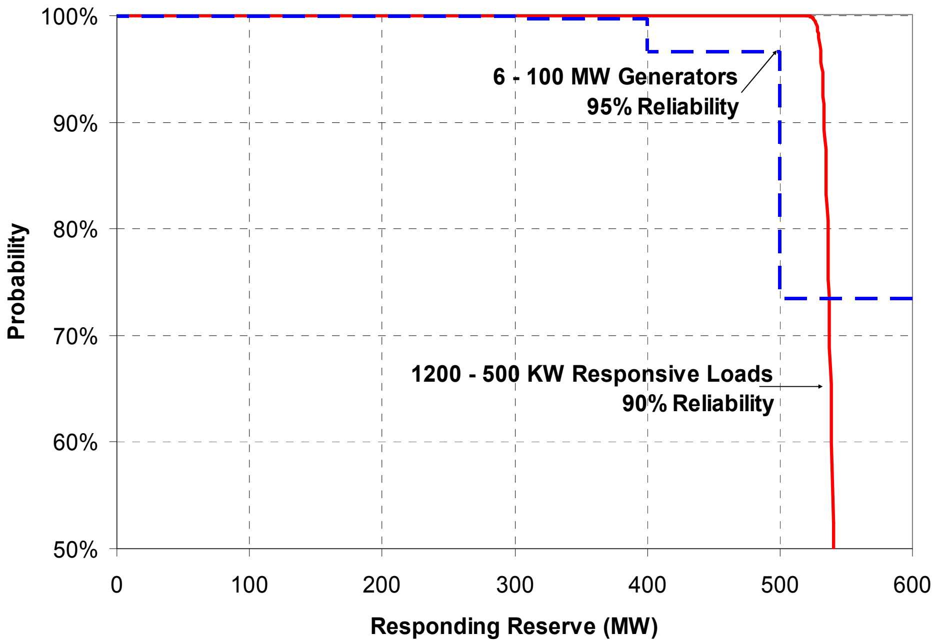
- **Objective: Demand could provide Ancillary Services when it would be costly or difficult through generators**
  - Figure source: NREL (USA), report NREL/TP-5500-51978



  - ENTSO-E: Resources for power balancing

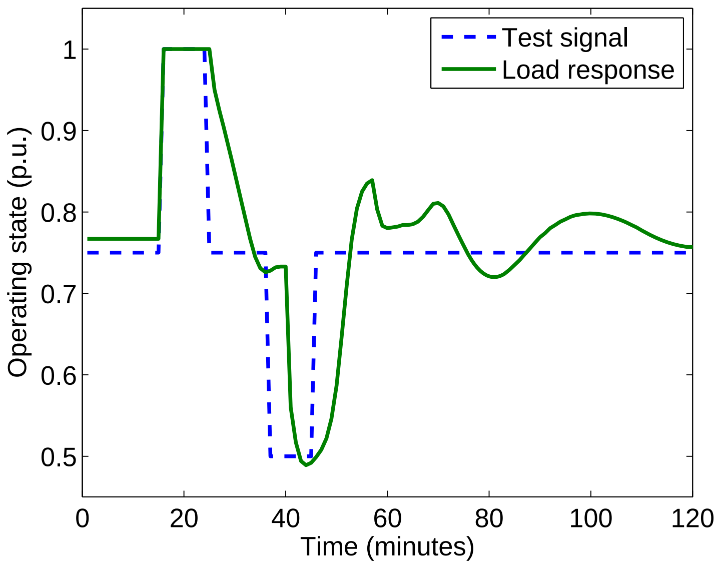


- **Benefits**
  - An example: Availability of demand-side (1200 loads) vs supply-side (6 generators)
    - Load is reliable enough (even more that generators)
    - Load is a geographically distributed resource ("conventional" generation is not)
      - **Figure source: Oak Ridge National Laboratory (USA)**

