New Markets and Network Access Arrangements

Michael G. Pollitt

Judge Business School, University of Cambridge

Supergen Energy Networks

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- Karim Anaya and colleagues at EPRG, UKPN and NG
- EPSRC Autonomic Power System (2011-16)
- 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.

Issues for research

- The role of DSO/TSO/ISO in future electricity system

- Future energy and ancillary service market design
- Connection charging and incentives
- Local ancillary service markets

- Network charging principles
- Impact of PV, EV on charging methodology

- Business models and consumer preferences

Global network arrangements are diverse

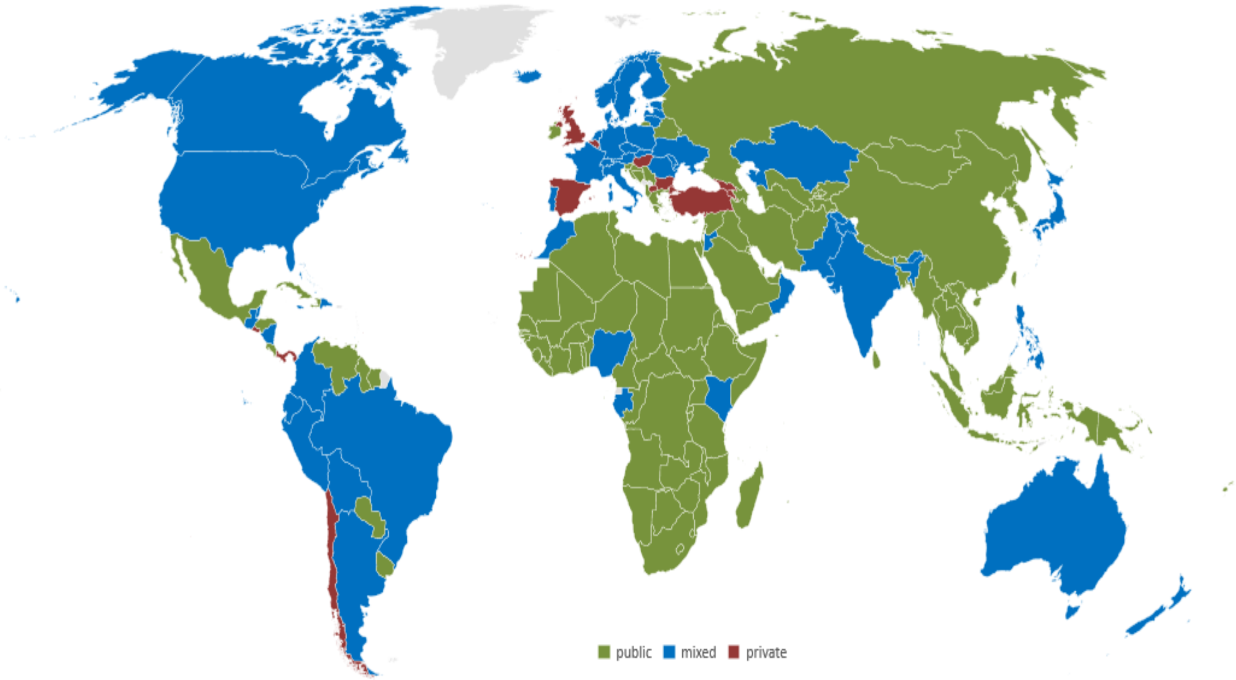


Fig.1 Ownership of the DSOs

Table 4

Summary of the legal structures of countries

legal structure	no. of countries
D	41
T, D	9
T, D, R	4
G, D, R	12
G, T, D, R	97
Other	12

S. Küfeoğlu, M. Pollitt, K. Anaya, “Electric Power Distribution in the World: Today and Tomorrow,” *EPRG, University of Cambridge, Working Paper*, 2018.

www.eprg.group.cam.ac.uk

DSO/TSO boundaries

- Countries highest highest distribution voltages (e.g. Russia 110kV)
  - UK – 132kV
  - US - 33kV
  - Germany - 110kV

- Countries lowest lowest transmission voltages (e.g. Chile 23kV)
  - UK – 275kV/132kV
  - US – 69kV
  - Germany - 220kV

