



# What are the prospects for electrical energy storage (EES)? Lessons from Europe and California

*Michael Pollitt*

*Judge Business School  
University of Cambridge*

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# Outline

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- With thanks to my student Francisco Ruz.
- EPSRC BEPP-Store Project
- A business model approach to electrical energy storage
- Market and regulatory design issues
- Capturing the value of electrical energy storage
- Examples from the UK and California

# Business Models

(see Teece, 2010)

Business models are about:

Value Proposition –

what services being sold and to whom?

Value Creation –

how will the service be created and provided?

Value Capture –

how will the value be monetised?

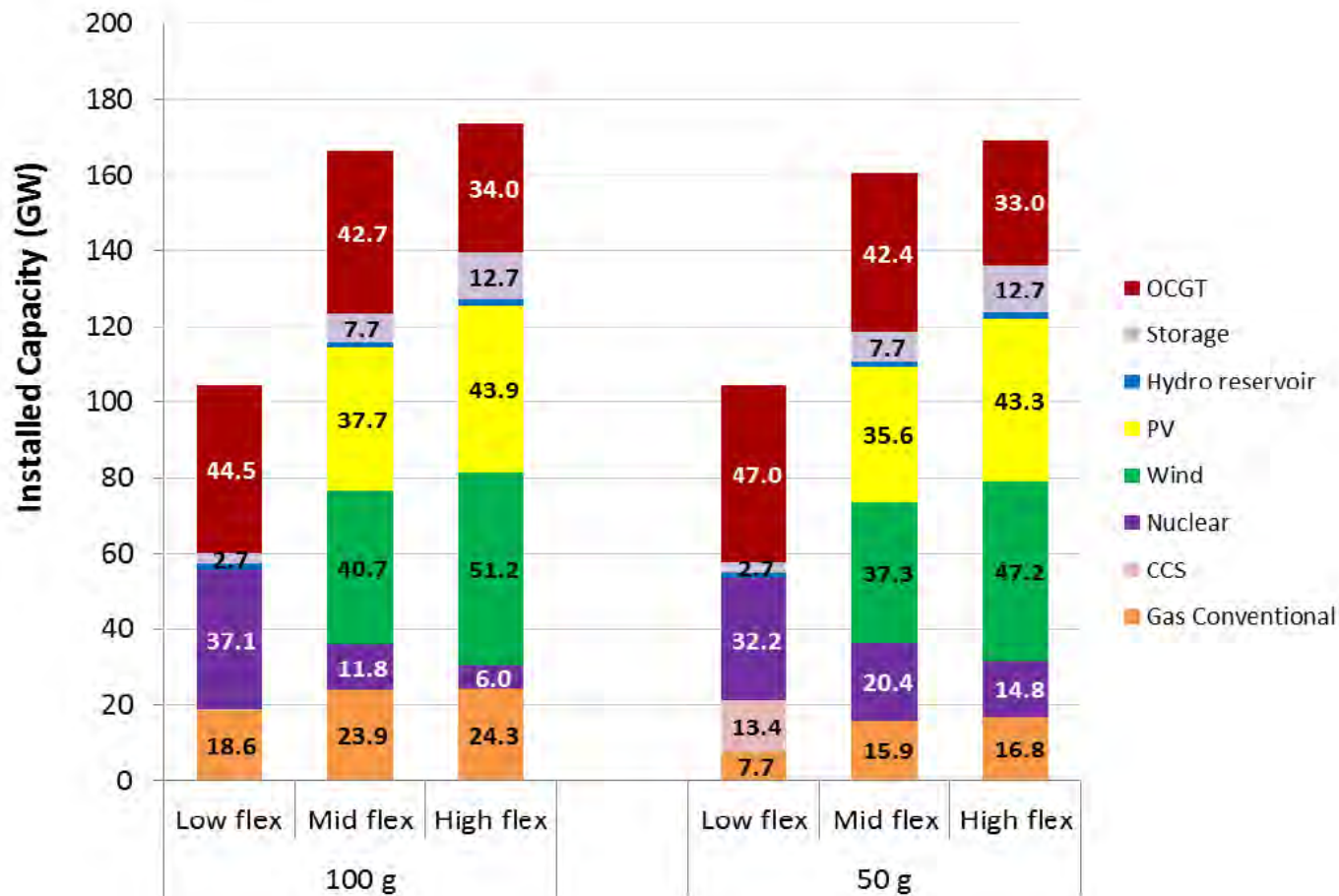
Business models are not just about pricing strategy...

