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Electricity storage: economics and regulation

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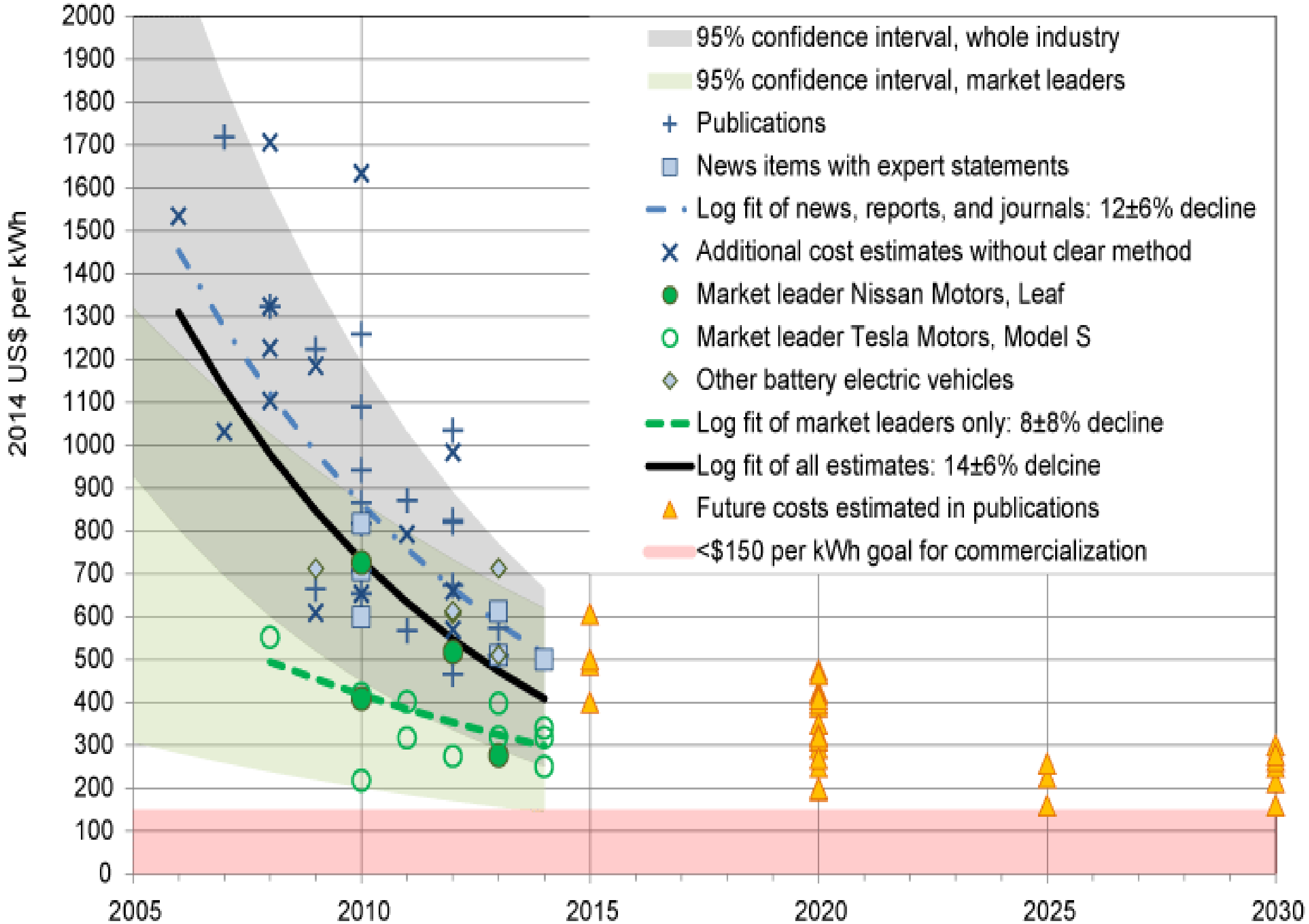
Introduction

Storage Costs

- Estimated costs of lithium-ion batteries for electric vehicles



(Nykvist and Nilsson 2015)

Storage value

- Storage can **provide value** at different levels of the power system
  - Generation: Arbitrage and ancillary services
  - Transmission: Congestion management and RES integration
  - Distribution: Congestion management and local reliability

- A new type of asset?
  - Incompatible with unbundling
  - Can DSOs or TSOs own and operate storage?

- Regulation and business models: Proposal
  - Competitive activity unbundled from transmission and distribution
  - Improve markets to send efficient signals and unleash the full value

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Services

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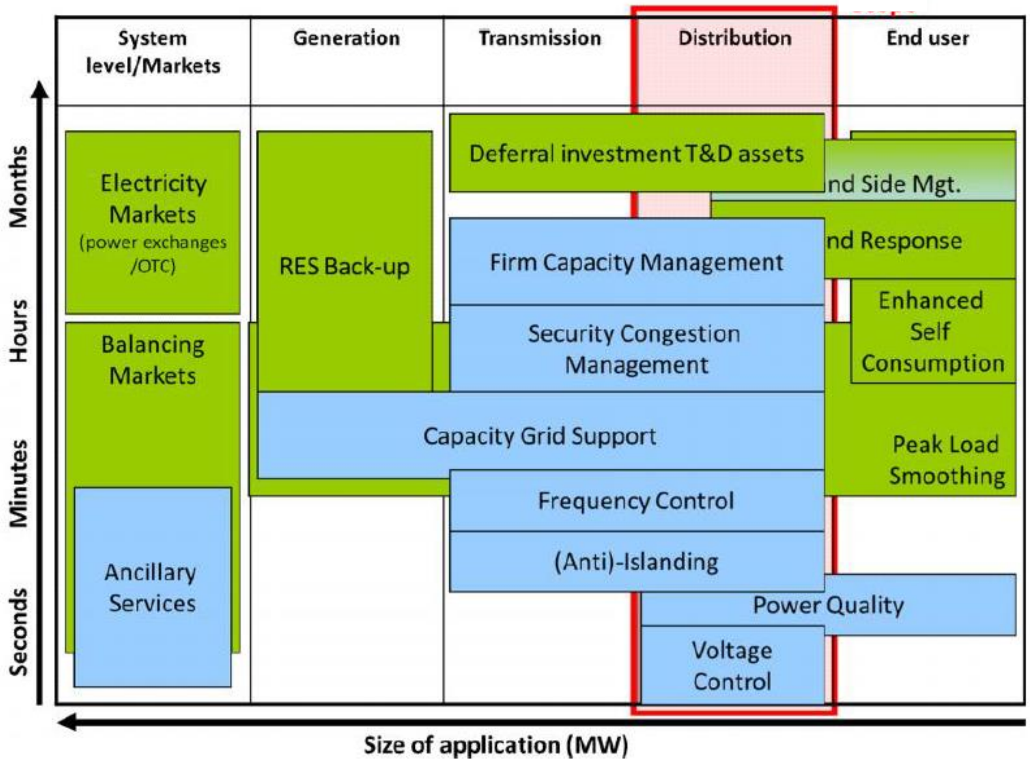
Services

- EU research agenda: from DG to smart grids to storage
- Storage can provide many different services: Affecting different segments of the electricity sector
- Regulation is key for most business models



Energy Management

Decoupling the generation of electricity from its instantaneous consumption.

System Services

Any service that is able to improve and support the quality of service and the security of supply in the electric power system

Source: (Eurelectric, 2012)

Role of regulation

Services/business models

- Price arbitrage
- Firm capacity
- AASS TSO
- AASS DSO
- Balancing/ reserves
- Primary Frequency control
- On-site generation balancing
- On-site demand balancing

Regulation: enablers/barriers

Storage operators

- Large-scale Transmission
- Small-scale Distribution
- Small-scale Consumer/prosumer
- Large-scale RES generation
- DSO-owned storage
- Small-scale RES generation

