Domestic and Small Scale Energy Storage Forum

January 2017

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Agenda

Chair: Merlin Hyman, CEO, Regen SW

14.00 **Registration, tea and coffee on arrival**

14.15 **Welcome and introductions from chair**
Merlin Hyman, chief executive, Regen SW

14.25 **Drivers for energy storage and flexibility services**
Johnny Gowdy, director, Regen SW
Olly Frankland Regen SW
Q&A

15.15 **Refreshment break**

15.45 **Domestic and small scale storage panel discussion**
Panel members include:

- Mark Dale, innovation engineer, Western Power Distribution
- Mark Smith, director, Wattstor
- Gabriel Wondrausch, managing director, SunGift Energy
- Alastair Gets, lead data analyst, Argand Solutions

17.00 **Refreshments and networking**

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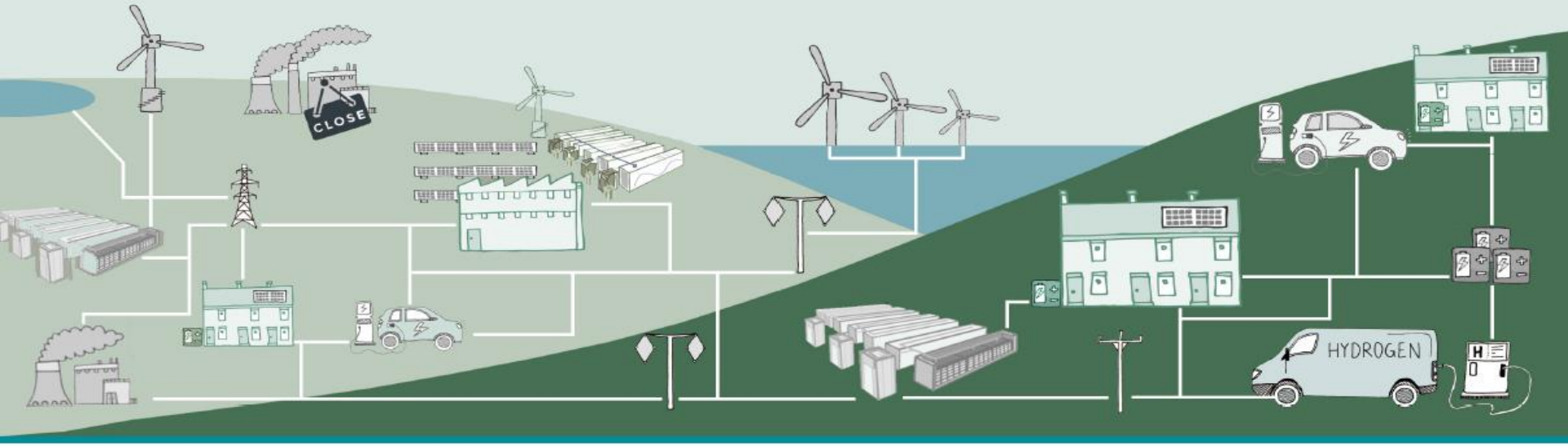
Pathways to Parity - Market insight series

Energy Storage - Towards a commercial model - 2nd Edition



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Solving the Rubik's Cube

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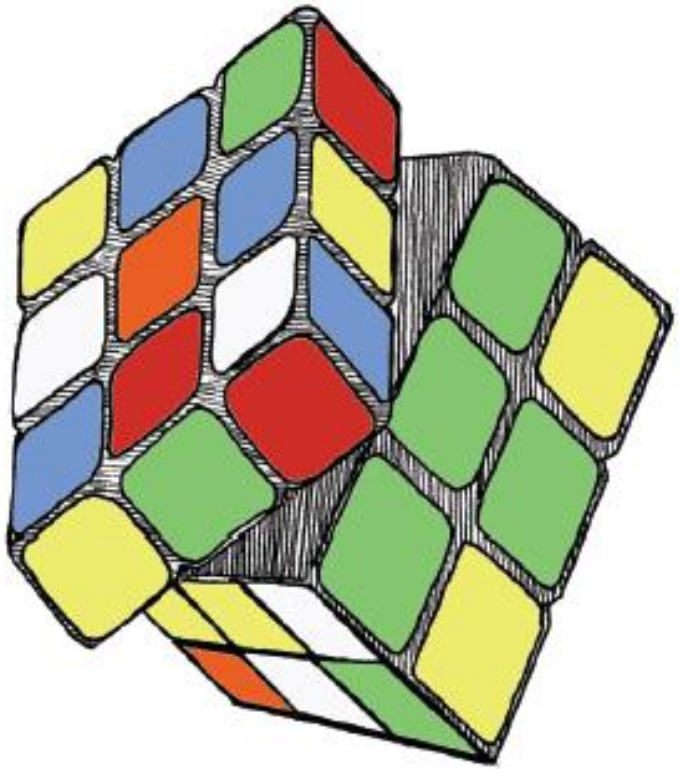
Route to market

Policy/regulation

Costs/finance

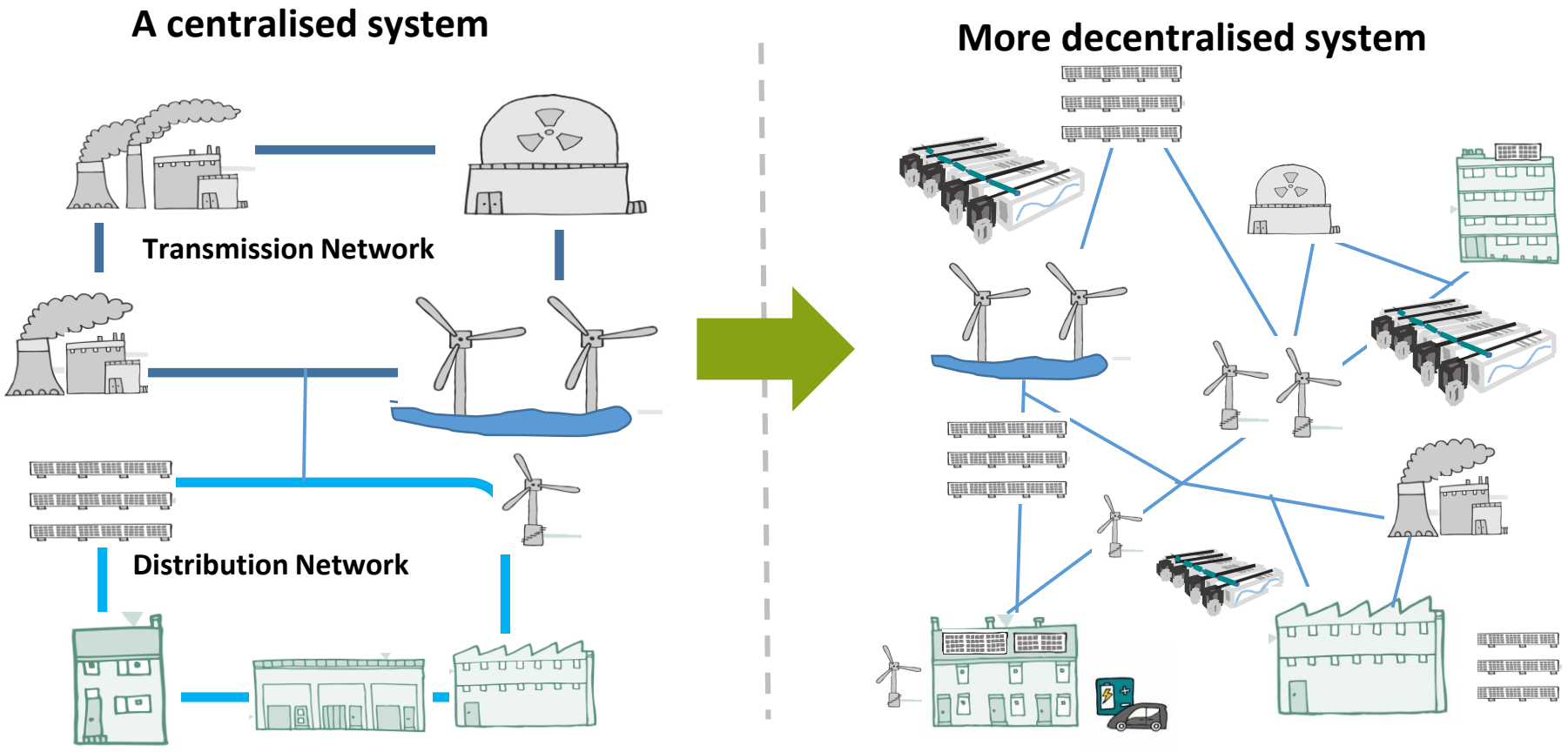


Technology

Timescales

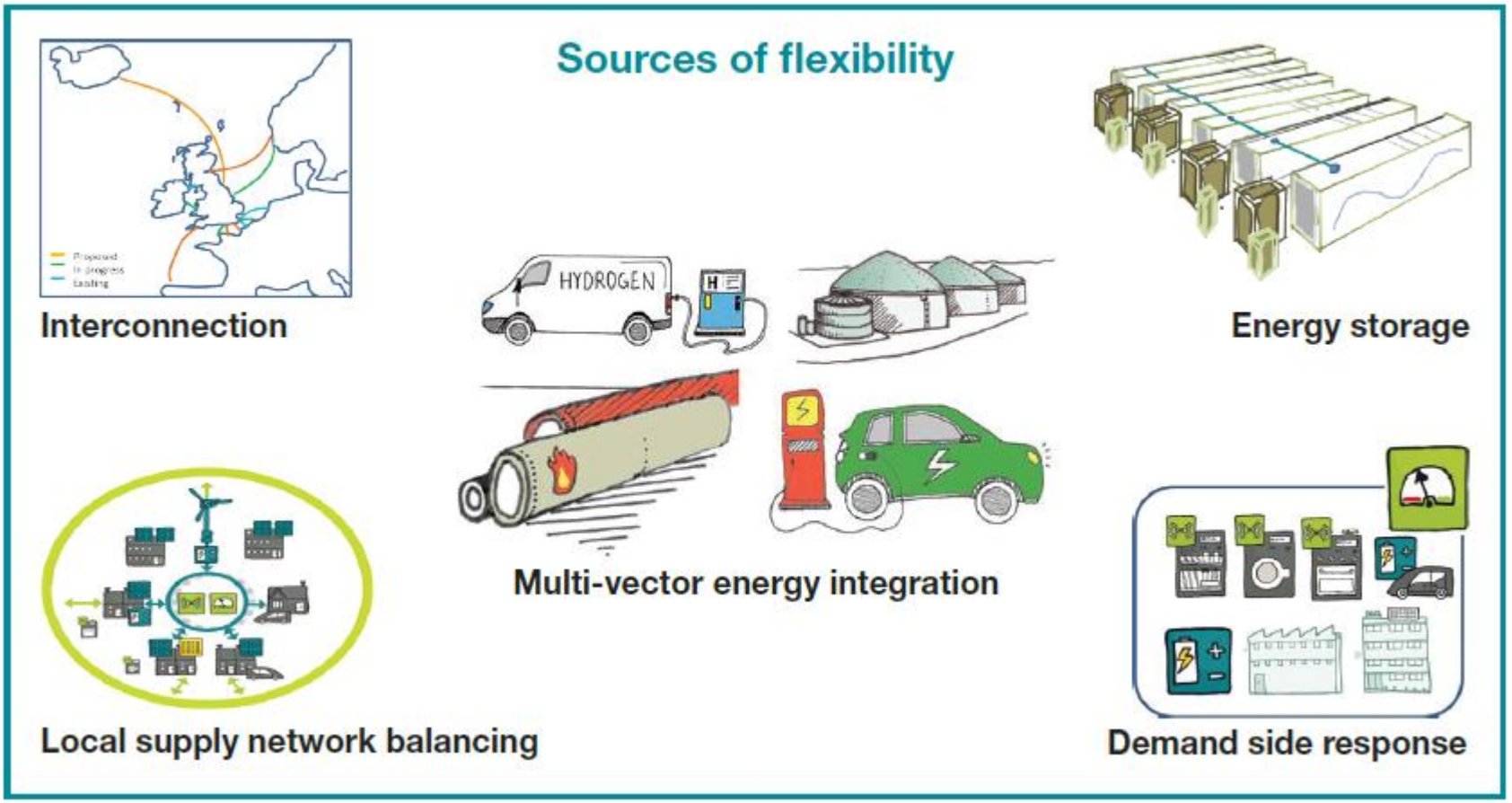
Revenue Streams

Energy system structural changes



"Our engineers say that 2015 was the last year we operated the system in the way it has operated for the past 50," he says. "The way we are operating now is fundamentally different." John Pettigrew Chief Exec. National Grid

Value of flexibility



"Three innovations will help us deliver greater flexibility – interconnection, storage, and demand flexibility – which have the potential to displace part of the need for new generating capacity, save money for businesses and domestic consumers and help the UK meet its climate reduction targets. The saving could be as large as £8 billion a year by 2030".