Autonomic Power System: energy market design: Future zoning structure algorithm

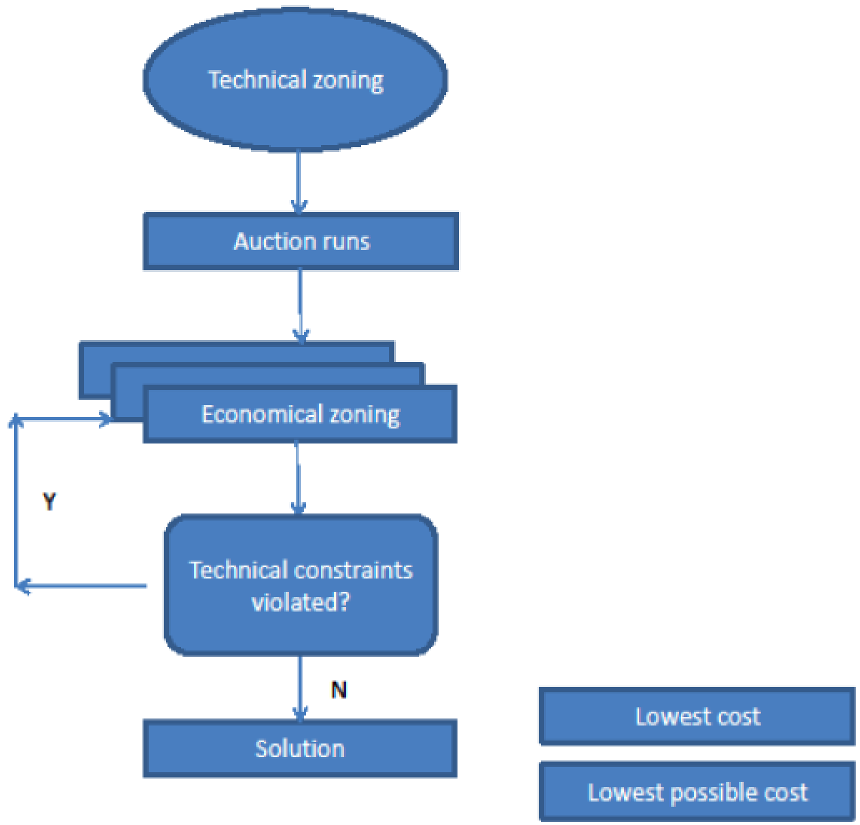


Fig. 3. Decision tree in distribution.

Source: Greve et al., 2016.

5000 nodes in GB
at 33kV/11kV boundary

Demonstrate how interaction of APS Self* Network Operation and Control (SNOC) and Economics might work.

Thoughts on A/S markets…

- Ancillary services (A/S) product definition needs to be clarified, too many ill-defined products.
- (T/D) SO needs to justify procurement quantities and express trade-offs transparently.
- Opportunities for gaming system may well exist and be increasing as the products become more important, especially if lack of penalties for creating A/S demand.
- Optimal contracts not currently clear because of the uncertain nature of the counter-party to the SO.
- DSO-TSO conflicts need to be resolved as DSOs increase their relative ability to supply A/S.

Work on auction design for Frequency Response (Greve et al., 2018)
Example 1: with one winning bidder
Different packages offered, auction clears, reveals less faster response

Table 10: Welfare effect

Response time (s)	SO (£/hour)	Supplier 1 (£/hour)	Supplier 2 (£/hour)	Welfare effect (£/hour)
1 and 1 and 1	25.2	17.2	17.0	+8.2
10 and 10 and 10	20.5	12.3	11.9	+8.6
1 and 1	20.1	11.8	10.7	**+9.4**
10 and 10	15.9	8.9	9.3	+7