Business models must add up in terms of risk-return payoff...

**Often they don't in smart energy...**

# A value proposition for storage?

## Impact of flexibility on the generation mix GB 2030



Source: Strbac et al., 2016, p.18.

# Optimal Storage on GB system

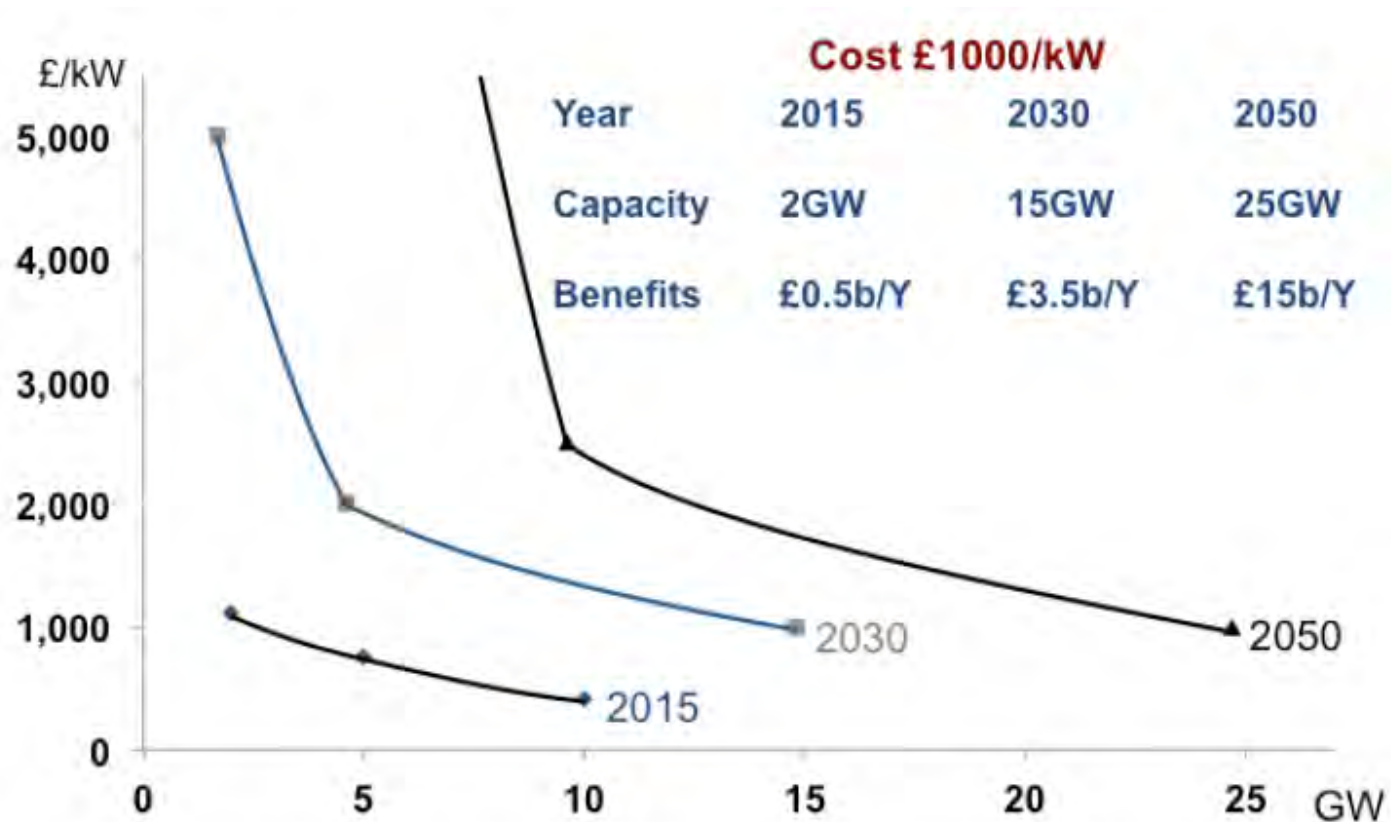


Figure 4: Optimal storage deployment levels for storage (x-axis) for different storage capital cost scenarios (y-axis) in the years 2015, 2030 and 2050.

Source: Strbac et al., 2016, p.23.

