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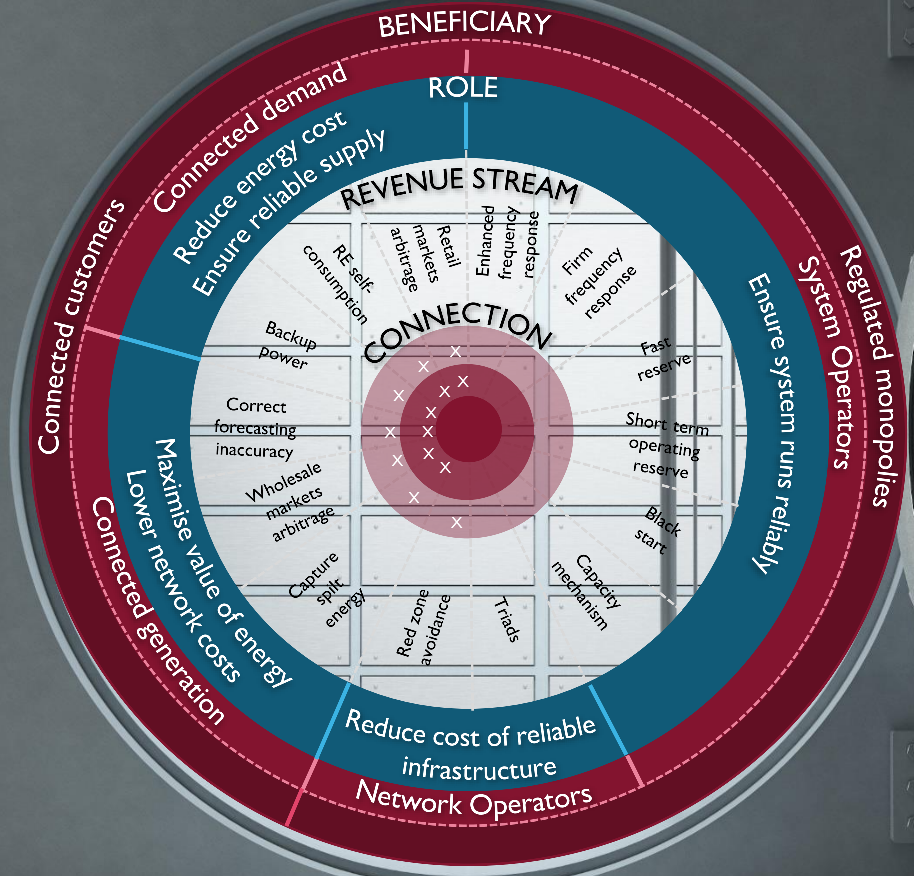
CRACKING THE CODE

A GUIDE TO **ENERGY STORAGE REVENUE** STREAMS AND HOW TO DERISK THEM



An Everoze report, commissioned by Scottish Renewables

July 2016

With input from RES and the Power Networks Demonstration Centre

scottish renewables

res

UNIVERSITY of STRATHCLYDE POWER NETWORKS DEMONSTRATION CENTRE

EXECUTIVE SUMMARY

THE ERA OF ELECTRICITY STORAGE IS UPON US

After many decades of trials and academic research, UK electricity storage is on the verge of breakthrough. With new and more diverse sources of electricity generation coming online, we need a smarter way of matching supply and demand: storage is a key part of the solution. The potential benefits are substantial; work funded by the Scottish Government, DECC and others suggest that if market barriers are removed, energy storage systems could unlock £2.4bn of annual savings across the UK by 2030, saving households £50/yr off their bills.

> "These technologies are now on the verge of being able to compete"
>
> National Infrastructure Commission

The potential is already manifesting itself in commercial interest

The response to National Grid's tender for Enhanced Frequency Response has been overwhelming: there are 60 prequalified parties with capacity in excess of 1.3GW bidding in, of which 888MW is bidding in with batteries. This is despite storage assets facing well-publicised challenges such as 'double charging' for government levies that are added to electricity costs. If anything, the UK is behind the trend: Germany has already installed 25,000+ domestic storage systems, and utility-scale storage for frequency regulation is becoming commonplace in parts of the U.S..

Scotland has a crucial role to play in this brave energy future

Storage refers to a diverse set of technologies, as outlined in Scottish Renewables' report *Energy Storage: The Basics*. Clearly, Scotland has a rich heritage in hydro power, making it a prime candidate for future pumped hydro deployment. Yet, activity in Scotland is already much broader than this; Scotland is already home to innovative storage projects. In part this is due to Scotland's status as a net energy exporter, its rich academic community and own pioneering startups.

This report takes services, not technology, as a starting point

It is common for storage reports to start by explaining different storage technologies. Our philosophy is different; we seek to take a technology-agnostic approach to exploring what benefits storage can deliver, focusing on how storage can serve the electricity system, rather than the other way around. Our starting point is to examine where storage can add value and what pricing signals currently exist to incentivise this. From this we derive a number of policy recommendations for Scotland and the wider UK.