Lord Andrew Adonis, Chair, The National Infrastructure Commission[10]

The role of energy storage

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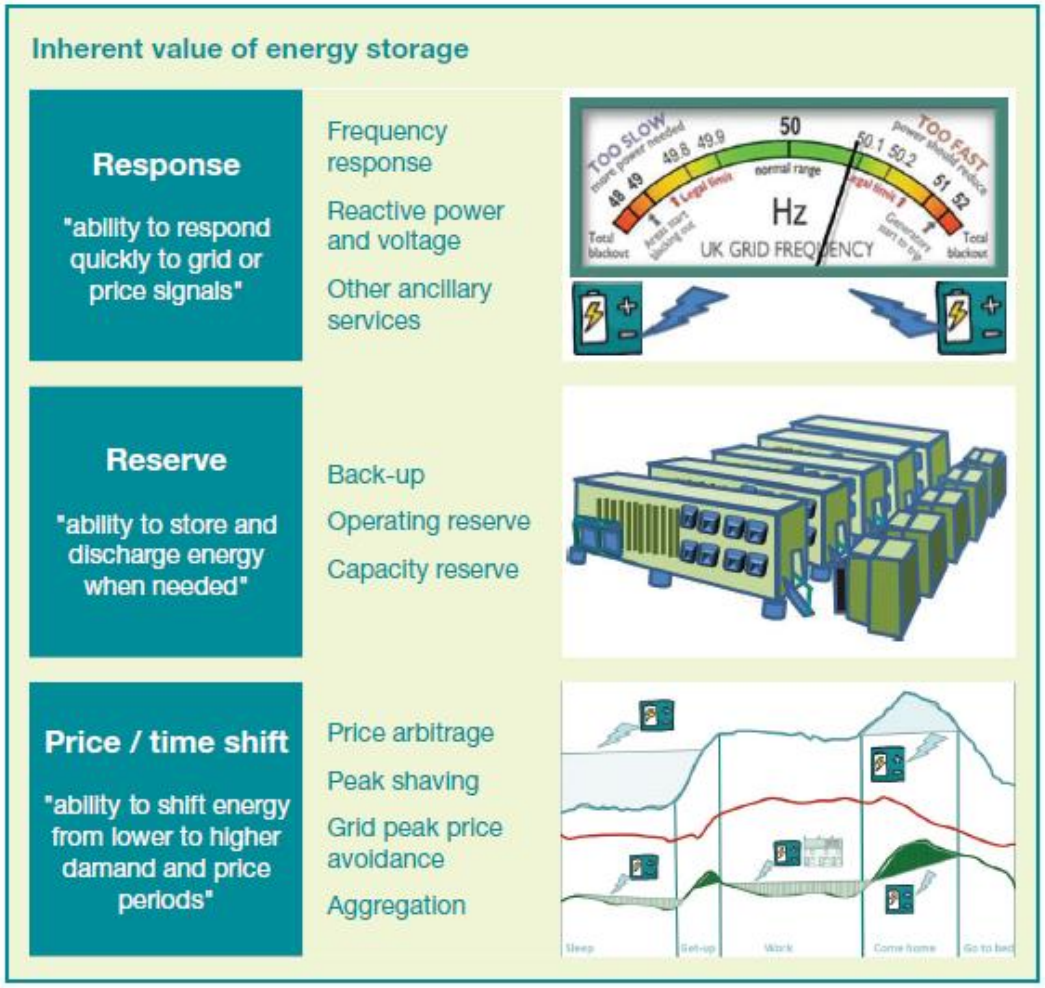

Response: The ability to respond quickly (milliseconds – minutes) to grid, frequency and/or price signals. Potential applications include the provision of ancillary network services such as frequency response and voltage support.

Reserve: The fundamental property of energy storage that enables the storage of energy to be used at a time when it is required. From a simple back-up capability for use as an alternative source of energy, to large scale capacity reserve and Short Term Operating Reserve.

Price and time shift: The capability to shift energy from lower to higher price/cost periods. A more sophisticated application of both reserve and response functions, allowing energy users and suppliers to take advantage of price variance (price arbitrage), avoid peak transmission and distribution costs and/or to recover energy that would be lost due to grid or other constraints.

Potential revenue streams

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	Major revenue stream	Route to market	Relative value	Market size*	Location options
Response	**Enhanced Frequency Response**	Tender (Auxiliary service)	High	200-700 MW	
Response	**Firm Frequency Response (generation or demand reduction)**	Tender (Auxiliary service)	High	2000-3000 MW	
Response	**Frequency Control by Demand Management (FCDM)**	Tender (Auxiliary service)	Med/high	??	
Reserve	**Fast Reserve**	Tender (Balancing service)	Med/high	250-600 MW	
Reserve	**Consumer backup power**	Contract	Variable	??	
Reserve	**Short Term Operating Reserve (generation or demand reduction)**	Tender (Balancing service)	Med	2-4 GW	
Reserve	**Capacity Market**	Tender - Capacity Auction	Med	GWs	
Time/price shift	**Transmission cost avoidance**	Market mechanism/cost avoidance	Med/high	GWs	
Time/price shift	**Distribution cost avoidance**	Market mechanism/cost avoidance	Med/high	GWs	
Time/price shift	**Generator "Own Use" (Domestic and non-domestic)**	Market via price/cost avoidance	Low	GWs	
Time/price shift	**Generator grid curtailment**	Market via price & subsidy revenue gain/reinforcement avoidance	Low/mid	GWs	
Time/price shift	**Price arbitrage (& peak shaving)**	Market via price variance/trade	Low	GWs	

Transmission grid connected

Distribution grid connected

Potential demand side response or behind the meter

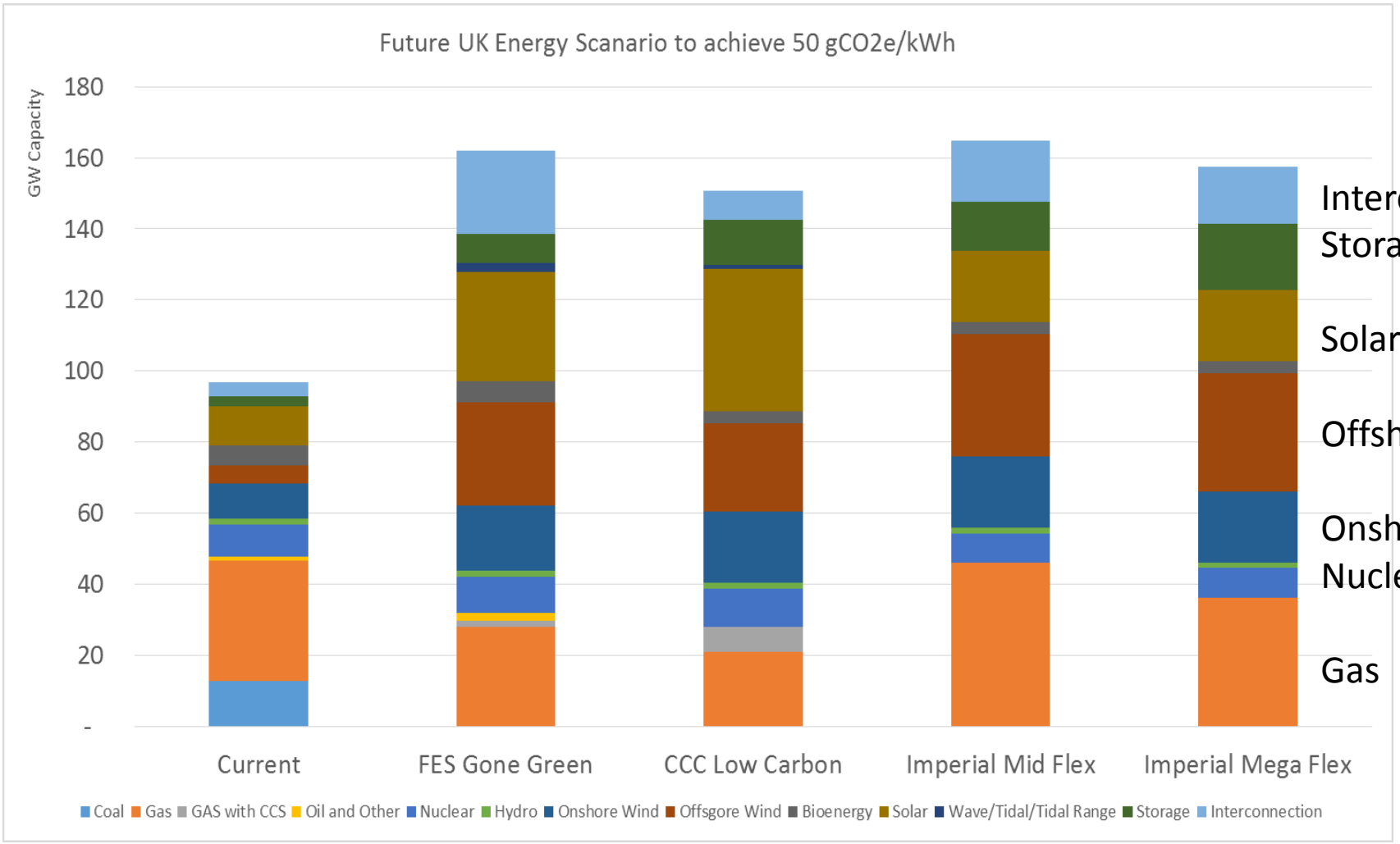
Co-location with renewables benefits

Table adapted from a number of sources including National Grid Future Energy Scenarios 2016

