Economics and Policy of (Electrical) Energy Storage

Prof. Michael Pollitt
Judge Business School

UKES Newcastle

4 September 2019

With thanks to

- Karim Anaya and colleagues at EPRG, UKPN, NG, Ofgem.
- EPSRC Autonomic Power System (2011-16) – with Phil Taylor!
- EPSRC Business, Economics, Planning and Policy for Energy Storage in Low-Carbon Futures (2014-17)
- LCNF – Flexible Plug and Play (2012-14)
- NIC – Power Potential (2017-18)
- Ofgem – ITPR (2012-15), Targeted Network Charging Review (2017) etc.

Outline

- Some important economics
- Business model challenges
- Future market design and storage
- Policy questions

SOME IMPORTANT ECONOMICS OF STORAGE

Economic challenge in energy storage

- 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.
- Even if storage is ‘free’ it involves use of space, cycle degradation and price risk (so capital cost not really the issue).

Business Models for new technologies

(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…

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.

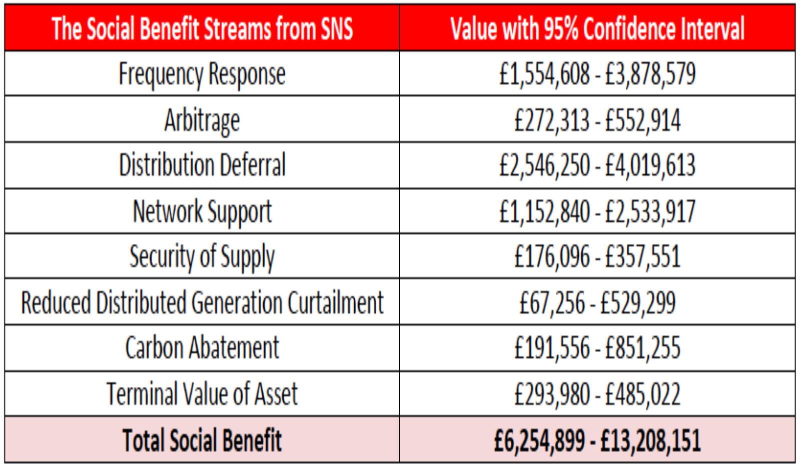
Some basic economics of energy storage

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

BUSINESS MODEL CHALLENGES

The value stacking challenge: the SNS project

Table 3: The Value of the Benefit Streams



The Social Benefit Streams from SNS	Value with 95% Confidence Interval
Frequency Response	£1,554,608 - £3,878,579
Arbitrage	£272,313 - £552,914
Distribution Deferral	£2,546,250 - £4,019,613
Network Support	£1,152,840 - £2,533,917
Security of Supply	£176,096 - £357,551
Reduced Distributed Generation Curtailment	£67,256 - £529,299
Carbon Abatement	£191,556 - £851,255
Terminal Value of Asset	£293,980 - £485,022
Total Social Benefit	**£6,254,899 - £13,208,151**