Table 11: Welfare effect, without the winner

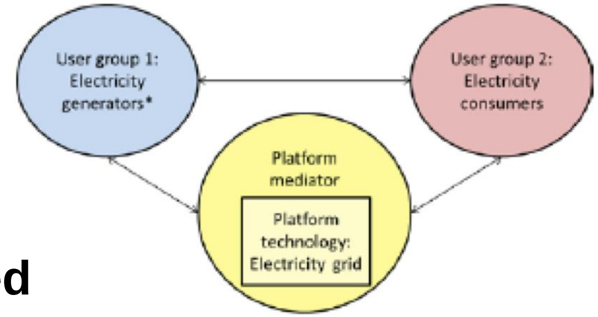
Response time (s)	SO (£/hour)	Supplier 1 (£/hour)	Welfare effect (£/hour)
1 and 1 and 1	25.2	17.2	+8
10 and 10 and 10	20.5	12.3	+8.2
1 and 1	20.1	11.8	**+8.3**
10 and 10	15.9	8.9	+7

Result: Winner (Supplier 2) receives £11.8, for delivering 2 MW of 1s response.

Chart 18: Electricity Service Platform markets - now and in the future

APS platform market design for local distributed energy resources

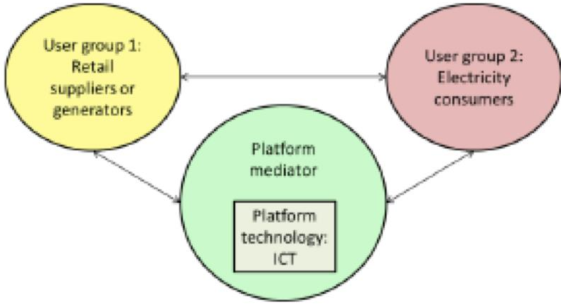
Drawing on 2 sided market platform economics



Platform mediator:
1. Market exchange
2. Transmission system operator (TSO)
3. Distribution Network Operator (DNO)
4. Energy supply company (ESCO)

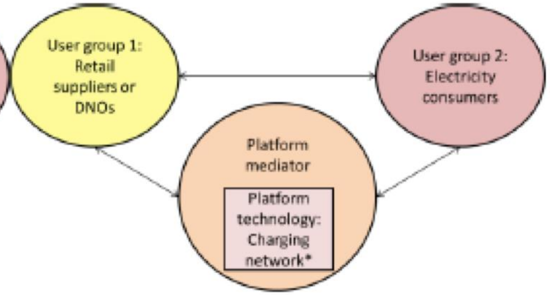
* Electricity generators can be owned by ESCOs

Figure 1. Platform in a traditional electricity market



Platform mediator:
1. Specialised *de novo* energy service company
2. ESCO
3. ICT or data management company
4. General service company (finance, retail, etc.)

Figure 2. Platform in balancing services market



Platform mediator:
1. Charging service company
2. Specialised EV aggregator
3. ICT or data management company