Emerging business models

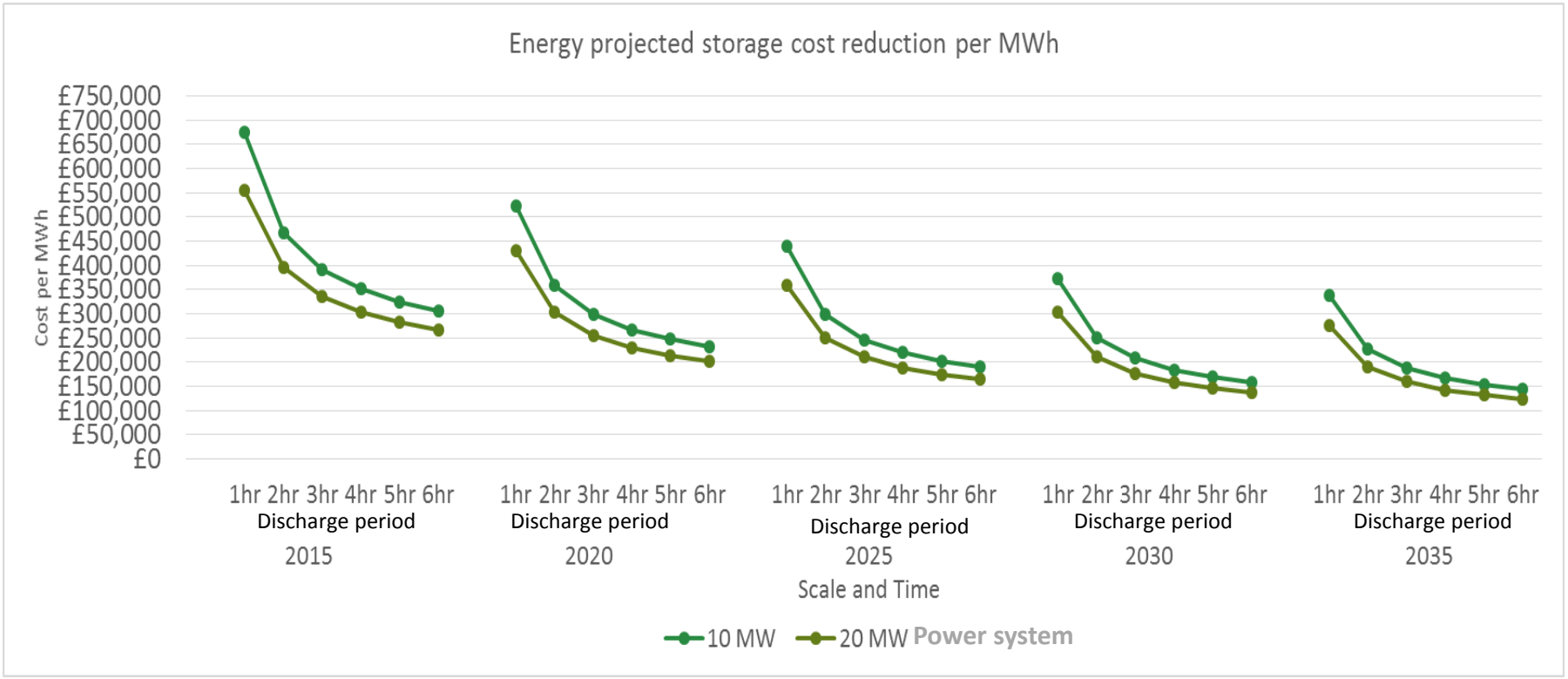
Response service	EFR and/or FFR	Combined with Embedded benefits (mainly TRIAD)	Combined with Capacity Market
Response service	STOR Peak Generation	Potentially combines with peak network charge avoidance and arbitrage	
High energy user "behind the meter"	With generation maximise own consumption	Peak Demand reduction appears as DSR	Sized for export for embedded benefits TRIAD and DNuOS
Domestic and community "own use" with PV	"Simple" maximise own consumption	Price sensitive Time of Use / variable Export Tariff	Peer-to-peer, virtual or private wire – micro grid
Generation co-location	Generation Time/price transfer	With grid curtailment	Winter use CM stress and Embedded
Energy trader	Arbitrage Time/price transfer	Aggregation	Market platform trader

Storage will be essential for UK energy mix



UK Electricity Generation scenarios to achieve 50gCO2e/kWh

Rapidly falling storage costs



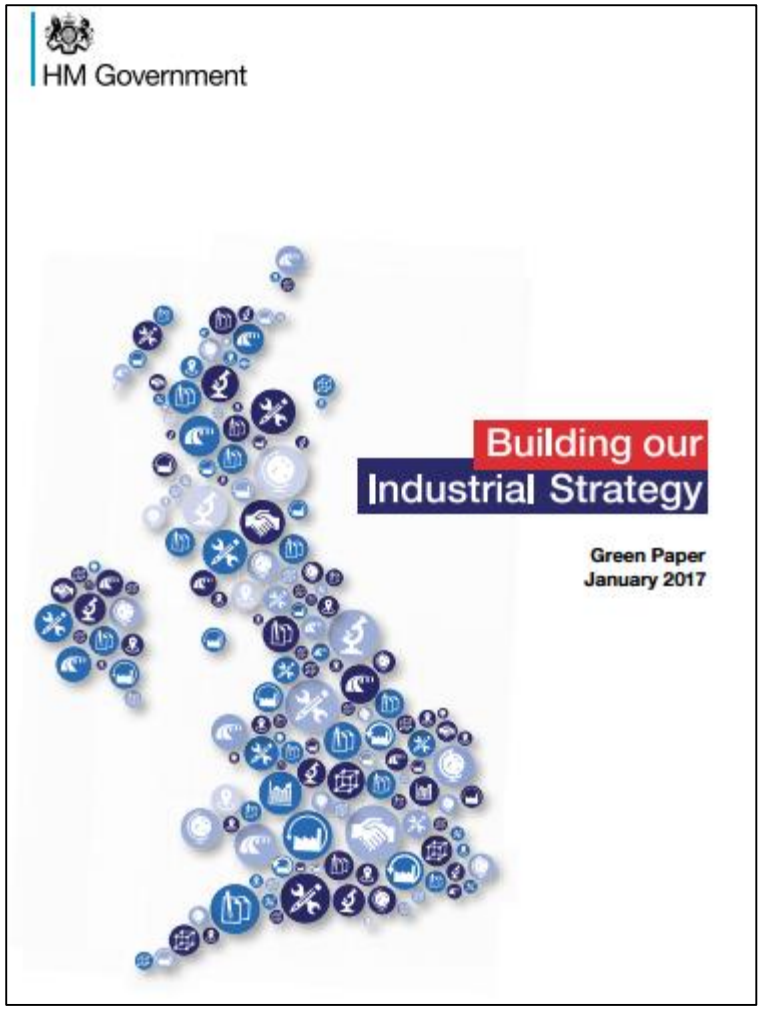
Potential Storage Market Scale

Business model	GB market scenario growth scenario by 2030 High Growth Scenario	Slower growth Scenario	Possible upside very high growth scenario
Response service	2 GW 2 GWh	0.5 - 1 GW 0.5 - 1 GWh	2 - 3 GW 4 - 5 GWh
Reserve Services*	3-4 GW 10-15 GWh	2-3 GW 6-10 GWh	4-5 GW 15-20 GWh
C&I high energy user & behind the meter	2.5 - 4 GW 10 - 16 GWh	0.6 - 1.2 GW 2.5 - 5 GWh	5 GW 20 GWh
Domestic and community own use with PV***	1.5 - 2 GW 6 - 8 GWh	0.37 - 0.75 GW 1.2 - 3 GWh	3 GW 12 GWh
Generation co-location	2 GW 6 - 8 GWh	0.5 - 1GW 2-4 GWh	4 GW 16 GWh
Total GB market	10 - 14 GW 30 - 50 GWh	5 - 6 GW 10 - 20 GWh	15-18 GW** 50- 70 GWh

* Larger scale specifically targeting capacity market, STOR and fast response services

** At very high growth levels the risk of revenue “cannibalisation” increases

UK Industrial Strategy

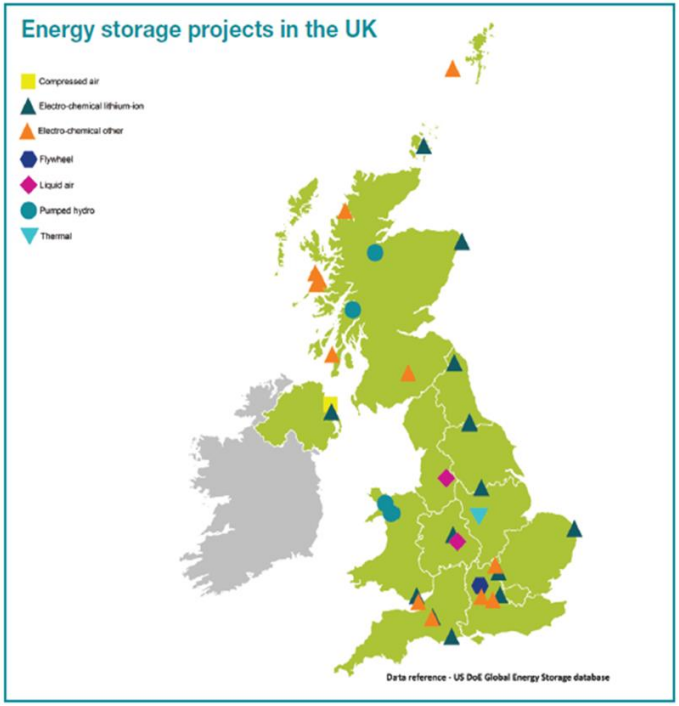


'Given the UK's underlying strengths in science and energy technology, we want to be a global leader in battery technology'

'Battery technology is of huge importance to a range of new technologies, including the automotive sector, smart energy systems and consumer electronics'

'Government has also asked Sir Mark Walport, the Government's Chief Scientific Adviser, to consider the case for a new research institution as a focal point for work on battery technology, energy storage and grid technology.'

£9m innovation funding



Funding for energy storage cost reduction and feasibility studies

Government has launched a competition with up to £9 million available to reduce the cost of energy storage technologies (including electricity storage, thermal storage, and power-to-gas technologies). This includes a further £600,000 to support feasibility studies for a potential first-of-a-kind, large-scale future storage demonstrator.

1. Feasibility study competition

2. Cost reduction competition

Registration by **16 March** 2017 or **1 June** 2017

Eligibility = large-scale storage 1MW/1MWh + [1]

[1]BEIS, 2017 https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems#funding-for-energy-storage-cost-reduction-and-feasibility-studies

Storage projects bidding into EFR and Capacity Market auctions

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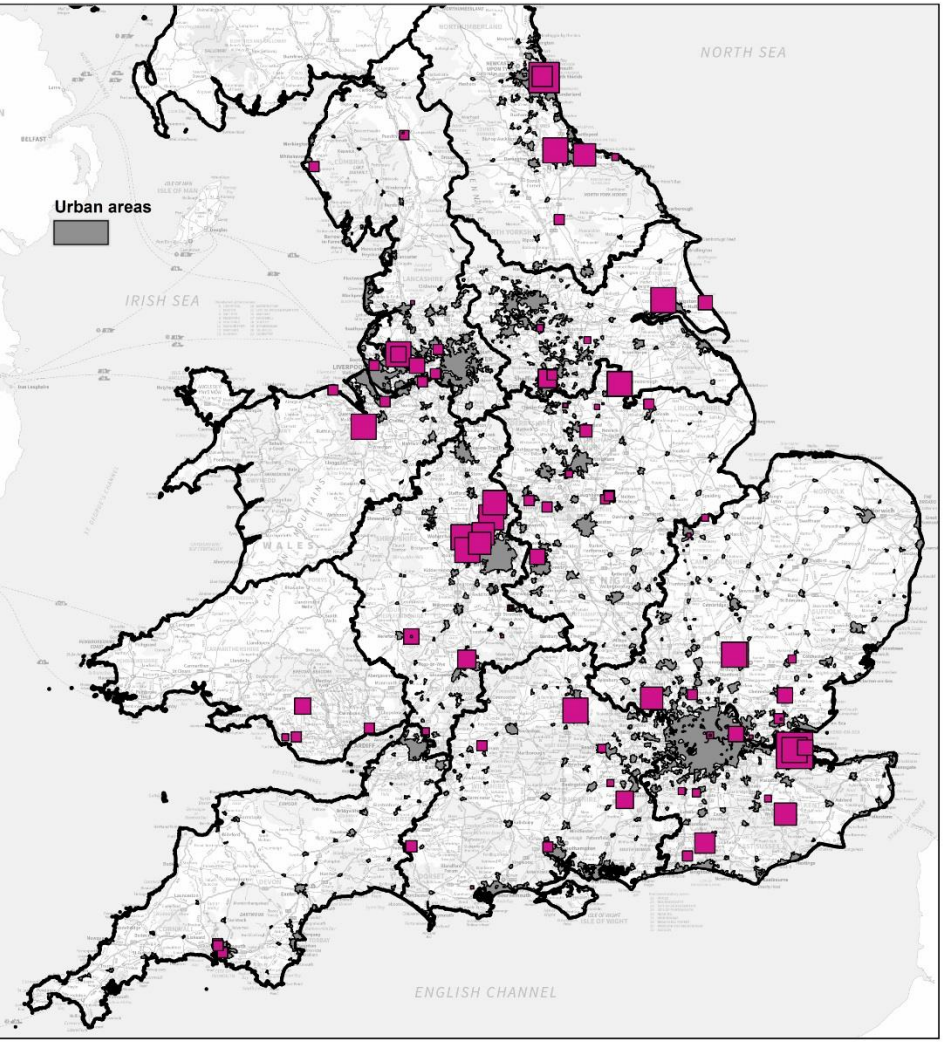