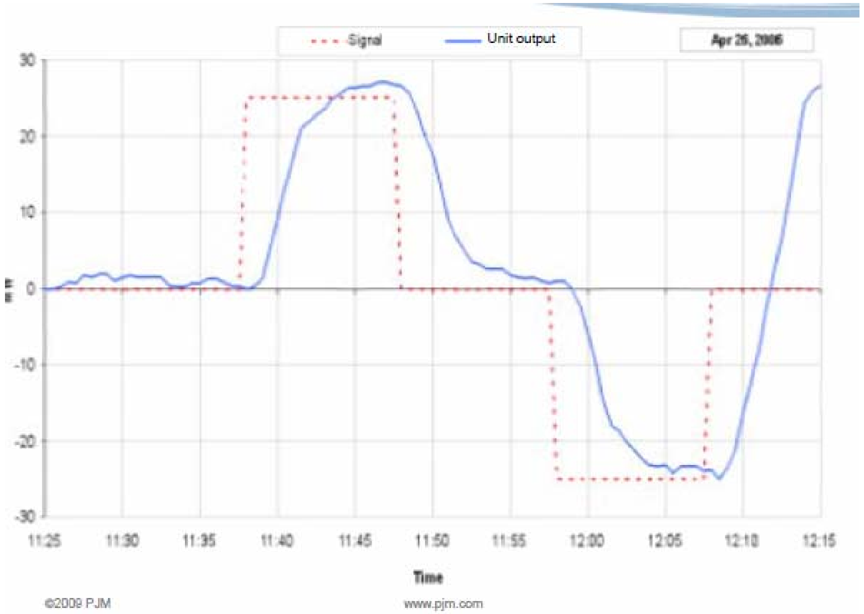


- **Difficulties:**
  - Aggregation <u>is needed</u> (rules and procedures)
  - Fast response, automation, **<u>load modelling (do not forget it)</u>**

- **Example: possibilities of AC loads to fit control test signal (a pulse signal similar to "PJM RegA" signal)**
  - Fast response of models (seconds-1min)
  - Accurate enough to respond within seconds or minutes to SO
    - **Figure source: Simulation of AC load www.demandresponse.eu**
  - **Example 1** **Example 2**



Load output (simulation)



Unit output (PJM, 2006)

- **RDR: Barriers and incentives**

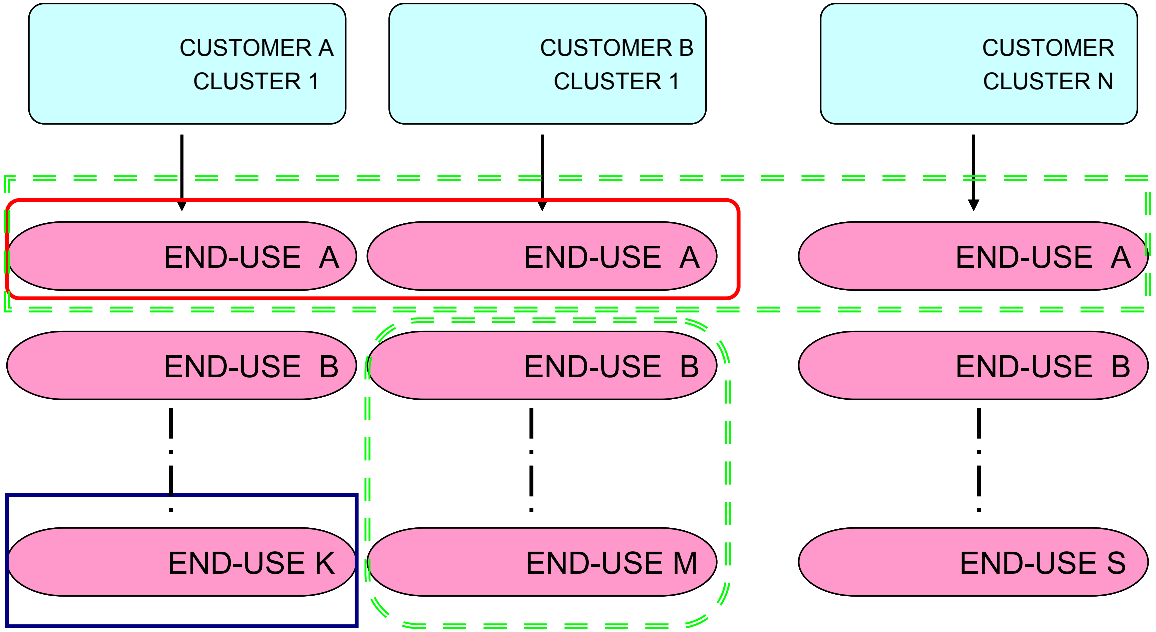
Complexity of small segments: aggregation is a basic tool

- **Aggregation means additional problems for DR:**
  - Classify, identify and forecast the demand of the customers
  - Manage information from and to the aggregated group
  - Assess the potential of the group and its ability to understand and to react face to internal or external signals
  - Maintain and develop technical and economic competence

Aggregation: how can we perform that?

