SR Feasibility & Site Selection: Electricity Storage CPD Seminar

In association with

Welcome & Chair

Hannah Smith
Scottish Renewables

Storage on the Network

Gary Bartlett

Scottish and Southern Electricity Networks

SR Feasibility and Site Selection: Electricity Storage CPD Seminar

Gary Bartlett
Commercial Manager

Scottish & Southern Electricity Networks

Storage on the network

Application activity to date

Making the right choices when applying for a connection

- Heatmaps
- Contract Manager
- Online resources

When you are ready to apply

Next steps and further engagement on storage

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Application activity to date

- 4.7 GW of applications received in our SEPD area
- Around 500MW of these have been accepted
- The majority of this was in response to the National Grid EFR tender, which was only seeking 200MW's across GB
- In our SHEPD area, we have only received 125MW of applications to date, but interest has been growing in recent months …..

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Making the right choices with Storage

- Check our generation and demand Heat-map tools
- Speak to our Contract Manager for that area
- Use the online resources and guides available

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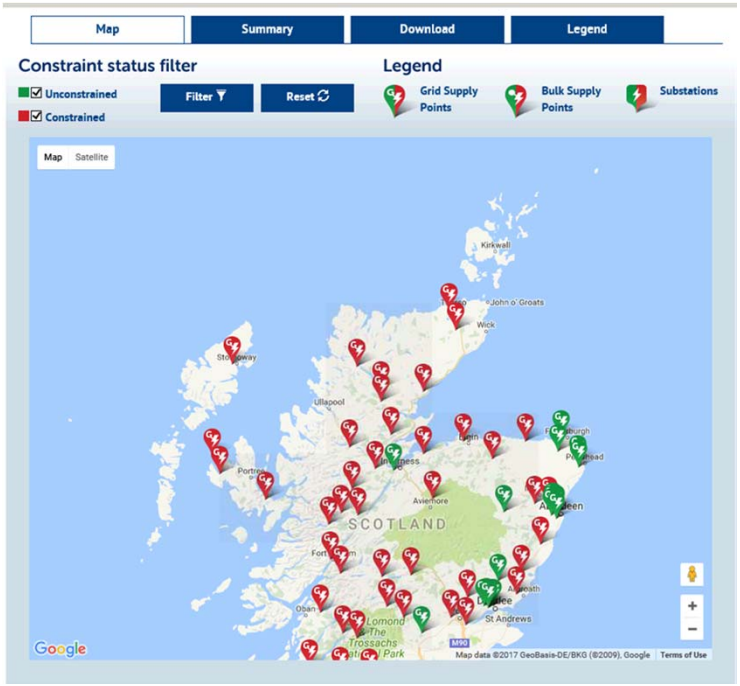
Heat-maps


Map
Summary
Download
Legend
Constraint status filter
Unconstrained
Constrained
Filter
Reset
Legend
Grid Supply Points
Bulk Supply Points
Substations
Map
Satellite
Kirkwall
John o' Groats
Wick
Ullapool
Portree
Inverness
Aviemore
SCOTLAND
Oban
Loch Lomond & The Trossachs National Park
St Andrews
Google
Map data ©2017 GeoBasis-DE/BKG (©2009), Google
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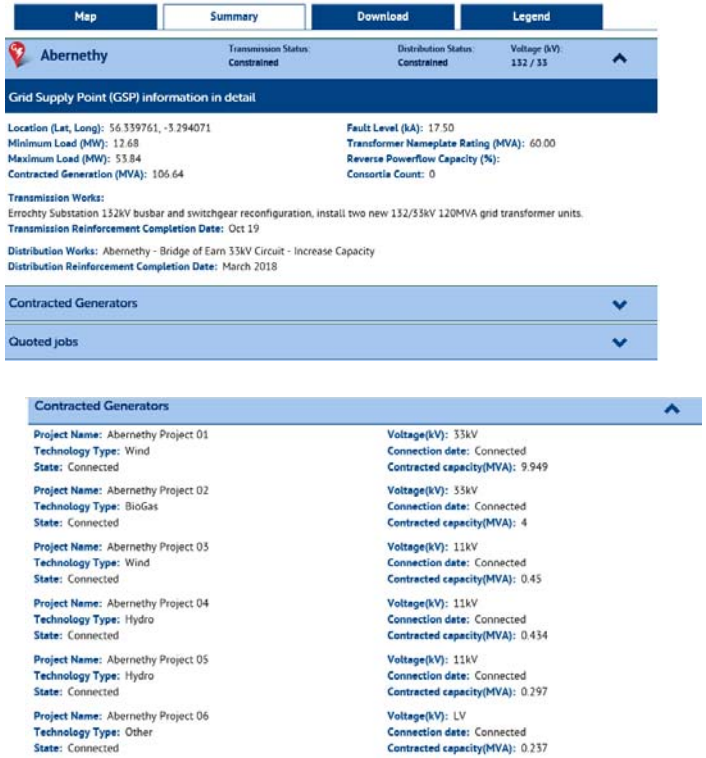

Map
Summary
Download
Legend
Abernethy
Transmission Status: Constrained
Distribution Status: Constrained
Voltage (kV): 132 / 33
Grid Supply Point (GSP) information in detail
Location (Lat, Long): 56.339761, -3.294071
Minimum Load (MW): 12.68
Maximum Load (MW): 53.84
Contracted Generation (MVA): 106.64
Fault Level (kA): 17.50
Transformer Nameplate Rating (MVA): 60.00
Reverse Powerflow Capacity (%):
Consortia Count: 0
Transmission Works:
Errochty Substation 132kV busbar and switchgear reconfiguration, install two new 132/33kV 120MVA grid transformer units.
Transmission Reinforcement Completion Date: Oct 19
Distribution Works: Abernethy - Bridge of Earn 33kV Circuit - Increase Capacity
Distribution Reinforcement Completion Date: March 2018
Contracted Generators
Quoted jobs
Contracted Generators
Project Name: Abernethy Project 01
Technology Type: Wind
State: Connected
Voltage(kV): 33kV
Connection date: Connected
Contracted capacity(MVA): 9.949
Project Name: Abernethy Project 02
Technology Type: BioGas
State: Connected
Voltage(kV): 33kV
Connection date: Connected
Contracted capacity(MVA): 4
Project Name: Abernethy Project 03
Technology Type: Wind
State: Connected
Voltage(kV): 11kV
Connection date: Connected
Contracted capacity(MVA): 0.45
Project Name: Abernethy Project 04
Technology Type: Hydro
State: Connected
Voltage(kV): 11kV
Connection date: Connected
Contracted capacity(MVA): 0.434
Project Name: Abernethy Project 05
Technology Type: Hydro
State: Connected
Voltage(kV): 11kV
Connection date: Connected
Contracted capacity(MVA): 0.297
Project Name: Abernethy Project 06
Technology Type: Other
State: Connected
Voltage(kV): LV
Connection date: Connected
Contracted capacity(MVA): 0.237

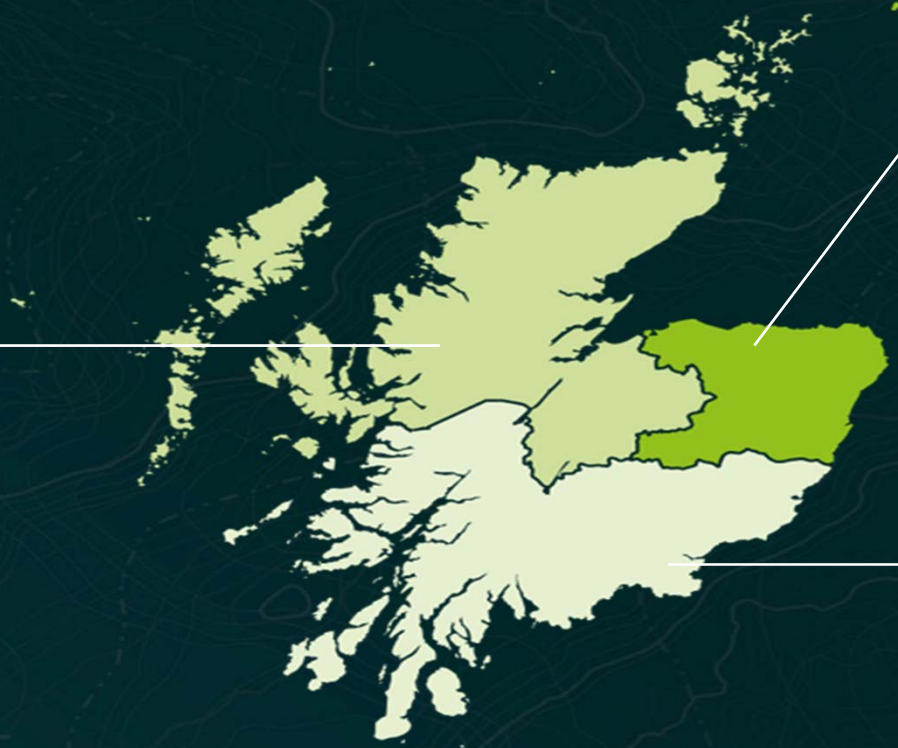
Speak to our local Contract Manager
Commercial Contract Team - North

Scottish & Southern Electricity Networks

North Regional Model

Scottish and Southern Electricity Networks regional model North
Director of Operations - Dale Cargill
Contact details - 07767 852890 dale.cargill@sse.com
Head of Connections - Barry Will
Contact details - 07767 852098 barry.will@sse.com

North Region



North Caledonia

Shetland Islands and North East Scotland – North Caledonia

Head of Region -
Neil Wilson - 07767 852350

Connection Delivery Manager -
Alan Bowie - 07810 858763

Customer Relationship Manager -
Shona Horn - 07500 912566

Customer Connection Manager -
Ian Jessiman - 07469 411438

Highlands and Islands

Highlands and Islands

Head of Region -
Colin Pirie - 07767 852305

Connection Delivery Manager -
George MacDonald - 07767 852803

Customer Relationship Manager -
Pamela Harvey – 07469 411432

Customer Connection Manager -
Ian Jessiman - 07469 411438

South Caledonia

South Caledonia

Head of Region -
Graeme Stewart - 07825 843868

Connection Delivery Manager -
Traci Kidd - 07767 852057

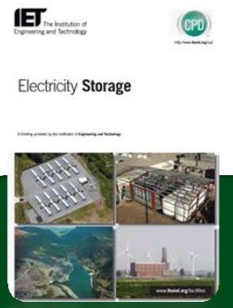
Customer Relationship Manager -
David Morrissey – 07767 852093