# Economic challenge in energy storage

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- Fossil fuel allows easy, flexible storage. It has high energy density and low decay, with relatively low capital costs per kWh stored.
- No-one demands storage as a final consumption good. What consumers want is continuity of supply quantity and quality. This they will pay a premium for.
- All economic processes seek to minimise storage and seek just in time matching of supply and demand.

# Barriers to a viable business model

- High fixed up front costs for storage versus multiple volatile revenue streams.
  - Volatility of returns to storage mean high cost of capital to compensate investors for increased risk.
- Stand alone storage businesses will face higher costs and lower ability to capture value than incumbents (generators, network companies and customers).
- Market design and regulation will determine the ability to monetise storage services.
  - We set these to support technologies we favour

# Market design issues

- Generators and retailers sell and buy defined products under license in electricity markets.
- Storage products need to be defined in order to allow them to be monetised. In general small facilities often excluded from directly trading in electricity markets.
- Historically, the system operator has directly procured response and reserve capacity from existing generators as by products, rather than used organised markets that would allow storage to compete.



# Regulatory barriers

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- These include definition of storage – is it generation or retail or something else?
- Regulated incumbent network companies may be able to include storage in their asset base, reducing the scope for non-regulated storage.
- Unbundling rules may mean that if network companies own storage they cannot dispatch it and must work through a third party.

# Some basic economics of energy storage

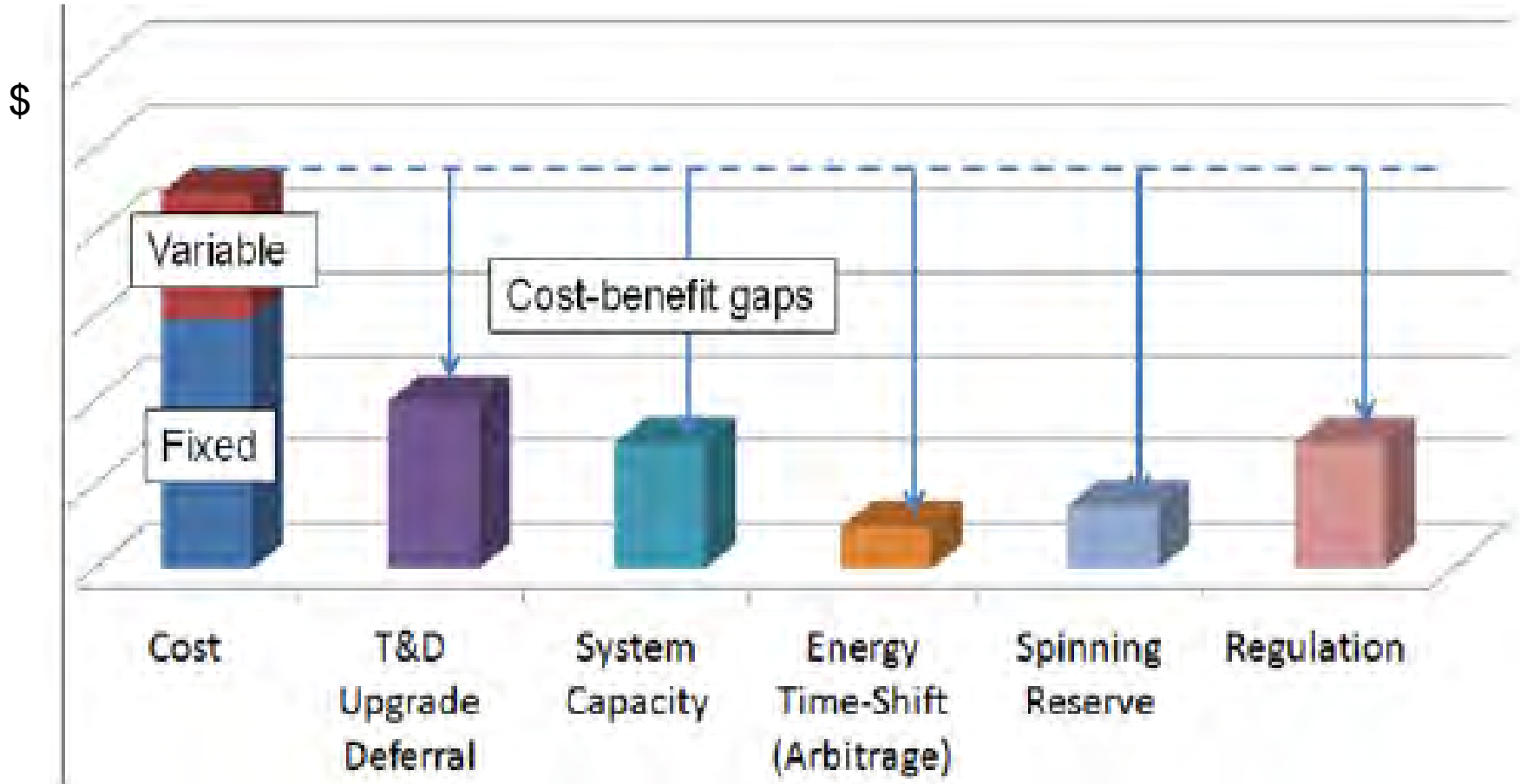
- High frequency of use storage is more profitable than seasonal storage, given high capital costs.
- Storage which relies on multiple sources of value faces higher transaction costs.
- More storage reduces the value of each additional unit of storage, meaning that if non-integrated storage is likely to be less than globally optimal.
- The value of storage will depend on what else is on the energy system in terms of storage, demand and generation.
- If storage is not about energy then residual fossil fuel systems will compete strongly with advanced forms of storage, in a so called sailing ship effect.

# Sources of value creation for electrical energy storage (EES)

Application	Definition
<b>Arbitrage</b>	Purchasing and storing energy when electricity price is low and selling it when the price is higher.
<b>Supply Capacity</b>	Deferring the cost of installation of new power plant or to "rent" generation capacity in the wholesale electricity marketplace.
<b>Load Following</b>	Serving as load following capacity that adjusts its output to balance the generation and the load within a specific region.
<b>Frequency control</b>	Changing output quickly to correct for unintended fluctuations in generation and load. It helps to maintain the grid frequency
<b>Supply Spinning Reserve</b>	Capacity that can be called upon in the event of a contingency such as the sudden loss of a generator. Three types: Spinning Reserve, Supplemental Reserve and Backup Supply.
<b>Voltage Support</b>	Maintaining the grid voltage by injecting or absorbing reactive power (VAR) that offsets reactance in the grid.

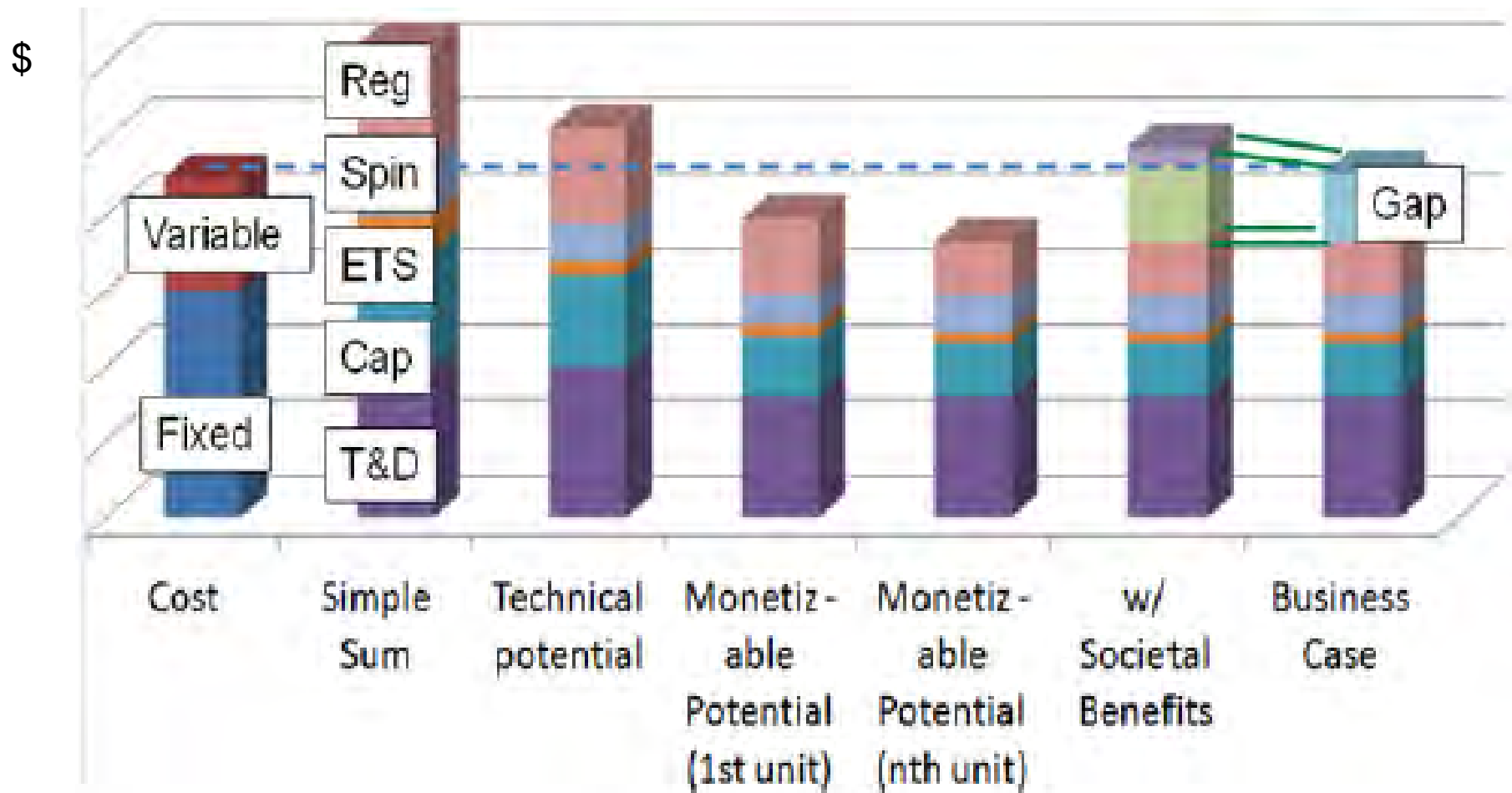
<b>Transmission VAR Support</b>	Enhancing the T&D system performance by providing support during the event of electrical anomalies and disturbances such as voltage sag, unstable voltage, and sub-synchronous resonance.
<b>Black Start</b>	Powering up a generating plant when the grid power is not available such as in blackouts.
<b>Transmission Congestion Relief</b>	Avoiding congestion related charges and costs when the transmission systems are becoming congested.
<b>T&amp;D Upgrade Deferral</b>	Energy storage could be installed to defer the installation/upgrade of T&D lines and substations where the grid is almost saturated.
<b>Service Reliability</b>	Back-up power systems at the utility side of the electric meter. Combination of batteries for momentary outages and diesel generators for longer duration outages.
<b>Power Quality</b>	Maintaining power quality when facing short-duration events such as variation in voltage and frequency or service interruptions.
<b>Renewable energies arbitrage</b>	Renewable resources do not align with typical peak load patterns. Having a storage device can provide a several advantages: (a) store and discharge renewable generation from low cost periods to high cost periods, (b) increase plant capacity factor.

# Sources of Value Creation for generic battery storage



Source: EPRI (2013, 2-2).