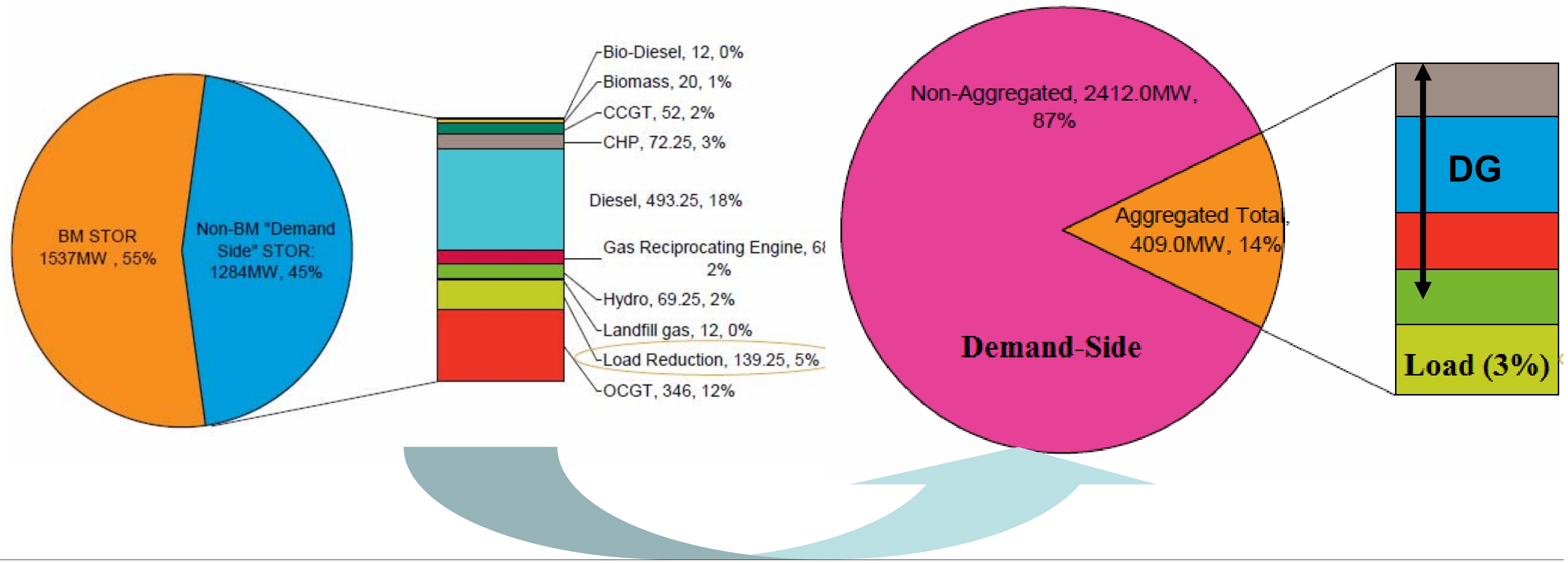
- Three levels
  - Homogeneous load group
  - Quasi-homogeneous load group
  - Heterogeneous load group