Figure 8: NPV of Identical Smarter Network Storage projects Installed in 2013

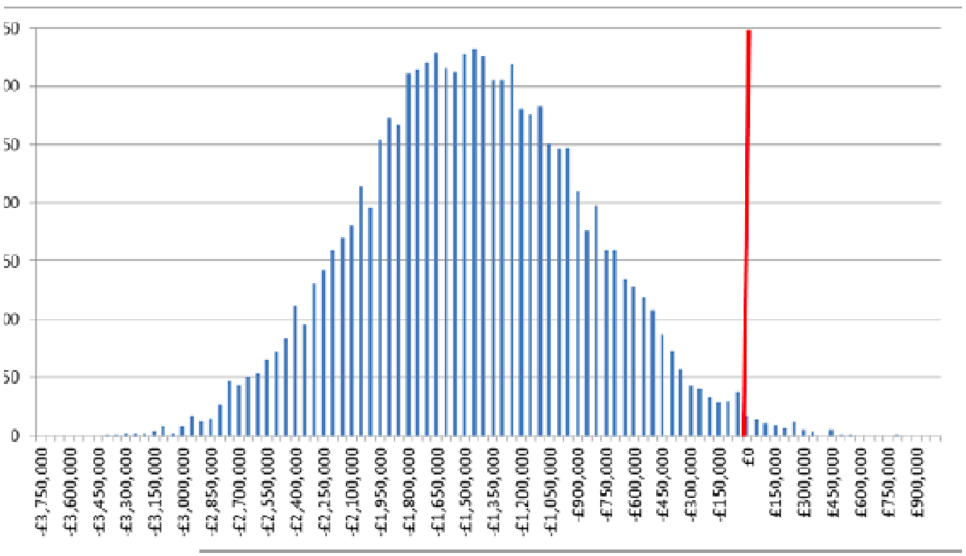
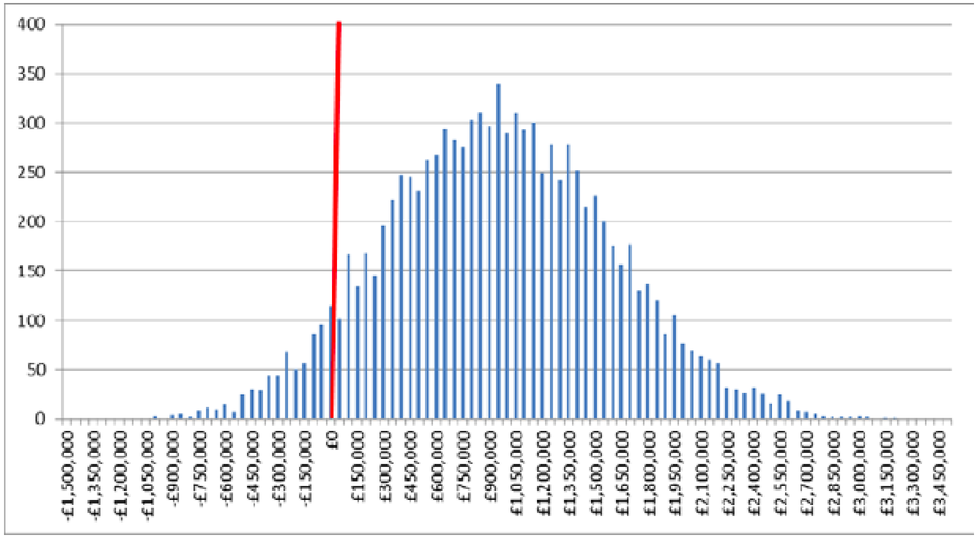


Figure 9: NPV of Identical Smarter Network Storage projects Installed between 2017 and 2020



6 MW/10 MWh battery
Leighton Buzzard

Source: Sidhu et al., 2018

Can storage exploit more price variation in time and space? Prospects for price differentiation