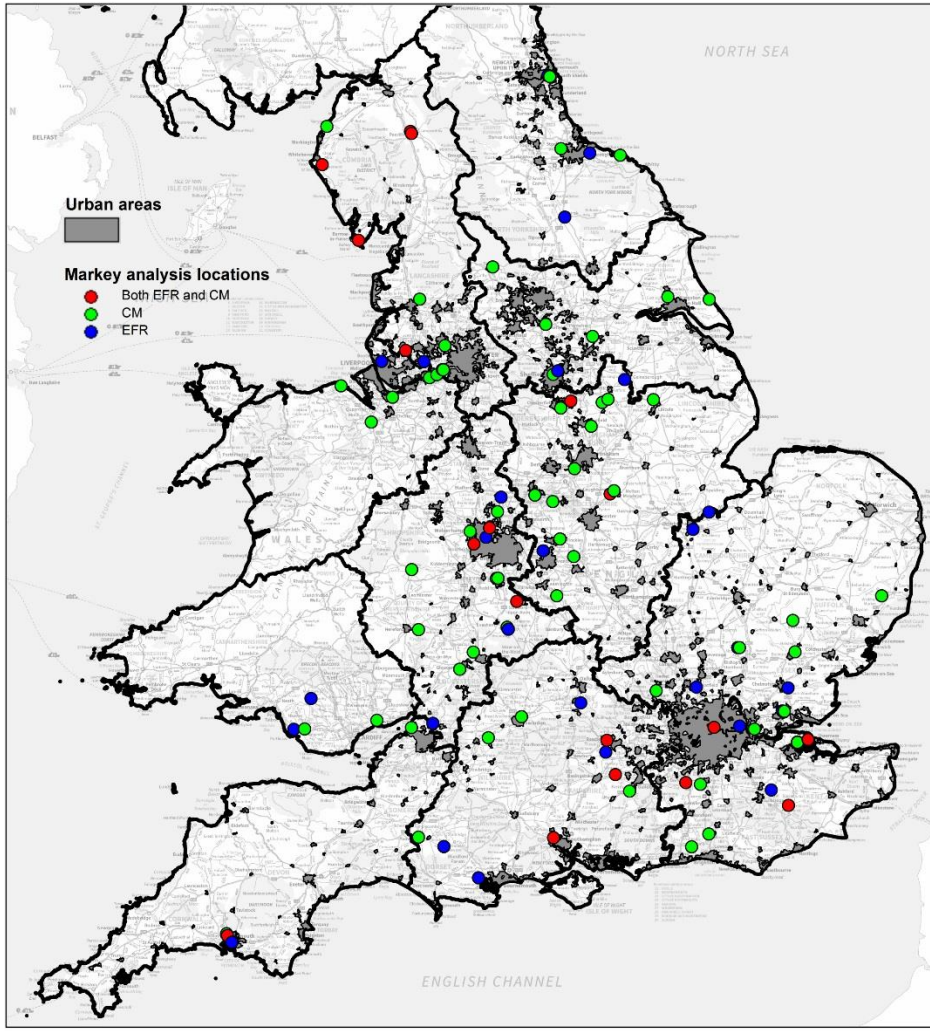

Total Bid Pipeline
Circa 1.9 GW

2016 EFR and T4 Capacity Market auction Winners - new build battery storage

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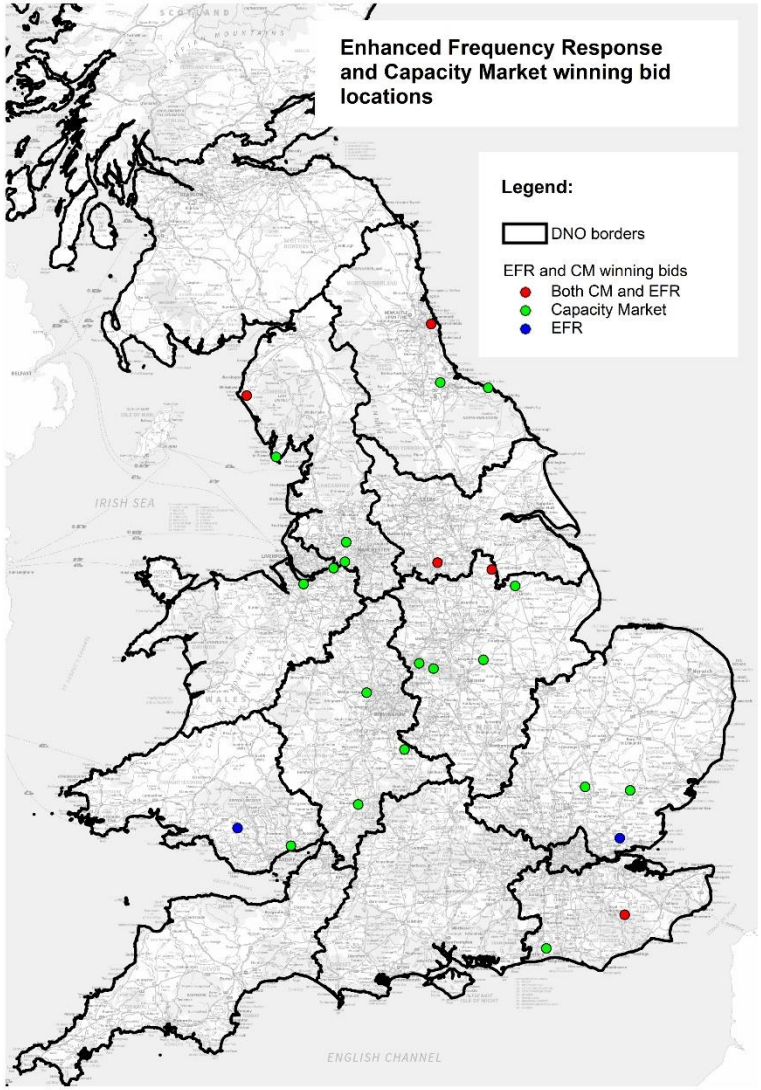
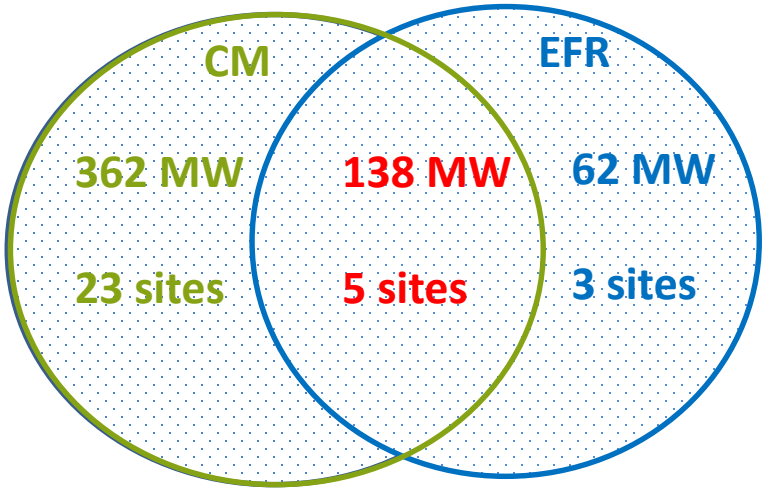


Capacity Market

500 MW
28 Sites

Enhanced Frequency Response

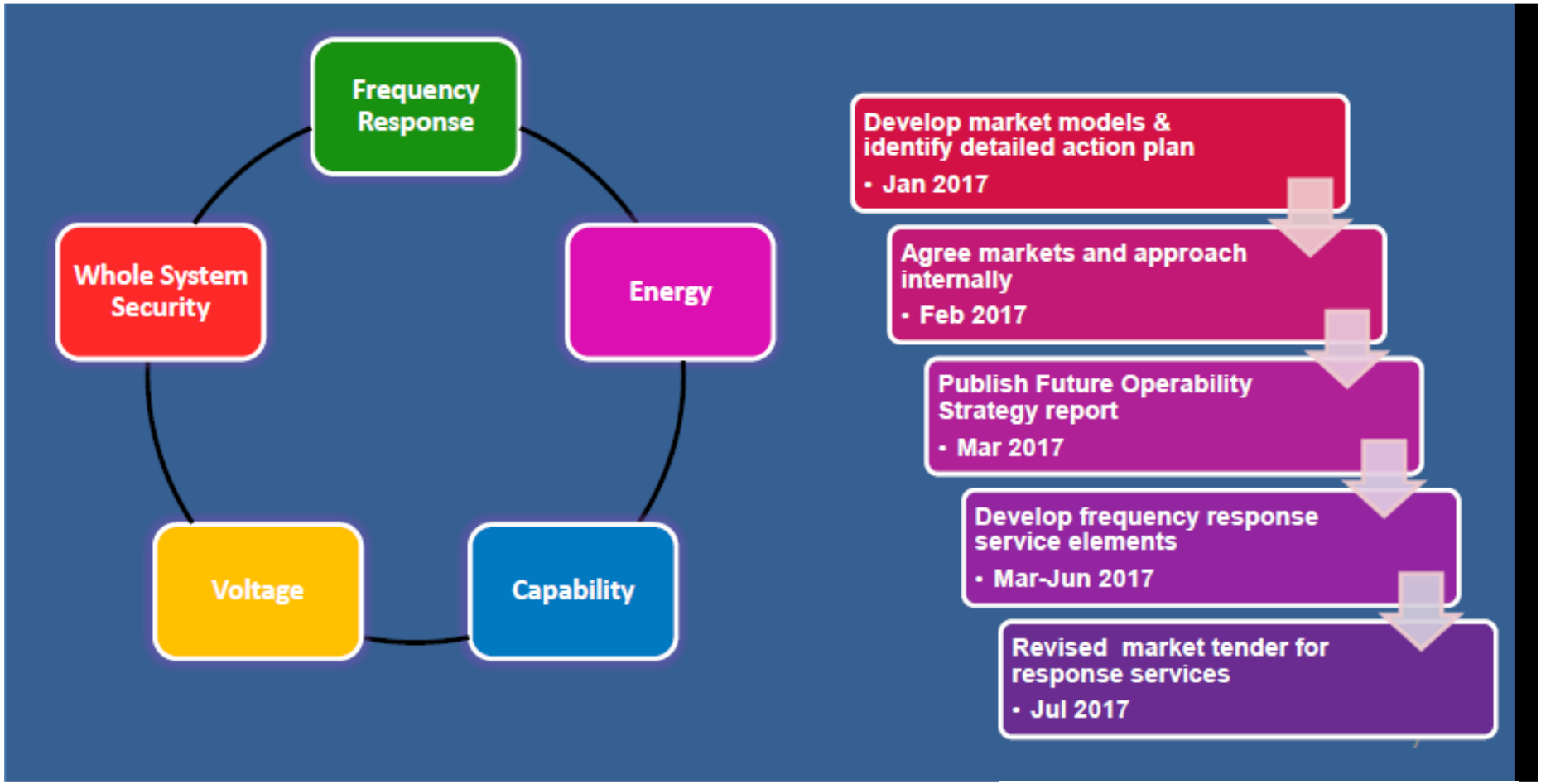
200 GW
8 sites



Total EFR and CM Winners
562 MW
31 Sites

* National Grid reports a lower figure @ 62 sites which could well be right

National Grid – future plans



Domestic and Small Scale Energy Storage Market development

Olly Frankland

January 2017

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Business

French oil firm Total bets on renewable energy with near €1bn bid for battery maker Saft