- **Aggregation mechanisms**

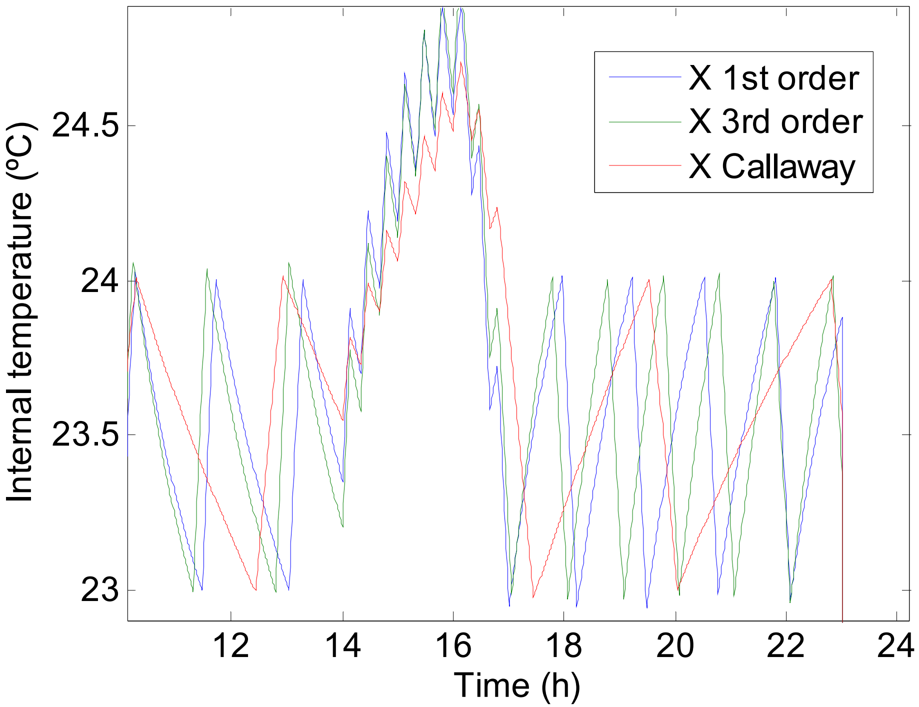


- Homogeneous (ex. = end-use & = customer)
- Quasi-homogeneous (ex. = end-use & ≈ customer)
- Heterogeneous (ex. ≠ end-use OR ≠ customer)

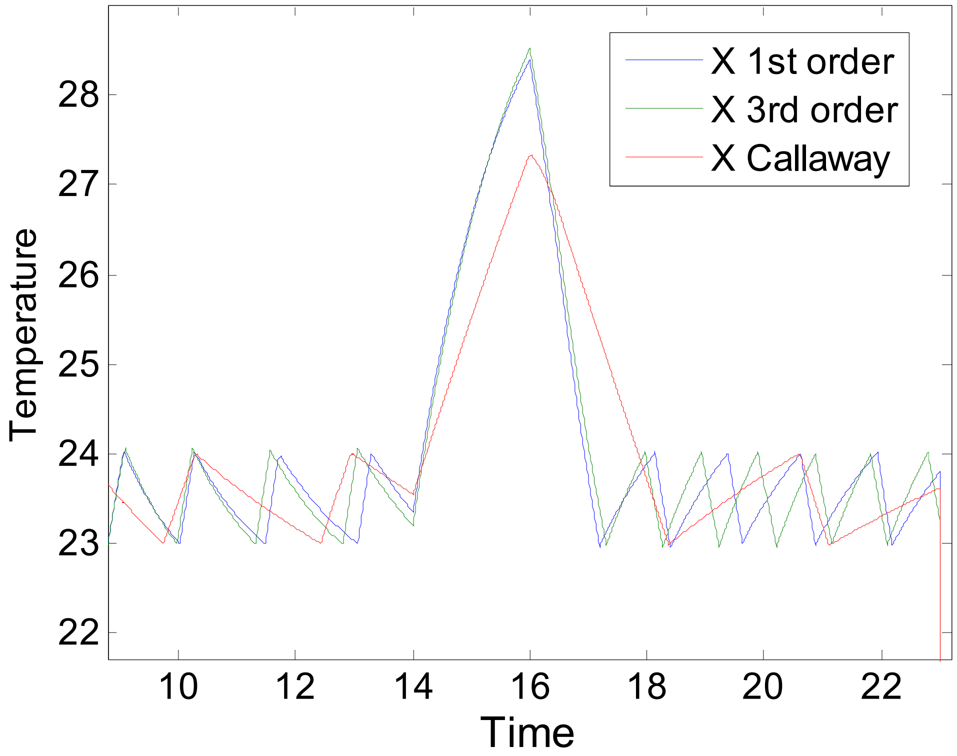
- **An example of AS in the EU: The Short Term Operating Reserve (STOR) in UK**
  - UK is traditionally very active and open to DR
  - Aggregation providers have been experiencing a growing trend (16 in 2013).
    - Remember: more than 80 CSP play in PJM, 34 in NYISO (USA).
  - The problems:
    - Supply-Side wins in balancing markets
    - In the Demand-Side, the main resource is generation
      - Figure source: J. Torriti (Florence School of Regulation, 2013)
  - Conclusion: the potential of aggregation need to be explored