STORAGE REVENUE: A CODE TO BE CRACKED

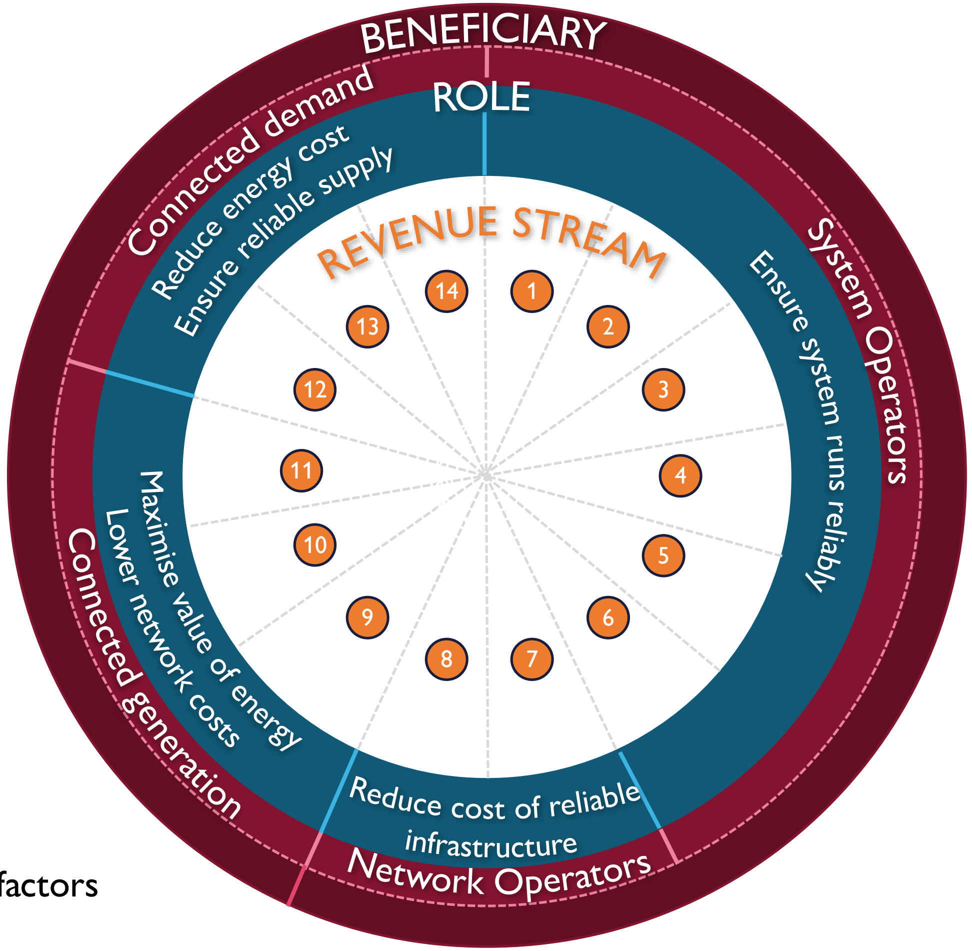
Storage revenue must be decoded

Storage revenue streams are complex. This is due to the vast range of roles that storage can play. To help crack the revenue code, we have mapped out the most significant opportunities currently available to GB storage providers. Whilst the ultimate beneficiary of storage is the consumer, through lower energy bills, our revenue wheel seeks to decode the benefits at a market participant level. Working from the outside in, the wheel shows:

- **Beneficiary**: Who might benefit from storage?
- **Role:** What might the storage unit do?
- **Revenue stream:** What are the current ways to monetise this role in GB?

Revenue streams are "stacked"

Revenue streams are commonly combined – or "stacked" together, to maximise project incomes. And it's here that storage gets tough. The optimal stack varies according to factors ranging from risk appetite and technology through to connection point.



THE REVENUE STREAMS	
1	ENHANCED FREQUENCY RESPONSE (EFR)
2	FIRM FREQUENCY RESPONSE (FFR)
3	FAST RESERVE
4	SHORT TERM OPERATING RESERVE (STOR)
5	BLACK START
6	CAPACITY MECHANISM
7	TRIAD AVOIDANCE
8	RED ZONE MANAGEMENT
9	CAPTURE SPILT ENERGY
10	WHOLESALE MARKETS ARBITRAGE
11	CORRECT FOR FORECASTING ACCURACY
12	BACKUP POWER
13	RENEWABLES SELF-CONSUMPTION
14	RETAIL MARKETS ARBITRAGE

THE FINANCING CHALLENGE

The fundamental challenge: defining a *financeable* revenue stack

In addition to the sheer market complexity, the core problem for storage projects is this: for historical reasons, revenue streams are designed to suit conventional generation, and storage projects have different characteristics to conventional generators.

In particular:

- **Storage is capital-intensive**
  The cost of storage plant is upfront; annual operational costs are typically just a small fraction of capex. This contrasts conventional generators, which have a more opex-heavy cost structure. It means that storage can be seen as a risky investment.
- **Flexibility is the *sole* role of storage**
  Conventional plant often provide *generation* as well *flexibility* services, with *generation* being the core revenue source. This contrasts storage, for which *flexibility* must by itself provide all revenue, rather than being treated as a bolt-on.

Three challenges prevent revenue stacks from being financeable

The revenue-based barriers to making storage projects financeable are threefold:

1. **Low bankability**
   Revenue streams are not easily bankable from a private sector perspective.
2. **Revenue interface risk**
   Revenue streams do not always match up from a timing, contractual and technical perspective.
3. **Lost potential**
   Storage operators cannot monetise the full range of services that their plant can deliver.

Together, these are the three barriers that need to be tackled to crack the code of the storage opportunity in Scotland and the rest of the UK. Removing these barriers is critically important to enable system and network challenges to be solved in the least cost way – and ultimately minimise costs to consumers.

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RECOMMENDATIONS: UNLOCKING THE POTENTIAL

It's time to improve bankability, address revenue interface risk and unlock potential

Revenue stacks need to attract cost effective debt and equity, to ensure that the lowest cost source of flexibility is able to access the market. This means designing revenue streams with investors and consumers in mind, reflecting the reality that the financial characteristics of new flexibility projects is different from those of the past. We recommend a number of changes to crack the code, the most important of which are:

1. IMPROVE BANKABILITY

Some revenue streams to support system operation are only accessible through monthly tenders. Extending contract length, and possibly introducing a cap-and-floor regime for large projects with long lead times would help reduce risks for investors. This would decrease the cost of finance, meaning that storage can be delivered at least cost.

2. ADDRESS INTERFACES

Ensuring that technically compatible revenue stream can work together is central to building the storage business case. Aligning tender timelines will help reduce the risk premium that investors assign to secondary revenue streams.

3. UNLOCK POTENTIAL

Distribution network owners have been taking active steps to trial 'storage-friendly' commercial innovations– but these have yet to become the norm. We now need to ramp up dissemination and private sector engagement, whilst maintaining the innovation momentum.

4. INVEST IN LONGER DURATION STORAGE APPLICATIONS

Much of the storage interest in the UK to date has focused on high power applications such as frequency response. But high energy applications with longer storage durations are of particular interest to Scotland, due to its high renewables penetration, its status as a net energy exporter, and comparatively low population density. We need to leverage expertise of both academia and Scottish development agencies through research, development and demonstration to craft a world-leading position.

The opportunity in Scotland

CONTENTS

1 REVENUE STREAMS

- Who might benefit from storage, and how?
- What revenue streams are currently available, where can projects be connected?
- What do revenue stacks look like?

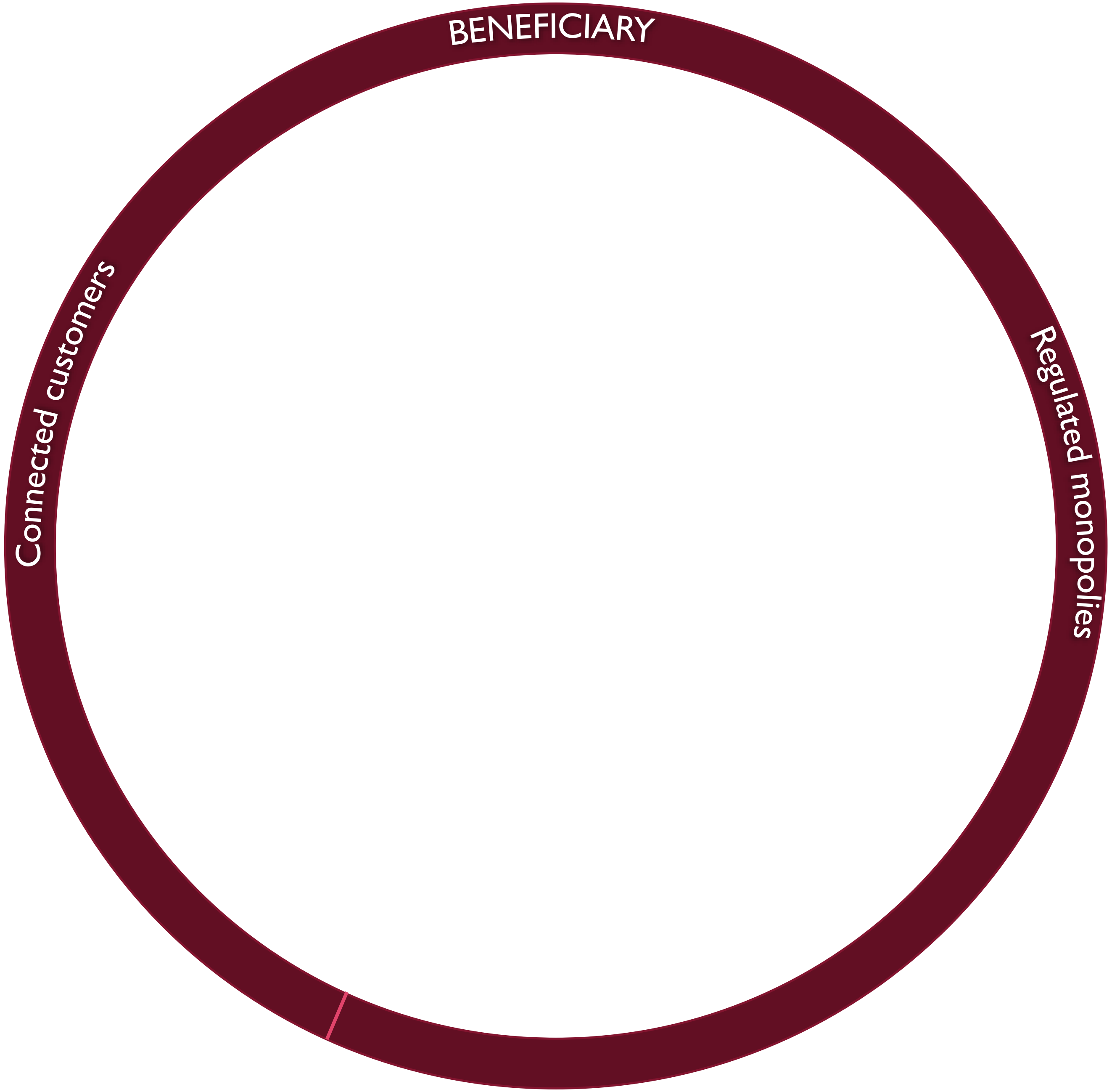
Two groups of beneficiaries

There are two groups who could potentially benefit from the services that storage can provide: the regulated sector and the private sector.

The Scottish electricity system ultimately exists to serve consumers. In its landmark report *Smart Power,* the National Infrastructure Commission clearly sets out how a smart power revolution spanning storage, interconnection and demand response is worth up to £8bn to UK consumers. Storage in particular has a key role to play: a recent report supported by government, industry and academic partners found that energy storage has the potential to save consumers £2.4 billion a year by 2030, meaning £50/yr off household energy bills.

To realise these savings, we need to ensure that the lowest cost technologies are able to provide the system with the services that it needs. The first step is to map out the key actors within the electricity system, and how storage can help these actors better fulfil their role. Put simply, the potential beneficiaries from storage services fall into one of two camps:

- **Regulated monopolies:** These bodies are natural monopolies, entrusted with helping to run and manage our electricity system.
- **Connected customers:** These are organisations who have a profit or community motive, rather than direct regulatory obligation. They tend to act in competition, and are not natural monopolies.



Four subgroups of beneficiaries

Within the regulated sector, the two key organisation types who can benefit from storage are system operators and network operators. Within the private sector, energy users and energy asset owners can benefit from storage.

Across the regulated and private sector, there are four types of organisation who benefit from storage services:

1. System operator: The system operator is responsible for managing the security of the electricity system in real-time. *National Grid Electricity Transmission* fulfils this role across the UK through the procurement of "ancillary services".

2. Network operators: Network operators are responsible for developing, operating and maintaining physical network infrastructure.

At a transmission level, the network operators are:

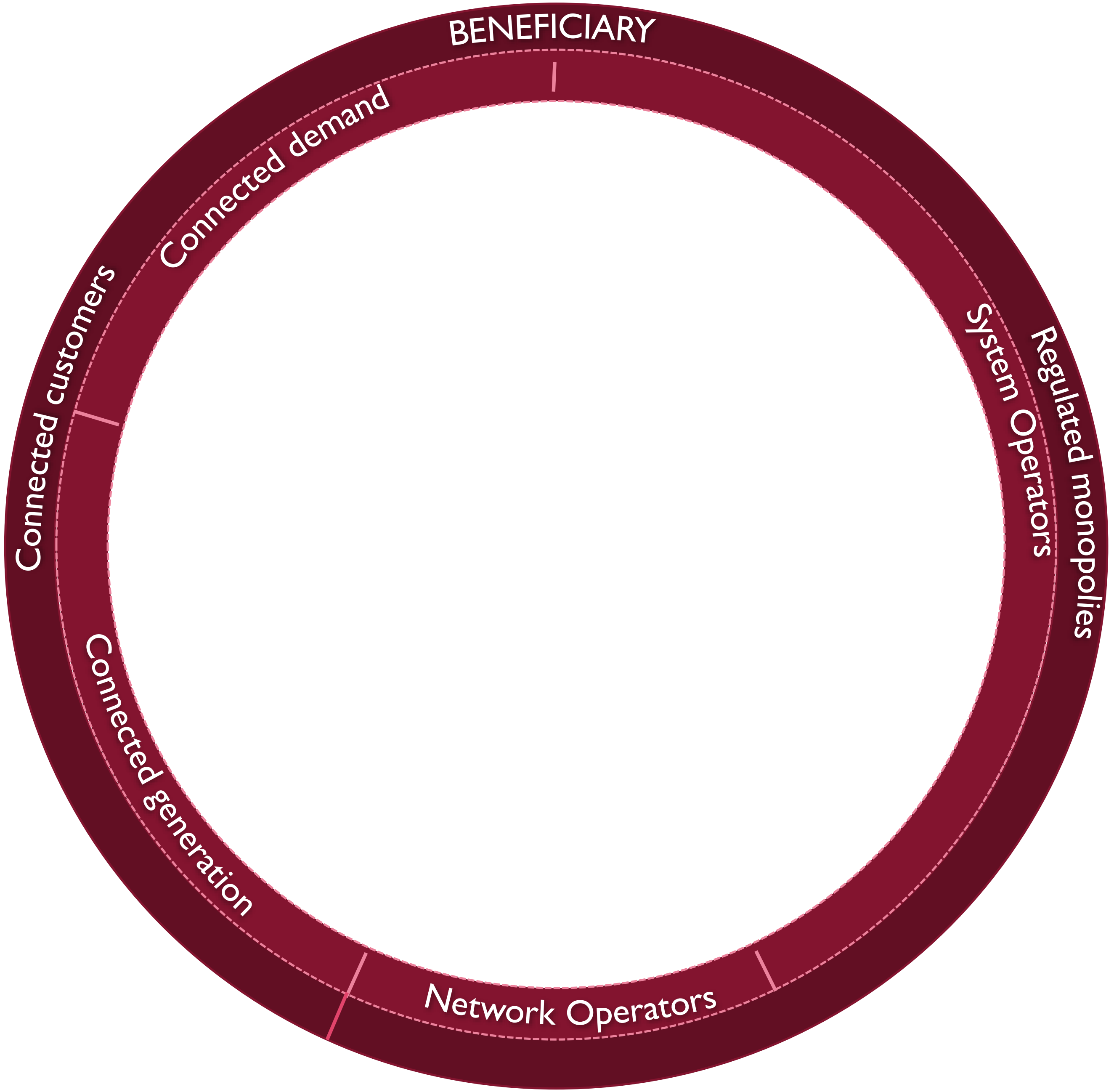
- *Scottish Power Transmission* for southern Scotland; and
- *Scottish Hydro Electric Transmission* for northern Scotland and the Scottish islands groups.

At a distribution level, the network operators are:

- *SSE Power Distribution* in north Scotland; and
- *SP Energy Networks* in central and southern Scotland.

3. Connected generation: These companies own assets such as renewables and storage plant, rather than being energy users. Energy is their core business; for them, energy is how they make money.

4. Connected demand: Connected demand refers to energy users who consume energy – from industrial scale through to homeowners. Energy is rarely their core business; for them, energy is a cost, rather than a source of revenue. However, in some instances they may have onsite microgeneration.



Four types of role

Storage plays different roles for different beneficiaries – ranging from improving system reliability through to reducing energy costs.

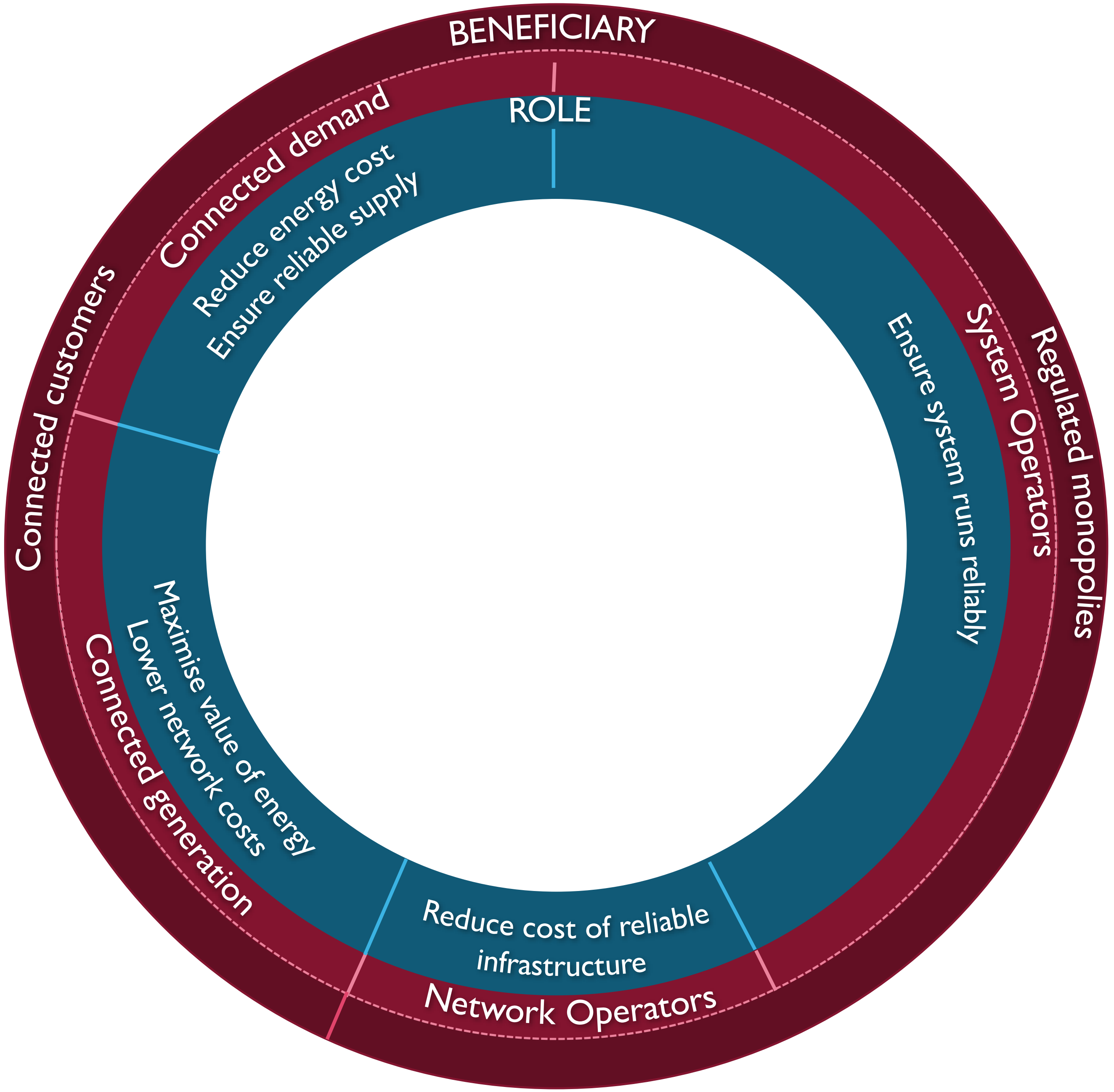
Storage offers the following services to each group:

1. **The system operator:** Storage can help the system operator achieve its goal of running the system reliably and safely and cost-effectively.

2. **Network operators:** Storage can help network operators find ways to minimise the cost of providing reliable grid infrastructure, including either deferring or avoiding investment.

3. **Connected generation:** Storage can help energy asset owners get the best price possible for their energy. In addition, storage can help lower their network and use of system costs, to the extent that this cost is borne by generators rather than just regulated monopolies.

4. **Connected demand:** Storage can help energy users minimise their energy bills, and ensure reliability of supply, so they can get on with their core business. These players are mostly passive in the energy market.

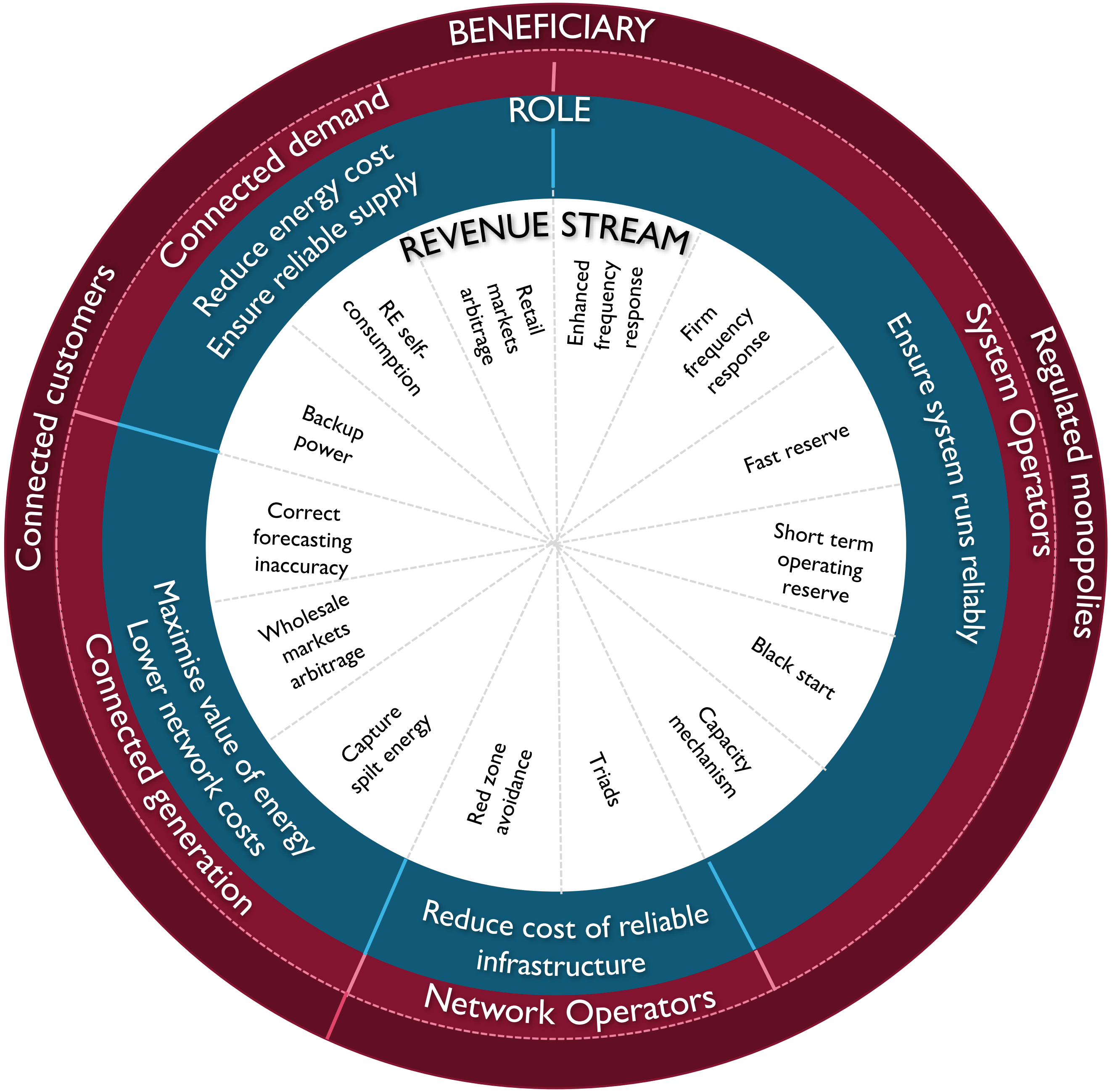


Fourteen (+) revenue streams

There are fourteen key ways for storage operators to monetise their storage plant

There are many ways that storage operators can monetise their services:

- **The wheel sets out higher value revenue streams:** This is not comprehensive; there are additional revenues available including voltage support, various behind-the-meter demand response schemes, and distribution network operator schemes. For simplicity, the revenue wheel focuses on revenues which are generally higher value and/or have broad applicability.
- **Beneficiaries are not always owners:** The beneficiaries associated with each revenue stream need not necessarily be the owners of storage plant; in fact, in some cases this can be prohibited. Beneficiaries are also not necessarily the counterparties for associated contracts. Intermediaries play a key role; for instance, aggregators play a major role in opening up flexibility revenue streams to smaller players.
- **Each revenue stream has a distinct risk profile:** The risk profile of revenue streams can vary: some revenue streams are accessible via tenders; others are delivered via energy markets. Some have location-specific values; others are system-wide.



The fourteen revenue streams presented in the diagram are summarised in the table below. These are the main ways that storage operators can monetise their storage units in the UK at present.

REVENUE STREAM	DESCRIPTION	VEHICLE
1. Enhanced Frequency Response (EFR)	System frequency is a continuously changing variable that is determined and controlled by the second-by-second (real time) balance between system demand and total generation. EFR is a new, fast frequency response product which helps manage frequency, requiring a full response in less than a second.	Tender
2. Firm Frequency Response (FFR)	A monthly electronically tendered service through which National Grid procures energy that can respond within 30 seconds.	Tender
3. Fast Reserve	A monthly tendered market designed to procure large blocks of reserve energy of 50MW to respond within 2 minutes.	Tender
4. Short Term Operating Reserve (STOR)	An important source of reserve energy for National Grid. Procured via 3 tenders throughout each year, a response time of up to 20 minutes is required.	Tender
5. Black Start	The procedure to recover from a total or partial shutdown of the transmission system which has caused an extensive loss of supplies.	Tender
6. Capacity Mechanism	The capacity mechanism is a catch-all term for the auctions for the Capacity Market that National Grid runs to guarantee capacity for any given year. The Capacity Market is one of the main building blocks in the UK Government's Electricity Market Reform (EMR) programme	Tender

The fourteen revenue streams presented in the diagram are summarised in the table below. These are the main ways that storage operators can monetise their storage units in the UK at present.

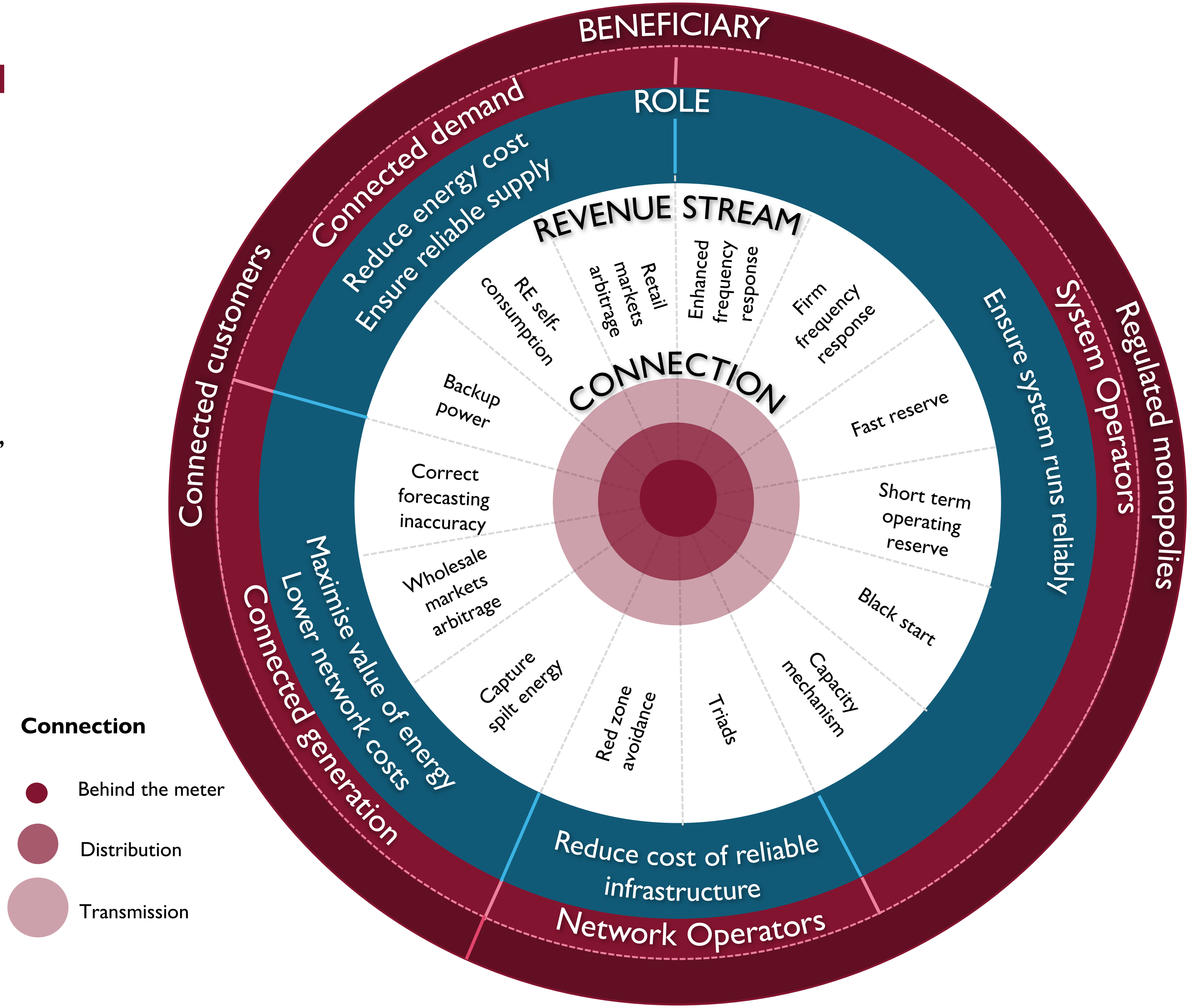
REVENUE STREAM	DESCRIPTION	VEHICLE
7. Triad Avoidance	Reducing consumption at periods where peak winter national demand is forecast, in order to proportionally reduce TNUoS (Transmission Network Use of System) charge.	Via supplier
8. Red Zone Management	Shifting consumption to avoid periods of highest distribution network cost (DUoS; Distribution Use of System), often referred to as "red-zones"	Via supplier
9. Capture spilt energy	Storing energy (particularly from wind/solar plant) that would otherwise be lost due to grid constraint or instances where the rated capacity of the generating plant exceeds that of the grid connection.	Markets / CfD
10. Wholesale markets arbitrage	Price arbitrage: buying energy cheap on the wholesale energy markets, and then selling when prices are higher.	Markets
11. Correct for forecasting inaccuracy	Store/release energy when generation is out of line with forecasts.	Imbalance cost
12. Backup power	Provide backup power in the event of grid failure	N/A
13. Renewable energy self-consumption	Maximise use of onsite renewable energy (minimize grid exports)	Energy bills
14. Retail markets arbitrage	Similar to energy arbitrage, but based on customer's retail tariff, not prevailing wholesale price	Energy bills

Three places to connect on the grid

Storage can be connected at transmission level, distribution level, or behind-the-meter.

The possible connection points for storage are as follows:

- **Transmission level:** on high voltage electricity "motorways", rated at 132kV, 275kV or 400kV in Scotland.
- **Distribution level:** at lower voltages (the "A-roads"), rated at 33kV or 11kV, used to supply towns and villages.
- **Behind-the-meter:** onsite with the energy user.



Different connections for each revenue stream

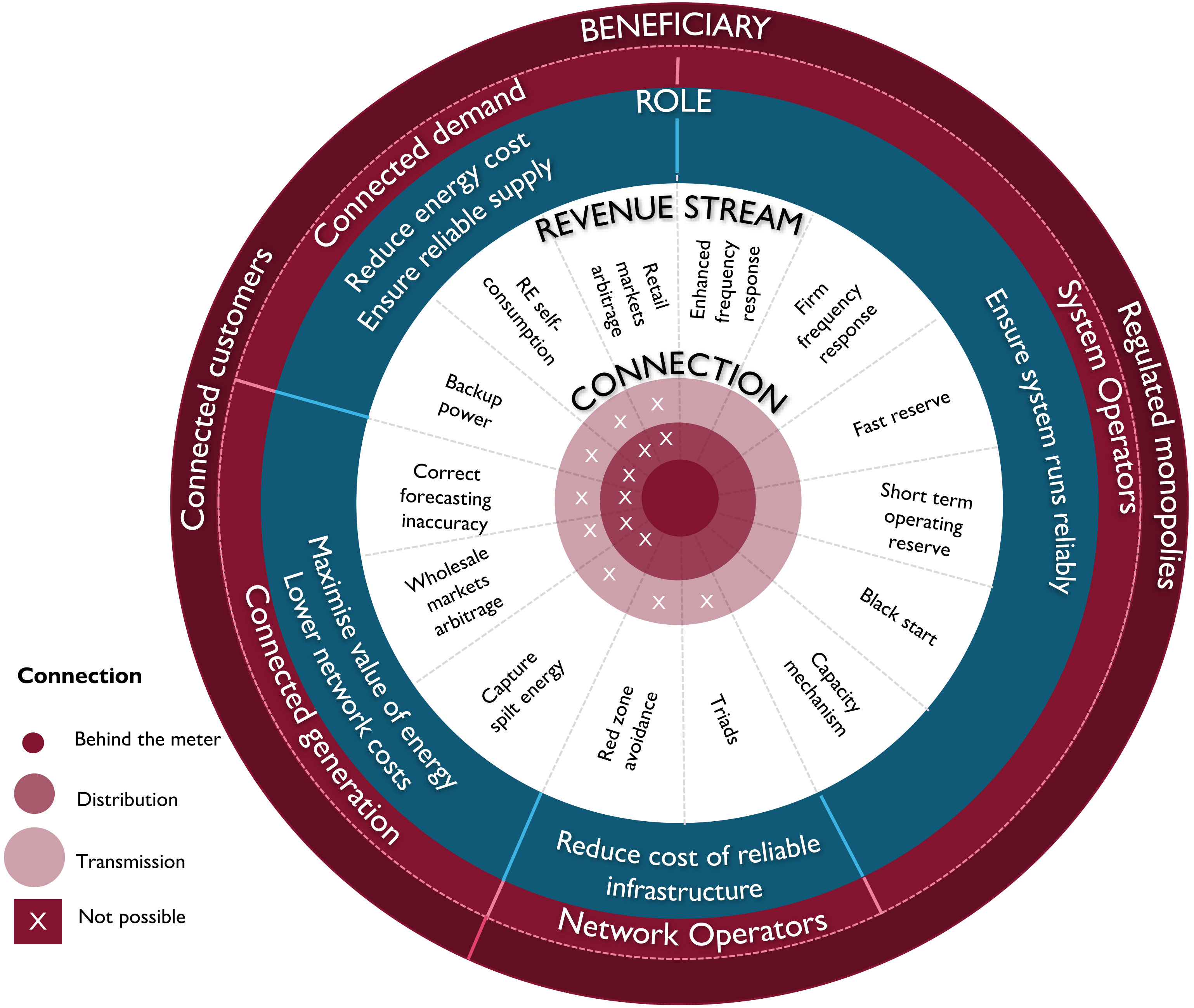
Connection point affects which revenue streams can be accessed.

System Operator streams: Revenue streams associated with transmission system operation can generally be accessed at all connection points. However, the point of connection is typically more constrained than for other revenue sources.

Network Operator streams: Network operation is by nature locational, and typically these revenue streams require either behind-the-meter or distribution connection.

Connected generation streams: Renewable streams associated with connected generation can be subject to complexities regarding precise positioning of the meter, particularly regarding the balancing market. DECC's May 2016 consultation on CfDs makes a number of recommendations here specific to co-location of storage and renewables, though at the time of writing this is still under review. The diagram currently presents a "cautious" approach to connection; other metering options may be possible.

Connected demand streams: Revenues associated with energy usage by necessity must be accessed by units that are behind-the-meter.



Accessible revenue streams vary by technology

Each storage technology has unique performance characteristics – and this drives which revenue streams it can access.

There are a range of different energy storage technologies for developers to choose from. Each technology is suited to different applications.

Key factors to consider when selecting storage technologies to access a particular revenue stream include cost, power rating, response time, discharge duration and site-specific constraints. For instance, batteries tend to be suited to applications requiring a quick response (eg frequency response), whereas other technologies such as compressed air energy storage are better suited to longer duration storage. Further information is provided in Scottish Renewables' report: *Energy Storage: The Basics.*

Revenue streams are typically combined, or "stacked"

Most storage projects will "stack" 2-3 different revenue streams.

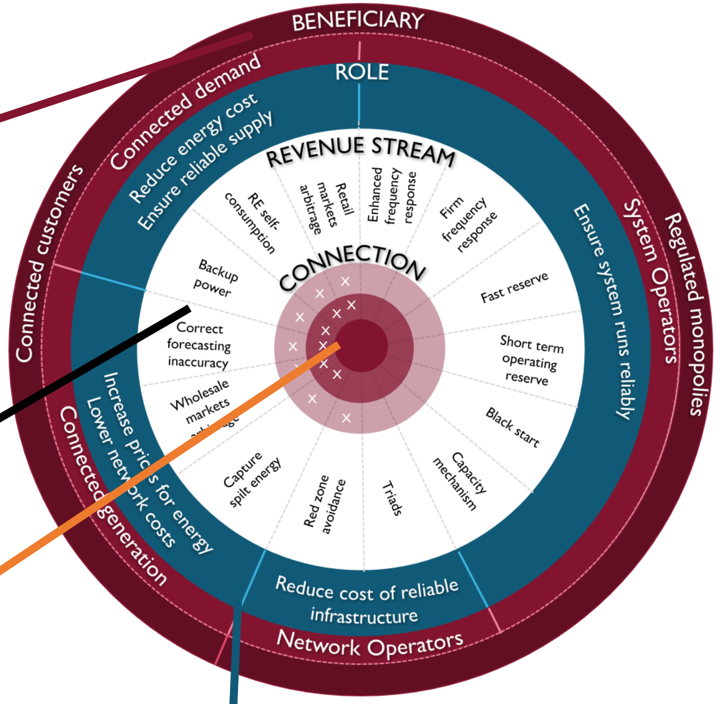
For a storage project to be profitable, project developers typically need to stack multiple revenue streams together.