share

TESLA MODEL S MODEL X MODEL 3 ENERGY CHARGING UPDATES

Blog Videos Press

Battery Cell Production Begins at the Gigafactory

The Tesla Team • 4 January 2017

Current market – domestic

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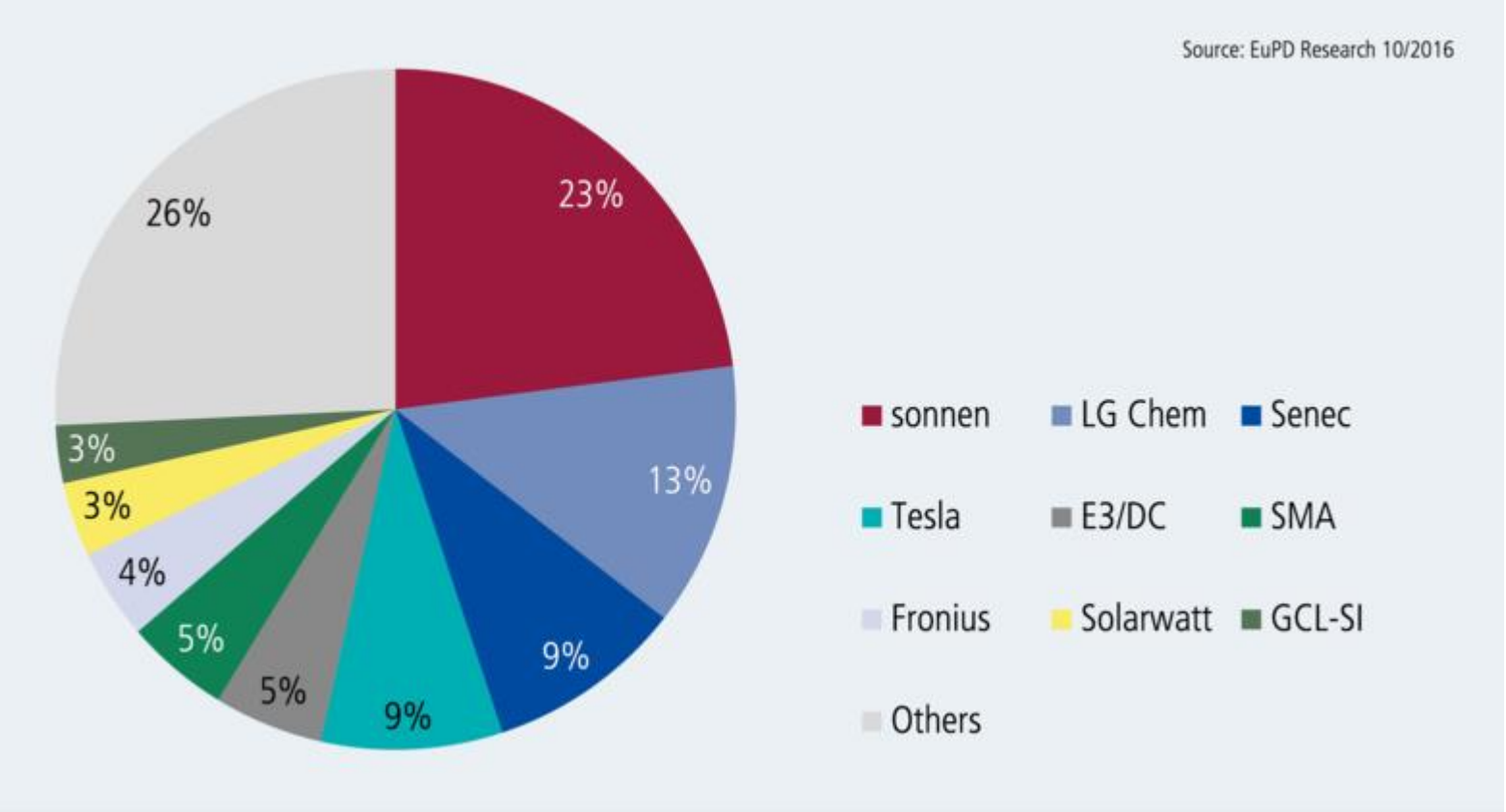
Domestic market – Germany

12,700 storage systems installed in Germany in first 6 months of 2016[1]



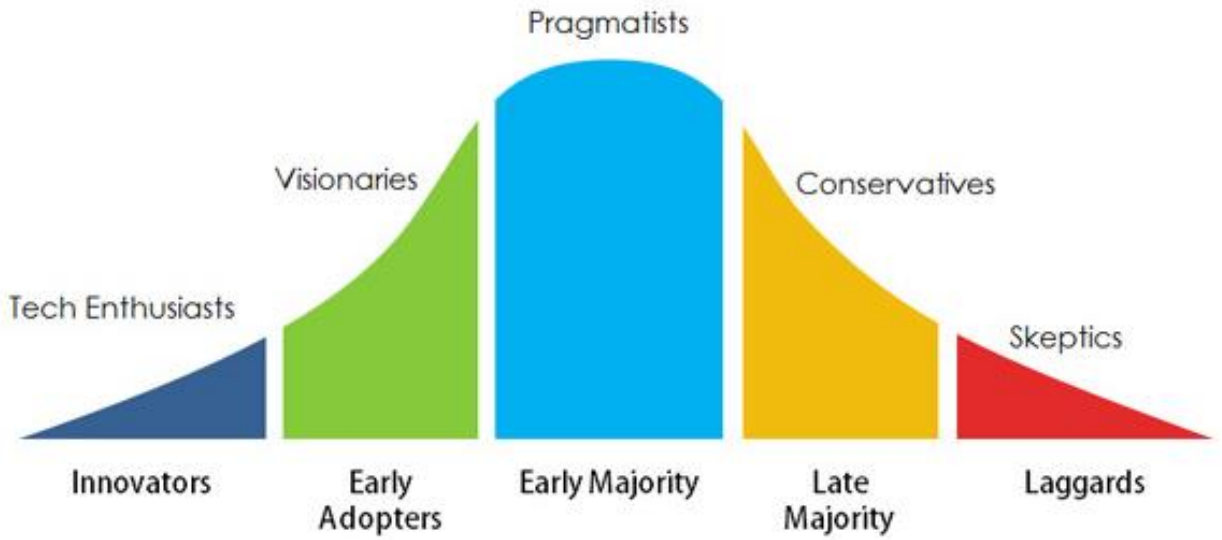
70% of those UK households interested in or owners of solar PV were not aware of energy storage options.[1]

[1]EUPD research 2016 http://www.eupd-research.com/en/news/view-details/the-market-is-talking-about-tesla-german-battery-storage-companies-leading-in-market-shares/

Domestic market – Consumers

Looking to:

- go off-grid
- increase ‘own-use’
- want back-up capability



Not financially motivated – return/payback

Future revenues:

- price arbitrage (time of use tariffs)
- aggregator payment

Current market - small commercial

Estimated 500 MW of capacity installed globally[1].

BYD

Younicos
Let the fossils rest in peace.

NEC
NEC ENERGY SOLUTIONS

POWERPACK
TESLA COMMERCIAL BATTERY

sonnen

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redT
energy storage

DELTA

green acorn
ENERGY STORAGE & BACK UP SYSTEMS

[1] Navigant research, 2016 http://www.navigantresearch.com/research/market-data-commercial-industrial-energy-storage

Current market – small commercial

Looking to reduce costs:

- TRIAD or DNuOS
- peak shaving
- price arbitrage

+ maximise ‘own use’ of generation

+ demand side response

Financially motivated – return/payback

Aggregator payments
Uninterruptible Power Supply – data centres, telecommunications

Small commercial – network charges

Network charges can change

Distribution Use of System (DUoS) Charges for the South West

	Baseline			Proposed new prices (April 2018)		
	Red	Amber	Green	Red	Amber	Green
High Voltage Half-Hourly Metered	18.014	0.103	0.057	6.397	1.303	1.279
Price change				-11.617	1.2	1.222
Percentage change				-64.5%	1165.0%	2143.9%

Innovative business models - domestic

- Discounted Tesla Powerwall (1 or 2) + SolarEdge + solar PV
- Annual CrowdNett payment (€450 or €650) for use of 30% of Powerwall over 5 years (+)
- Virtual Power Plant sells services to network
- 400 households initially

https://www.eneco.nl/actie/crowdnett/zo-werkt-crowdnett/

UK worked domestic e.g.

4kWp domestic solar PV
Retrofit Tesla Powerwall 2 (14 kWh) – approx. **£6,350** installed (+VAT)

€650 = £554.12 x5 = **£2770.60**
+ savings of £176.80 per year (+time of use tariff/price arbitrage?)

	Unit	Value
Energy from 4kWp solar PV system	kWh	3,400
Current use of PV in home		35%
Use of PV in home with battery		75%
Units of energy saved	kWh	1,360
Financial benefit of energy saved	£	176.80

Cost of electricity 13 p/kWh

Technology

Existing

Li-ion – 83% of new global energy storage capacity in 2016 (excl. pumped hydro)[1]
Lead acid

New

Flow batteries in domestic market
Redflow ZCell (Zinc Bromide)

Aqueous hybrid Ion
Aquion Energy – 50% cost reduction in 2 yrs (rather than 10 yrs)[2]

Hybrid? Ultracapacitors/Aqueous Hybrid Ion trial[3]

[1] Navigant research, 2016 http://www.navigantresearch.com/research/energy-storage-tracker-3q16
[2]Energy storage report, 2016 http://energystoragereport.info/aquion-cuts-cost-reduction-target-eight-years/
[3]Duke Energy, 2016 https://www.greentechmedia.com/articles/read/Hybrid-Energy-Storage-Systems-Get-Best-of-Both-Worlds