Customer Connection Manager -
Asante Mtalimanja - 07979 854433

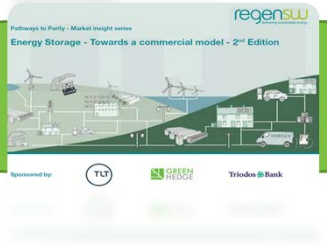
Use the online resources available

IET storage guide

https://www.regensw.co.uk/storage-towards-a-commercial-model



Energy Storage - Towards a Commercial Model 2nd edition
https://www.regensw.co.uk/storage-towards-a-commercial-model



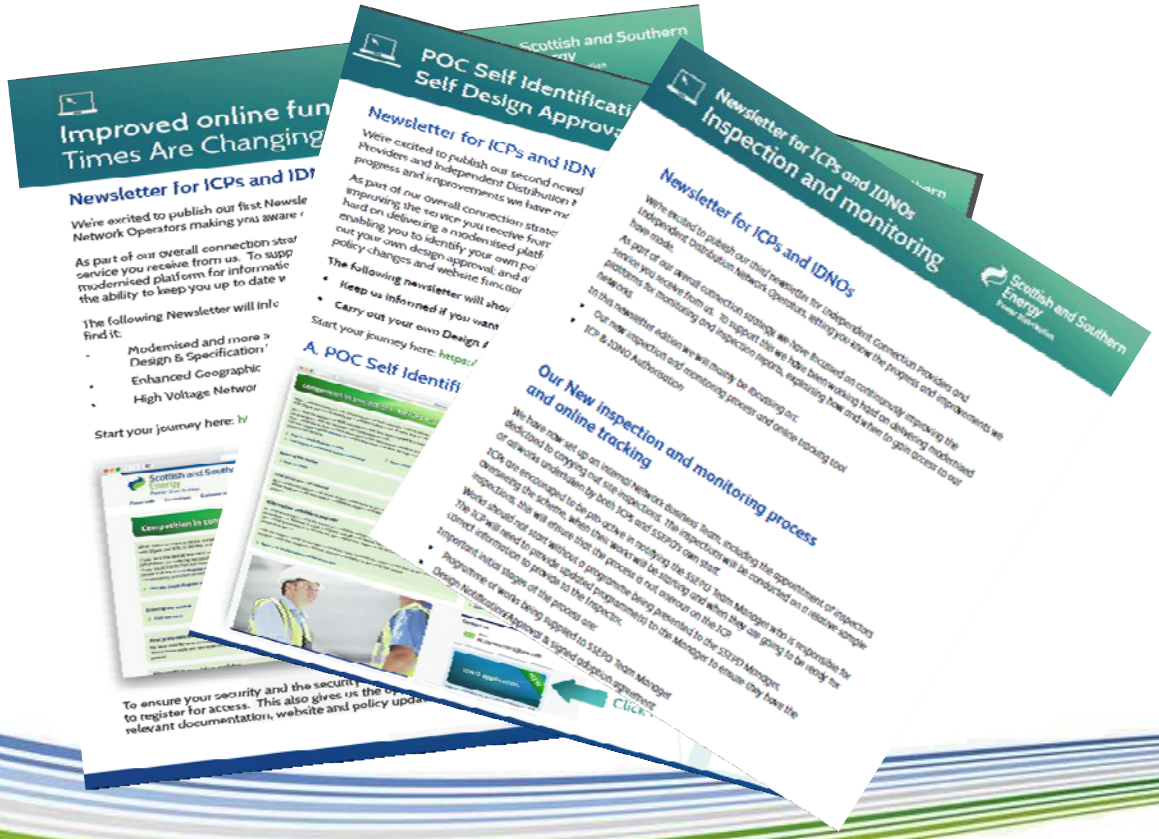
Guide to connecting electricity storage guide for communities and independent developers

https://www.regensw.co.uk/guide-to-connecting-electricity-storage-guide-for-communities-and-independent-developers

When you are ready to apply for a connection

- Provide as much information as possible on the intended use and mode of operation for your storage project
- Storage applications currently follow the ‘DG application process’, however there are currently plans underway to finalise a specific process for storage
- Be clear in your application whether your storage project will be ‘new’, or whether it is being paired with an existing connection
- Where you are pairing with an existing connection, we will need to consider whether the request is a ‘material change’
- The Active Power, Reactive Power and Apparent Power characteristics are very important when completing your ENA application form for storage
- Introduction of new milestones specific to storage technology:
  -SO contract award such as EFR

Newsletters and Events



Scottish & Southern Electricity Networks

We have a full calendar of events lined up to engage with our customers in 2017

- National Events
- Engagement days
- Connections Surgeries
- Online

View our events calendar on the SSEN website to find out where we will be next…….

www.ssen.co.uk/stakeholderevent/basicsearch

Scottish & Southern Electricity Networks

Thank you

Engage with us online

Stay updated with the latest news and improvements by following us online:

- Search 'SSEN Connections Engagement'
- Twitter.com/ssencommunity
- Facebook.com/ssencommunity
- www.ssen.co.uk

connectionsfeedback@sse.com

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Euan Norris

SP Energy Networks

8th March 2017

SP Energy Networks

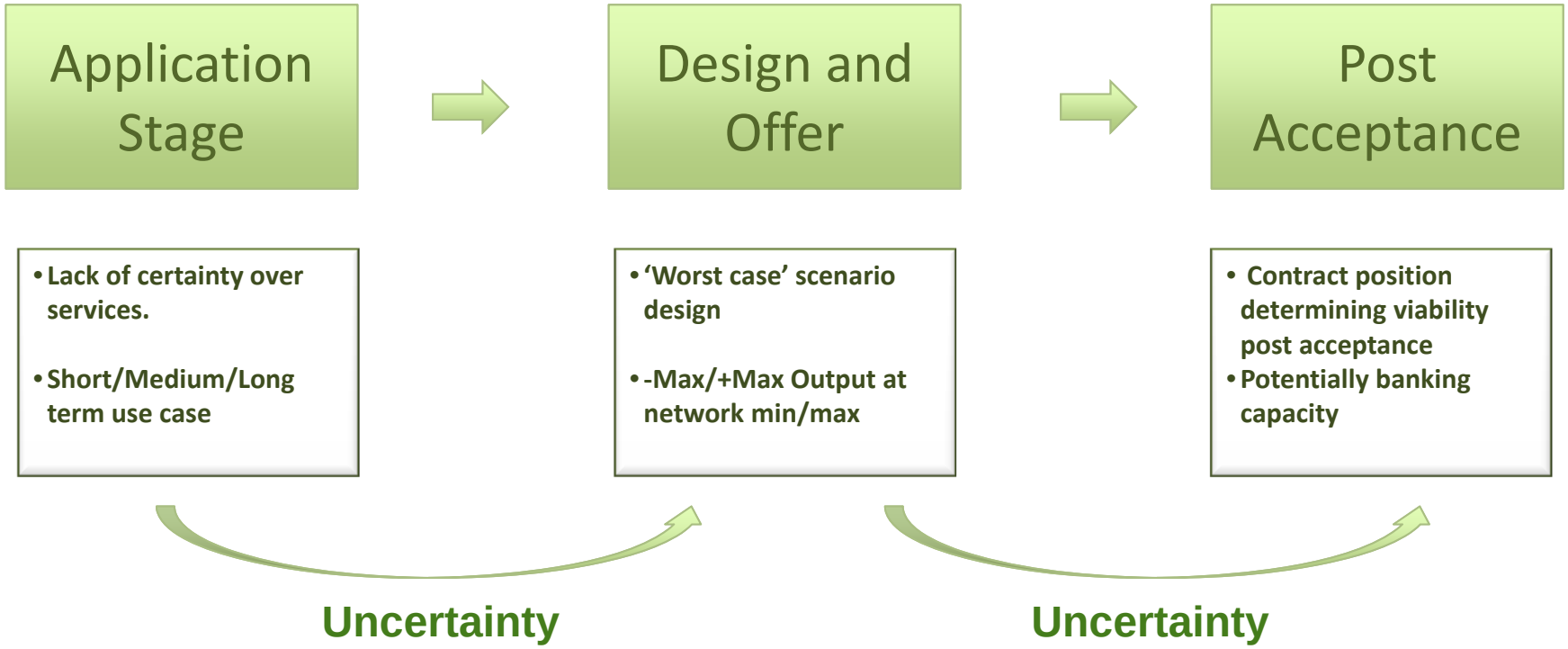
Euan Norris – Senior Project Manager

SP Energy Networks Storage Applications

900 MW applications in 2016

200MW accepted offers

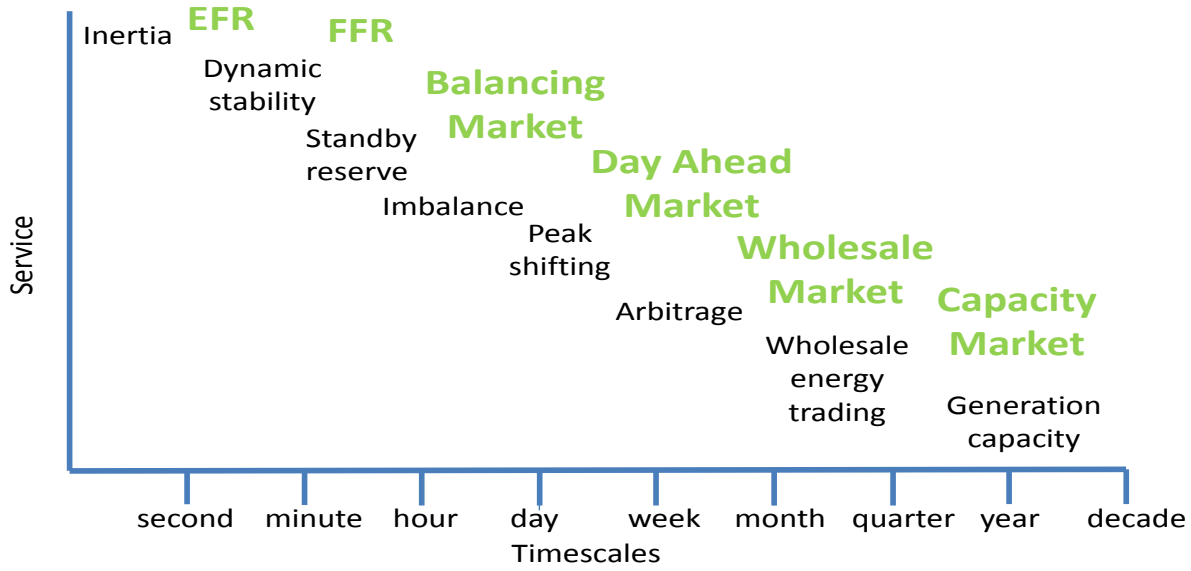
Storage Application Process – Challenges



Need to work together to manage uncertainty

Application Stage – Balancing Mechanism market

By understanding the services that you seek to provide we can better understand the system impact of your connection



Wide range of services currently procured by National Grid

Deferral of reinforcement

Storage developers could provide a service to DNOs as an alternative to conventional reinforcement. However there are a number of barriers currently in place:-

- No established market – trials have taken place but not an established price for the service
- Needs to complete with both conventional and Smart solutions – over whole lifecycle
- Communication from DNOs on where this would be a valuable service – e.g. heatmaps

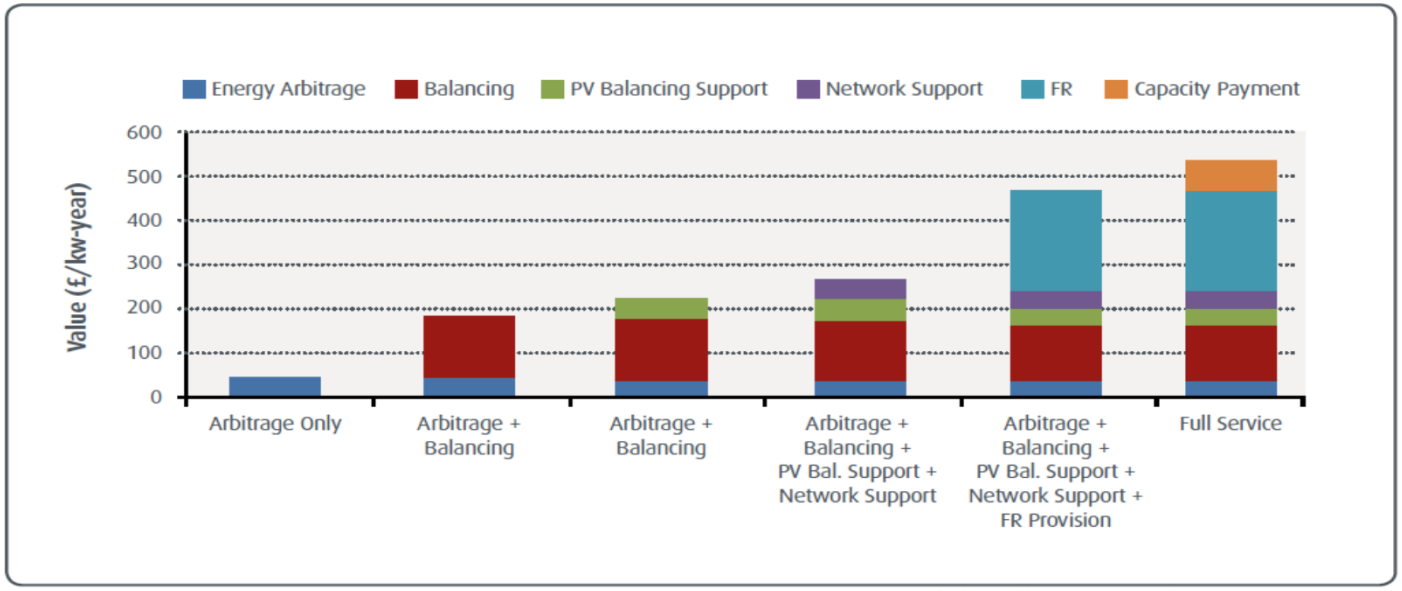
Example

Add 20% capacity (4.8MW) to an existing 12/24MW Primary substation		
4.8MW/9.6MWhr battery	-	£6.0M
Conventional Reinforcement Costs	-	£4.0M
FFR service		£17/MW/hr (up to £148/kW per year)
10-year deferral of £4.0M investment	=	£100k/year
	=	£20/kW

Application Stage – Stacked Services

It will often be critical for developers to ‘stack’ services in order to make a project financially viable. It is key that:-

- we understand how a storage site will be operated
- the range of services of any site are complementary and not mutually exclusive



Source: Imperial College, London

Design Stage – ‘Worst case’ design approach

Winter Max Demand	+10MW
Summer Min Demand	-10MW
Max Generation	-10MW
Min Generation	+10MW

It is our duty as a network operator to operate an economic, safe and reliable network

- We need to ensure that assets we connect to the network to not negatively impact the existing network or those customers already connected to it.
- That is why to date we have designed to this principle
- We recognise a need to change and be more flexible but we need to manage risk, physically, contractually or through the use of smart network control

We recognise that this is not an optimal approach but need to work with developers to manage uncertainty

Fault Level Impact

Storage solutions may alleviate thermal or voltage issues but will still contribute to fault level

- Clarity on battery characteristics is key
- We will explore a range of options with you to mitigate fault level issues/reinforcement
- We are also exploring a range of options to monitor fault level in real time as part of ANM solutions

Contract Duration

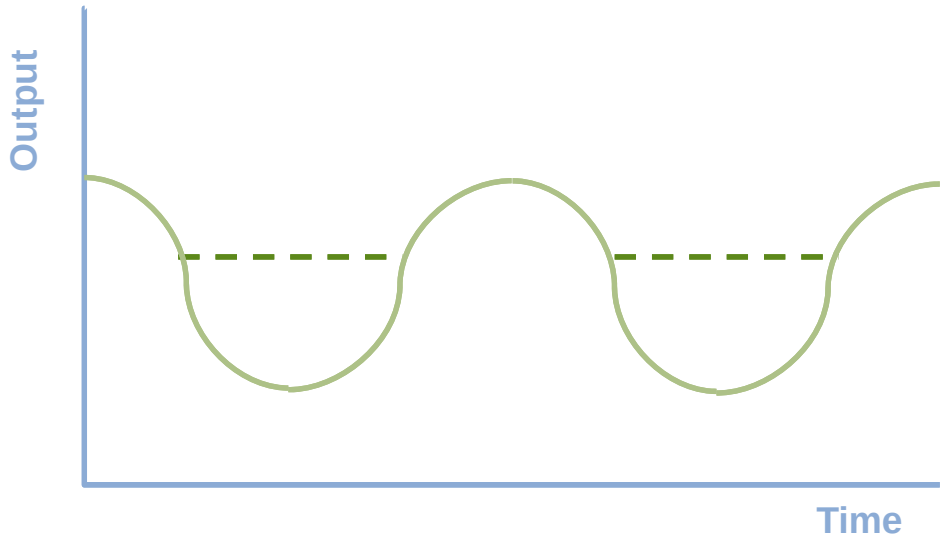
If the use case of a storage development changes this may affect your connection

- Build for all eventualities is not a sustainable approach
- Material change process may be appropriate
- In some cases there may be a cost implication if there are adverse network impacts
- Alternative is that these network costs be covered by DUoS – unlikely to be see favourable by Ofgem

Design Stage – Behind the Meter Storage

We anticipate that storage will be considered as an option for flattening the output profile of intermittent generation technologies. It is key that:-

- We understand how the storage technology will be operated
- We are given the opportunity to assess its impact on our network
- A formal **Modification Application** is submitted to network operators



Post Acceptance

SPEN's Queue Management principles will be applied equally to accepted connection offers for storage. It is key that:-

- Accepted offers are able to progress in accordance with agreed progression milestones.
- Consented (shovel-ready) projects should be given the opportunity to advance where possible.

We cannot wait for the outcome of future tender processes

Project	Initial Queue Position		Project	Revised Queue Position	
A	1	Stalled	B	1	Consented
B	2	Consented	A	2	Stalled
C	3	Stalled	C	3	Stalled
D	4	Consented	D	4	Consented*
E	5	In planning	E	5	In planning

Subject to reinforcement

Conclusions

Need to work together to manage uncertainty

Better information on the use case will result in better connection offers

The short duration of service contracts is a challenge

Storage has a significant role to play in system balancing

Site Selection

scottish renewables

Anthony Price

Swanbarton

Site selection

How can you maximise the value of your asset through strategic site selection?

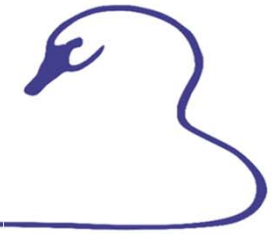
What does the site selection process look like in practice?

Anthony Price

Swanbarton

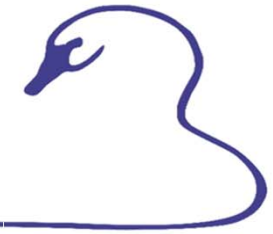
SMART ENERGY STORAGE

Swanbarton



- Consultancy specialising in the commercialisation of electrical energy storage systems since 2003
- Clients from North America, Europe and Asia
- Market trading devices for electrical energy storage
- Organiser of the International Flow Battery Forum
- Founder of the Electricity Storage Network
- Member of the ESA
- Business based on knowledge of electrical energy storage

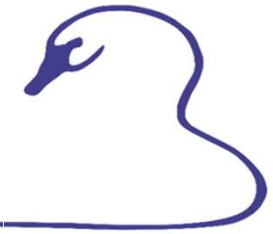
Site selection



Where do we put electricity storage?

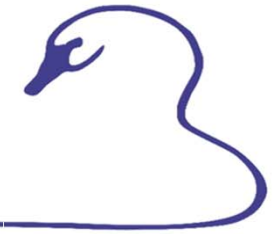
- Maximising value: choice of site, application and situation
- The site selection process

If storage was a warehouse



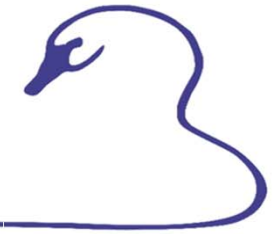
- Put the warehouse in the best place – to optimise the supply chain
- Only one warehouse in each supply chain
- Make the doors in and out as big as possible
- Build the warehouse as low cost as possible
- Link the warehouse to other parts of the supply chain to increase its value

Project issues



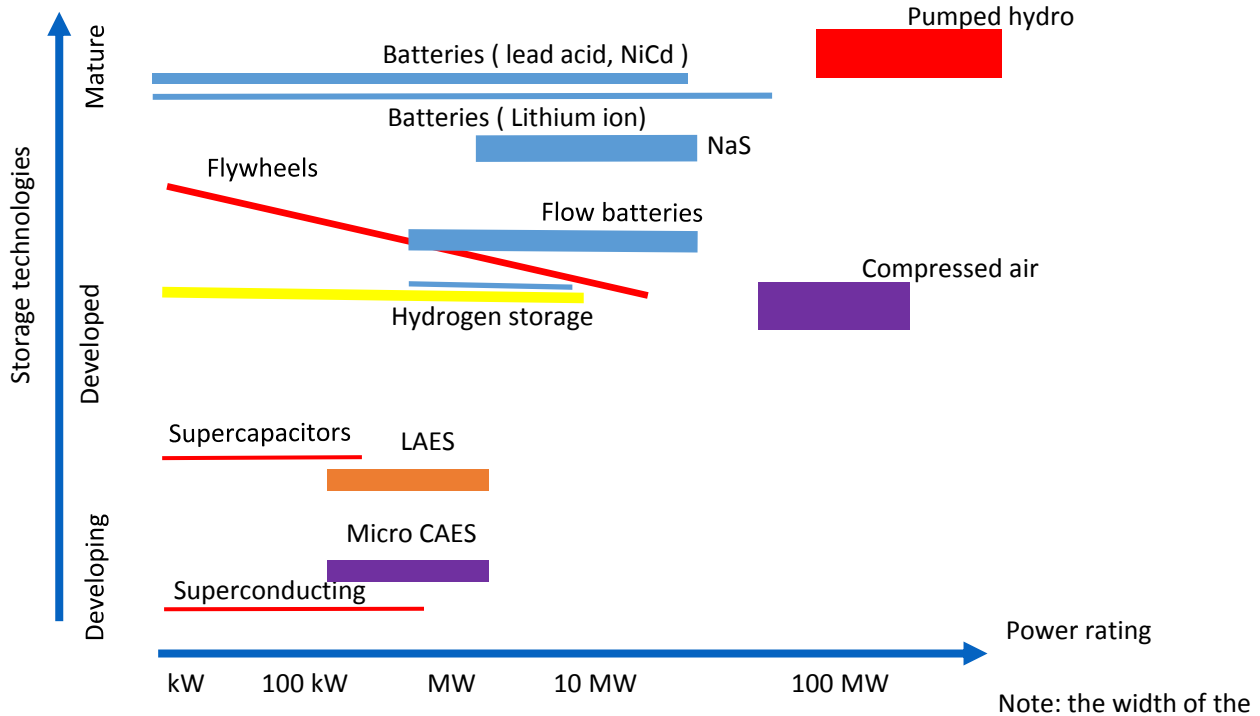
- Connection voltage and power rating
- Availability of connection
  - Technical constraints on the connection
- Ownership & licensing issues
- Consenting and permitting
- Ownership and remuneration
  - sharing benefits
  - Predictability of income
- Practicality
  - O & M
  - Decommissioning
- Contracting choice
  - Self design / build
  - EPC
  - Bespoke / commodity
  - Financiers' requirements
- Technology choice
- Site

Storage types



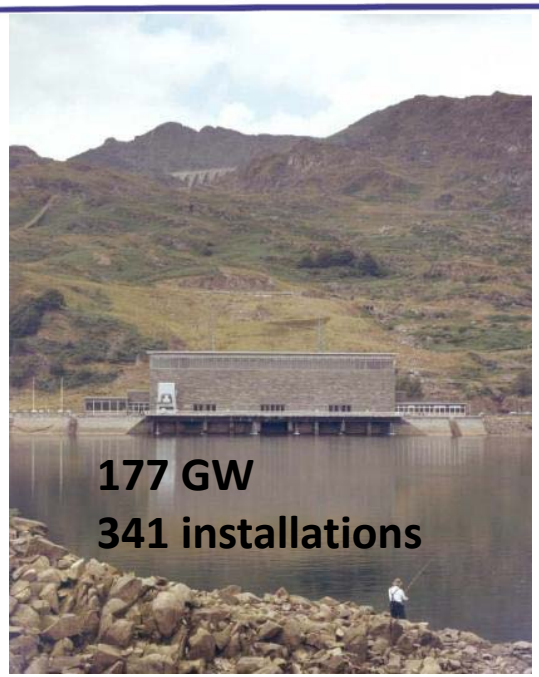
Type	Sealed systems			Separate power / energy	
Mechanical / kinetic	Flywheels			Pumped hydro	
Thermodynamic	Heat engines			Compressed air	Cryogenic storage
Electrical	Capacitors	SMES			
Batteries	Lead acid	Lithium	High temperature		Flow Batteries
Hydrogen / electrolyser				Electrolyser / fuel cell or ICE	H2 / organic cycle
Thermal	Molten salt	Ceramics	Ice		Pumped heat, heat engines

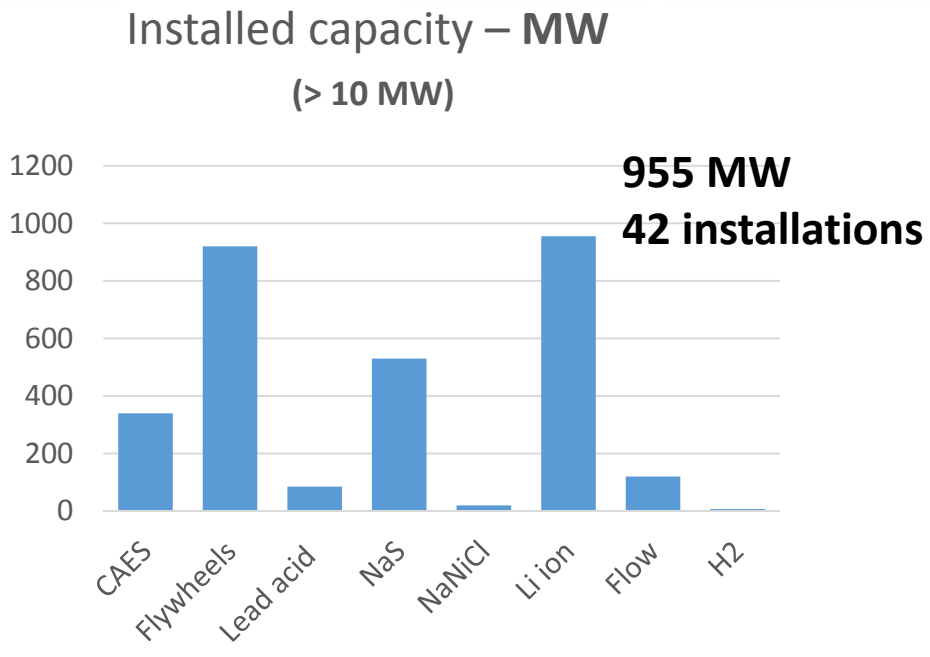
Development status



Note: the width of the bar indicates storage capacity

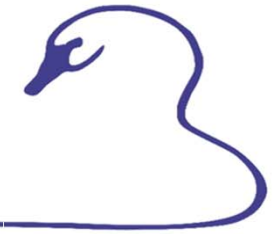
Grid connected energy storage





Source: US Department of Energy, accessed 1 Mar 2017

“Licence” uncertainty



New build

- 50 MW threshold – does it apply?
  - Planning act
  - Join BSC
  - Expenses and time
- Below 50 MW
  - Relatively simple
- Behind the meter
  - Commercially simple

Existing site

- IPPC – is there a significant change?
- Change to EIA
- Update fire assessment
- Change to COSHH or COMAH
- Business rates
- Change to connection
- Change to generation status if close to threshold

Storage projects

Photograph © Swanbarton Limited

Leighton Buzzard

Photographs © Swanbarton Limited

Pellworm

Photograph © Swanbarton Limited

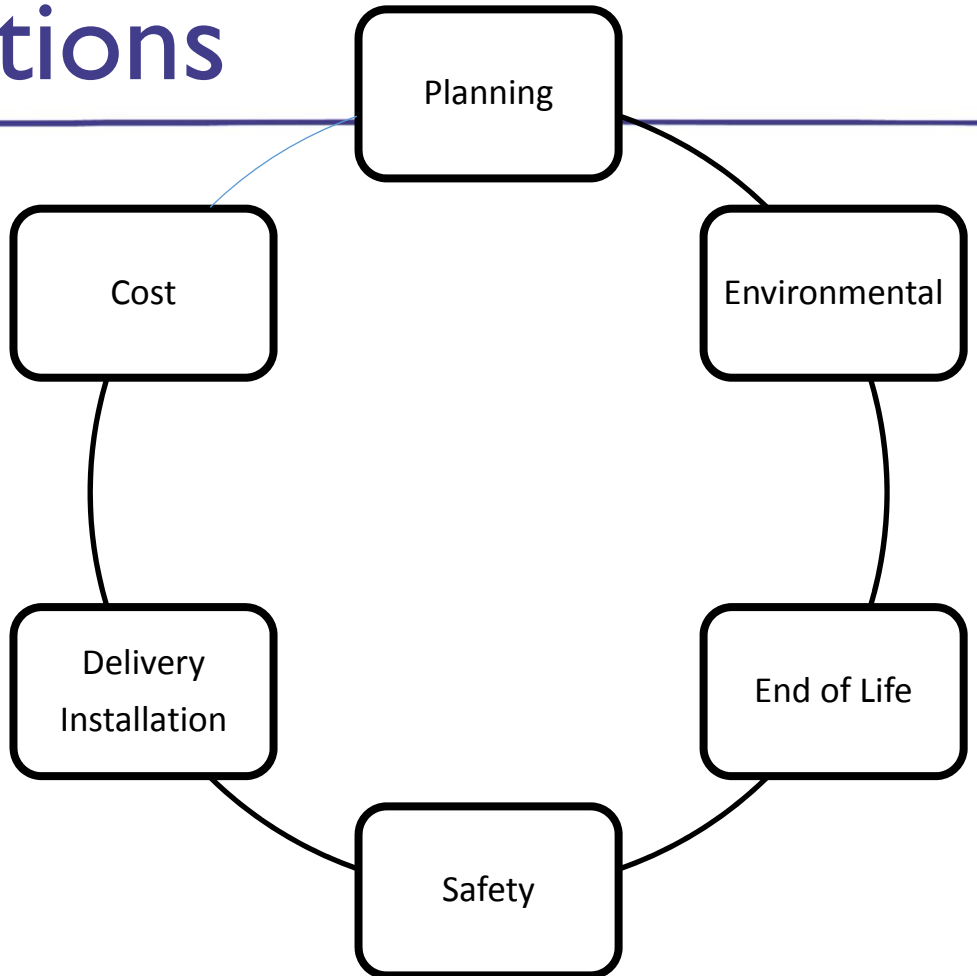
Yokohama

Photograph © Swanbarton Limited

Slough

Photograph: Highview Power Limited

Considerations



Building or containerised

Building

- Permanency – Full planning application required
- Visually acceptable in residential areas
- Business rates applicability

Containerised

- Perhaps considered temporary

Delivery / Installation

- **Building**
- Significant construction project
- Larger development footprint for site
- Longer construction timescale

Installation of Leighton Buzzard building housed battery

- **Containerised**
- Fewer workers on site and for less time
- Smaller construction site, but larger footprint
- More off-site work (Longer lead time)
- Not necessarily lower shipping/delivery cost

Installation of Pellworm containerised battery

Environment

- **Building**
- Environmental protection for whole installation
- Extra divisions required to protect key equipment
- Battery warranty protected by good internal environmental control

- **Containerised**
- May require additional environmental protection between containers
- Containers require protection from weather
- Battery warranty can be reduced

Safety

- **Building**
  - Efficient fire suppression and HVAC systems

- **Containerised**
  - Duplication of fire suppression and HVAC systems
  - Requirement for space between containers requires a greater footprint than expected
  - Low cost second-hand containers are not viable

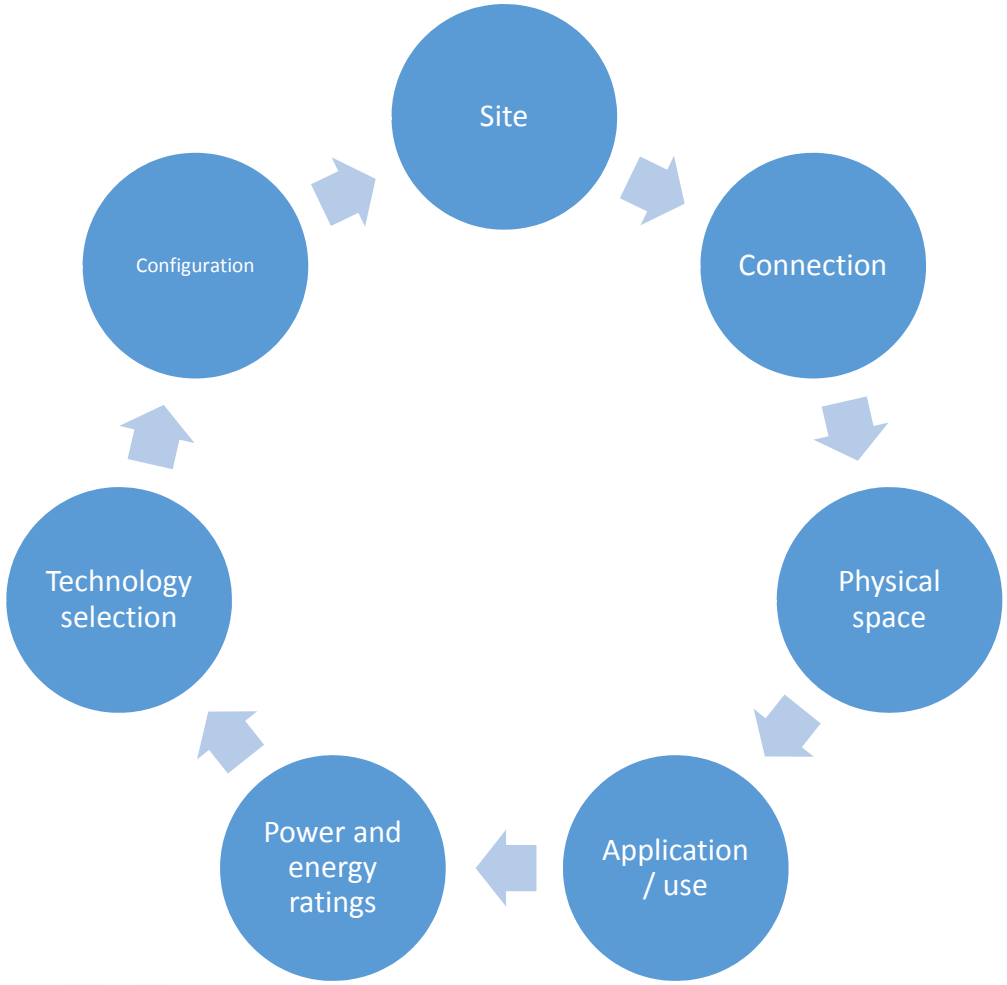
End of life

- **Building**

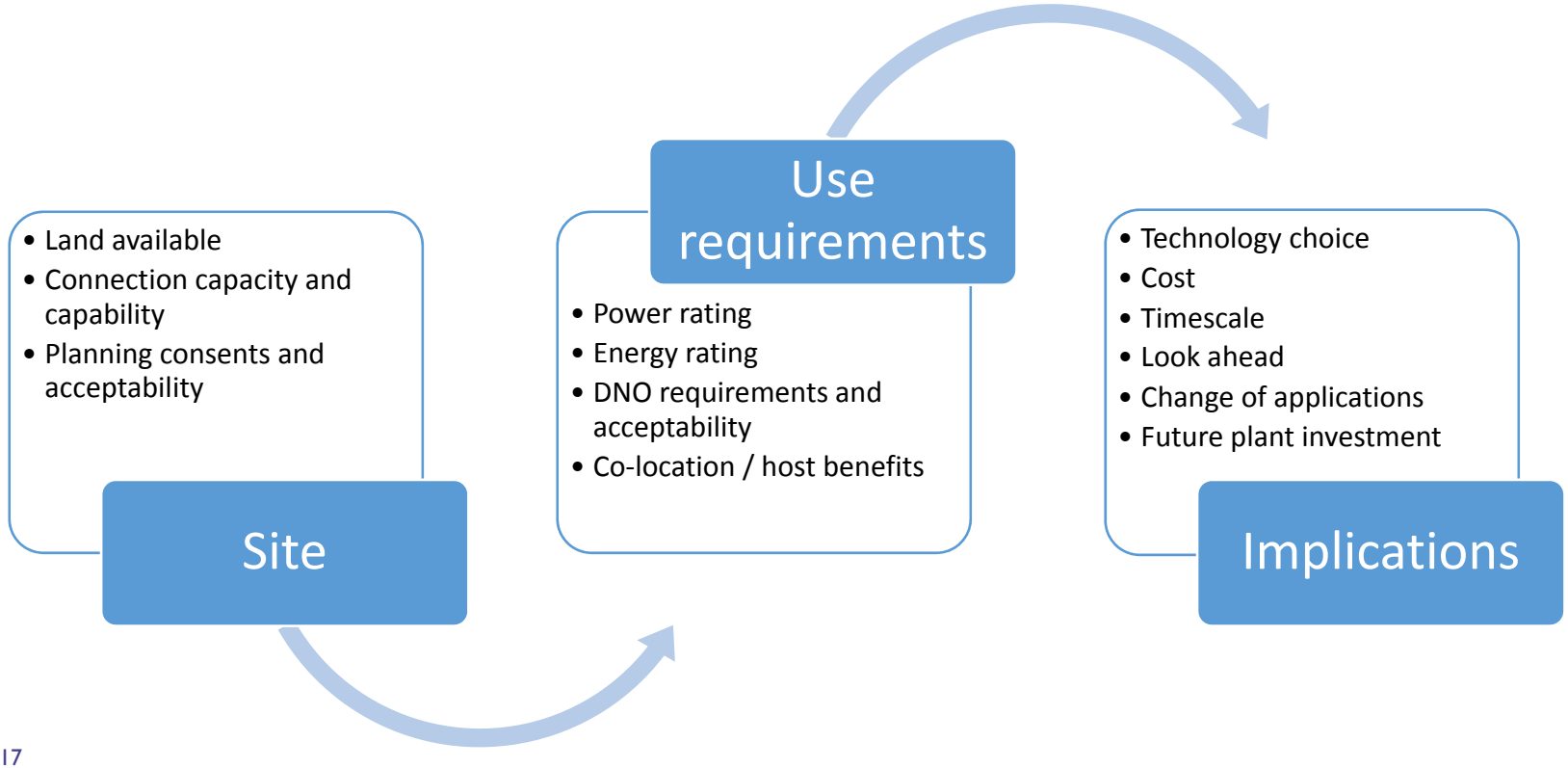
- Relocation difficult – individual modules can be decommissioned easily
- Building could repurposed

- **Containerised**

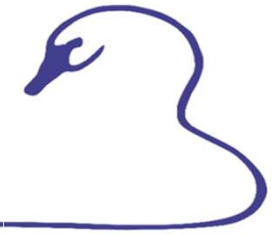
- Easier relocation
- Decommissioning
  - Reduce weight of container
  - Ensure container is undamaged and ready for transport


Site
Connection
Physical space
Application / use
Power and energy ratings
Technology selection
Configuration

Site selection



Site selection in practice



- Luck
- Wisdom
- Planning
- Good advice

Swanbarton Limited

www.swanbarton.com

Anthony Price 01666 840948

scottish renewables

Q & A

Networking Break

Planning for Storage

Nick Brown

LUC

Planning

for Storage

Nick Brown MRTPI
Environmental Planner

8th March 2017

RTPI
Chartered Town Planners

Who are LUC?

Environmental Planning, Design & Management Consultancy

Registered Town Planning Practice

Offices in Glasgow, Edinburgh, Bristol and London

Working within the energy sector
in Wind, Solar, Grid and Storage.

Storage in Planning

Evidence base

Technology

Pumped hydro and battery storage most widespread in planning

Battery storage gaining the most momentum but still few applications in Scotland

Scale

Mostly small to medium scale

Below Section 36 (up to 49.9 MW)

Battery Storage sub EIA

Storage in Planning

Evidence base

Location	Next to existing Grid Co-located with other technology Storage element within broader proposals (e.g. mixed use)
Success	Moderate success rate Much faster decisions (+ & -) in Battery Energy Storage Higher success if principle of development is clearer(co-location, energy parks, mixed use)

Planning for Storage

What can you expect?

Not a turnkey process...

Innovation = knowledge gaps (applicant and authority)

Guidance and policy vacuum (strategic and local)

SPP and NPF supportive but light touch

Use class confusion – Sui Generis, Class 5 (General industrial) or Class 6 (Storage and Distribution - See **APP/Y0435/X/09/2103771**)

LPA's not geared to deal with storage applications

Planning Authority 'Energy' experience counts

Prepare to answer more questions/provide more detail

Planning for Storage

What can you expect?

- Site sensitivities need to be considered fully

  Ecology
  Flood risk
  Landscape

- May need to massage public opinion

- Non-material considerations creep in
  (e.g. Building Reg issues/H&S/Politics)

- Precautionary decision making

- Decisions focus on the principle of the development

Planning for Storage

Policy Considerations

Principle of Development

- Strategic significance
- Accordance with the LDP
  - Policy considerations
  - SPG
  - Material considerations
- Set your consent strategy !

Policies:

Drainage and Flooding

Ecology / Ornithology

Land/Ground Contamination

Renewable Energy

Security, CCTV and Privacy

Agriculture / Countryside

Design and Visual Impact

Residential Amenity Road Safety

Noise

Planning for Storage

Setting the Strategy

Know your region

- Planning Authority (energy experience)
- Look at the Local Development Plan
- Scheme of Delegation – 5/10/20 objections? likely for committee decision?
- Elected Members – Politics/record

Check for precedence

- Existing applications
- Contentious decisions and outcomes
- Submission materials

Planning for Storage

Setting the Strategy

Know your Site

Land use

Sensitivities

Survey considerations – No EIA? but still policy requirements!

Assess any fatal flaws

Siting and Design principles – Modular/enclosed?

Weight & Balance

What constraints matter to the development

Are they relevant to planning? (consider material weight)

Predict the planning balance.

Planning for Storage

Setting the Strategy

Engage

Use pre-application consultation where you can (it is material)

Take your proposals to the authorities

Evidenced justification

Justify

Planning , Design and Access Statement

Robust demonstration of principle for development

Rationalise exclusions (if there is a need to)

Future Planning

What can be expected?

- Need to understand ‘fit’ with wider planning reform
    - Energy a key message but no means of implementation
- Development front end less cumbersome/less costly
    - Site selection and design practice more standardised
    - Guidance and policy will aid consenting speed
- Support for the decision makers
- Public understanding/perception engrained

Planning for Urban Storage?

What are the opportunities?

- Battery or ‘modular’ storage opportunities in urban settings
- Brownfield development
- Gap sites
- Synergies with commercial development
- Storage close to demand

Siting and Design Considerations

- Security issues & Integration issue
- Visual setting issues
- Interactions with housing/business
- Scalability
- Grid connections
- Change of use?

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Planning for Storage: Land Considerations

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Introduction

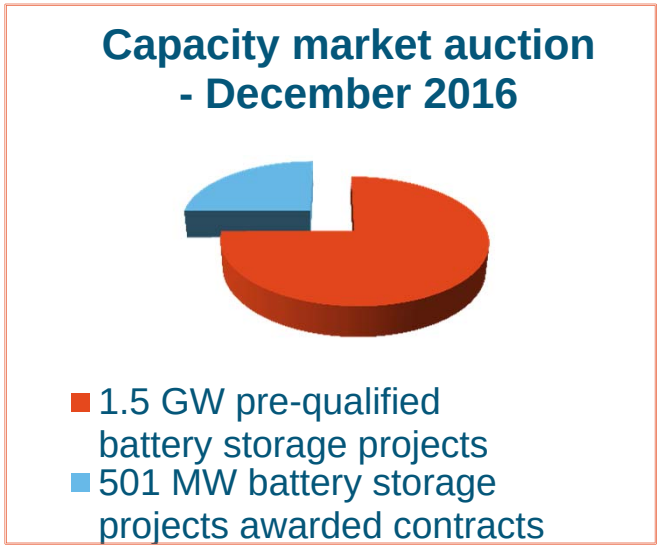
- Energy Storage & TLT's experience
- What will we cover?
  - Our experiences of storage development activity
  - Types of energy storage projects & legal pointers
  - Challenges/barriers to successful deployment
  - Funding/Investment considerations for energy storage development

Battery Storage in Action

- Inaugural Enhanced Frequency Response (EFR) tender
- 200MW of EFR contracts (for 4 years) awarded across 8 projects
- Capacity Market Auction – 501 MW battery storage projects covering 28 sites were awarded 15 year contracts

Battery Storage in Action

- 5 sites that were successful in EFR were also successful in Capacity Market
- Over 1.4GW of Demand Side Response projects received one year contracts
- Clear indication of the crucial role battery storage will play in the future of the national grid



Project Structures

- Option Agreement
- Form of lease (or disposition if purchasing the land)
- Title due diligence
- Negotiation of key documents with suppliers
- Corporate structuring
- Tax structuring
- Fundraising - debt v equity

Standalone Projects

- Greenfield and brownfield sites as well as conversion of solar option agreements for storage
- Capacity Market & revenue stacking
- Flexibility to terminate
- New Grid Connection
- Reinstatement
- Land Due Diligence – Access & Verges
- Lease footprint
- Ownership of equipment
- Rent

Behind the Meter Projects

- Electrically connected to a customer with a significant energy demand at its site
- Significant potential with industrial manufacturers, data centres, hospitals, supermarkets
- Benefits – arbitrage, peak shaving, Triad avoidance, uninterruptable power supply
- Revenue streams – ancillary services to the National Grid

Behind the Meter Projects

- Key legal considerations:
  - Ownership - is the site operator the owner of the land?
  - Counterparty strength – this may be fine on day 1 but what happens if they decide to sell the site during the term of the Lease?
  - Grid connection – will this continue to be in the name of the Landlord – what Landlord covenants do I need?
  - Export – if the site operations are discontinued do you need the ability to export directly to the grid?
  - Network – will BTM storage be connected to a constrained network?

Co-location of Storage

- Existing project structure:
  - Ownership
  - Funding constraints
  - Do sufficient rights exist for storage?
- Shared grid connections and other infrastructure
- Mitigating risks arising from a temporary loss (de-energisation) of the shared connection
- Termination of arrangement
- Revenue Sharing Agreement
- Grid Sharing Agreement

Challenges

- Storage doesn't fit within UK legislative & regulatory framework
- Potential for double-charging of system use charges
- Is planning permission required?
- Lack of current Health & Safety Standards
- Complex nature of revenue streams and regulatory uncertainty – Ofgem Embedded Benefits Consultation

Funding/ Investment Lease Considerations

- Funding remains challenging due to revenue uncertainty – what is a bankable revenue model ?
- Flexibility to assign/ change of ownership
- Notification to funder on termination events/ irritancy
- Step in/ direct agreement provisions
- Tenant break provisions
- Rights over wider landlord's property/ standard security
- Consents/ property rights in place for grid to point of connection.

Conclusion

- Secure land rights (and prior exclusivity)
- Careful legal structuring around co-location projects
- National Grid tender requirements
- Future proof project documents for funding (and sale)
- Emerging Scottish storage market/ opportunities post subsidy

Thank You

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Q & A

The Outlook for Storage Co-located with Renewables

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Catherine Cleary

TNEI

The outlook for storage co-located with renewables

Catherine Cleary

8th March 2017

tneigroup.com

Overview

1. Why co-locate with renewables?
2. Key barriers to deployment
3. Storage revenue streams
4. Irish approach – a view of the future?
5. A case study: modelling a co-located battery
6. Opportunities

Why co-locate storage with renewables?

Co-location of energy storage behind the meter on renewable energy generation sites offers certain benefits:

- **Reduced development CAPEX**

  By sharing grid connection assets and land costs

- **Increased capacity factor**

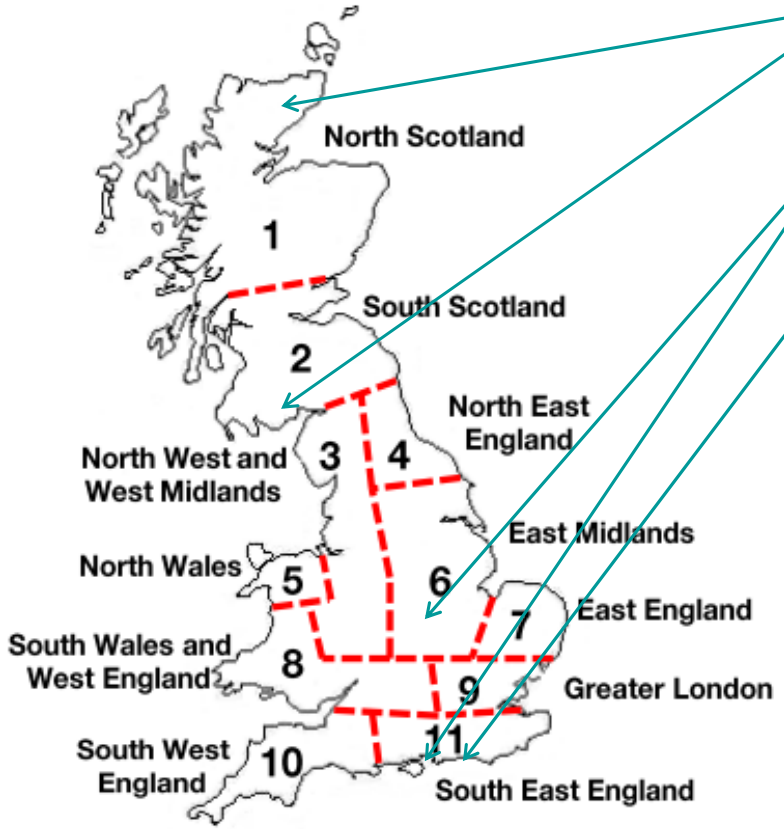
  For sites with a constrained grid connection

- **Accessing additional revenue streams**

  Through charge avoidance and ancillary services

Why co-locate storage with renewables?

Strong correlation between locational ancillary service requirements and high renewables penetration:



- Transmission constraint management
- Voltage Control
- DNO reinforcement deferral

Key barriers

Barriers to storage in general have been widely discussed already:

- Cost
- Regulatory uncertainty
  - Interaction with ROCs and CfDs
  - Definition of storage
  - Network charging
- Grid connections – worst case assessment
- Accessing revenue streams from benefits to network
- Revenue stream stacking
- Suitable contracts
- Lack of experience

Some are key to unlocking co-location potential

GB storage revenue streams

For now...

Revenue stream	Type	Contract with	Procurement process	Contract duration
Energy arbitrage	Through PPA or direct action in BM	PPA or BM	Electricity trades. Bids and offers in the BM	Variable
Super-red tarrifs	Embedded benefit	DNO	Automatic (result of the charging structure)	Project duration
EFR	Balancing service	National Grid	Market tender	4 years
FFR	Balancing service	National Grid	Market tender	1 – 24 months
Constraint management / Reinforcement deferral	Balancing service **(Future DNO service?)**	National Grid (or DNO)	Bilateral agreement or tender	Annual (or variable)
Reactive power	Balancing service	National Grid	Market tender	Annual (or variable)

GB storage revenue streams

For now...

A sensible “shortlist” of services for a battery development in the next 2-3 years:

Stand-alone Frequency Response concept

- EFR or FFR (excluding peak time periods)
- Triad avoidance
- Super-red DNO Use of System charges

Revenues not location specific.
Clear prioritisation of Frequency response

OR

Co-located “flexibility” concept

- Time-shifting constrained generation output
- Wider transmission/distribution constraint management
- Energy arbitrage
- Network charge avoidance
- Reactive power (Voltage control)

Revenue is location specific

GB storage revenue streams
The future...?

More “flexibility” services aimed at resolving local network issues (DSO level)

- Network Reinforcement Deferral
- Phase Balancing
- Power Flow Optimisation
- Dynamic voltage control

Simplified National Grid balancing services

- Frequency Response
  - Pre-Fault
  - Post-Fault
  - Margin
- Voltage Services
- System Security Services

The Irish model

In Ireland, Eirgrid have undertaken a major review of system services:

Part of SEM DS3 programme:

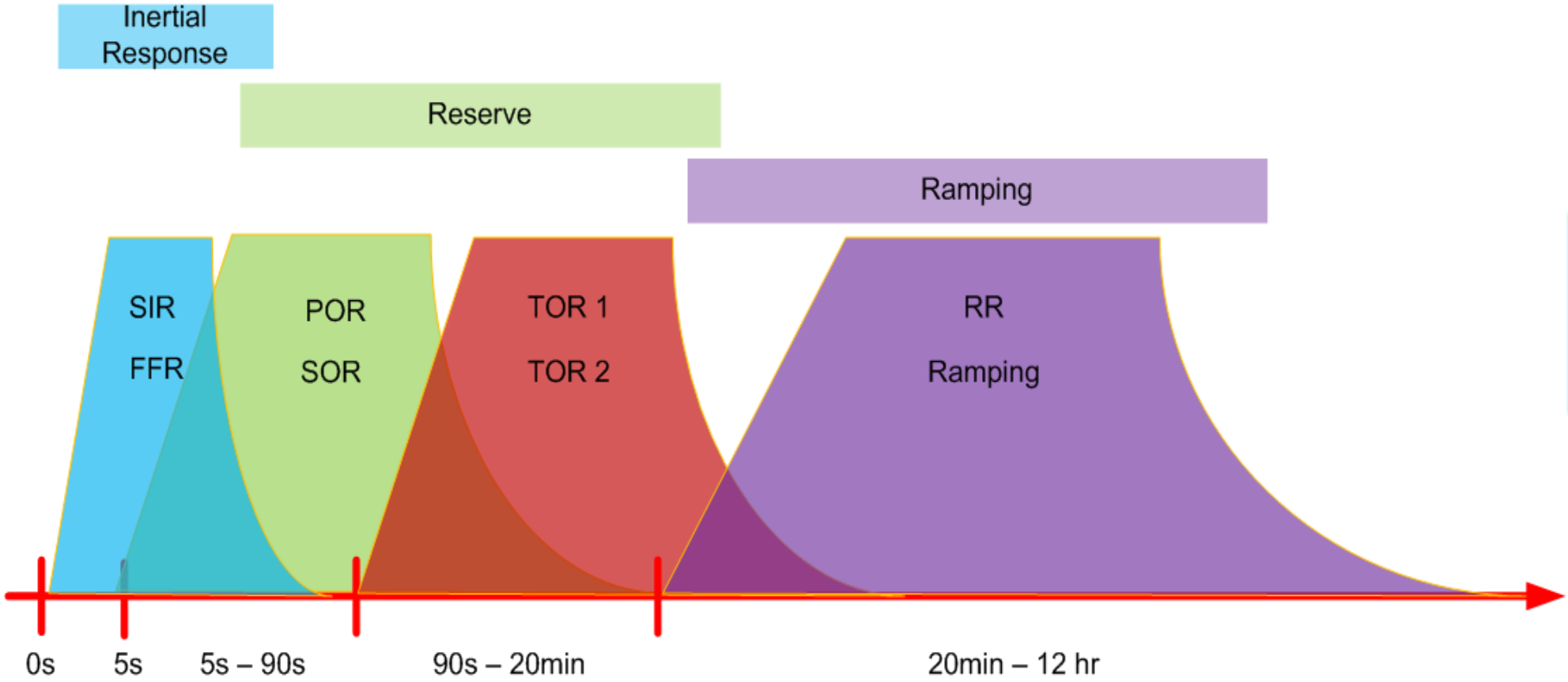
- Intention to operate securely at up to 75% instantaneous penetration of wind and other renewable generation
- 14 new and existing services
- System services will be procured from all providers using a auction based market
- Services of interest to energy storage and renewables.

The Irish model

New services		Existing services	
SIR	Synchronous Inertial Response	SRP	Steady State Reactive Power
FFR	Fast Frequency Response	POR	Primary Operating Reserve
DRR	Dynamic Reactive Response	SOR	Secondary Operating Reserve
RM1	Ramping Margin 1 Hour	TOR1	Tertiary Operating Reserve 1
RM3	Ramping Margin 3 Hour	TOR2	Tertiary Operating Reserve 2
RM8	Ramping Margin 8 Hour	RRD	Replacement Reserve (Dyn)
FPFAR	Fast Post Fault Active Power Recovery	RRS	Replacement Reserve (Syn)