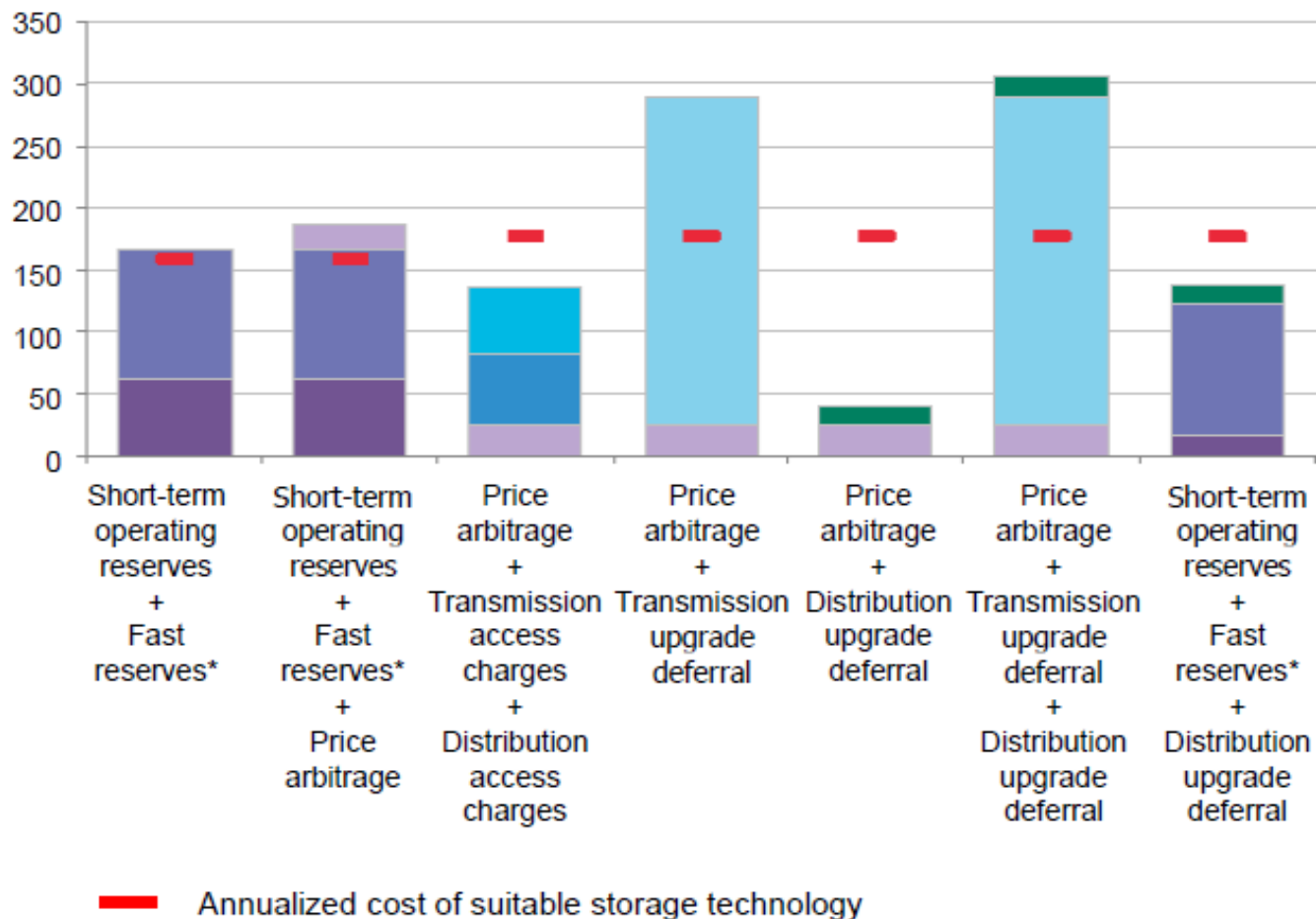
# Can value be captured?



Source: EPRI (2013, 2-2)

# Value capture in the UK

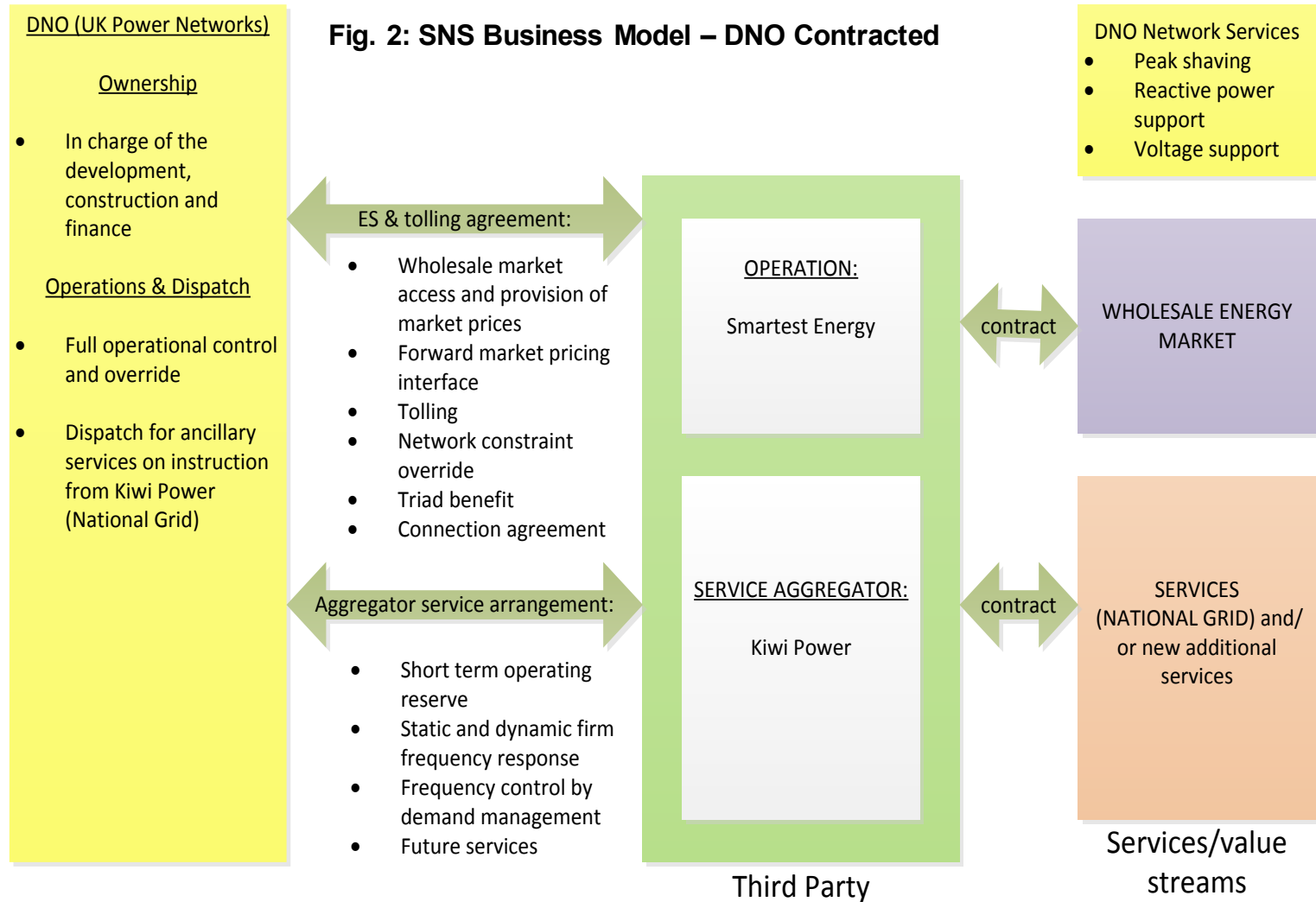
£ per MWh installed per year



Source: SBC (2013, 83).

# It's complicated: Business Model (an example): Smarter Network Storage by UK Power Networks

6MW / 10MWh of lithium-ion storage



Source: UKPN (2014a). Own elaboration.

# Electricity product markets need redesigned...

Service	The UK		Germany		Spain	
	Procurement	Remuneration	Procurement	Remuneration	Procurement	Remuneration
Primary Frequency Control	Tendering	Pay as bid	Tendering	Pay as bid	Compulsory	None
Secondary Frequency Control	-	-	Tendering	Pay as bid	Spot Market	Clearing price
Spinning Reserve	Tendering	Pay as bid	Tendering	Pay as bid	Spot Market	Clearing price
Voltage Control	Compulsory and tendering	Pay as bid	Compulsory	None	Compulsory	None
Enhanced Voltage Control	Tendering	Pay as bid	Bilateral Contracts	Pay as bid	Tendering	Regulated price
Black Start	Bilateral Contract	Pay as bid	Compulsory	None	Compulsory	None

**Table 1. Procurement and remuneration methods in the UK, Germany and Spain (Ministerio de Industria, 1998, 2009, 2014; Rebours et al, 2007; National Grid; regelleistung.net; Castro, 2013)**

National Grid will be contracting a new service launched in April 2016 – Enhanced Frequency Response (EFR) – a product to provide frequency response within 1 second.



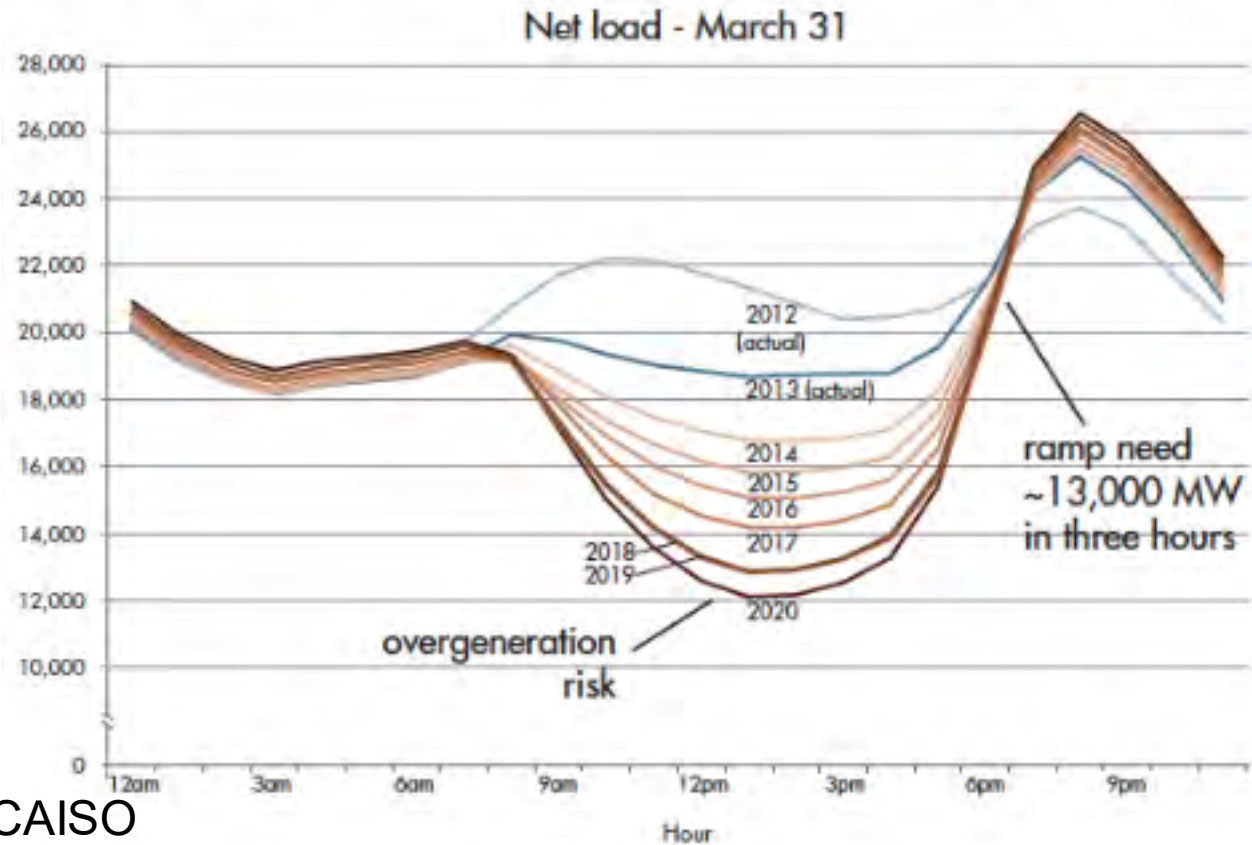
# Plans for storage in California

Utility	Point of interconnection	2014	2016	2018	2020	Total
SCE	Transmission	50	65	85	110	310
	Distribution	30	40	50	65	185
	Customer	10	15	25	35	85
	<b>Total SCE</b>	<b>90</b>	<b>120</b>	<b>160</b>	<b>210</b>	<b>580</b>
PG&E	Transmission	50	65	85	110	310
	Distribution	30	40	50	65	185
	Customer	10	15	25	35	85
	<b>Total PG&amp;E</b>	<b>90</b>	<b>120</b>	<b>160</b>	<b>210</b>	<b>580</b>
SDG&E	Transmission	10	15	22	33	80
	Distribution	7	10	15	23	55
	Customer	3	5	8	14	30
	<b>Total SDG&amp;E</b>	<b>20</b>	<b>30</b>	<b>45</b>	<b>70</b>	<b>165</b>
	<b>Total - all 3 utilities</b>	<b>200</b>	<b>270</b>	<b>365</b>	<b>490</b>	<b>1325</b>

Proposed energy storage procurement targets (MW) (Source: CPUC, 2013, p<sub>175</sub>)

# Driver of demand for storage in California...

Figure 2: The duck curve shows steep ramping needs and overgeneration risk



Source: CAISO

More extreme ramping, no reduction in system peak...

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# Conclusions on business model barriers to more EES

- **The prospects do look different in different jurisdictions.**
- **Inadequate definition and classification of EES** which results in EES treated as generation asset. This, together with the unbundling requirements, prevents EES from providing multiple services across the different levels of the power system.
- **Lack of markets** for some of the services that EES can provide such as black start and voltage control.
- **Inadequate market design** that does not reflect all the value that the asset provide to the system. EES can perform better than traditional flexibility providers but both are paid the same under the current market conditions.
- **The need for EES – i.e. the fundamental economics - to deal with flexibility issues is not clear** in some jurisdictions.

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