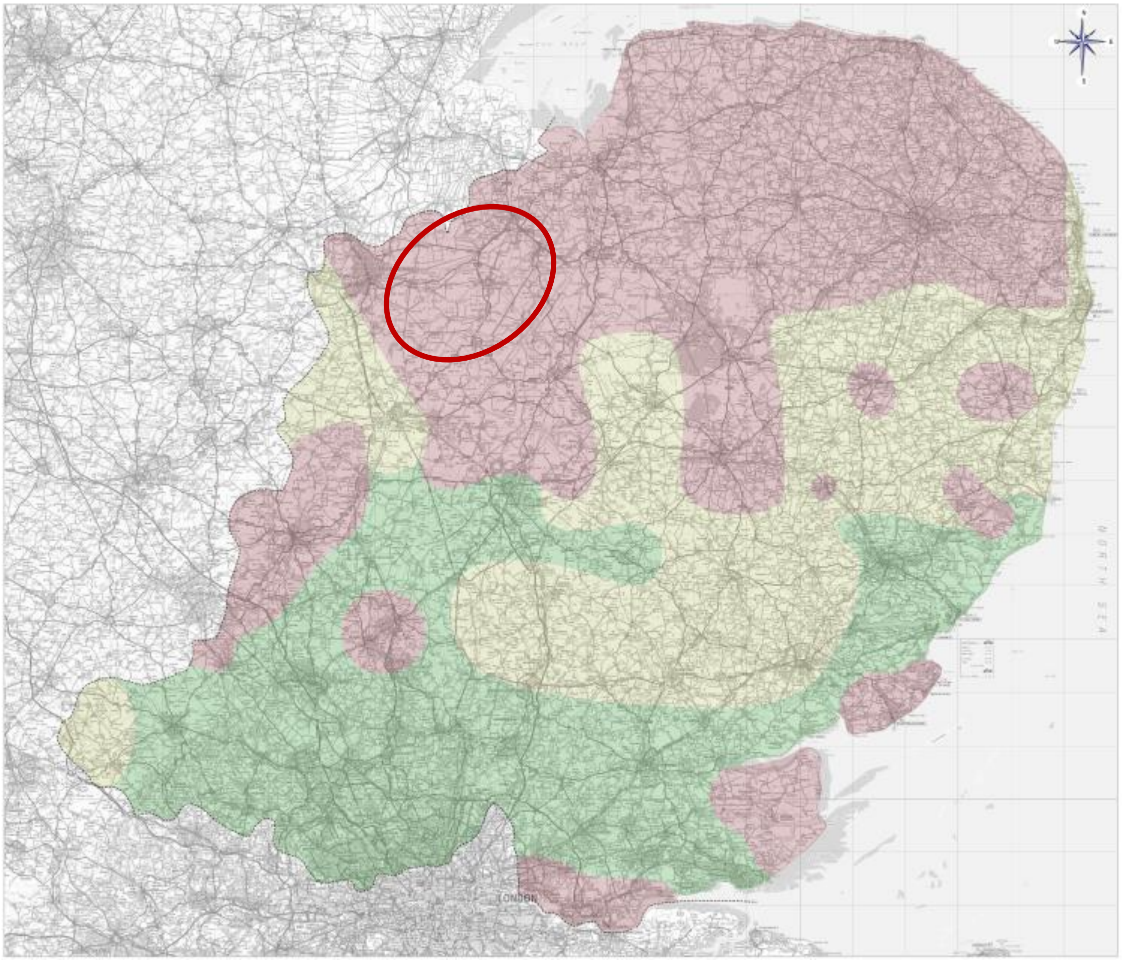
* The term "network" refers to the combination of ICT and hardware infrastructure

Figure 3. Platform in electric vehicle market

Source: Weiller and Pollitt (2013), p.28.

Connection charging: Cost Benefit Analysis of Smart Connection : The case of UK Power Networks - FPP Project (Anaya and Pollitt, various)

Figure 4: Heat Map of East Anglia



Courtesy of UK Power Networks

Constraints (33 and 11kV):

(1) Reverse power flow limitations
(2) Thermal line limits

700 sq. km Trial Area circled in red.

Connection offers for smart connection with Pro Rata curtailment, with maximum quota.

Highly utilised
Capacity available
Significant capacity available

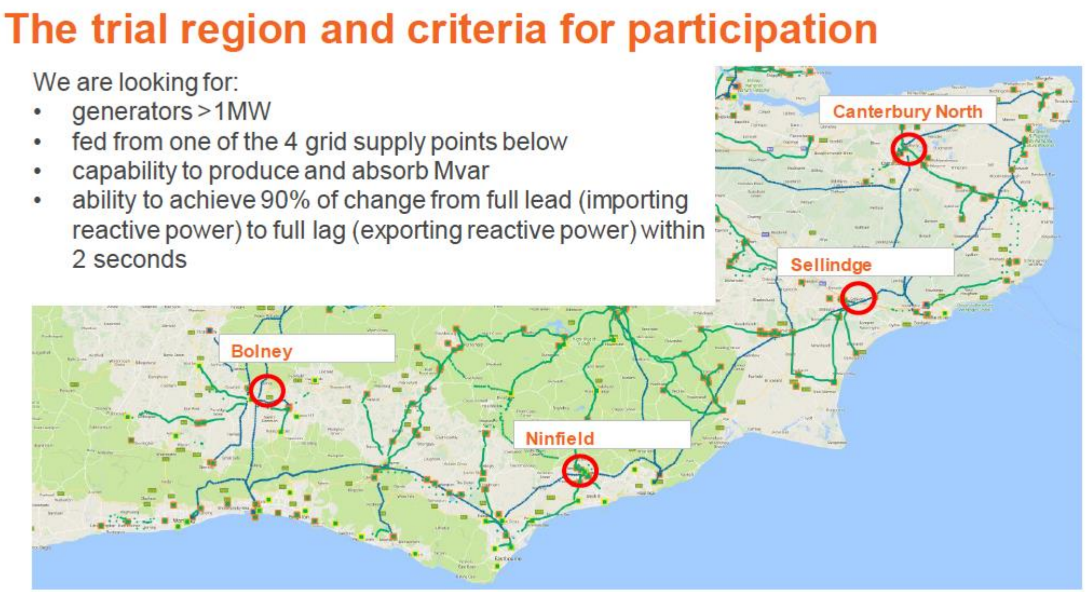
Ways to reduce connection costs: Flexible Plug and Play