- **A simple an fast model is needed**
- **Proposals in the literature**
  - First order Callaway: (ACEEE 2012) Validation? "…We verified the TCL parameters by comparing the model-predicted mean annual energy consumption per appliance to actual California data (EIA 2005)…"
  - First order S. Rahman (IEEE-PES, 2013). Validation? Steady state
  - Second Order, Zhang (IEEE-PES13) Criticize Callaway models
  - G. Andersson (2012, IEEE SG): Water Heater
- **First order slave of a master third order model (physically based)**



- **Response in transient state (DR)**
  - The error has increased dramatically
- **Conclusion: validation both in steady and transient states**



State of the art in Europe vs. USA

- USA: Growing activity of aggregators (for eg 80 in PJM)
    - CSP list http://www.pjm.com/markets-and-operations/demand-response/csps.aspx
    - Some examples: Siemens, SUEZ, EDF, Enernoc,….(USA?)
  - FERC 745&755
  - Removing legislative barriers: eg CalCAN, SB594 (CA)
- USA: DR is theoretically open to all electricity markets
  - Ancillary Services & Capacity Markets in the last decade
- Europe: positive trends, but there are barriers to be removed yet
  - 5% at maximum, 3% in average (source: UCTE, 2010)

ISO/ RTO	Min Size (MW)	Rules of Regulation Services			Rules of Spinning Reserves	
		Aggregation	Symmetric Bid?	Energy period	**Aggregation**	Energy Period
CAISO	0.5	No	No	60 min	No	30 min
ERCOT	0.1	No	No	NA	No	NA
MISO	1	No	Yes	60 min	**Yes**	60 min
PJM	0.1	**Yes**	Yes	NA	**Yes**	NA
NYISO	1	No	Yes	NA	No	60 min
ISO-NE	NA	NA	NA	NA	**Yes**	NA

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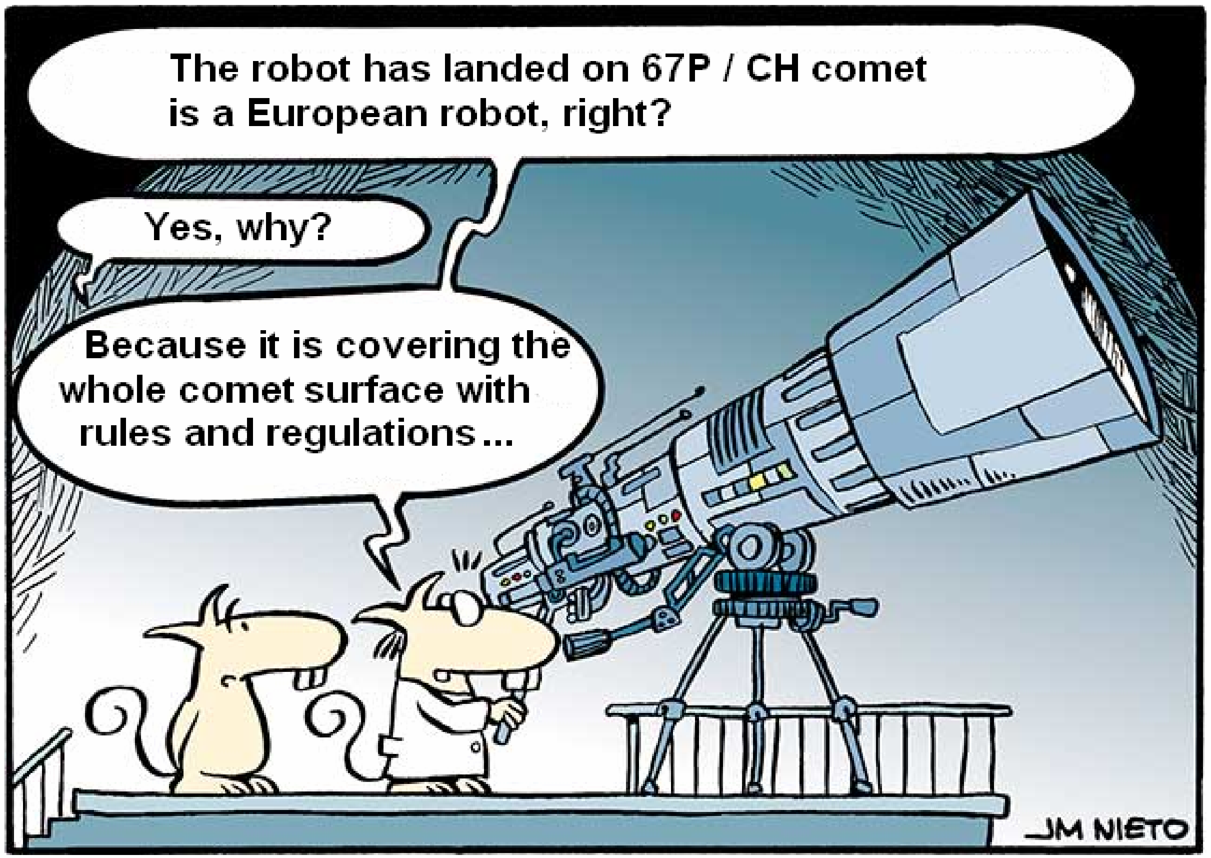
- **Regulation:**
  - Has been a barrier in the past… and in the present for DRD
  - Should be a cornerstone in the future
  - EU people is skeptic with CE regulations (directives) due to past experiences
    - **Figure source: J.M. Nieto, ABC, November 2014**