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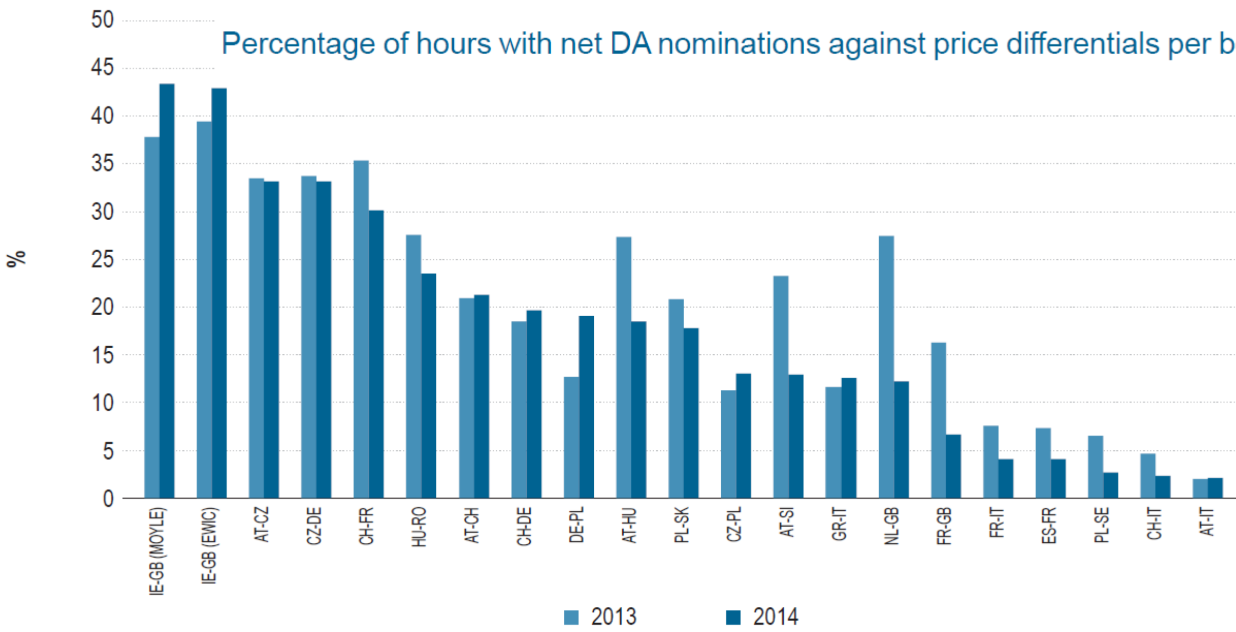
Market design

Market design: day-ahead & intraday

- Price arbitrage:
  - Market design → short-term market liquidity
  - Market access rules: e.g. minimum sizes/aggregation
  - Pricing rules: e.g. existence of negative prices as in Nord-Pool or EPEX
  - EU day-ahead price convergence



(ACER, 2015)

Market design: day-ahead & intraday

- Bidding protocols:
  - In US (NYISO & CAISO): market clearing algorithm decides the economic schedule (charge and discharge of pumped hydro)
  - In EU the Price of Coupling of Regions (PCR) uses EUPHEMIA, bids are formulated as
    - Aggregated hourly orders
    - Complex orders
    - Block orders (linked)

that implies a risk for ex-ante scheduling of storage anticipating the periods for charging and discharging

Market design: EU Intraday markets

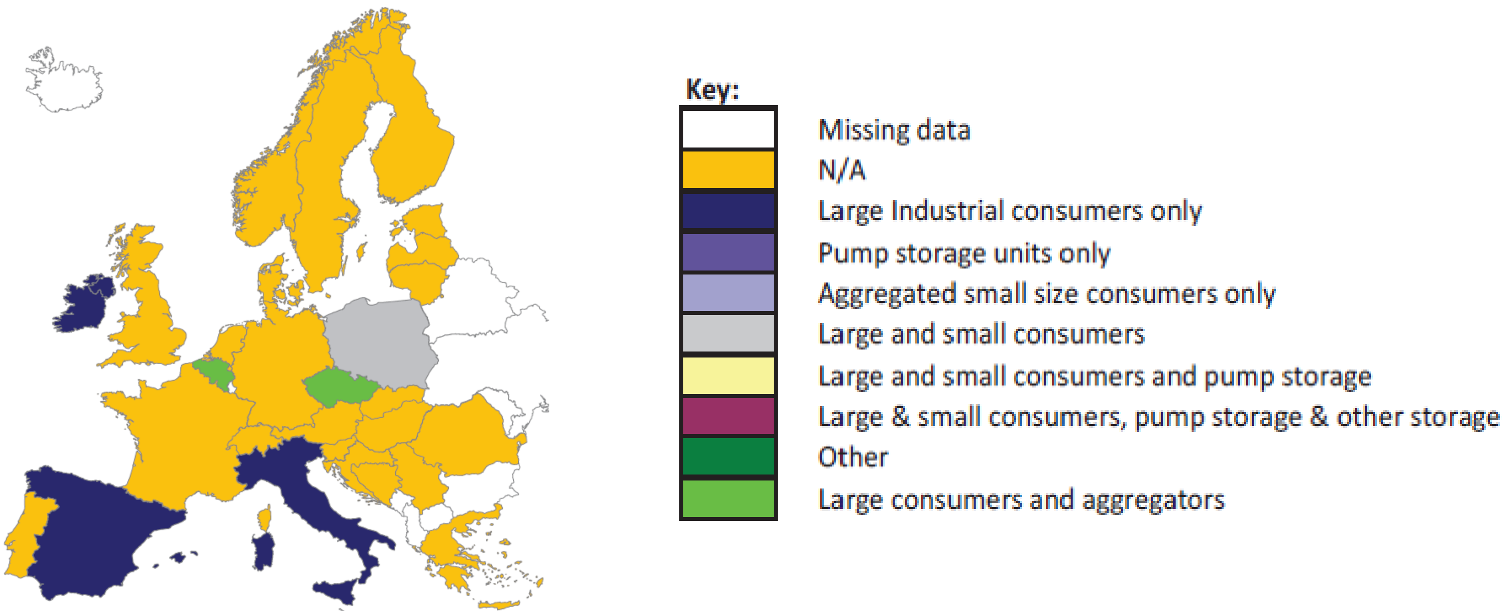
	Nationally specific elements of ID markets						Elements of (national and cross-border) intraday trade that are envisaged in the intraday target model			
Market	Ratio ID volumes/ demand	Intermittent generation (% installed capacity)	ID auctions	Exclusive (no alternative to organised market)	Portfolio bidding/Unit bidding	Market time unit (in the organised market)	Balance responsibility for RES	Implicit allocation of cross-border capacity	Close-to-real-time gate closure (1 hour or less, national market)	Standard and non-standard products available
Spain	12,1%	22%	Yes	Yes	Unit bidding	1 hour	Yes	On one border	No (2-3 hours)	Yes
Italy	7,4%	18%	Yes	Yes	Unit bidding	1 hour	Not fully	No	No (2-3 hours)	Yes
Portugal	7,6%	21%	Yes	Yes	Unit bidding	1 hour	No	Yes	No (2-3 hours)	Yes
Germany	4,6%	28%	Yes (for 15 min. product)	No	Portfolio bidding	1 hour and 15 min	Not fully	On one border	Yes (45 minutes)	Yes
Great Britain	4,4%	12%	No	No	Portfolio bidding	30 min	Yes	No	Yes (1 hour)	Yes
Slovenia	1,0%	7%	No	No	Portfolio bidding	1 hour and 15 min	No	No	Yes (1 hour)	Yes
Belgium	1,0%	19%	No	No	Portfolio bidding	1 hour	Yes	On one border	Yes (5 minutes)	No
Sweden	1,0%	11%	No	No	Portfolio bidding	1 hour	Yes	Yes	Yes (1 hour)	Yes
Lithuania	1,0%	8%	No	No	Portfolio bidding	1 hour	No	Yes	Yes (1 hour)	No
France	0,7%	10%	No	No	Portfolio bidding	1 hour	No	On one border	Yes (45 minutes)	Yes
Czech Republic	0,7%	10%	No	No	Portfolio bidding	1 hour	Yes	No	Yes (1 hour)	No
The Netherlands	0,2%	10%	No	No	Portfolio bidding	1 hour (standard) and 15 min	Yes	On some borders	Yes (5 minutes)	Yes
Poland	0,1%	9%	No	No	Portfolio bidding	1 hour	Yes	No	No (Gate closure at 14:30)	No

(ACER, 2015)

Source: ACER survey on ID liquidity, ENTSO-E, data provided by NRAs through the ERI and CEER national indicators (2015).

Market design: reserves and balancing

- Reserves provision (capacity and energy):
  - Procurement schemes
  - Deviation settlement rules: single unit, BRP
  - Duration of energy provision
  - Access rules: min. size/aggregation, allowed providers



Load participation - Type of consumers participates in the balancing services

Source: (ENTSO-E, 2015)

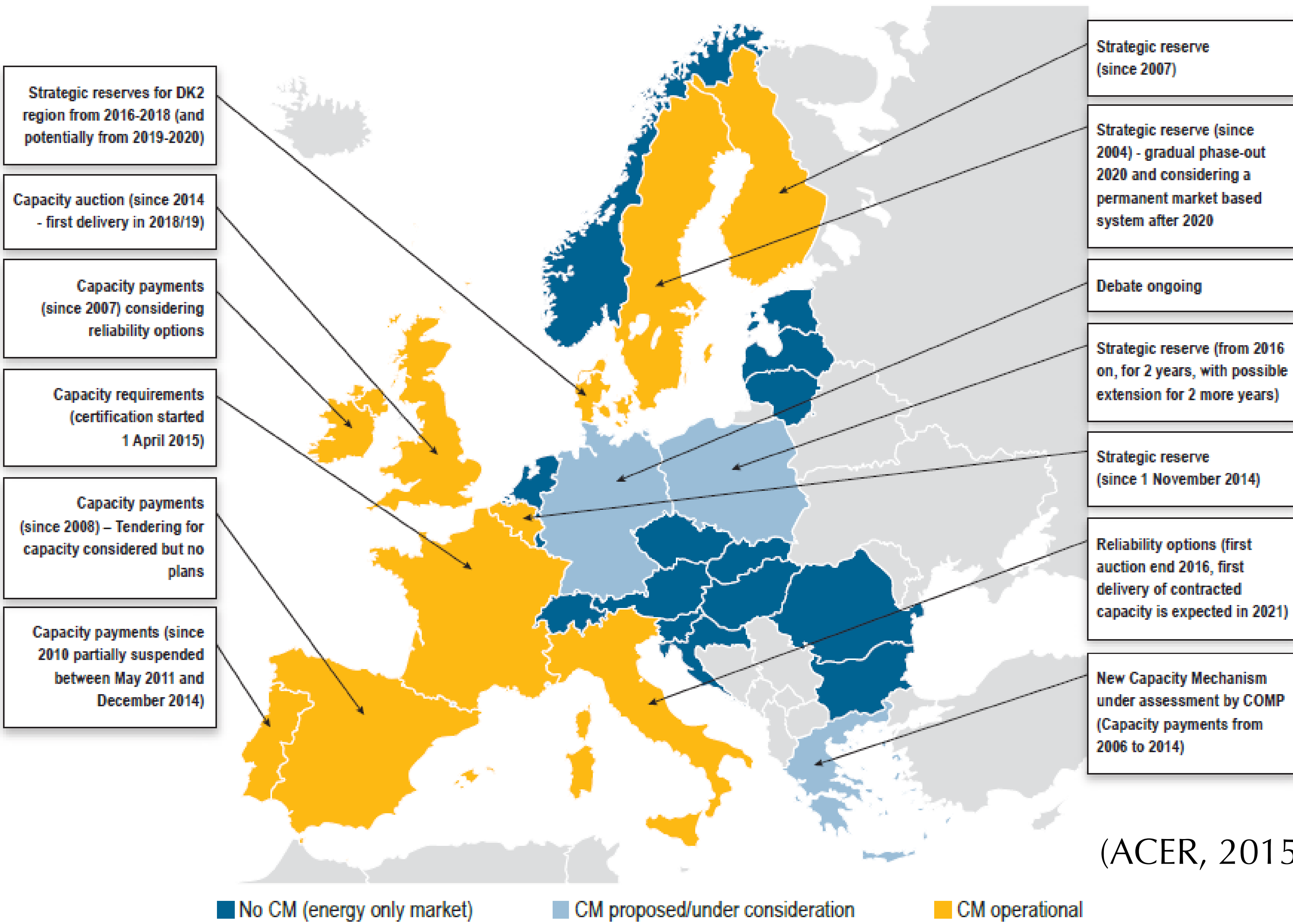
Market design: reserves and balancing

- Storage has high dynamic capabilities but limited energy
- EU Electricity Balancing Network Code acknowledge and foster storage participation as Balancing Service Provider, still there is a need for more details on how this can be achieved
- Good practice: Regulation market in PJM
  - Resources providing regulation are remunerated based on their performance
  - New dynamic fast-responding signal (Reg D) providing zero net energy over a period shorter than 15 minutes (adequate for storage participation)

Market design: capacity remuneration mechanisms

- Firm capacity/adequacy:
  - Relevant regulatory issues:
    - Mechanisms: capacity payments, capacity markets, reliability options, strategic reserves
    - Methodology to calculate firm capacity
  - EU: Harmonize national assessments (RES), consider interconnections, remove barriers for demand response and storage in short-term markets
  - Definition of events to provide firm capacity is critical for limited-energy storage participation
  - Good practice: PJM capacity (RPM) market in US
    - Allows resource aggregation and define emergency situations during hot weather periods

Capacity mechanisms in EU



(ACER, 2015)

Source: NRAs (2015)

Market design recommendations

- For all time frames, markets should be based on **technology neutral products** that acknowledge the **value of new flexible resources**

- Short-term (day-ahead/intra-day)
  - Bidding rules that represent the constraints of storage
- Very short-term (reserves/balancing)
  - Re-evaluate reserve requirements to include faster responding resources
  - Define separate products for upwards/downwards reserve
  - Reduce minimum size limits (10 MW ES; 5 MW NL; 1 MW DE; 0,1 MW PJM)

- Long-term markets
  - The problem: Capacity products are made for traditional generation
  - Potential solution: Products with softened requirements for 'firm supply'
  - How to adequately evaluate capacity and flexibility?

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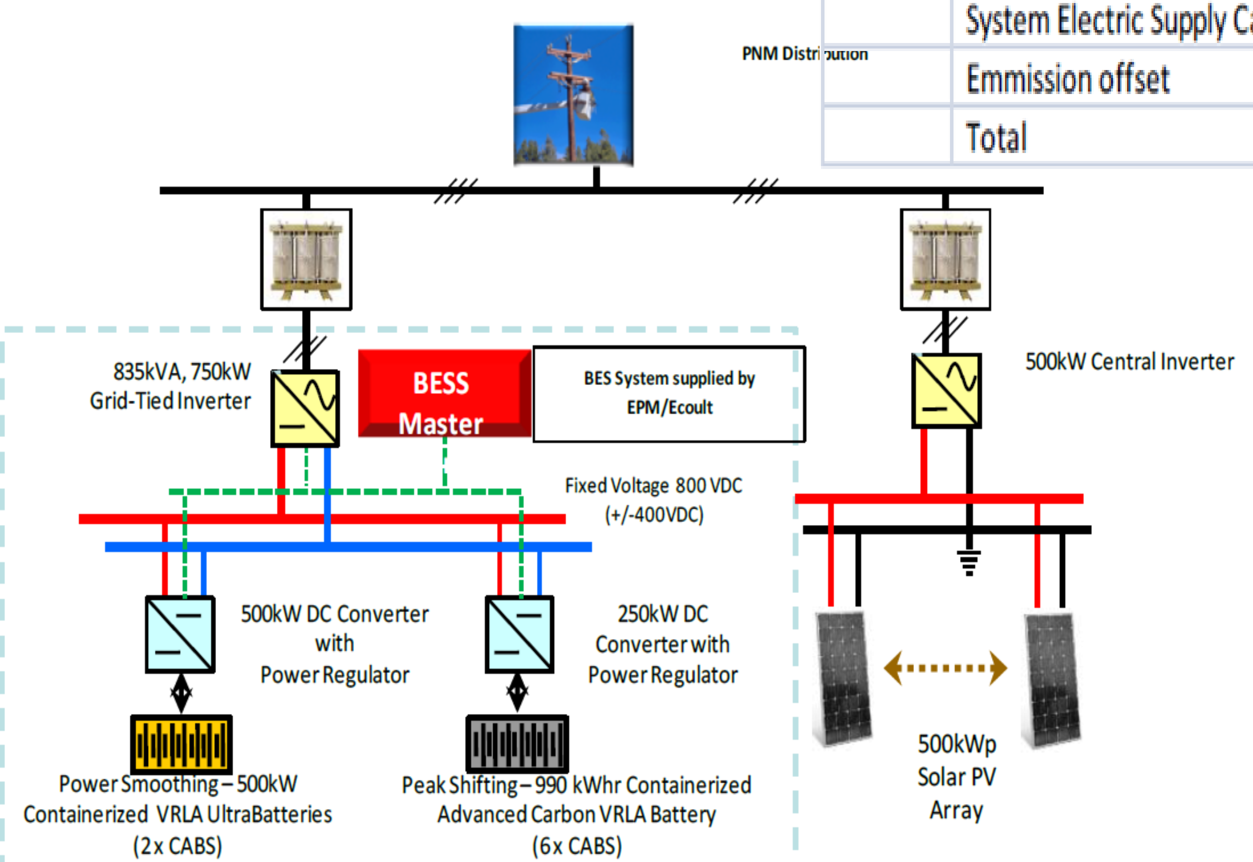
Distributed storage

Distributed storage: costs & benefits pilot project

Base Case	Utility Rev. Requirement (Variable)	$ 51,576.11	$ -
	Utility Rev. Requirement (Fixed)	$ 2,929,123.43	$ -
	Electricity Sales	$ -	$ 114,735.61
	Distribution Investment Deferral	$ -	$ 333,987.30
	Distribution Losses Reduction	$ -	$ 15.80
	System Electric Supply Capacity	$ -	$ 177,036.26
	Emmission offset		$45,583.56
	Total	$ 2,980,699.54	$ 671,358.53



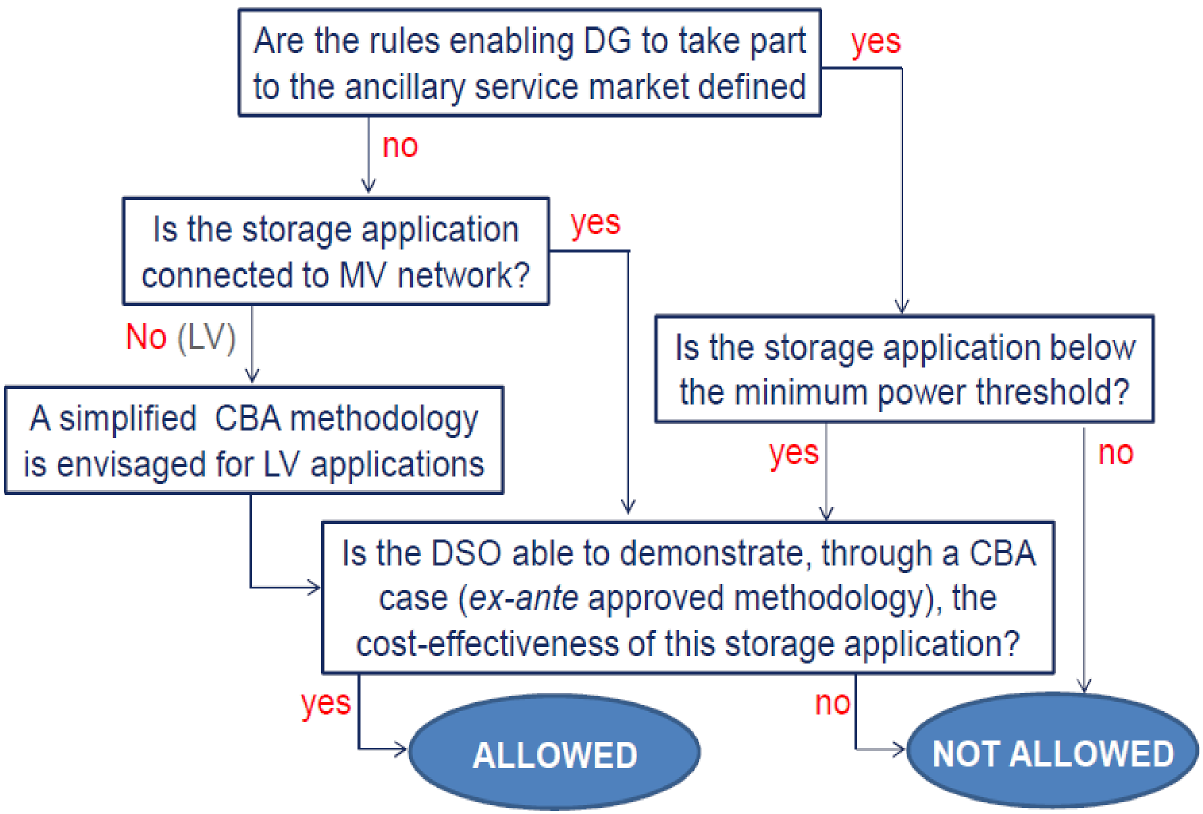
(PNM ,2014)

Storage providing services to DSOs

- DSO support:
  - Services: investment deferral, congestion management, voltage control, islanded operation
  - Relevant regulatory issues:
    - Unbundling provisions: need to re-think it?
    - Local AASS provision: markets-agreements?
    - Remuneration schemes for DSOs (CAPEX, reliability)
    - Load/generation differential treatment
    - Technical requirements/grid codes
    - Aggregation
  - Many **on-going demo projects**: FP7-EC, LCNF-UK, smart grid incentives-Italy, other initiatives

Storage ownership & DSO unbundling

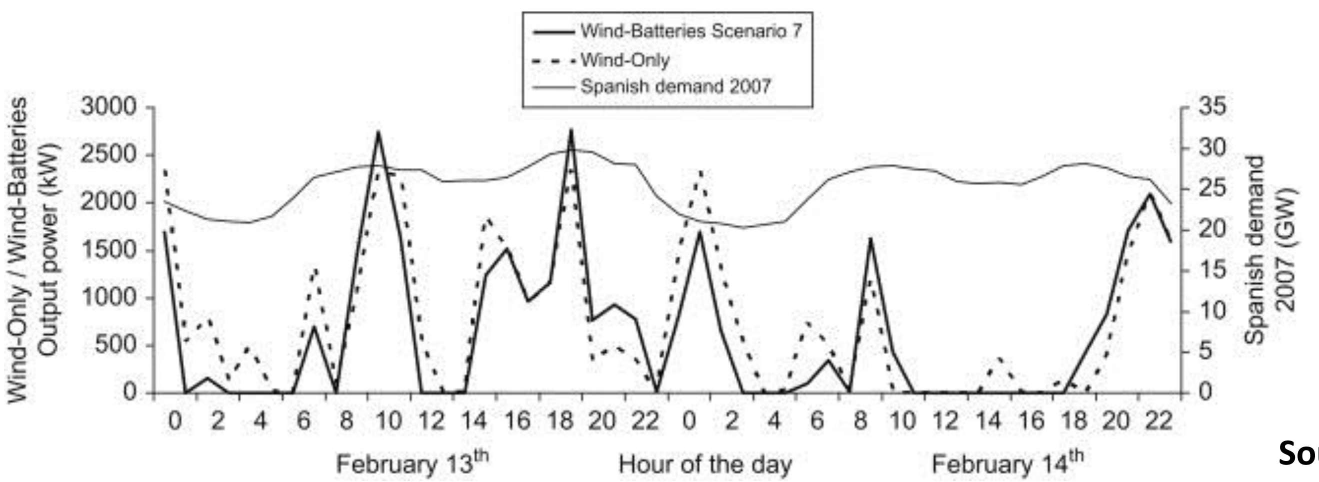
- Italian regulator proposed framework



(Lo Schiavo, 2015)

On-site generation plus storage

- On-site generation balancing:
  - Drivers: generation shift, avoid network charges (e.g. connection charges), minimize imbalances, firm capacity
  - Additional relevant regulatory issues:
    - Design of support payments and eligibility criteria
    - Design of connection charges for generation



Source: Dufo-López, 2009

Storage support mechanisms

- Why support mechanisms?
  - Presence of externalities
- How to design support mechanisms for storage?
  - Many of the lessons learned for RES apply
  - How to combine RES and storage incentives?
  - Government measures that incentivize the deployment of storage
- Review of international experiences (Rodilla, 2016)
  - North America: California, New York, Hawaii, etc.
  - Europe: Germany, United Kingdom, Portugal
  - Asia: Japan, South Korea, India, China

Storage support mechanisms

- Targets in California (MW) imposed on IOUs
- Exemptions from interconnection fees, costs for distribution upgrades and standby charges

Storage Grid Domain Point of Interconnection	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	**90**	**120**	**160**	**210**	**580**
Pacific Gas and Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	**90**	**120**	**160**	**210**	**580**
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	**20**	**30**	**45**	**70**	**165**
Total - all 3 utilities	**200**	**270**	**365**	**490**	**1,325**

(CPUC 2013)