- <u>Substantial benefits from smart connection</u> arrangements over conventional alternative for all generators below maximum available network capacity.
- Towards maximum available network capacity<u>, smaller generators might prefer to share reinforcement costs over smart connection.</u>
- <u>Pro-Rata curtailment may encourage too much connection</u> behind a constraint boundary.
- However there is <u>substantial value from smarter connection if it accelerates connection and early reinforcement.</u>
- This implies <u>Pro-Rata may be better than LIFO in medium run</u>.

- ***<u>Smart commercial arrangements need further investigation</u>, as the savings in costs and the benefit to DG acceleration appear to be substantial.***

- ***However <u>the benefits of faster, smarter connection need to be shared out better</u>, in a way that all parties (particularly DNOs and wider society) clearly benefit.***

NG-UKPN Power Potential Project –
DSO procurement of Reactive Power (RP) (see Anaya and Pollitt, 2018)



Source: Shaw (2018, slide 20), UKPN and NG

Power Potential initiative is consumer funded network innovation project:

- Trials technical/commercial solutions, new roles and new interactions.
- Identifies regulatory barriers that may limit the value of procuring RP competitively from DER at large scale.
- Create a regional market for RP as represented by a group of grid supply points (GSPs).
- Be a first mover in the procurement of RP using DER globally.

Reflections on local Reactive Power Markets

- Reactive power costs are currently small. (c.£80m p.a. for whole of GB)
- Are they about long term investment for competitive provision of RP?
- Or, are they about solving short term problems ahead of network asset investment?
- Can the liquidity of RP markets (or indeed any ancillary service market?) ever be comparable to energy markets? (see Pollitt and Chyong, 2018)
- Raises fundamental questions about optimal scale of markets and the ability to model prices (and to check the modelling of the system operator) in small markets in a way which gives investor confidence?
- There is a need to experiment, possible that technology makes better short term use of assets, while not really affecting the long term upgrade pattern of the network. This will yield some delay to investment benefit and ability to better handle uncertainty in network demand.

TSO – DSO relations with DSO responsibility for ancillary services (Kim et al., 2017)

- Set up: single TSO, multiple DSO areas.
- Easy to show, cost-causality based cost allocation scheme (CC-CAS) is superior to the current area energy-amount based cost allocation scheme.
- Fairly allocates DSO system balancing cost among multiple DSOs based on the cost-causality principle.
- Problem is that decentralisation is risky as DSO share of total balancing costs may be more variable.
- We propose an optimal balancing payment insurance (BPI) contract sold by the TSO which helps DSO hedge the risks associated with uncertain balancing payments.

Recovering network fixed costs:
Network Charging Principles (Pollitt, 2018)

- The **principles of how to charge for electricity networks are various.**
- Any charging methodology for an electricity network **has to deal with fixed cost recovery.**
- The **rise of DERs offers increased opportunities to exploit the existing system** of network charges in ways not originally envisaged.
- A final significant issue is the danger of letting new investors in flexibility capture such a large share of the system benefits that **they produce that no net benefit to the existing customers.**

Network Charging Principles

- **New uses of the network creates opportunities for reallocating charges to new users** and away from existing users who may be poor and/or vulnerable.
- In many cases we are **simply seeing the extension of well-known issues from higher to lower voltages on the network.**
- Hence **new dimensions to network charging** (such as per maximum kW export / import tariffs) **which already exist** at the transmission level at lower voltages, can be introduced.

Innovating charging models: solar PV and distribution of network charge payments in South Queensland, Australia

	Household A No air-con No Solar PV	*Household B Air con No Solar PV*	*Household C No air-con Solar PV*	*Household D Air-con Solar PV*
Maximum Demand (kW)	1.41	2.14	1.40	2.09
Metered import (kWh)	6253.4	7560.6	3820.1	4707.1
Solar Export (kWh)	0	0	2259.1	1838.8
Gross Demand (kWh)	6253.4	7560.6	6253.4	7560.6
Number of customers	283849	694643	26151	235357
% of customers	23%	56%	2%	19%
Base Network Tariff	$1006.14	$1171.37	$698.57	$810.69
Differences	A-C	B-D		
	$307.57	$360.68		

Note: Solar PV took off in 2009; charging basis 20% fixed, 80% per kWh import.
Source: From Simshauser (2014), p.22, Table 3. Modeled impact for 2014.

Clearly there is a case for regulatory action to change charging basis.

Impact of EV and PV roll-out (Kufeoglu and Pollitt, 2019)

- Significant redistributions of payment possible.

Table 8. Tariff per year per customer group, LPN & SHEPD

	LPN		SHEPD	
	Tariff (£ per year) 1% EV &1%PV	Tariff (£ per year) 50% EV &50%PV	Tariff (£ per year) 1% EV &1%PV	Tariff (£ per year) 50% EV &50%PV
no EV, no PV	68.43	56.26	144.14	126.96
EV, no PV	100.65	93.48	212.47	185.03
PV, no EV	52.20	43.71	117.23	104.09
EV, PV	84.41	80.92	185.55	162.15

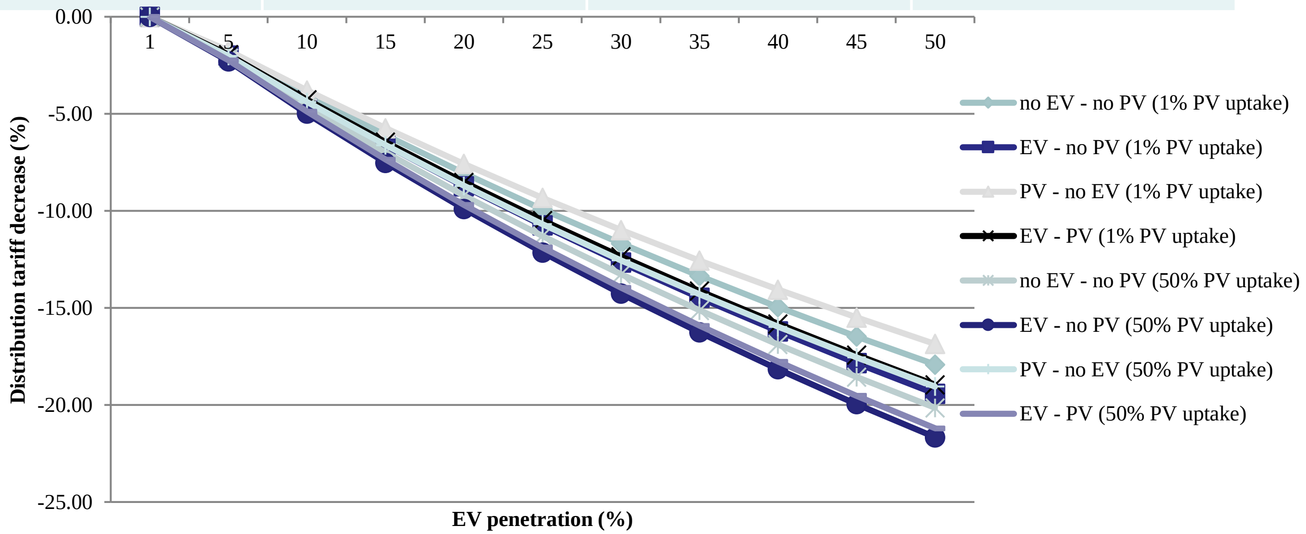


Figure 14. Distribution tariff variation in SHEPD with respect to EV penetration with 1% and 50% PV usage.