- **New "winds" for Demand Response (reasons)**
  - The rising share of RES by 2050: ►uncertainty in Supply
  - Small-size resources (37%) ► they need aggregation and opportunities (i.e. SME could reduce their costs)
  - Economic concerns ►€44 billions of benefits can be lost (the potential of enabling technologies deployed in EU)

- **The EU actors interested to enhance DR (I)**
  - Public authorities (European Commission)
    - Energy Efficiency Directive 2012/27/EU
      - Includes aggregation in a nondiscriminatory way (art 15.8)
      - New markets and possibilities: AS markets (art 15.8)
    - Commission Staff Working Document on DR (2013)
      - Make DR-side participation fairly respect to Supply-Side
      - Remove, if any, discriminatory treatment in markets
    - Energy Efficiency Plan 2011
      - Are ESCOs (and aggregators) developing its full potential? **There is a lack of expertise in complex energy products!**

The actors interested in new resources (II)

- Energy regulators
  - ACER (Agency for the Cooperation of Energy Regulators) in "Framework Guidelines on Electricity Balance (2012)"
    - Balancing allowed for load entities (through aggregators or not)
  - CEER (Council for European Energy Regulators) in "Regulatory and Market Aspects for DS Flexibility"
    - Issue: NRA (National Regulation Authorities) address a clear role for aggregators in the near future.
    - Consider the possibility of aggregation in the offer for balancing

- The Electricity Industry: Eurelectrics (see, for example, "Flexibility and Aggregation. Requirements for their aggregation in the markets (2014)"
  - "… aggregation offers the opportunity to exploit DR flexibility potential…"
  - "… better access of the customers to the markets"
  - Market rules will need to be adapted to enable aggregators to participate in energy, balancing and constraint management

Smart metering and aggregation

- Smart meters are a key for the energy policy in EU
- Measurement and verification are of the highest interest for DR:
  - Demonstrate its full potential
  - Assure a correct distribution of benefits (opposite to fixed revenues strategy: eg Water Heaters in Christchurch, NZ)
- The measurement in aggregated loads is complex
- Aggregated load ≠ large generators
  - Measurement requirements must be different
- Monitoring: some questions…
  - Is it necessary to have real time monitoring? Cost (M&V)/incomes and dynamics of demand vs. generators, number of “units”…
  - Is it possible an statistical monitoring? I.e. to measure or request feedback from some loads only.

Conclusions

- Small segments should be taken into consideration for DR policies
- DRD involves aggregation and modelling
- DRD needs specific regulation and erase some barriers
- It is necessary to revisit requirements and propose a new equilibrium attributes (AMI) vs flexibility (DR resource)

- More research is needed in these topics

EES-UETP Course

Thank you. Questions?

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