Cost reduction

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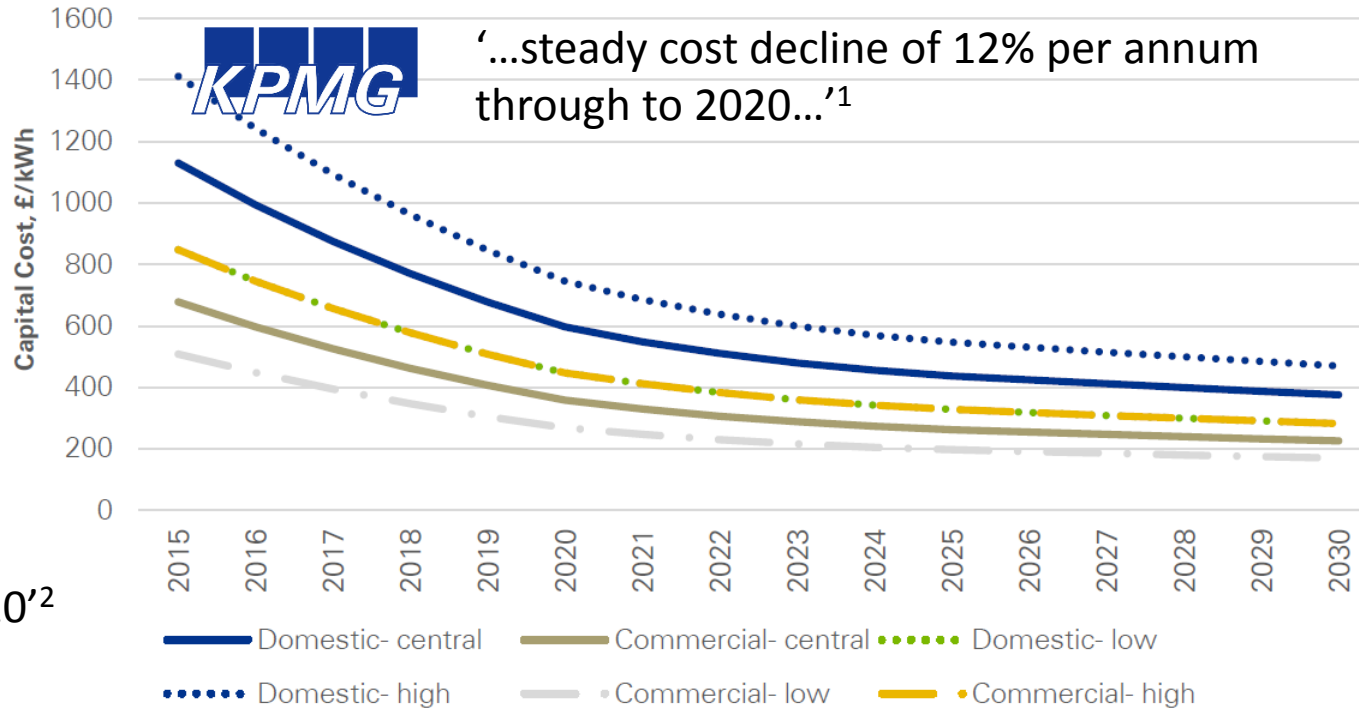


IRENA
International Renewable Energy Agency

'costs fallen 65% since 2010'[2]

Bloomberg NEW ENERGY FINANCE - '20% reduction in 2016…15-20% predicted for 2017'[3]

LAZARD - '40% reduction over next 5 years'[4]

[1] KPMG, 2016 https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/rea-storage-report-may-2016.pdf
[2] IRENA, 2016 http://www.irena.org/DocumentDownloads/Publications/IRENA_REthinking_Energy_2017.pdf
[3] BNEF, 2016 https://www.bloomberg.com/company/new-energy-outlook/
[4] Lazard, 2016 https://www.lazard.com/media/438041/lazard-lcos-20-executive-summary.pdf

Cost reduction cont.

Battery cell costs have come down

Storage inverters are still relatively expensive[1]

'LG supplying General Motors Li-ion cells - $145 per kWh….Focus now on reducing cost of enclosures, thermal management systems, installation, controls ..' (Balance of System costs)[1]

[1]ESN, 2016 http://www.energy-storage.news/analysis/energy-storage-in-2016-where-do-we-go-now

Impact of smart meters

With solar PV

FIT - 50% export assumed (under 30kWp)

'deemed export was intended as a temporary measure to be in place until smart meters are available'[1]

Time of use tariffs

Elective half-hourly settlement for domestic and small commercial due early 2017[2]

Mandatory due soon after

[1] BEIS/Ofgem, 2016 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/576367/Smart_Flexibility_Energy_-_Call_for_Evidence1.pdf

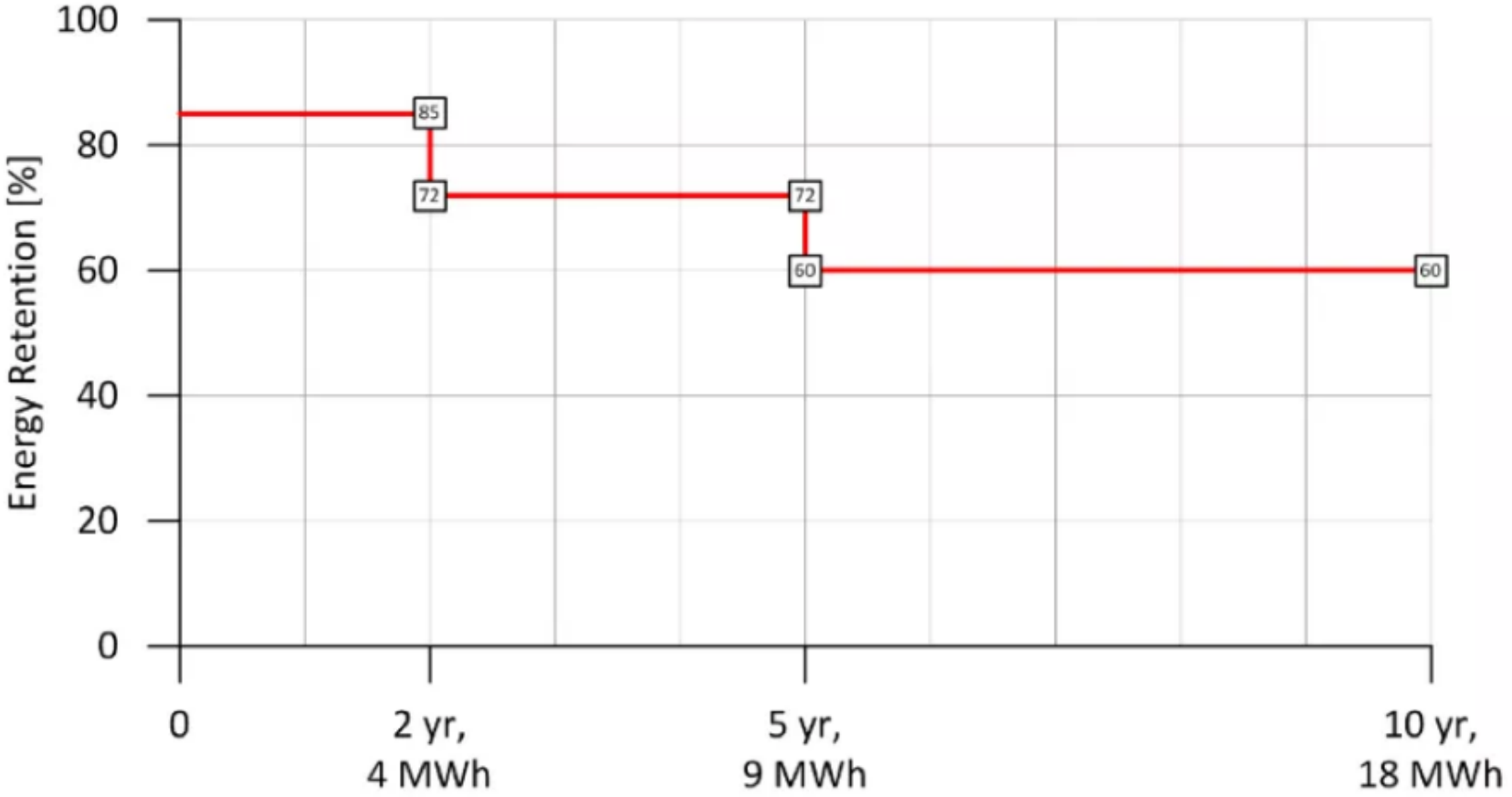
[2] Ofgem, 2016 https://www.ofgem.gov.uk/system/files/docs/2016/11/mandatory_hhs_planning_consultation.pdf

Warranties

- Set limits – e.g. specific number of cycles covered per year (250), voltage, temperature
- Product vs performance warranties
- Separate parts of system have different warranty periods
- Added cost of extending warranty (e.g. 5 to 10 years)

Warranties cont.

Tesla Powerwall 1 recently removed minimum performance guarantees for ‘normal degradation’. Now there is no definition of ‘normal degradation’.[1]



[1] Blog, 2016 https://notalotofpeopleknowthat.wordpress.com/2016/07/02/teslas-incredible-shrinking-powerwall-warranty/

Depth of Discharge/Lifetime

DOD: 90% Li-ion
50% Lead acid
100% flow batteries

250 – 365 charge cycles per annum

Discharge past DOD limit = lower lifetime of battery

LG Chem Resu 10
8.8 kWh
3200 cycles @ 90% DoD

60% capacity at 10 yrs or 30,000 kWh

Sonnen
16 kWh
10,000 cycles at 100% DoD

10 yrs or 10,000 cycles

Lifetime of Li-ion = 10 yrs (?)

Barrier - grid connection

- Witnessing costs – approx. £1000

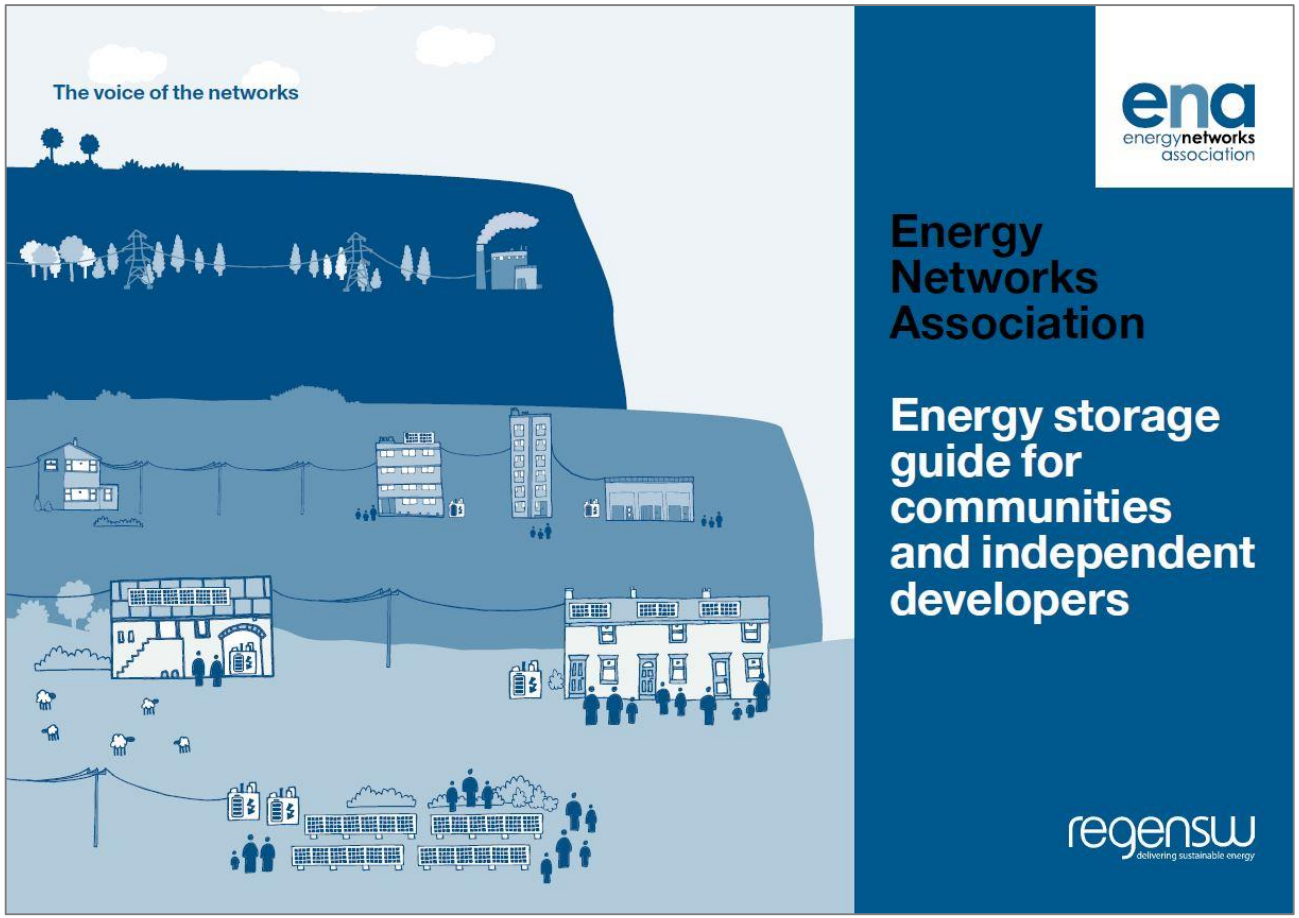
- Variance in how DNOs dealing with applications

(even for a 1kWh install)

Fast track application process in draft stage:

- online application with instant approval
- Witnessing rules relaxed
- Could come into force in 4 months (approx.)