Future business models in energy (see Teece, 2010)

Business models are about:

<u>Value Proposition </u>–

what services being sold and to whom?

<u>Value Creation </u>–

how will the service be created and provided?

<u>Value Capture </u>–

how will the value be monetised?

Business models are not just about pricing strategy…

Business models must add up in terms of basic economics of risk-return payoff…

<u>Often they don't in smart (or even dumb) energy…</u>

Stacking Storage NPV

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

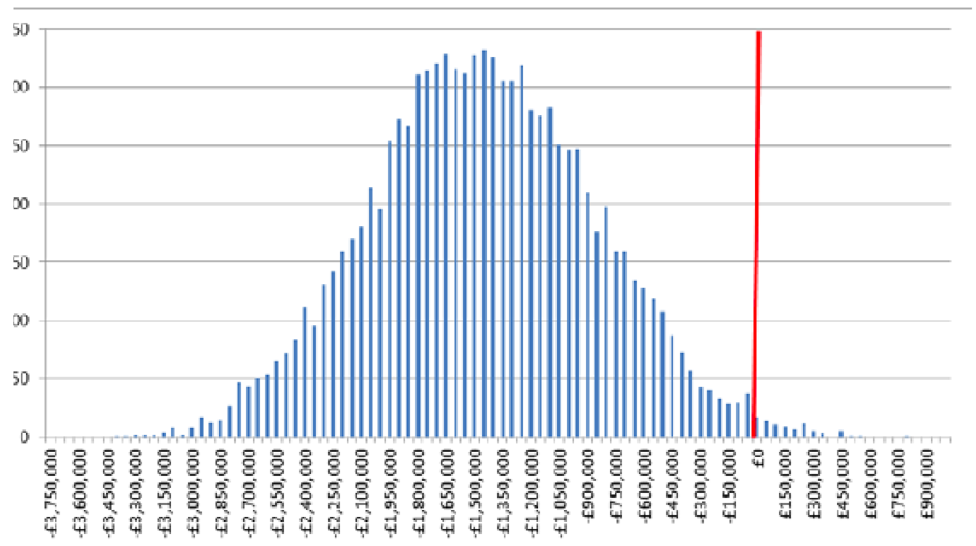
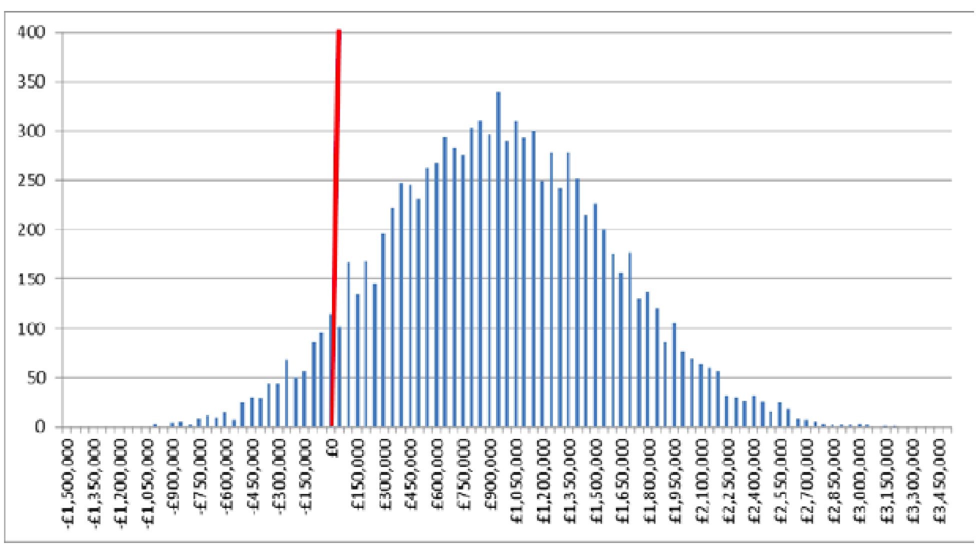