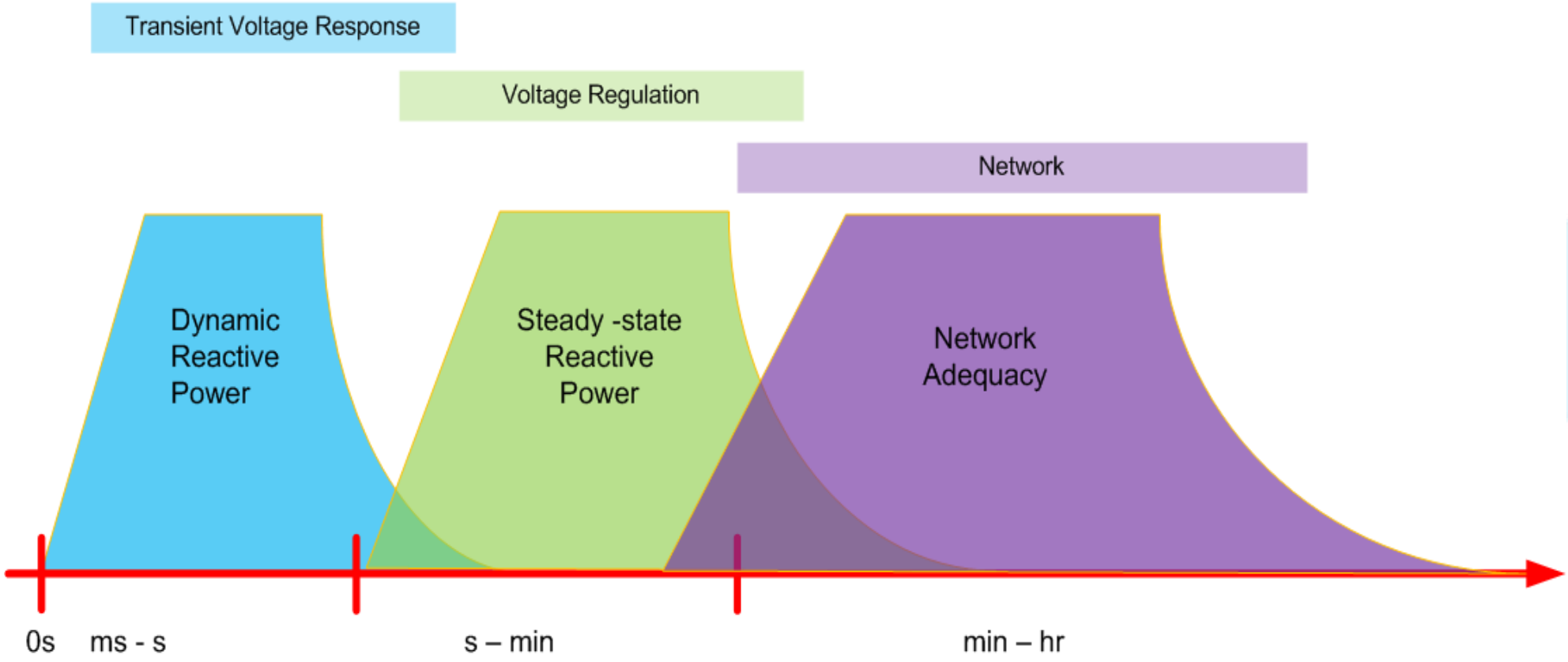
The Irish model

Frequency / inertia services



The Irish model

Voltage services



Storage accessible services

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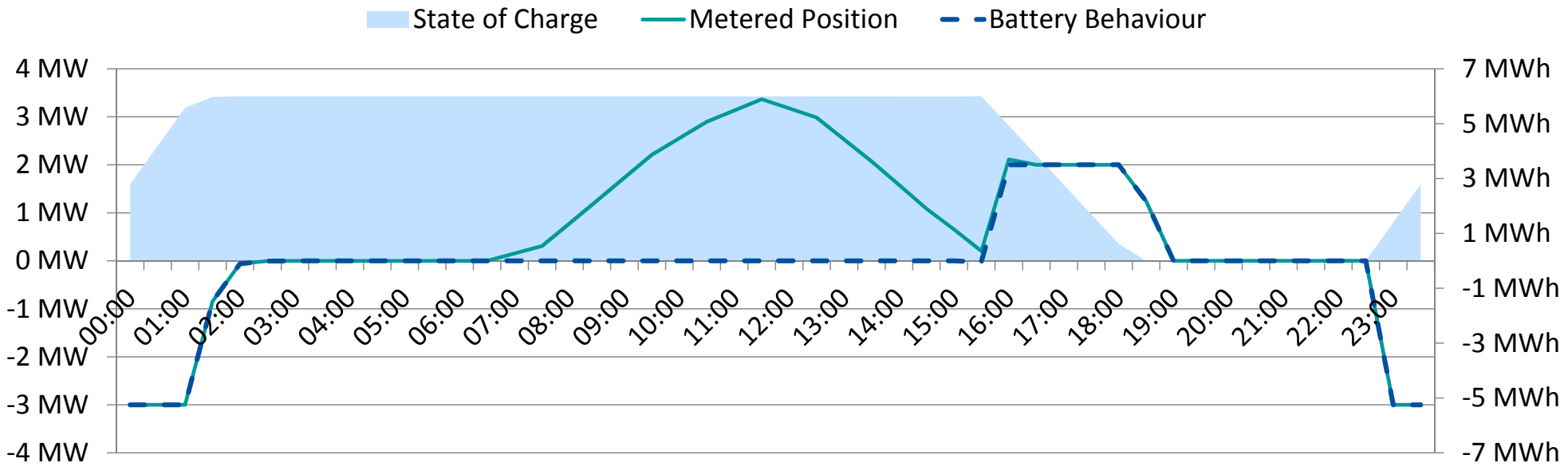
Case study

- Planned renewable energy site – future development
- No RO / CfD
- Constrained grid connection
- Consider the benefit of adding X MW battery storage **“behind the meter”**
- Main revenues:
    - Arbitrage
    - Use of system – triad avoidance and super-red credits
    - Capturing lost generation
    - Capacity market
- Revenue streams prioritised to optimise returns.

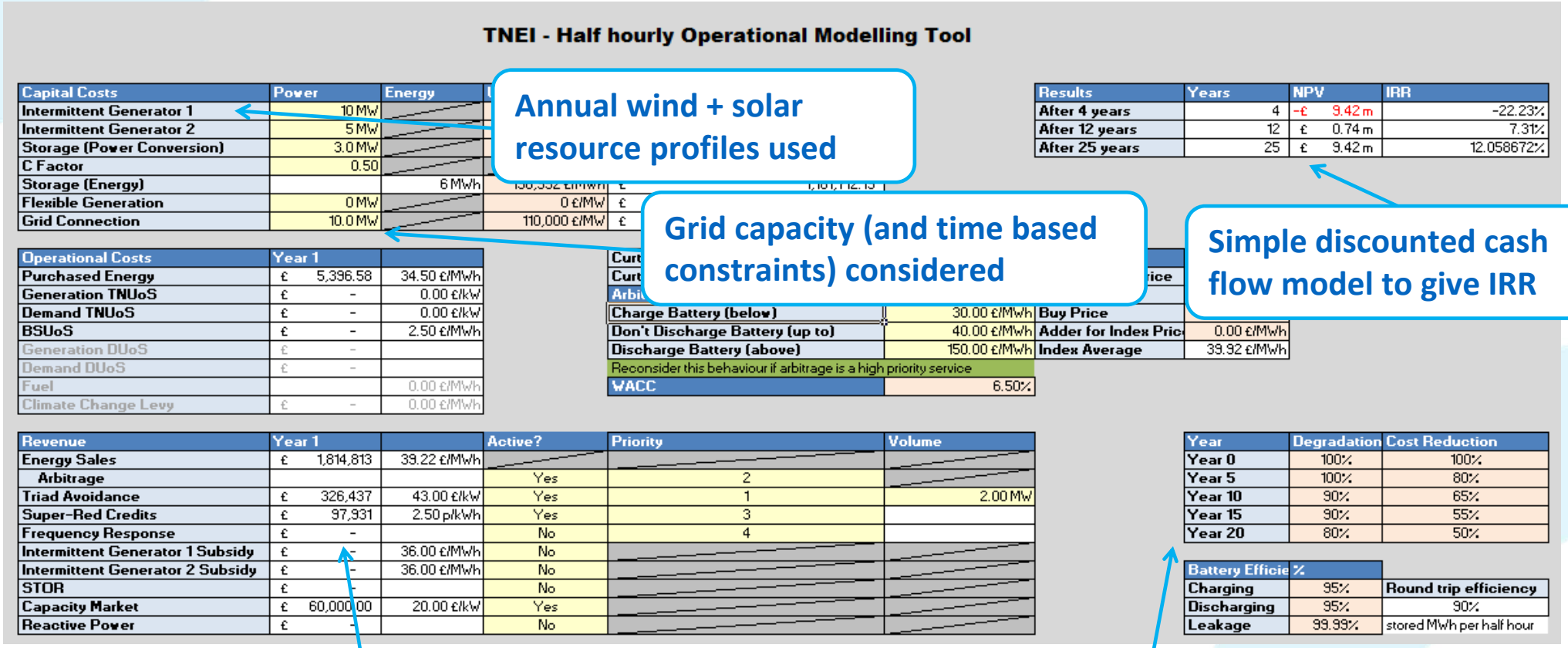
Case study: battery modelling

Excel based tool, can model multiple generation types + battery storage

- **Behaviour over a year in 30 minute time steps**
- **Simple logic to determine battery behaviour**
- What revenue stream is the site responding to? (service priority)
- Constraints of charging/discharging rate (MW) and capacity (MWh)



Case study: modelling tool



TNEI - Half hourly Operational Modelling Tool

Capital Costs	Power	Energy	
Intermittent Generator 1	10 MW		
Intermittent Generator 2	5 MW		
Storage (Power Conversion)	3.0 MW		
C Factor	0.50		
Storage (Energy)		6 MWh	
Flexible Generation	0 MW		0 £/MW
Grid Connection	10.0 MW		110,000 £/MW

Results	Years	NPV	IRR
After 4 years	4	-£ 9.42 m	-22.23%
After 12 years	12	£ 0.74 m	7.31%
After 25 years	25	£ 9.42 m	12.058672%

Operational Costs	Year 1	
Purchased Energy	£ 5,396.58	34.50 £/MWh
Generation TNUoS	£ -	0.00 £/kW
Demand TNUoS	£ -	0.00 £/kW
BSUoS	£ -	2.50 £/MWh
Generation DUoS	£ -	
Demand DUoS	£ -	
Fuel		0.00 £/MWh
Climate Change Levy	£ -	0.00 £/MWh

Charge Battery (below)	30.00 £/MWh	Buy Price	
Don't Discharge Battery (up to)	40.00 £/MWh	Adder for Index Pric	0.00 £/MWh
Discharge Battery (above)	150.00 £/MWh	Index Average	39.92 £/MWh
Reconsider this behaviour if arbitrage is a high priority service			
WACC	6.50%		

Revenue	Year 1		Active?	Priority	Volume
Energy Sales	£ 1,814,813	39.22 £/MWh			
Arbitrage			Yes	2	
Triad Avoidance	£ 326,437	43.00 £/kW	Yes	1	2.00 MW
Super-Red Credits	£ 97,931	2.50 p/kWh	Yes	3	
Frequency Response	£ -		No	4	
Intermittent Generator 1 Subsidy	£ -	36.00 £/MWh	No		
Intermittent Generator 2 Subsidy	£ -	36.00 £/MWh	No		
STOR	£ -		No		
Capacity Market	£ 60,000.00	20.00 £/kW	Yes		
Reactive Power	£ -		No		

Year	Degradation	Cost Reduction
Year 0	100%	100%
Year 5	100%	80%
Year 10	90%	65%
Year 15	90%	55%
Year 20	80%	50%

Battery Efficie	%	
Charging	95%	Round trip efficiency
Discharging	95%	90%
Leakage	99.99%	stored MWh per half hour

Annual wind + solar resource profiles used

Grid capacity (and time based constraints) considered

Simple discounted cash flow model to give IRR

Model tracks most profitable revenue streams

Battery degradation and round trip efficiency considered

Case study: results

- 10 MW wind farm + 5 MW solar + 3 MW battery storage
- Constrained grid connection

Adding storage gives a modest increase in IRR for this project

- Main revenues:
  - Arbitrage
  - Use of system – triad avoidance and super-red credits
  - Capturing lost generation
  - Capacity market
- Battery prices need to continue to decrease
- Viability depends on site specifics and optimising installed battery size.

Finding the opportunities

Conditions where co-location of storage is most suitable	
Grid connection	• Constrained or actively managed connection • Connections delayed by upstream reinforcement
Regulation	• Subsidy-free future development – no RO/CfD conflicts
Network charging	• Sites with high time-of-use credits available
Ancillary services	• Location-specific revenue streams (e.g. reactive power) • Tapping into trials / new local DSO services as they emerge
Onsite loads	• Sites with high non-controllable demand • Sites where onsite generation and onsite demand occur at different times
Site suitability for battery?	• Physical space • Low expected landscape impacts • Low noise impact • Low ecological impact • Low flood risk

Thank you

Any questions?

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Q & A

SR Feasibility & Site Selection: Electricity Storage CPD Seminar

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