ENA storage guide



- Introduction to area of energy storage and ways to connect to the network
- For community energy groups and smaller independent developers
- Publication - due very soon

Big Question

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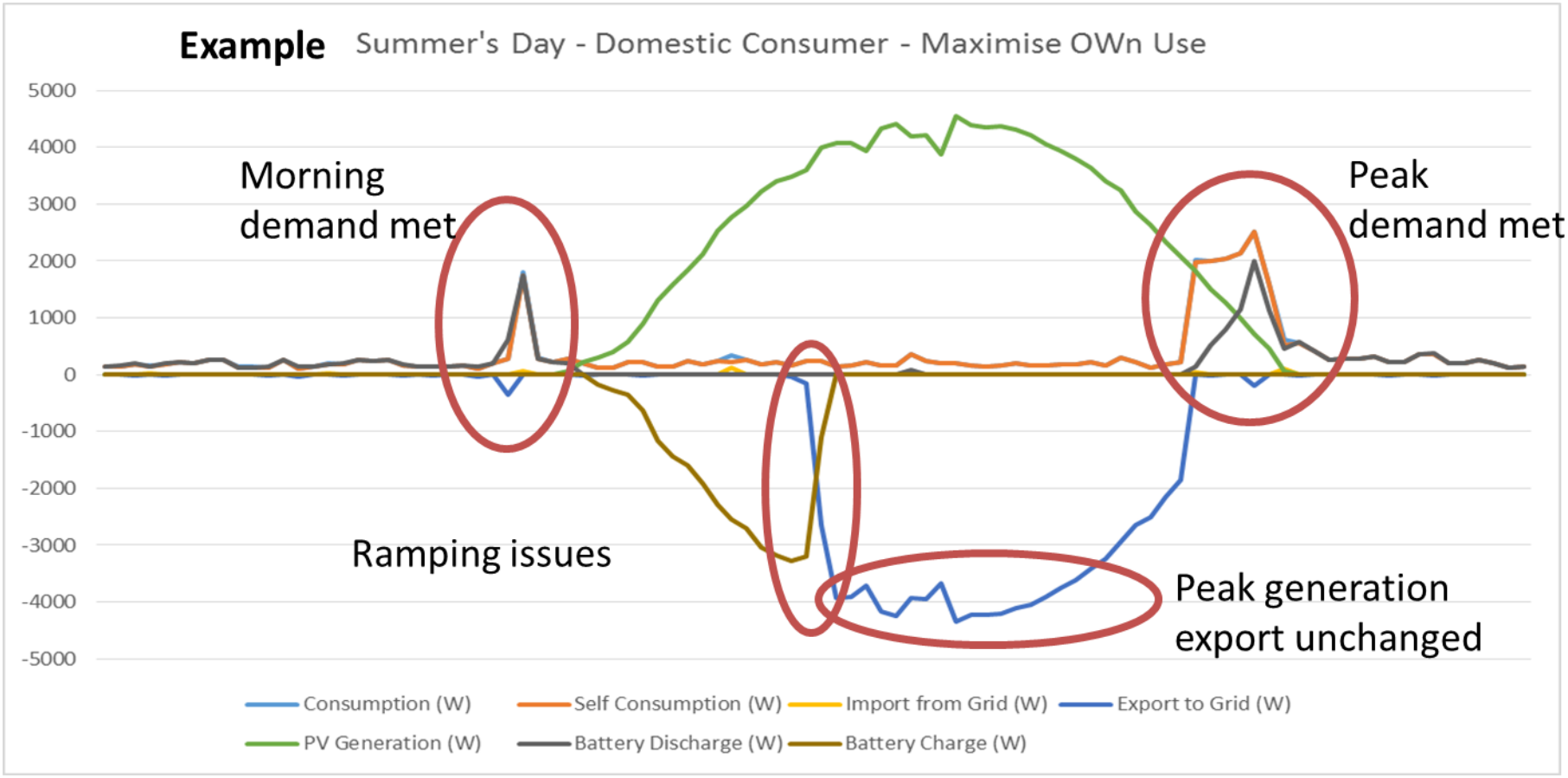
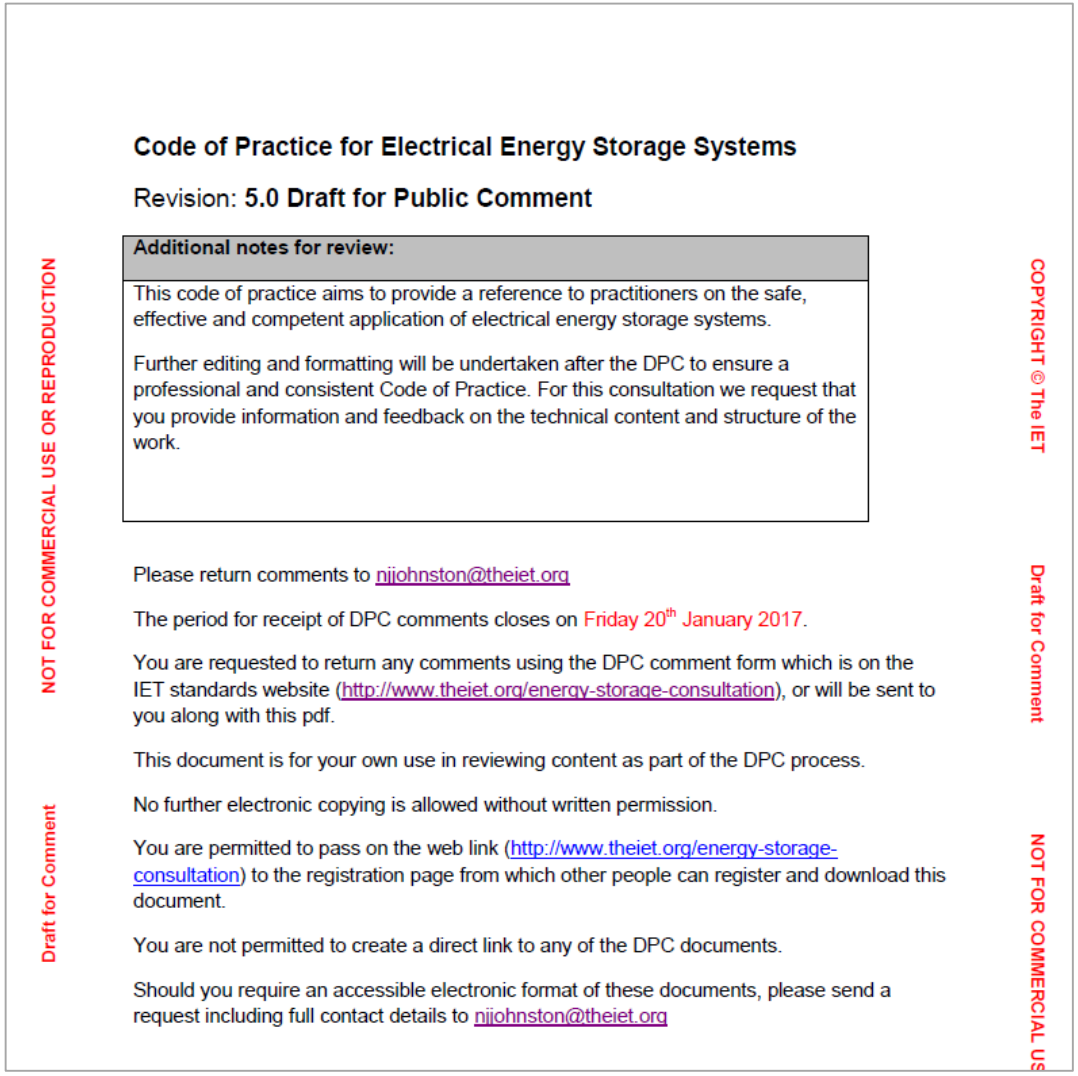
In practice – how will energy storage interface with the grid and local network??



IET code of practice

- Due for release April 2017
- ‘information for practitioners to safely and effectively specify, design, install, commissioning, operate and maintain a system’
- Closed for public comment 20 Jan
- 142 pages



Code of Practice for Electrical Energy Storage Systems

Revision: **5.0 Draft for Public Comment**

Additional notes for review:
This code of practice aims to provide a reference to practitioners on the safe, effective and competent application of electrical energy storage systems. Further editing and formatting will be undertaken after the DPC to ensure a professional and consistent Code of Practice. For this consultation we request that you provide information and feedback on the technical content and structure of the work.

Please return comments to njjohnston@theiet.org

The period for receipt of DPC comments closes on Friday 20th January 2017.

You are requested to return any comments using the DPC comment form which is on the IET standards website (http://www.theiet.org/energy-storage-consultation), or will be sent to you along with this pdf.

This document is for your own use in reviewing content as part of the DPC process.

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Should you require an accessible electronic format of these documents, please send a request including full contact details to njjohnston@theiet.org

Overview - Current market

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Domestic	Small commercial
Mainly new solar PV + battery installations due to lower rate of VAT (5%) Innovators/early adopters – non-financial drivers Cost and lack of awareness main barriers	Behind-the-meter high energy user (with generation) Early adopters with financial case possible - mainly through network cost reduction Changes to DNuOS in SW undermine model Cost and lack of finance main barriers

Q&A

WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

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Agenda

14.25 **Drivers for energy storage and flexibility services**
Johnny Gowdy, director, Regen SW
Olly Frankland Regen SW
Q&A

15.15 **Refreshment break**

15.45 **Domestic and small scale storage panel discussion covering:**

- Market growth prospects
- Domestic and small scale storage in association with on-site generation and energy demand
- Impact of storage on the network

Panel members include:

- Mark Dale, innovation engineer, Western Power Distribution
- Mark Smith, director, Wattstor
- Gabriel Wondrausch, managing director, SunGift Energy
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17.00 **Refreshments and networking**