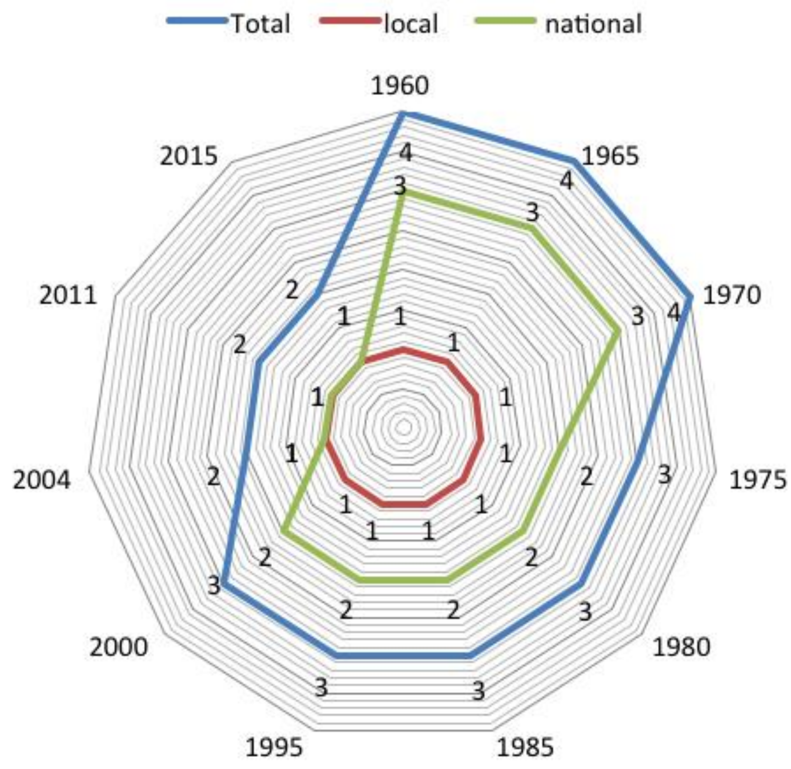
Figure 9: NPV of Identical Smarter Network Storage projects Installed between 2017 and 2020



Source: Sidhu et al., 2018

Smart energy prices: lessons from 50 years of telecoms pricing

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.

Regulating the System Operator: Lessons for GB (How would these apply to (D)SO?) (Anaya and Pollitt, 2017)

- Good regulation involves not only assessing the efficient amount of revenue that the ISO requires but also about the efficiency of its procurement methods (market-based) and system optimisation (procurement levels).
- Stakeholders play a key role in the proposal and design of detailed implementation rules for new initiatives for the best ISOs.
- Complex voting rules are observed and are worthy of study for the lessons they might have for GB.
- High level of internal and external oversight of ISO decision making is observed which is becoming more complex and subject to high levels of uncertainty.
- In electricity, State of Market Reports provide excellent examples of regular updates on key recommendations for future market design.

Concluding thoughts

- There is no clear right answer to future market and network charging arrangements globally, though there may be better answers for the UK.
- Economic principles important (as well as network physics) and these include equity and efficiency and customer willingness to pay.
- Price determination transparency and investability are important.
- Protecting the business model of incumbents and promoting the business models of entrants not the same and may contradict. NB. Promoting entrants per se not necessarily beneficial to final consumers.
- Lots of unsubstantiated claims about the future of energy systems are made which require careful theoretical/first principles consideration, case study evidence, cost benefit analysis.
- There is clearly much to learn from international experience as many other markets have the same issues.
- The future issues in networks most importantly include the decarbonisation of heat and what to do with the gas network. This looks an order of magnitude more challenging than decarbonising electricity.

Future Research

- Governance arrangements for Ofgem/BEIS/ESO
  - Future NIC/NIA
  - Promotion of learning from abroad
  - Investigation of governance arrangements
  - Competition between network and non-network solutions
- Use of big data
  - Promote research through data provision
  - Smart meter DCC?
  - Network condition data
  - LCNF/NIC data
- Impact on consumers
  - Consumer satisfaction tracking and assessment
  - Willingness to pay for additional services

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