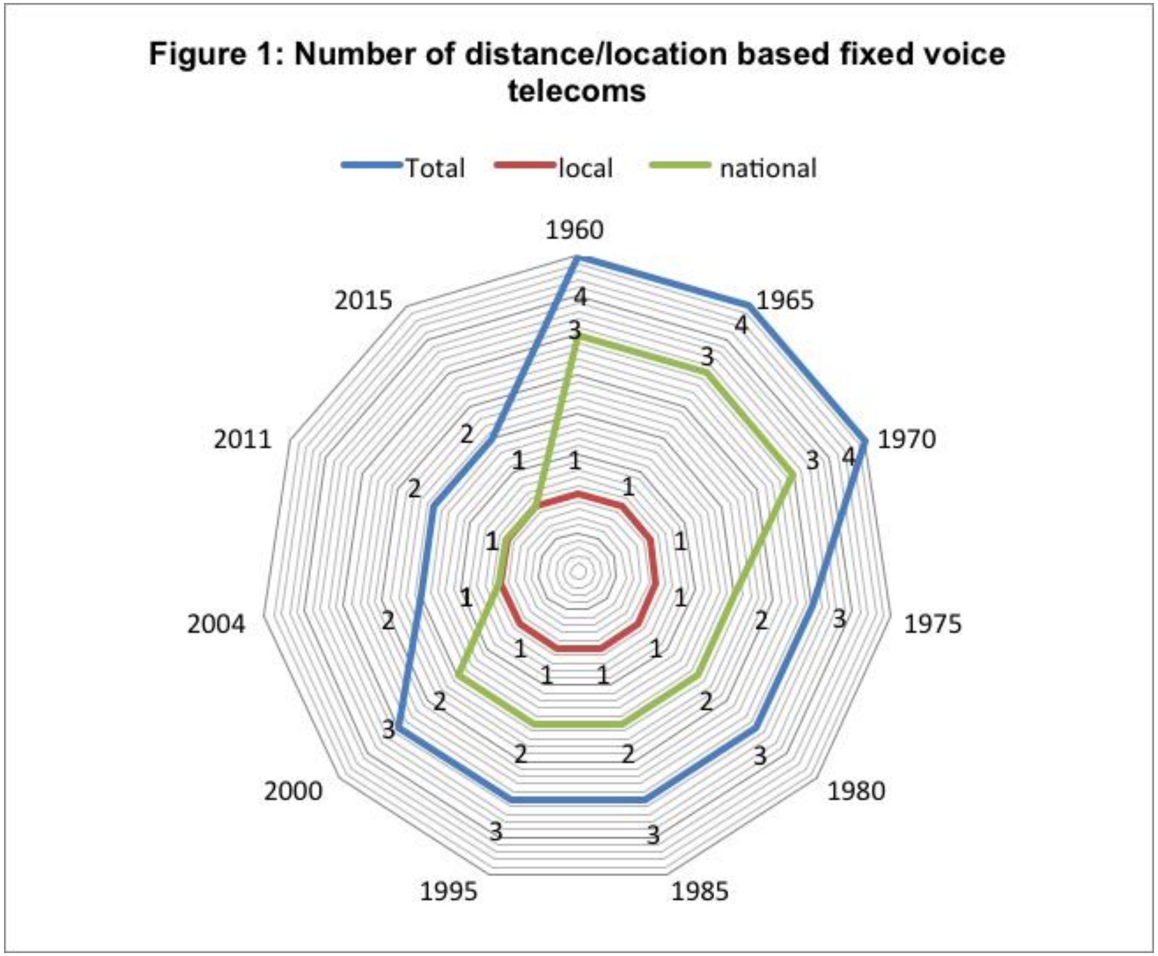


Figure 1: Number of distance/location based fixed voice telecoms

Source: Oseni and Pollitt, 2017.

We show, if anything time and distance price discrimination has declined since 1960.

This suggests that increasing price differentiation in final prices is unlikely.

Accessing the residential storage: willingness to provide energy services

- In a discrete choice experiment Richter and Pollitt (2018) find that customers ask for significant compensation to…
  - Accept automated remote control & monitoring
  - Share usage & personally identifying data
- They are willing to pay for…
  - Ongoing technical support & premium support services

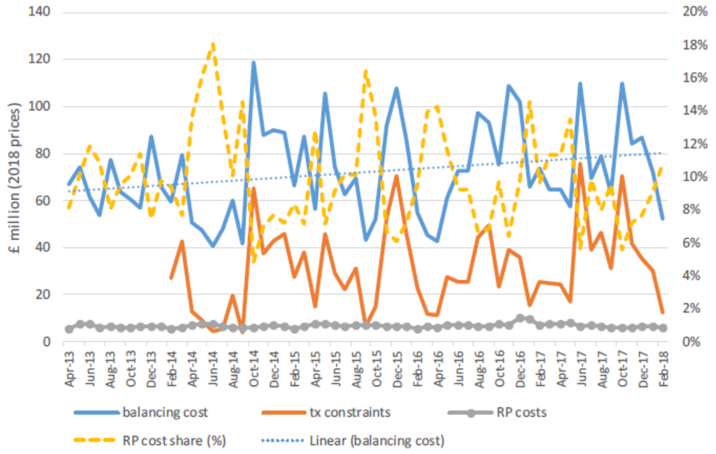
- The overall economics of offering smart services are challenging.
  - Need to offer £26.28 (2.19*12) up front, and then give 50% of savings, <u>so if company saves customer £100, then it gets £23.72 gross revenue.</u>
- Parsons et al. (2014) find similar sort of result for use of EVs to provide services.

- However it might be worth targeting subgroups of customers.

Pots of gold for storage?
Markets for ancillary services

- Is there a lot of money in ancillary services with more intermittent RES?
- Demand in GB has not risen much even though RES share has risen significantly.
- Prices have fallen for these recently due to increase competition, including from EES.

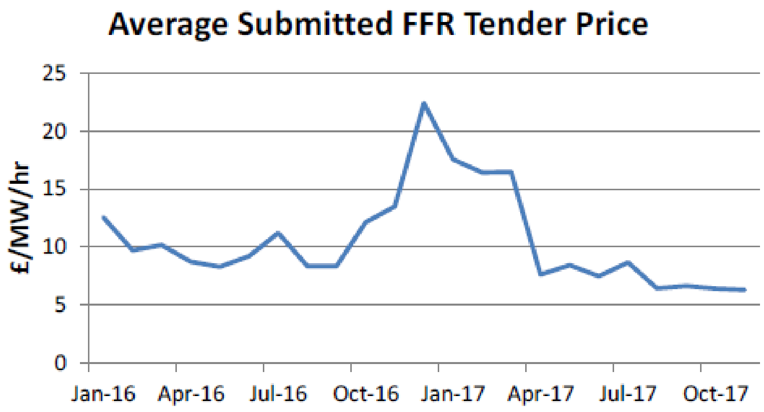
GB ancillary services costs

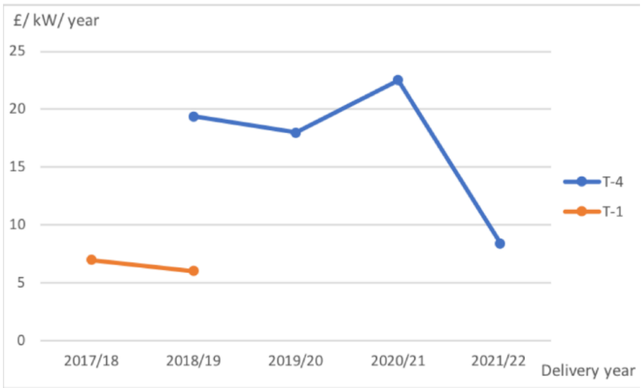


Source: National Grid monthly Balancing Services Summary, Office for National Statistics (ONS).

Source: Anaya and Pollitt (2018)

GB capacity market prices

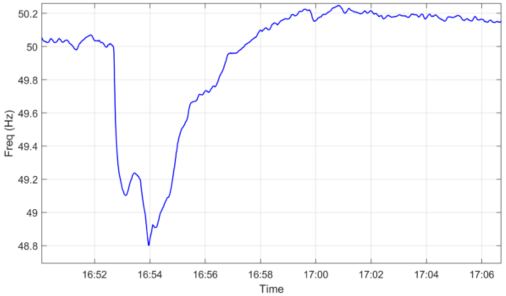




Source: Cathy McClay, National Grid

https://reneweconomy.com.au/wp-content/uploads/2018/02/uk-capacity-market.png

August 9th 2019 GB blackout analysis: value of more storage



Source: UKERC

- *System cost:*
  - Assume: 1000 MW of Tesla batteries
  - Cost £558m (at South Australia battery price)
  - Annualised at 15% per year (10 year life, 5% return)
  - Charge to 1000 MWh every day @ £50/MWh
- *Value of storage backup:*
  - Assume: Lost load 250 MWh @£10,000 / MWh (SO currently uses £6,000 / MWh, could be as high as £17,000 / MWh).
- Annualised cost: c.£100m; Value: £2.5m.
- Currently not worth it (at regulated return)…
- If capital cost falls, other revenue streams could be exploited, frequency of events rises ?

The challenge of network fixed cost recovery and storage (Pollitt, 2018)

- Any charging methodology for an electricity network has to deal with fixed cost recovery. Network users should pay *on same basis* unless working for network or behind meter.

- The rise of distributed storage offers increased opportunities to exploit the existing system of network charges in ways not originally envisaged.

- A significant issue is letting new investors in flexibility capture such a large share of the system benefits that they produce that no net benefit to existing customers.

Lessons from Non-Electrical Storage Experiences

(Anaya and Pollitt, 2019)

Natural Gas Storage	Frozen Food Storage	Cloud Storage
• To be worth: US$763.6 b by 2019, with underground SC of 16.2 trillion cb. feet. • Market leaders: USA (1st): 4.8 tr.cb.feet, EU: Germany, France, Italy (52%) • Ownership: multiple options depending on regulation (EU vs USA) • Type of products: physical and virtual gas storage, SBU/unbund. • Allocation methods: auctions (reserve prices, multiplier), bilateral, mandatory (EU countries): 3% (Czech R.) to 24% (Hungary) • Main concerns: Lower utilisation rate Decline in seasonal spread/short term price volatility Underrate: flexibility, security of sup.	• Frozen food global sales: US$297b (2019), 3.9% CAGR (2013-2019) • Global cold storage capacity 600 m.cb.metres (2016) lead by India, USA, China In USA: public cold storage with 75% share (vs public) • Growth driven by: household income, supermarkets develop., transport infrastructure • Benefits: waste food reduction: global costs: US$400b/year, 7% GHG, 3.3b ton/year • Type of products: storage only, and additional bundled services • Ownership: third party logistics, retailers, producers • Allocation methods: market forces (bilateral)	• Move to the cloud in imminent • Internet growth a key factor: Access (2016): 97% firms&50% EU pop., 6.2b dev. worldwide • Cloud storage growth in line with public cloud data centres - PCDC PCDC: 70% total storage cap., traditional ones: 12% by 2020. • Security bridge a main concern in cloud storage • Cybersecurity costs: US$6 trillion/year (up from US$400 b/year in early 2015). • Type of products: fixed storage plans based on size of storage (GB, TB) • Ownership: dominated by IT private firms (Google, Dropbox, Microsoft, Apple, Amazon) • Allocation methods: market forces (bilateral)

www.eprg.group.cam.ac.uk

FUTURE MARKET DESIGN AND STORAGE

Will the market design adapt to change?

(see Pollitt and Chyong, 2018, Chyong et al., 2019)

- Via further interconnection & market integration, extension of single market areas (e.g. in Europe).
- Batteries / demand side management (DSM) may save us!
- Subsidies will fall, renewables will get cheaper, marginal prices will still be set by fossil fuels a lot of the time.
- Limited, competitive, zero expected cost contracts for differences *may* sufficiently de-risk renewables.
- Sharper real time, locational, 5 minute prices
- Better ancillary services markets for reserve, security, frequency and voltage.

Or will there be a tipping point towards a new market design?

- Empirical question: at what level of renewables do we observe discontinuities in volatility of hourly and annual prices?
- These could be only at very high levels of intermittent RES which may not be likely before 2030.
- At this point widespread long-term contracting might be necessary and short term reserve prices cannot drive long run investment. At this point radical redesigns might be imagined:
  - Indeed internet-type quantity rationing of load in priority order under shortage conditions might be preferable to price based rationing.
  - A return to vertically integrated utilities or contractual versions of them, with negotiated short term arrangements.
- This requires modelling for markets like the European single electricity market (SEM) of how much storage is likely needed.

POLICY QUESTIONS

Some policy questions

- How should storage be treated by the regulator?
  - Should it be a network asset (fully or partially)?
- How should EES services be procured by the SO?
  - Via short term ancillary services markets
  - Or via long term contracts
- How should network charges be adjusted in the light of the presence of storage?
  - Network charges need to take presence of behind meter storage arbitrage as given
- How to limit storage gold rushes?
  - Don’t make same mistakes as for solar PV.
- When, if ever, to back particular technologies at scale?
  - Option value of waiting, risk of smart meter type disaster.

References

- Anaya, K.L. and Pollitt, M.G. (2018), *Reactive Power Procurement: Lessons from Three Leading Countries*, EPRG Working Paper, No.1829.
- Anaya, K.L. and Pollitt, M. (2019), ‘Storage Business Models: Lessons for Electricity from Cloud data, Frozen Food and Natural Gas’, *The Energy Journal*, Vol 40(S1): 409-432.
- Chyong, C.K., Pollitt, M. and Cruise, R. (2019), *Can wholesale electricity prices support “subsidy-free” generation investment in Europe?,* EPRG Working Paper Series No.1919.
- Oseni, M. and Pollitt, M. (2017), ‘The prospects for smart energy prices: Observations from 50 years of residential pricing for fixed line telecoms and electricity’, *Renewable and Sustainable Energy Reviews*, 70, April 2017, pp.150–160
- Parsons, G.R., Hidrue, M.K., Kempton, W., Gardner, M.P. (2014) ‘Willingness to pay for vehicle-to-grid (V2G) electric vehicles and their contract terms’, *Energy Econ.* 42: 313–324.
- Pollitt, M.G. (2018), ‘Electricity Network Charging in the Presence of Distributed Energy Resources: Principles, problems and solutions’, *Economics of Energy and Environmental Policy*, Vol.7, No.1, pp.89-103. http://www.iaee.org/en/publications/eeepinit2.aspx?id=0
- Pollitt, M. and Chyong, K. (2018), *Europe’s Electricity Market Design: 2030 and Beyond*, Brussels: CERRE.
- Ruz, F.C. and Pollitt, M. (2016), ‘Overcoming barriers to electrical energy storage: Comparing California and Europe’, *Competition and Regulation in Network Industries,* Vol.17, No.2., pp.123-150.
- Shaw, R. (2018), *The technical solution: DSO enabling DER contribution to transmission services, Presentation at Power Potential Industry Event*, 30 October 2018, https://www.nationalgrideso.com/sites/eso/files/documents/Main%20_slide_pack_0.pdf
- Sidhu, A., Pollitt, M. and Anaya, K. (2018), A social cost benefit analysis of grid-scale electrical energy storage projects: A case study, *Applied Energy*, 212 (15 February 2018): 881-894.
- Teece, D. (2010), ‘Business Models, Business Strategy and Innovation’, *Long Range Planning*, Volume 43, Issues 2–3, April–June 2010, Pages 172–194.