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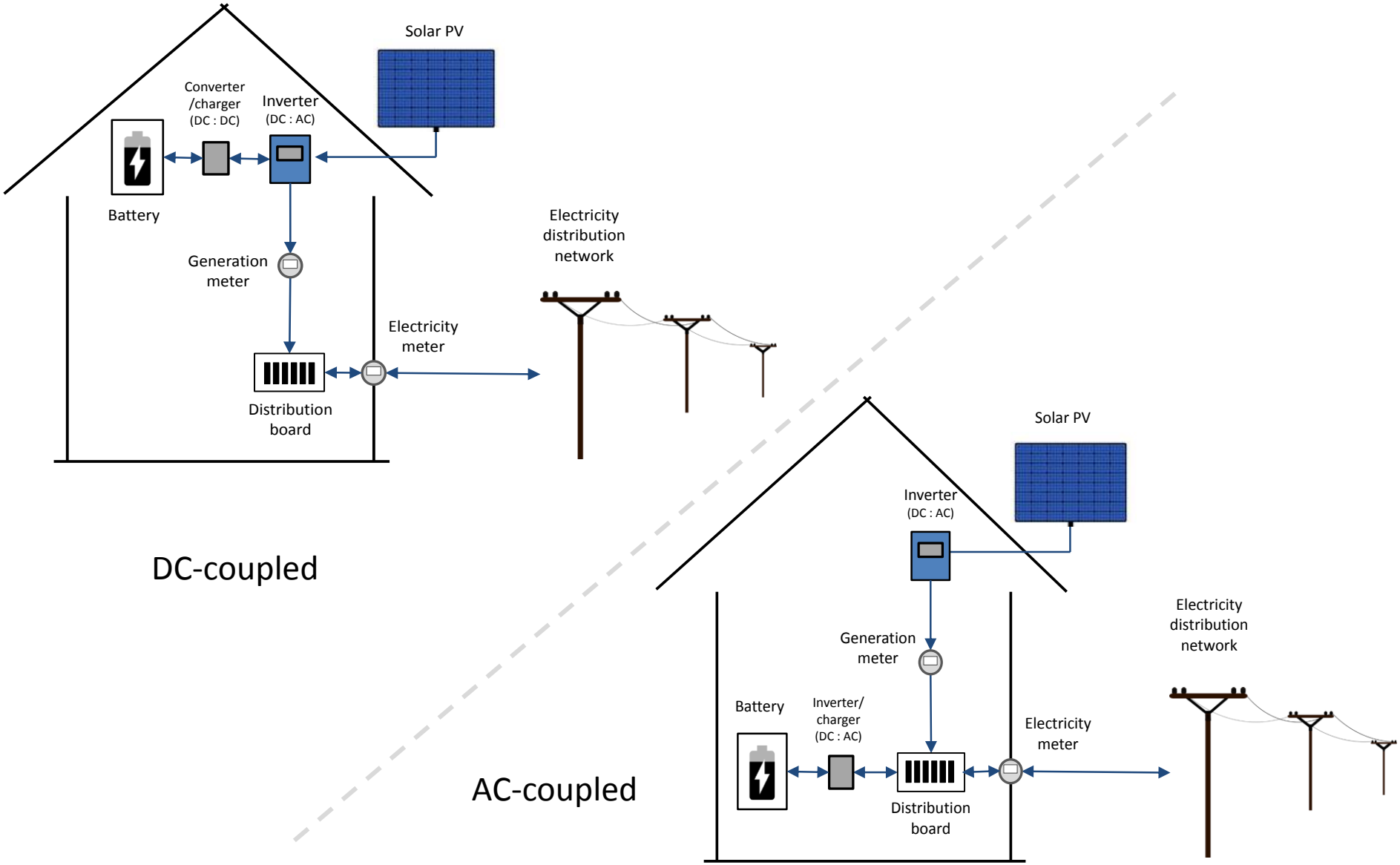
Enhanced Frequency Response (EFR)	Firm Frequency Response (FFR)	Fast Reserve	Short Term Operating Reserve	Capacity Market
Similar to FFR but a faster response service to provide sub-second frequency response services. Service specifically targeted at battery storage providers with a high response capability. National grid tender for 200 MW announced in August 2016 that 8 EFR bidders had been awarded 4 year contracts using battery storage. Further tenders are expected. No aggregation. Pre-tender speculation suggested rates of between £20 and £40 per MW per hour of service. Auction outcome was however lower at an average of £9.40 per MW per hour with a range from £7-£11.97	Service to maintain overall grid frequency within a tolerance range of 50Hz. Service may be dynamic (constantly responsive) or static (trigger response). Service is tendered on a monthly basis and rates vary depending on service level, of which there are several. Short term tenders – 1-23 months although most > 6 months. Suitable for battery applications, response within 10 sec (primary) or 30 sec (secondary) and sustained for up to 30 mins. 10 MW minimum but can be aggregated. Potential also for Demand Response - FCDM.	Fastest reserve service, 2 minute response to unexpected demand increase or loss of generation. Service utilisation for a up to 15 min (or as specified) unit but generally <5 minutes Contract duration 1-23 month (can be up to 10 years) but typically < 6 months. Morning and evening availability. Minimum capacity 50 MW but aggregation is possible through an integrator. Relatively small market and few current providers. Complex payments for availability, positional, nomination and utilisation. Potential for Demand Response.	Short term and a slower reserve service. 3 MW minimum but typically 10-15MW. Ramp up within 20 mins desirable to win contract, typically asked to maintain energy output for a minimum of 2 hours and a recovery within 20 hours. 3 seasonal auctions, seasonal & daily time periods. Payments for availability £/MW/hr and utilisation £/MWh. Prices and revenues have been falling suggested increased competition. Revenue is uncertain depending on availability and utilisation. Competitive threat from diesel generators. Potential for Demand Response	The Capacity Market instrument to secure existing, and incentivise, new capacity to maintain capacity margins. In return for capacity payment revenue, generators must be available to deliver energy at times of peak demand or system stress. Annual auction tender for future years capacity. Duration varies – longer for new capacity. Intended for larger capacity but energy storage could deliver. UK 2015 T4 tender for 2019/20 lower than expected at only £18 per KW. Rules and penalties for non-delivery have been increased. Competitive threat from diesel generators.
Relative value –high	Relative value - High	Relative value – Med/high	Relative value - Med	Relative value – Med
Based on 2016 EFR auction outcome: annual Revenue £60-£105k per MW per year	Varies according to service. Rough estimate £40-150k per MW per year depending on service and hours tendered.	Difficult to estimate for a storage provider new entrant. Very rough revenue estimate £50-70k per MW per year based on analysis of National Grid 2015/16 market data.	Combined annual potential revenues circa £20-35k per MW per annum (assuming availability). Based on 2014/15 and 2015/16 total STOR expenditure Ref National Grid Service Reports	£20-35k per MW per year, possibly higher, depending auction* outcomes. *UK 2016 T4 (Dec) tender price is expected to be higher than 2015,

Transmission cost avoidance	Distribution cost avoidance	Generator "own use" (domestic and non-domestic)	Generator Grid Curtailment	Price arbitrage (& peak shaving)
The cost of UK transmission network is charged to generators and demand users via a number of mechanisms. Demand based charges (73% of total charges) are mainly recovered through the Transmission Network Use of System (TNUoS) & Balancing Services Use of System (BSUoS). Both are based on peak time demand – for TNUoS this is calculated using the "TRIAD" peak demand periods. There is a value in using storage to reduce net demand during the peak time & TRIAD periods to avoid these charges. Revenue could come in the form of payments from energy off-takers ("Embedded Benefits") or	The cost of running the distribution network is recovered from generators and demand users. Energy storage and distributed generators can therefore offset demand earning a credit from DNO's, or offsetting high energy users costs. For intermittent generation the credit is a flat rate, for non-intermittent the credit is time banded and are highest during the peak demand period "Red Zone" (4-7pm daily) and in the winter period "Super Red Zone". The value is greatest if connected at the Low Voltage network and varies (greatly) by region.	Located alongside variable generation such as PV and wind, energy storage could be used to store energy during peak generation periods and deliver energy during periods of user demand. Value for the energy user comes from maximising their own use of generated electricity, avoiding the peak price for electricity during high demand periods. An example would be charging batteries linked to solar PV during the day, and time shifting the energy to the early evening peak when costs are highest. This will be facilitated by the roll-out of smart meters and "time of use" tariffs (TouT).	Energy storage could be used to store, and time shift energy which would otherwise be "lost" due to grid curtailment. This opportunity has grown due to the increase in constraints in the distribution network especially in high renewable energy regions and the increase in constrained grid connection offers. An alternative value would be avoidance of grid reinforcement. This could potentially be combined with an "own use" high energy user or as a standalone application co-located with an energy generator.	Although co-location alongside energy generation and a high energy users would deliver greater value, it is also possible that energy storage could be used simply to exploit price variance in the energy market. Storing energy during low price periods for delivery during peak price periods. Wholesale price variance in the UK ranges from <£20 MWh during low demand periods to £80 MWh plus during the peak. Extremes of negative pricing and very high spot prices have also become more common.
Relative value – Med/high	Relative value - High	Relative value – Low	Relative value - Low	Relative value – Low
Potentially a good revenue stream especially if the TRIAD periods are successfully targeted.* Together TNUoS, BSUoS and transmission loss embedded benefits or cost savings could be worth £40-50k per MW per year.	Potentially attractive. depending on location and how energy storage is treated by DNO's*. Potentially £40-80k per MW per year in the south west of England.	Low relative value because a relatively high storage capacity is required to store variable generation and capture revenue from daily price variance between wholesale and retail tariff.	Combined with own use would deliver higher value but a relatively high storage capacity (and therefore capital cost) is needed to meaningfully time shift generation.	The challenge for energy storage is the capital investment required to store significant energy capacity to effectively price arbitrage.
*Note: The mechanism to recover transmission costs is expected to be overhauled and the future of TRIADs is uncertain – see "Paying for our grid"	*Note: at the moment energy storage is defined as "intermittent" generation and therefore does not qualify for the highest level of peak banded credits.			

Impact on FIT



DC vs AC

Main considerations	Type of connections between battery and domestic solar PV	
	AC-coupled	DC-coupled
FIT income	No impact	Some losses associated with charge and discharge
Price arbitrage revenue	Available – will improve with more Time of use tariffs	Not available
Aggregator payment	Available when market develops	Not available
Installation costs	May be higher (inverter/controls)	May be lower
Location of battery	Flexible	Needs to be close to solar PV inverter

Cost reduction cont.

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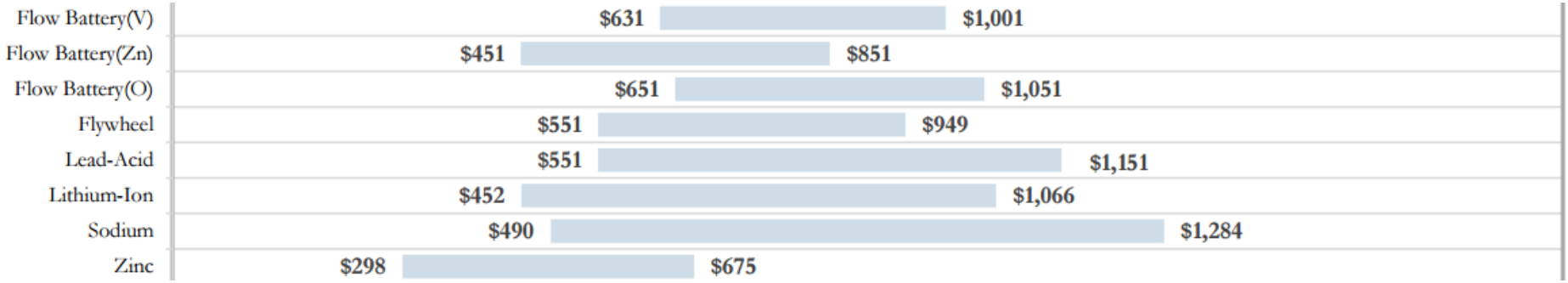
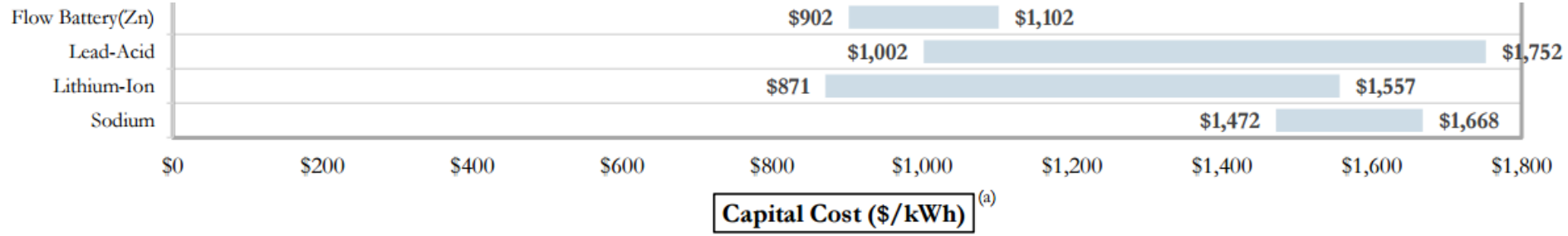
Commercial & Industrial



Residential



$1250 = £1000

[1]Lazard, 2016 https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf