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Market design for energy storage systems

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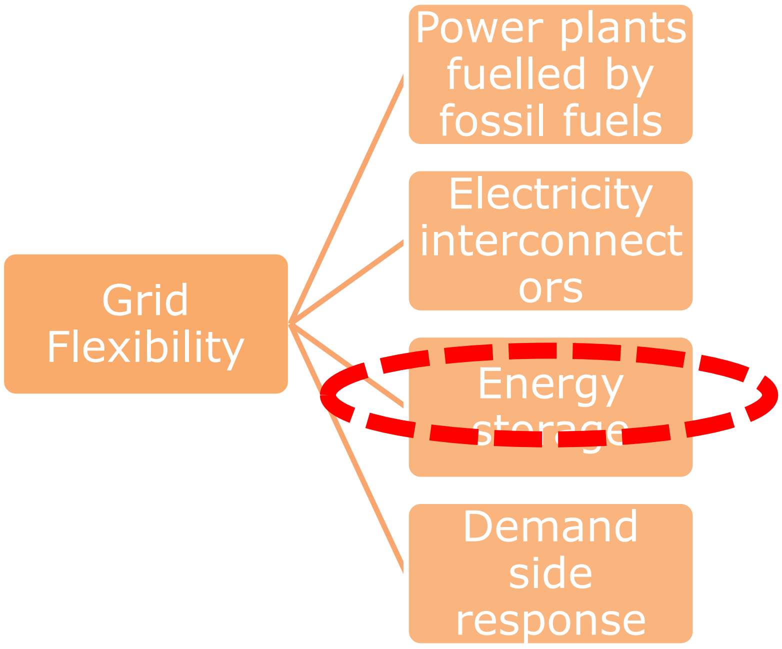
Outline

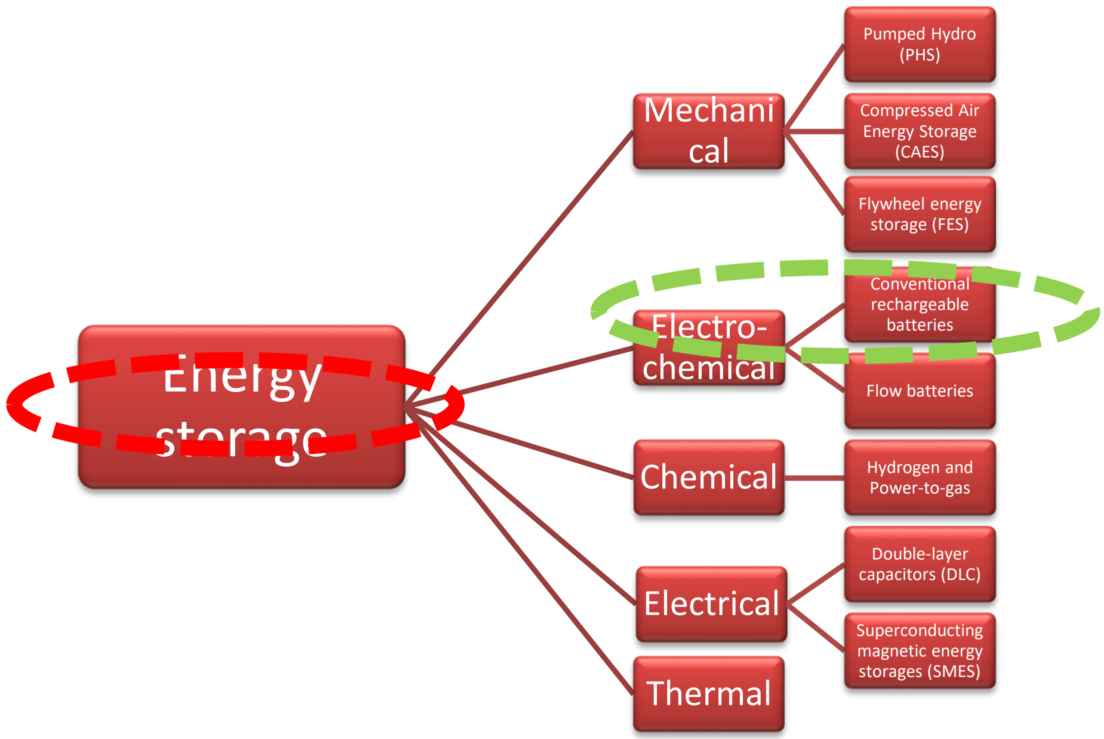
- Framing the problem
- Regulation of storage as commodity services
- Regulation of storage as network services
- Summary of regulatory alternatives
- Final remarks

Framing the problem

Electricity systems need more flexibility services



….but different storage technologies can provide different flexibility services



The view of the energy industry: European Association for Storage of Energy (EASE)

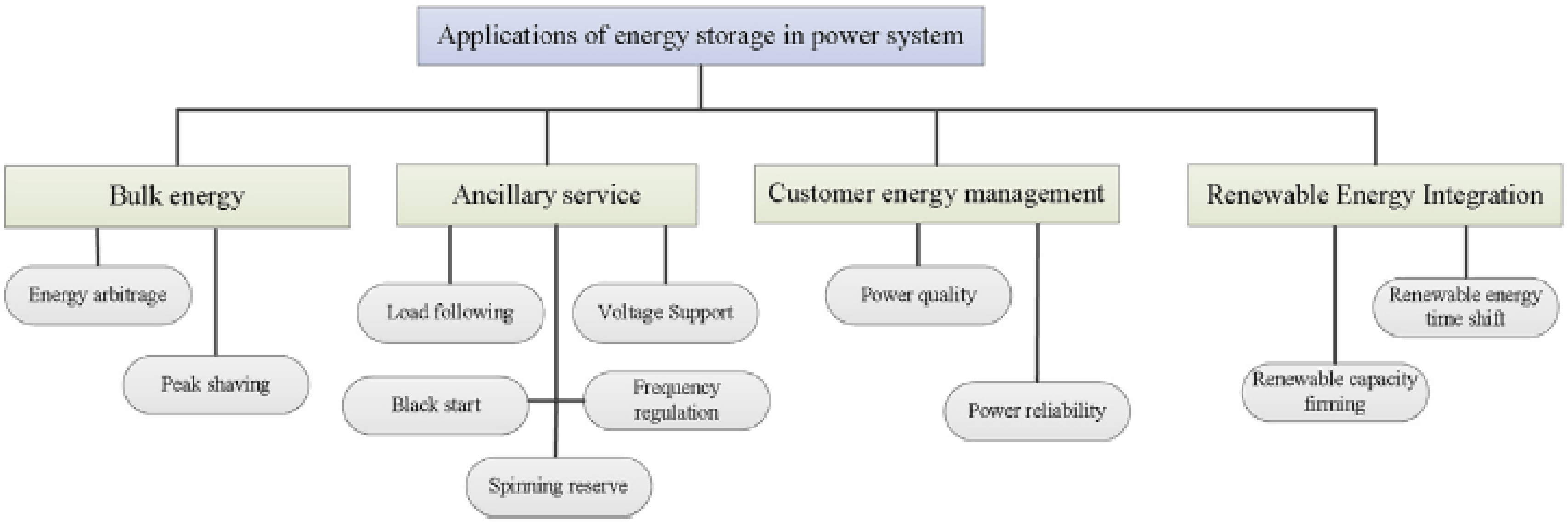
Generation		Transmission	Distribution	Customer services
Conventional	Black start	Participation to the primary frequency control	Capacity support	End-user peak shaving
Conventional	Arbitrage	Participation to the secondary frequency control	Dynamic, local voltage control	Time-of-use energy cost management
Conventional	Support to conventional generation	Participation to the tertiary frequency control	Contingency grid support	Particular requirements in power quality
Renewable	Distributed generation flexibility	Improvement of the frequency stability of weak grids	Intentional islanding	Continuity of energy supply
Renewable	Capacity firming	Investment deferral	Reactive power compensation	Limitation of upstream disturbances
Renewable	Limitation of upstream disturbances	Participation to angular stability	Distribution power quality	Compensation of the reactive power
Renewable	Curtailment minimisation		Limitation of upstream disturbances	

The view of the institutions: European Commission

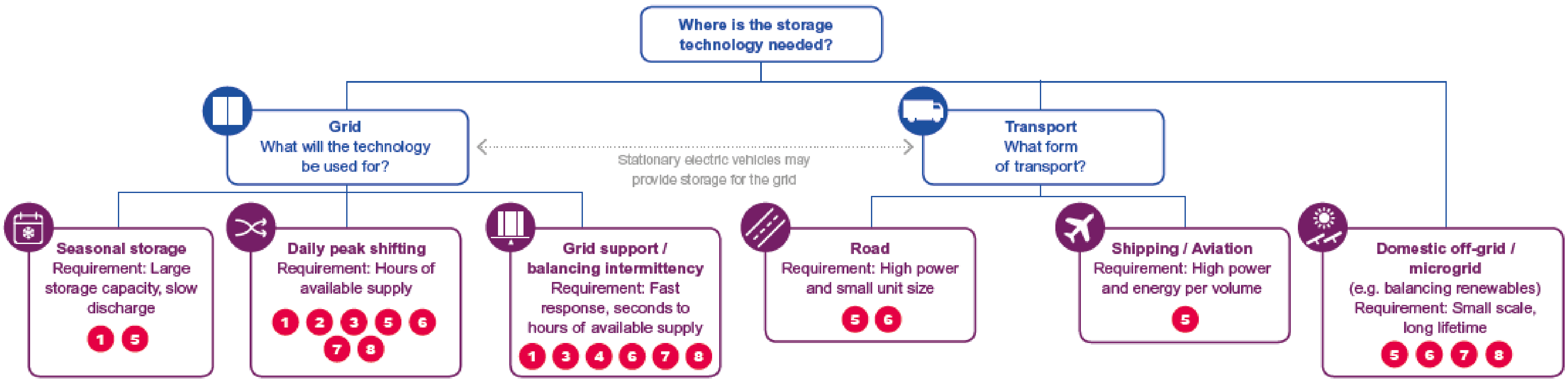
The future role and challenges of Energy Storage, DG ENER WP (2013)

Storage applications	Centralised	Decentralised	End-use
Balancing demand & supply	- Seasonal/weekly fluctuations - Geographical imbalances - Variability of wind & solar	- Daily/hourly fluctuations - Peak shaving - Integrate with heat/cold storage	- Daily/hourly fluctuations - Integrate with heat/cold storage
Grid management	- Voltage & frequency regulation - Participate in balancing markets	- Voltage & frequency regulation - Defer grid reinforcement - Substitute existing ancillary services	- Aggregate to provide grid services
Energy efficiency	- Time shifting: off-peak to peak	- Demand side management - Integrate with districtheating & CHP	- Increase value of PV& micro wind - Facilitate behaviour change

The view of the academia (1): Palizban & Kauhaniemi, Journal of ES, February 2016



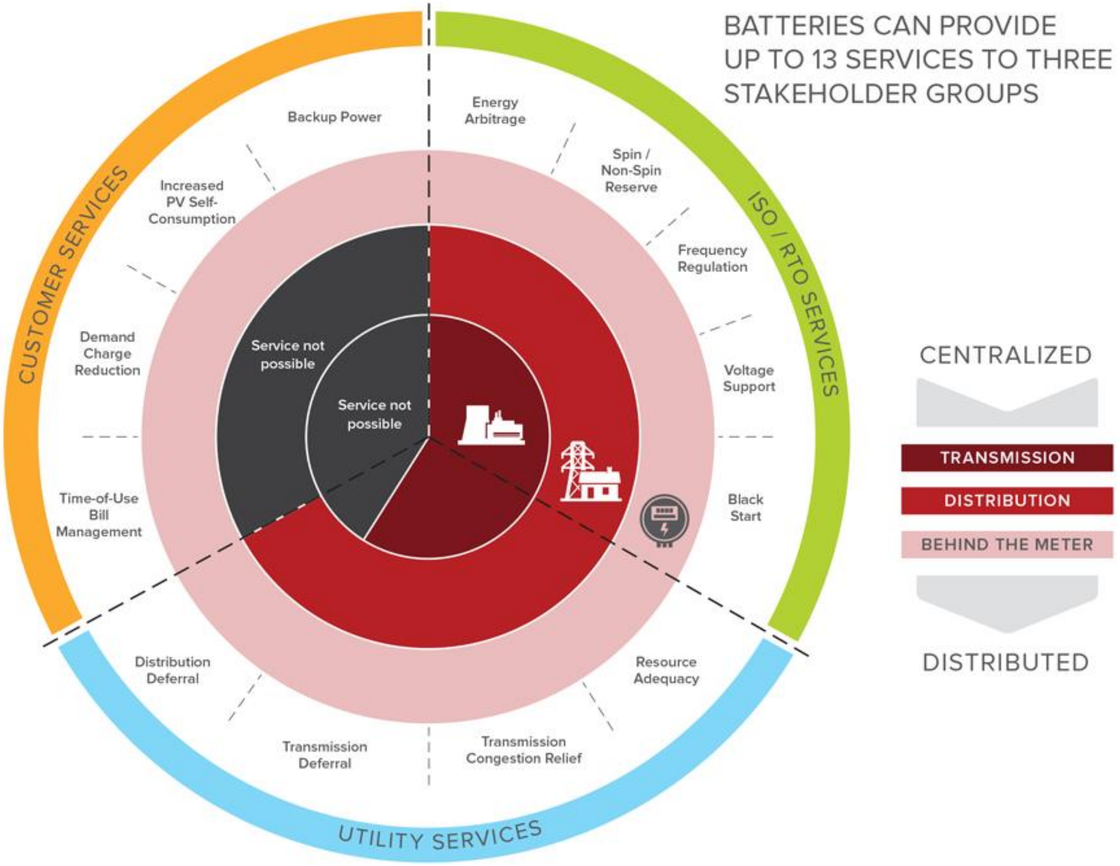
The view of the academia (2): Imperial College London – Grantham Institute



- 1= pumped storage; 2=CAES; 3= pumped heat; 4=flywheels/supercapacitors; 5=hydrogen; 6=lithium-ion batteries; 7=lead-acid batteries; 8=redox flux batteries.

The view of think tanks: Rocky Mountain Institute

- Focus on batteries and market segmentation, i.e. TSO, utilities and customers



Two kinds of regulatory challenges: Market design and network regulation

- ESS offer different types of services
  - Buy and sell energy in different periods
  - Avoid the need to transport energy from one point to another
- They are substitutes for different types of services
  - ESS can sell services in "competitive" wholesale markets
  - ESS can avoid the use of "regulated" networks
- Thus ESS involve two kinds of regulatory challenges:
  - The design of the wholesale market.
  - The regulation of energy networks.

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Regulation of storage as commodity services

Definitions

- Energy storage may provide multiple services so we need to understand the economic properties of those services
  - Energy services – Commodity trading between two market players
  - Balancing services – Trading of services to deal with imbalances, also trading among market players
  - Ancillary services – Trading between SOs and market players in order to guarantee system integrity
- From that standpoint, we may look at storage as a flexibility service. Thus, relevant questions to be tackled
  - Who decides on the offer of flexibility?
  - Who pays, who benefits from flexibility?

The traditional logic

- We identify changes brought by storage in the traditional power market design
- When designing power markets, one faces two basic choices
  - Choice #1: Trading system – Centralized vs bilateral
  - Choice #2: Congestion management – Rules to deal with constraints

Choice #1 – Trading system

Centralized Trading

- Generators participate in an auction, offer to sell power (bid in to auction every half hour)
- Auctioneer accepts lowest bids
- In each half hour, plants with accepted bids generate
- Can adapt this mechanism to deal with: demand-side participation; technical constraints on plant operation (eg maximum "ramp-up"); transmission constraints
- Largely a continuation of pre-liberalization "dispatch algorithms" used by monopoly

Bilateral trading

- Generators sign contracts with retailers and large consumers to supply power
- Transmission constraints dealt with by system operator and/or "physical transmission rights"
- Analogous to other commodity markets (e.g. gas with virtual hubs)

Choice #2 – Congestion management

How to prevent someone from trying to send additional power to other zones?

Centralized Trading

- No problem, the auctioneer decides which plants run, makes sure not to order too much generation from the zone
- Can choose to pay everyone the same price, or to have different prices for generation at different locations

Bilateral trading

- a) require exporters to hold rights to use the cross-border wires ("physical transmission rights"), make sure not to create too many rights; or
- b) system operator buys some power back off exporters, "sends it back to the other zone" ("counter-trading")
- Under the first option, can have different prices in different zones

Trend to switch from centralized to bilateral trading in the 2000s

- Trading
  - Chose bilateral because of concerns about "gaming", and belief that wholesale power trading would evolve to look like other forms of commodity trading
  - Accept risk of less efficient dispatch (auctioneer can identify overall most efficient way to meet demand)
- Transmission constraints
  - Chose uniform geographic prices to promote liquidity, and in some cases for political reasons
  - Accept that generators in low cost areas may in some sense get "over-rewarded"
  - Physical transmission rights for cross-border trading rather than a centralized system that would require sharing/ giving up control of borders

The effect of intermittent renewable generation

- The combination of
  - Increased penetration of intermittent renewable generation
  - Lack of storage capabilities
- ...Implied increased concern with efficiency
  - Especially, bilateral trading and uniform pricing lead to inefficient use of transmission system
- Shift towards more centralized system (market coupling) and more locational pricing (more price zones)
- [Concerns about investment are a separate problem]

Lessons from history

- Centralized trading is a solution for the lack of flexibility in the system in the presence of intermittency
- What would be the market design with more flexibility coming from storage?
  – In a situation where markets do not need to be so "instantaneous"
  – Hence closer to other commodities (e.g. gas)

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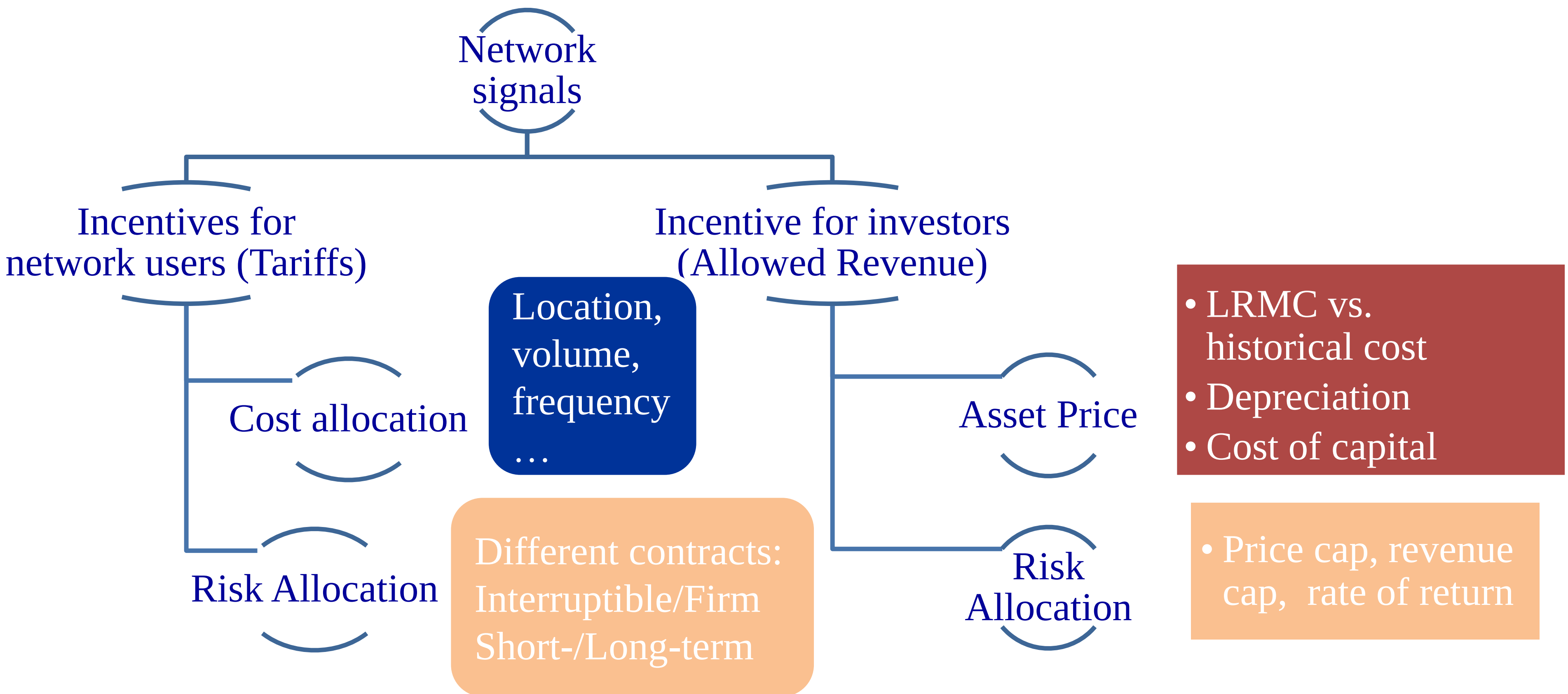
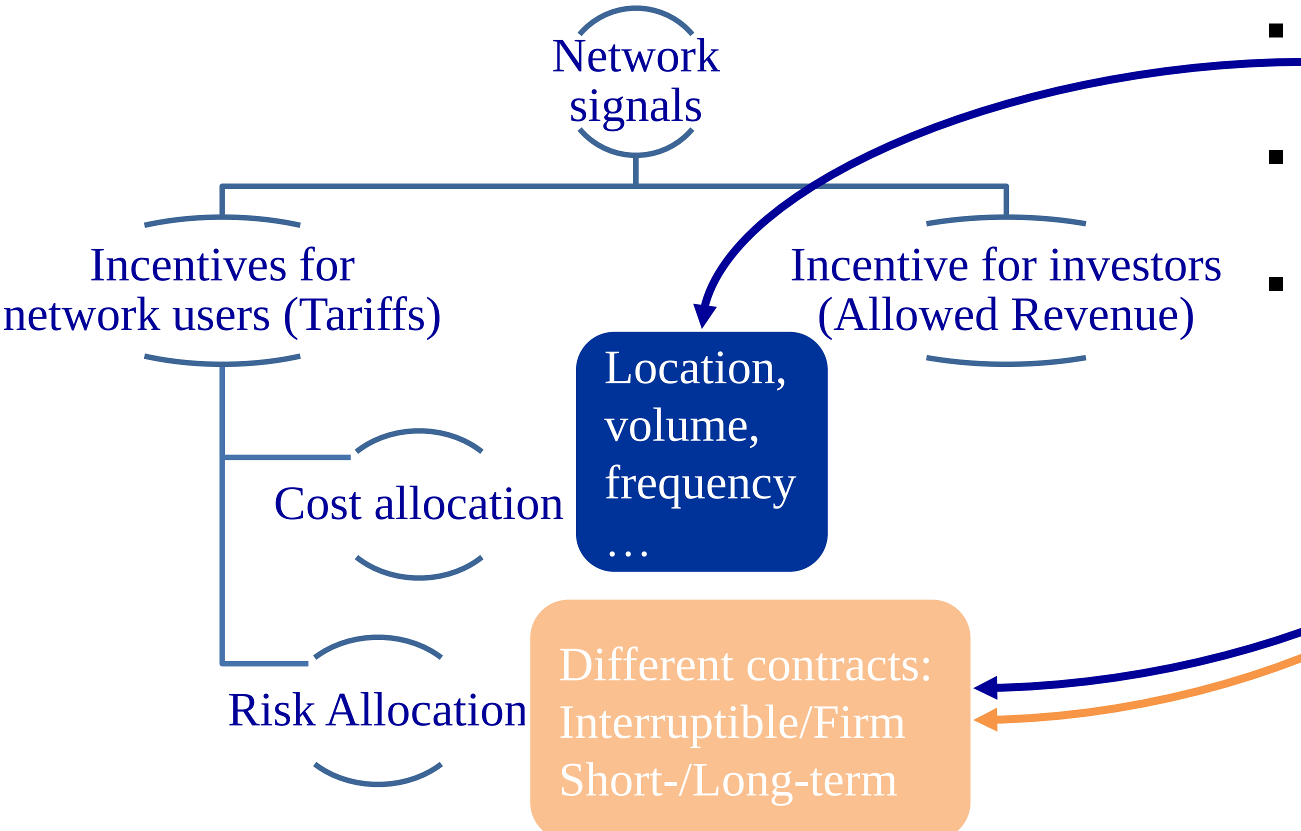
Regulation of storage as network services

Basic elements of network regulation



Basic elements of network regulation



At least, two dimensions of the problem:

- Different charges for different uses (location)
- How long will your network fees be in force?
- Charges on capacity or charges on energy?

Problem #1 – Commodity/capacity split (The popular problem)

Technical characteristics...

- Very high portion of the cost is investment cost
- Lumpy investment + economies of scale, which cause capacity to be in excess very frequently
- (Non-convex)

...Make usage tariffs conflictive

- If the tariff is set to the average cost of transmission
  - charges pay for the investments made...
  - ... but the excess capacity may be underutilized
- If the tariff is set to the marginal cost of transmission (much lower)
  - Ok for using optimally the existing capacity
  - but not enough money will be collected and therefore no line would be constructed

Solutions well identified for transmission

- If possible, long-term contracts
- If not, non-linear pricing (optimal pricing) – Aligns usage incentives with cost recovery (but it does deal with investment incentives)
- The traditional solution: two-part tariffs
  - High fixed cost, charged on capacity
  - Low variable cost, charged on actual use

Not so ok for distribution

- For retail markets, variable charges are in general much larger than variable costs
  - The assumption is that retail demand will change almost nothing upon changes in the access fee
  - A kind of Ramsey pricing: those who consume more will pay a larger share of grid costs
- But the first assumption is being challenged by distributed resources
  - Distributed systems are being rewarded as if they could save network costs, but they do not
  - In fact, quite often they are rewarded as if they could save also regulated subsidies
- Is this a problem?
  - Solutions identified and easy to design
  - Changes on their way
  - Conflicts in the transition

Problem #2 (different charges for different uses)

Consider an instance:
Expanding the distribution network by a wire alternative or installing a battery and thus deferring the wire-based solution?

Extreme solution #1

"There is no room for optimization since the influence of network costs on decisions is negligible" (the second best idea). In this case, where to build batteries is decided by network users without signals. As before, tariffs :

- Ramsey pricing
- Postage stamp

Shortcomings #1

Deciding whether the DSO should expand the distribution network (by means of a wire alternative) or a market players should install storage to defer wire alternatives is extremely difficult.

Extreme solution #2

"Grid optimization
needs to be enforced". In this case, all decisions are the responsibility of TSOs/DSOs. Thus,

- Batteries are installed directly by DSOs/TSOs

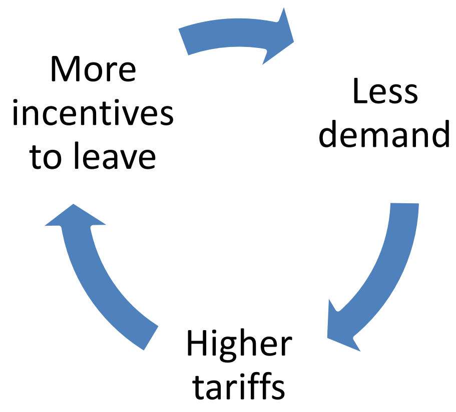
Shortcomings #2

There are elements that grid operators completely ignore. Without signals from network users it is difficult to know the needs for flexibility of the system

Alternatives to provide signals that allow competition of storage

- Use of an alternative strategy: "Define economic signals and let players decide" (Complex tariff design)
- Lack of economic signals is certainly in effect in the EU
- Introduction of at least locational signals
- Ideally, also flexibility signals

Problem #3 (different charges for different uses)



- Grid tariffs are hop-on-hop-off tariffs
  - Today's costs are paid by today's users
  - The assumption is that users will be stable (or growing) in time ("They have nowhere else to go")
- But this assumption is being challenged by the increasing potential to leave the market
  - Dismantling or mothballing of CCGT...
  - ... And self-consumption (solar, biomass), where storage plays a major role

Potential alternative designs

- Ideally, connecting to the grid should imply a commitment to pay for all of the network costs caused
- Example: Typical scheme for a private regasification facility
  - Access fee, charged on contracted capacity, committed for ~10 years
    - If stable demand of transmission, then reselling in the secondary market would be feasible with no loss
    - If reducing demand of transmission, then players should not leave without paying the network costs incurred for them
  - Complex when multiple facilities are in place
- At least three factors should be considered during the process of calculating the access fee for each market participant
  - Location in the grid
  - Use of the system (flexibility)
  - Time to enter the market (or to increase consumption)

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Summary of regulatory alternatives

	Revised mechanism	Solution to what problem	Services competing with storage
Market design			
Storage as standard product	Including storage as player in all auctions (energy auctions and ancillary services auctions)	Storage cannot compete with other energy sources (including demand response)	Energy sources
Reduce need for standardization	Implement power markets based on bilateral trading, with reduced need for auctions and hence for standard products	Standardization is difficult when services and technologies are rapidly changing	Energy sources

	Revised mechanism	Solution to what problem	Services competing with storage
Network regulation			
Capacity/commodity split	Network variable charges reflect variable costs	Many distributed sources are being rewarded as if they could save network costs, hence creating an extra cost for other sources as energy storage	Energy sources
Locational signals	Tariffs reflect the costs to the network associated with installation of equipment at different locations	Without economic signals, market players cannot decide the cost of storage when compared to wire network expansions	Wire network expansions
Grid defection	Grid connection represent commitment, so access fees are calculated according to capacity reservation	Grid defection leads to higher tariffs, which leads to more incentives to defect	Wire network expansions

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Final remarks

Regarding energy services

- US models are based on centralized trading (auctions)
  - That requires standard products, including those to trade storage
  - The challenge is to be able to innovate quickly enough...
  - ...or rely on regulated businesses (as utilities) to build storage
- EU systems may rely more on bilateral trading
  - The need for standardization is lower
  - Market payers may adapt more quickly to innovation

Regarding network services

- US models rely heavily on utilities (especially distribution) in charge of batteries installation – No signals to markets (it might be viewed as the "extreme solution #2" of problem #1)
  - Challenges are related to the difficulty of planning without all the required information
- Germany relied heavily on incentives to consumers to install batteries (it might be viewed as the "extreme solution #1" of problem #1)
  - Suboptimization of grid expansion is the main challenge

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Thank you

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