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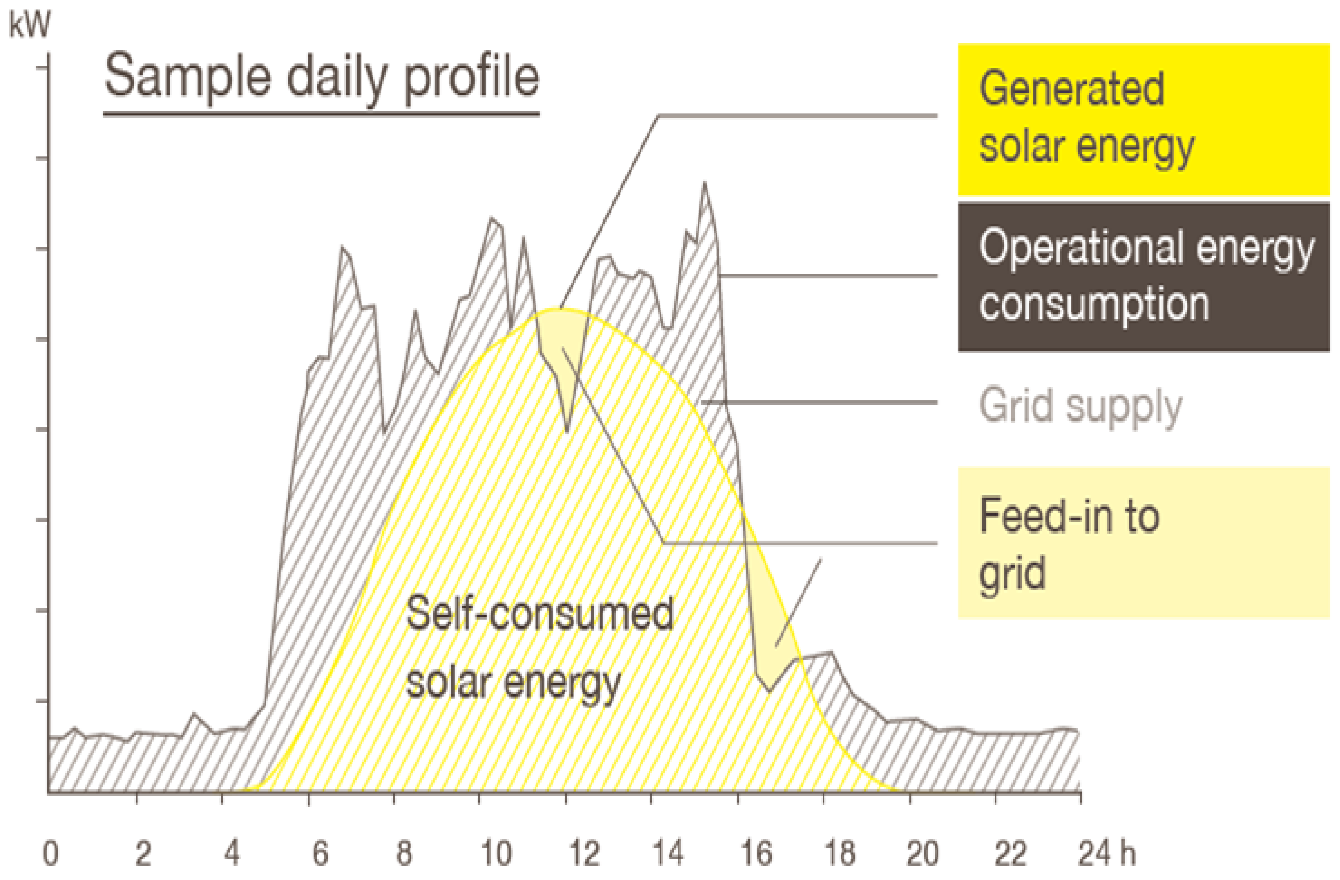
Self-consumption and tariff design

Self-consumption and net metering

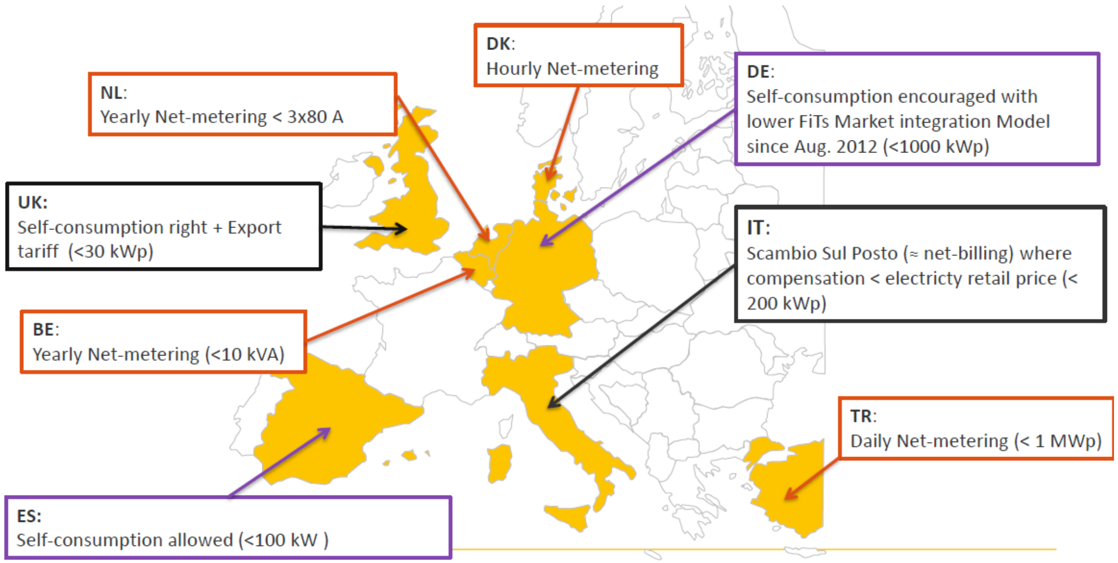


Sample daily load profile for a plastic manufacturing company with self-consumption from PV (Kraftwerk 2015)

Net-metering and tariff design: drivers for on-site generation

- Demand response/prosumers:
  - Relevant regulatory issues:
    - Tariff design: volumetric charges (per kWh) without time discrimination, incentives self-generation netting demand & kills storage
    - Net-metering production/consumption over long periods (month, year) kill the business case for on-site storage

Net-metering and network tariff design in EU

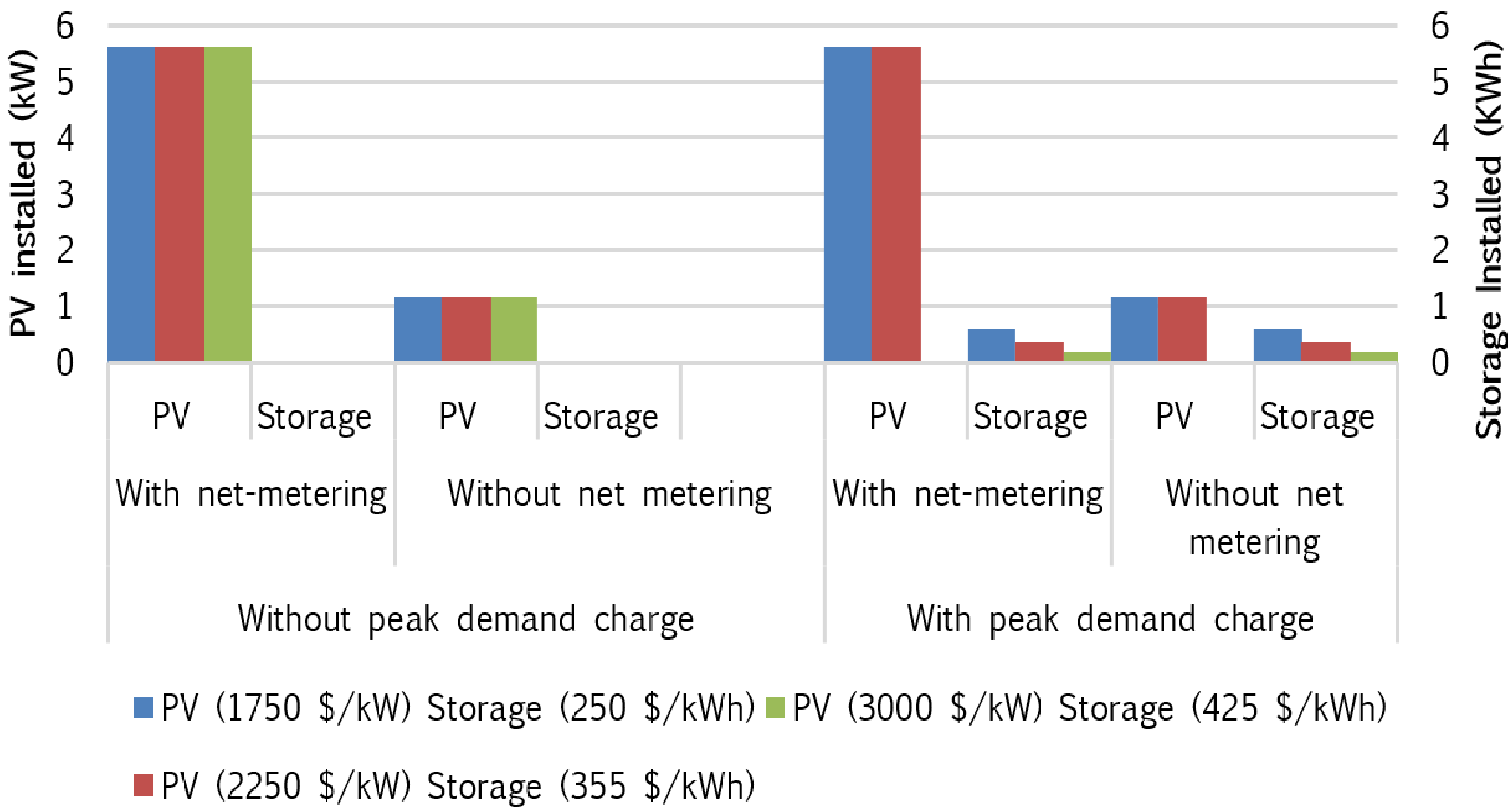


Source: (EPIA, 2013)

	Structure of network tariffs for household customers			
	Fixed charge [€]	Capacity charge [€/kW]	Energy charge [€/kWh]	Reactive energy (€/kvarh)
BE	Yes	No	Yes	No
CH	Yes (max 30%)	Seldom	Yes (at least 70 %)	No
CZ	Yes	No	Yes	No
DE	Possible	No	Yes	No
DK	Yes	No	Yes	No
EE	Yes	No	Yes	No
ES	No	Yes	Yes	No
FI	Yes	No	Yes	No
FR	Yes	Yes	Yes	No
GR	No	Yes	Yes	No
IT	No	Yes	Yes	No
LT	Possible**	No	Yes	No
NL	Yes	Yes	No	Possible, depends on DSO
NO	Yes	Seldom+	Yes	No
PL	Yes	No	Yes	No
PT	No	Yes	Yes	No
SE	Yes	Seldom+,	Yes	No

Source:(Eurelectric, 2013)

Consumer DER investments & retail prices



Influence of pricing signals on PV and storage investment decisions (Burger 2015)

Self-consumption and DER: new tariff design

- **Prosumers** should **contribute to cost recovery** as other consumers
- **Net-metering** exacerbates the **regulated cost recovery** problem
- Value the **injected energy** into the grid **below the retail price**, that would incentive efficient operation (increase of self-consumption) and investment decisions (sizing of onsite DG)
- New tariff designs are needed moving away **from purely volumetric tariffs** to **demand/capacity charges** and **fixed charges** to recover fixed costs
- New retail tariffs with **advanced metering** composed of
  - **Energy prices**: time and location discrimination
  - **Network charges**: cost-reflective according to the use of network assets in periods of maximum utilization
  - **Other regulated costs**: mainly fixed charges

Tariff design for storage: recommendations

- Prosumers (load and on-site generation including storage) should be charged according to their net injection/consumption profile
- Allocation of network costs and other regulated costs should be based on
  - **Long run marginal cost** – calculated as cost-reflective taking into account the impact of prosumer profiles on the need for incremental network reinforcements. This component is not enough to recover the total regulated costs.
  - **Residual costs** – Allocated following the Ramsey criterion. Prosumers with storage assets are highly price elastic. It is efficient not to charge the residual costs to them.
- Interference of RES support mechanisms (Net metering)
  - Uses the grid as 'virtual storage'
  - Kills the incentive for storage

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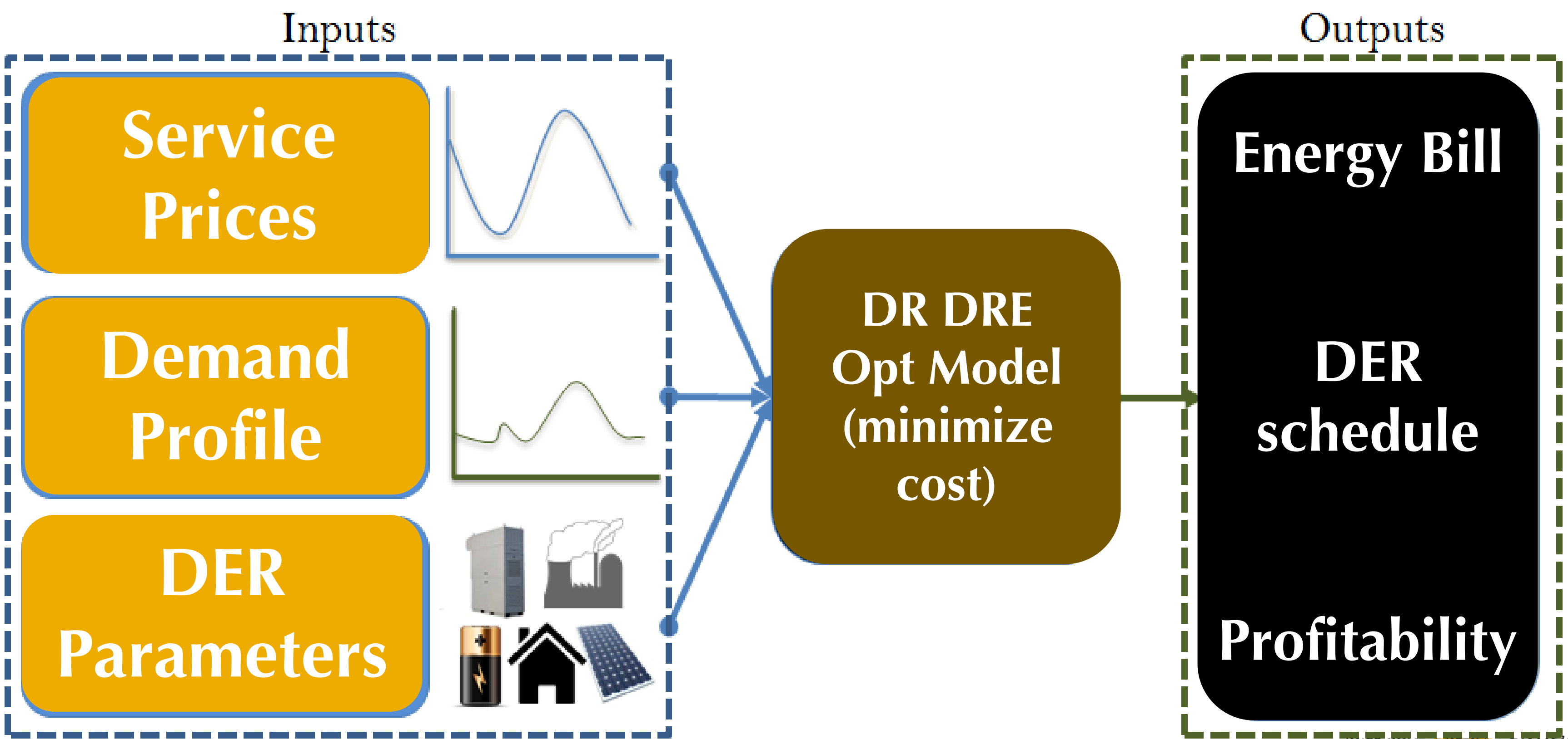
Case studies

Case Study 1: Approach

- Compare the economics of storage under varying levels of demand flexibility, for given geographic, economic & regulatory conditions



Case Study Assumptions

Customer Type: single-family residential

Locations: Austin, Texas; Westchester, NY

Tariff:

- Energy variable rates (based on LMP)
- $5/peak-kW/month Demand Charge

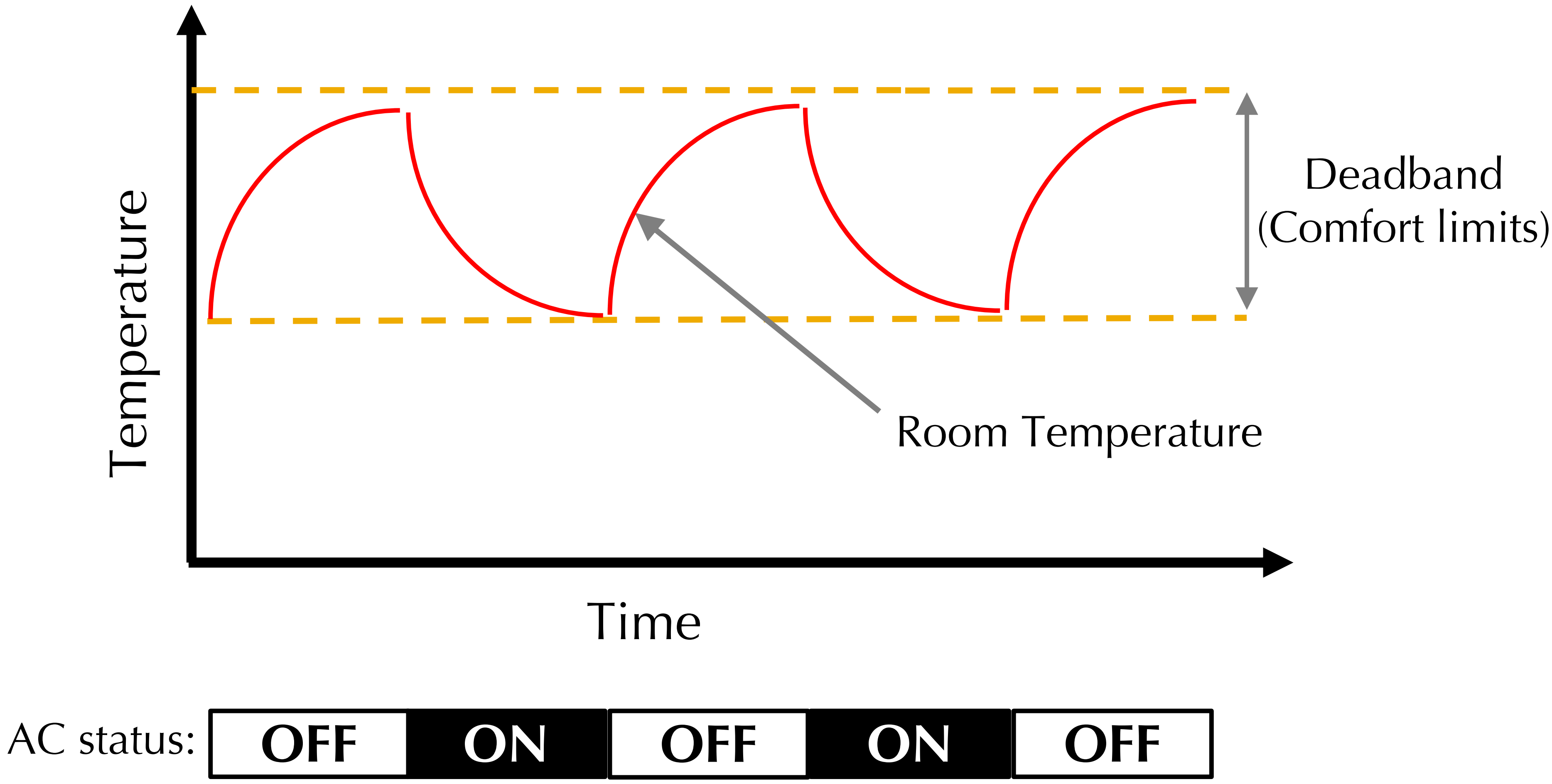
Battery Parameters:

- Based on Tesla Powerwall
- 7 kWh of energy, 3.3 kW capacity
- Cost: $425/kWh – $140/kWh

Demand Response (Air Conditioning and Water Heater control) scenarios:

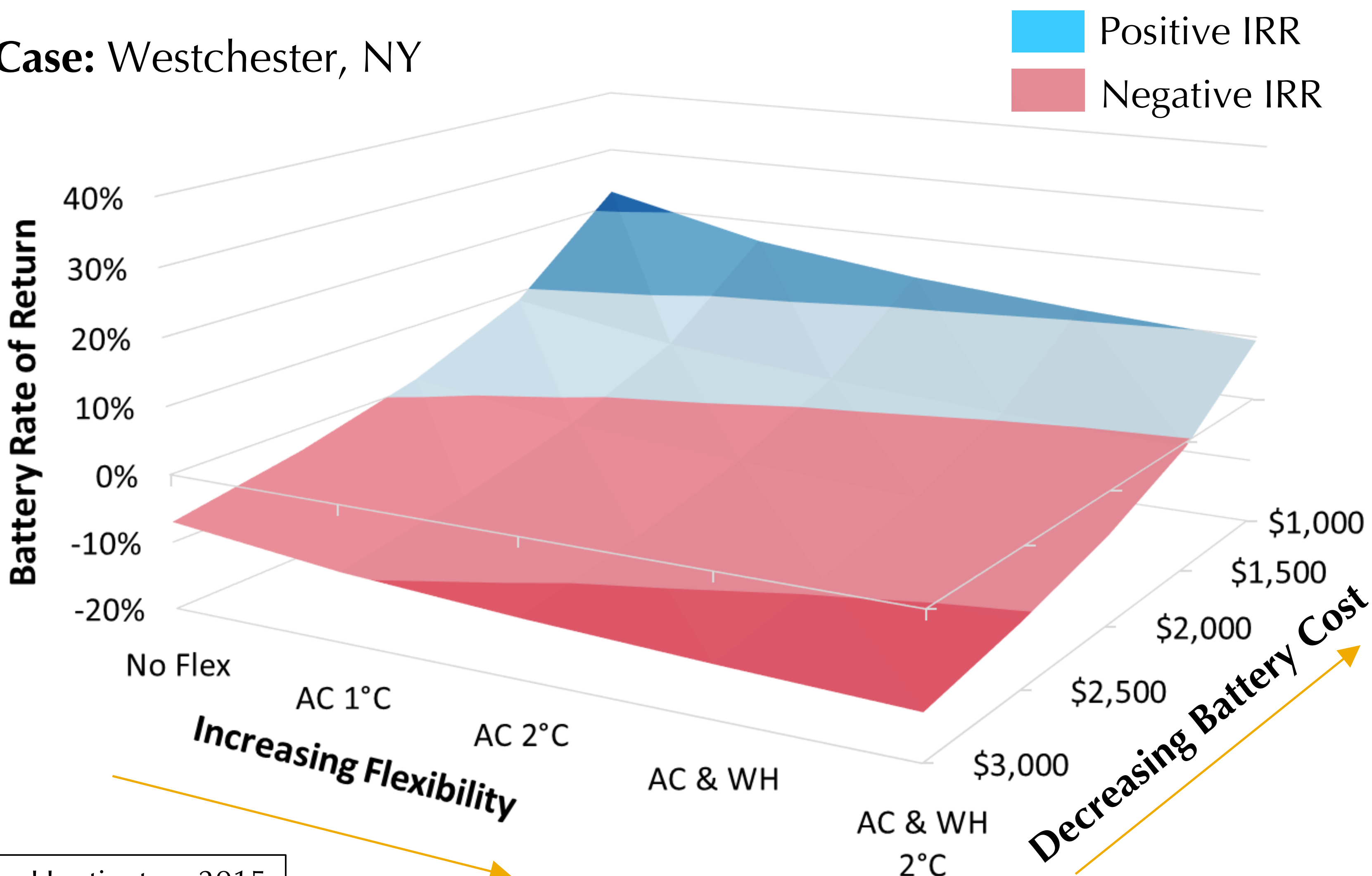
No Flexibility → Increasing Flexibility = Increasing appliances / deadband

Flexibility from Increasing the Temperature Deadband



Results: DR Flexibility reduces Battery IRR

Case: Westchester, NY

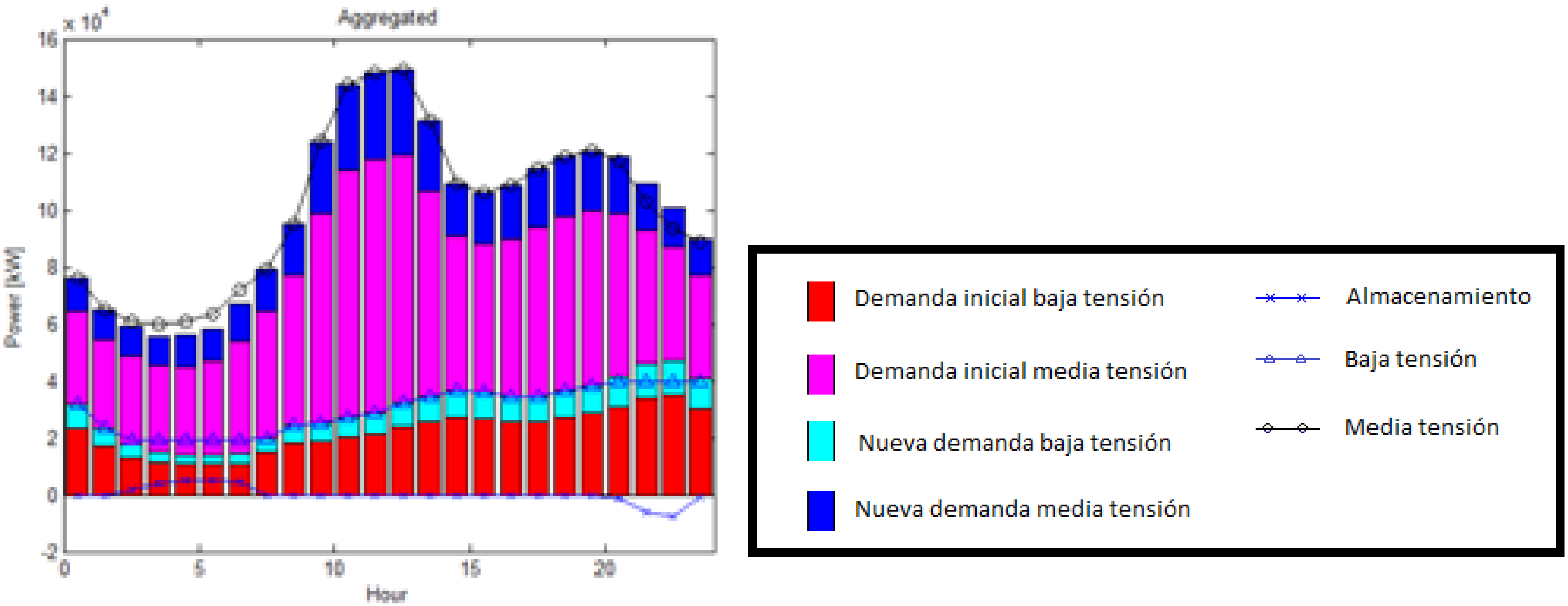


Source: Huntington, 2015

Case study 2: Storage for distribution network deferral

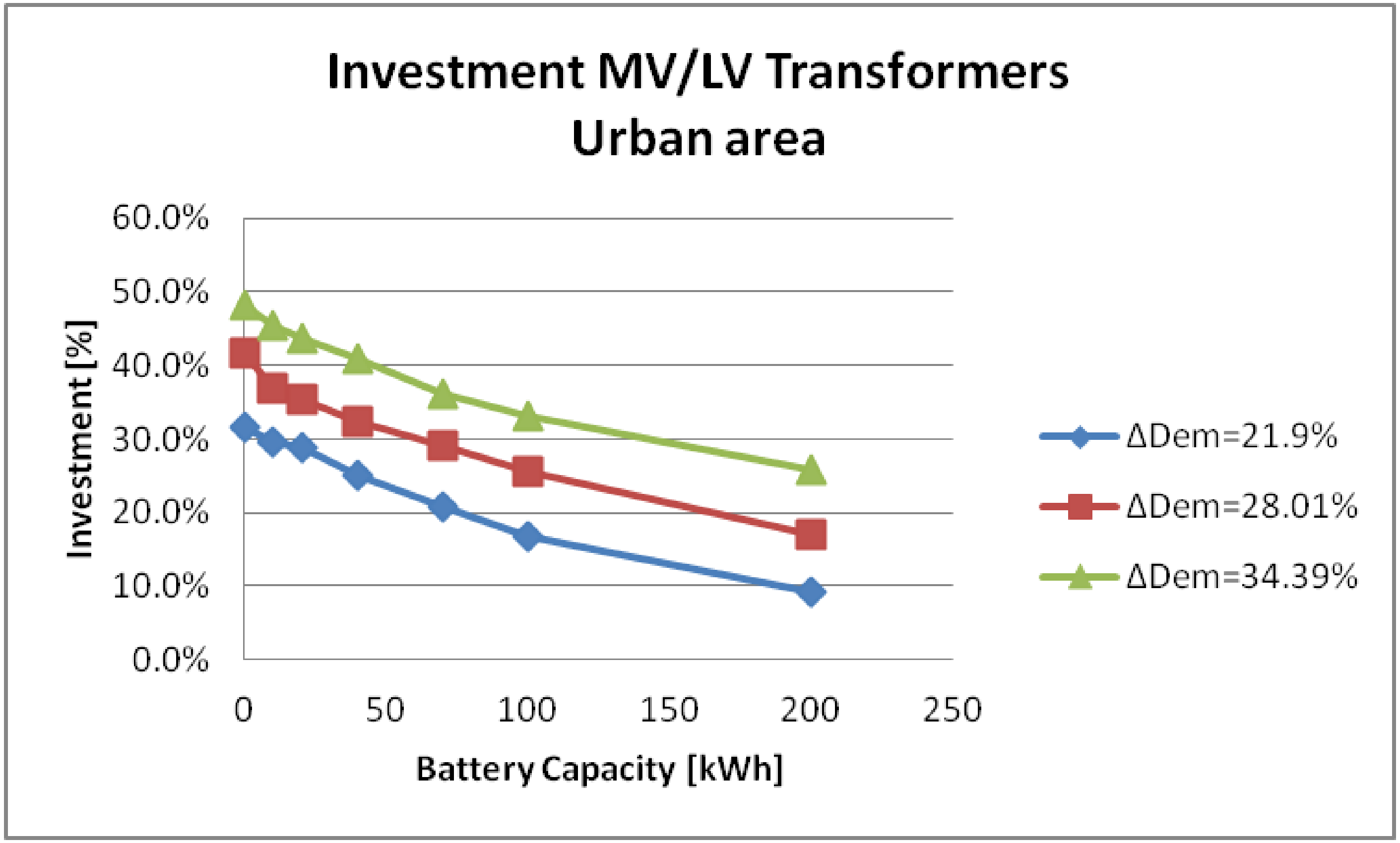
- Storage in distribution transformers for reducing future peak demands

200kWh of storage per transformer



(Mateo et al, 2015)

Investment in distribution transformers



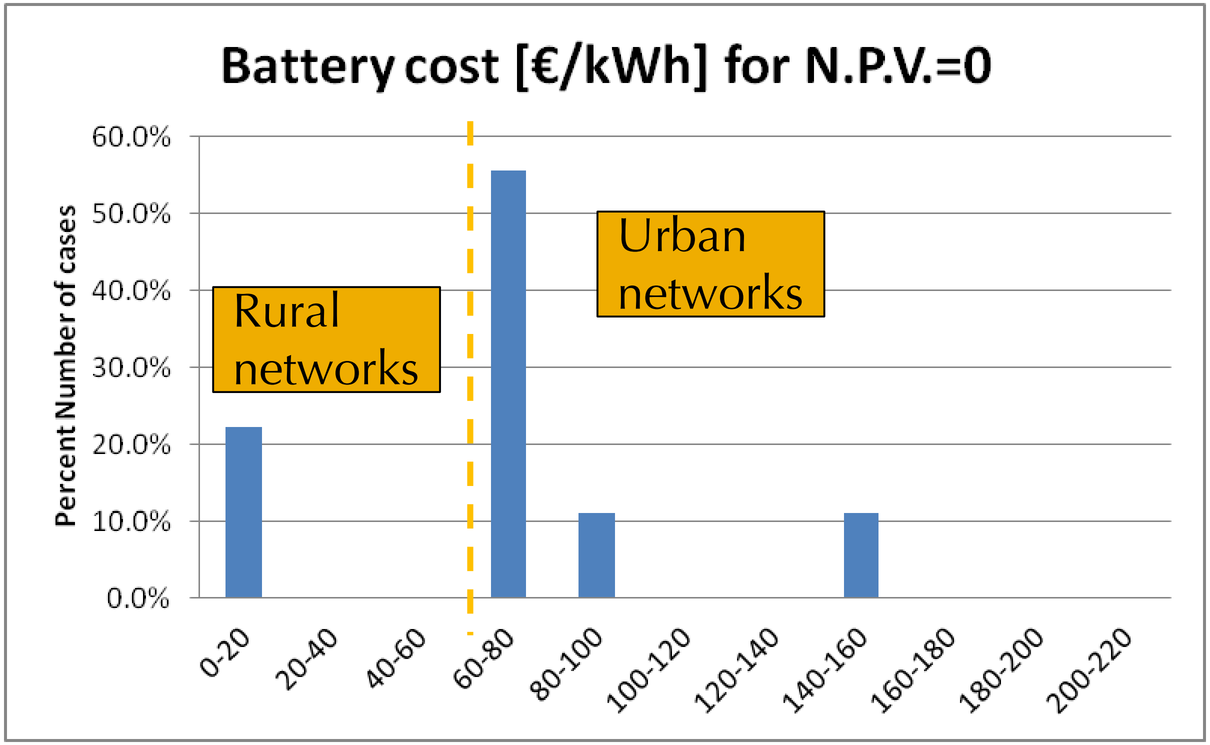
The required investment as a percentage of the existing assets depends on the storage capacity connected at each transformer

Cost-benefit analysis

Urban				
Storage (kWh)	Battery Cost (€/transf)	ΔDem=21.9% CAPEX (€/transf)	OPEX (€/transf)	N.P.V. (€)
0	-	-	-	0
10	5,000	892	31	-8,154
20	10,000	1,702	49	-16,578
40	20,000	4,122	124	-32,064
70	35,000	5,895	194	-57,771
100	50,000	7,579	268	-83,499
200	100,000	11,279	403	-172,789

Assuming €500/kWh of storage this case study is not profitable

Cost-benefit analysis for 10 kWh batteries



(Mateo et al, 2015)

A storage cost of €60-80/kWh would make this case study profitable in urban networks considering batteries of 10kWh and 10-years life cycle

Concluding remarks

- Business models for **storage affect several segments** across the electricity supply chain
  - Not a single specific topic but a whole revision of regulatory arrangements: market designs, retail prices and network tariffs

- The full business model of an actual storage asset in combination with generation/demand will presumably be a **combination of providing several services**
  - But regulation does not have to define these value propositions

- Role of regulation is to create a long-term **technology neutral level-playing field**
  - Short-term incentives aim at specific purposes: testing & demonstration and take up deployment

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Thank you for your attention!

This presentation has been prepared with inputs from
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