There is no such thing as a one-size-fits-all revenue approach. The revenue stack chosen is informed by a range of factors including the risk appetite of funders, the technology, location and grid connection.

As a result, it can be helpful to approach revenue streams through illustrating "typical use cases". Three examples are shown on the following slides. At present, most storage business models are based on 2-4 core revenue streams.

New opportunities over time

Revenue opportunities for storage will grow over time, as energy systems become more decentralised and more synchronous power stations come offline.



BENEFICIARY

- **Devolution of the system operator role**: This role may (or may not) be carved out into a separate Independent System Operator. More generally, Ofgem has clearly signalled via the DECC/Ofgem Smart Grid Forum that responsibilities are likely to become more devolved to the distribution level as distribution network operators transition to becoming distribution system operators.

REVENUE STREAM

- **Growth in volumes procured:** To date, the storage focus has largely been on *high power* applications, such as frequency response – and the system need for this will increase as conventional generation comes offline. There will also be a growth in *energy* applications, such as arbitrage, over time, reflecting increased system need as wind and solar deployment grows.
- **Increased revenue stacking**: Developers will move from stacking 2-3 revenue streams today to 4+ in future, due to removal of regulatory/market barriers, improved understanding and enhanced sophistication of control systems.
- **New subsidiary revenue streams:** New revenue streams will emerge, for instance, potential roll-out of Enhanced Frequency Control Capability (EFCC) by National Grid, and possible innovations from DNOs including services for localised grid balancing, phase rebalancing and harmonics mitigation.

ROLE

- **Growing role for storage:** Growth in renewables will increase the need for flexibility technologies such as storage, as signalled by Imperial College's recent study for the Committee on Climate Change on the value of flexibility.

CONNECTION

- **More behind-the-meter applications:** for instance, through growth in electric vehicles

2 RISKS AND RECOMMENDATIONS

- What are the key risks?
- What should we do about them - recommendations?

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Key risks

There are three key risks associated with revenue streams available in the UK which can prevent storage projects from being bankable.

Industry has highlighted a number of challenges to storage investment, including issues such as 'double charging' for the various government levies that are added to electricity costs; this paper focuses specifically on *revenue* related challenges.

In addition to the sheer market complexity, the core problem for storage projects is this: revenue streams are designed to suit conventional generation, and storage projects have different characteristics to conventional generators.

In particular:

- **Storage is capital-intensive:** The cost of storage plant is upfront; annual operational costs are typically just a few percent of capex. This contrasts conventional generators, which have a more opex-heavy cost structure. It means that storage can be seen as a risky investment.
- **Flexibility is the *sole* role of storage:** Conventional plant often provide *generation* as well as *flexibility* services, with *generation* being the core revenue source. This contrasts storage, for which *flexibility* must by itself provide all revenue, rather than being treated as a bolt-on.

Following on from this, there are three major key commercial risks to securing a bankable revenue stream from storage plant in Scotland and the wider UK.

LOW BANKABILITY: Revenue streams are not easily bankable from a private sector perspective.

REVENUE INTERFACE RISK: Revenue streams do not always match up from a timing, contractual and technical perspective.

LOST POTENTIAL: Storage operators cannot monetise the full range of services that their plant can deliver.

These three key risks, and associated recommendations, are explored further on the following pages.

LOW BANKABILITY: Financiers can struggle to get comfortable with the merchant risk associated with storage revenue streams

ROOT CAUSE

The system operator: Although the system operator is familiar with valuing ancillary services, it is transitioning to the new reality of contracting these services from a large number of small players, for whom ancillary services might be a primary, rather than secondary, revenue stream.

For network operators: Network operators are transitioning to new roles where they tender for services.

For markets more generally: Increasing penetration of renewables makes future market dynamics difficult to predict.

IMPACT

Low bankability pushes up the cost of capital – and ultimately storage costs.

Various issues in ancillary services design can cause barriers to bankability and raising project finance, in particular:

- **Short contract lengths**
  Most importantly, the term of ancillary services contracts can be as short as a month, far shorter than storage asset lifetimes, which can be 10+ years, depending on the technology. Short contract length is a familiar problem: the demand response industry has suffered similar challenges in accessing the Transitional Arrangements (TA) of the Capacity Market in terms of contract length.

Another key challenge affecting revenue streams associated with both regulated monopolies and connected customers is:

- **Limited long-term policy and regulatory visibility**
  Expected changes in regulation disrupts the "rules of the game" – particularly in relation to network charging. In addition, whilst National Grid's System Operability Framework report provides some guidance on future system needs, the volume and projected prices of specific revenue streams is unclear beyond the next 5 years or so. Whilst there has been strong policy interest in storage, there is arguably a lack of a coherent "vision" for where the network is going, and a number of potentially inconsistent policy measures/reviews driving unnecessary risk. This becomes particularly important to storage technologies with potentially large scales, long lead times and long asset lives. When investors lack visibility on future flexibility markets, the long-term revenues are substantially discounted.

LOW BANKABILITY: Financiers can struggle to get comfortable with the merchant risk associated with storage revenue streams

DEFINITION

Revenue streams are not easily bankable from a private sector perspective.

ABILITY TO ADDRESS

MID
Storage revenue streams will always carry a substantial risk, due to issues such as cannibalisation – ie the more storage units are installed, the more they cannibalise each other's revenue. Nonetheless, there is scope of system and network operators to better design their contracts with bankability in mind.

IMPROVE BANKABILITY

RECOMMENDATIONS

ACTION	PARTY
Increase contract length of ancillary services, to include the system operator being explicitly permitted by Ofgem to take a procurement horizon beyond 2 years.	System Operator and Ofgem
Provide urgent clarity on the future approach to network charging, particularly triads.	National Grid and Ofgem
Provide greater clarity on the timelines and volumes of future tenders – i.e. interpreting in greater detail the implications of the System Operability Framework for procurement.	System Operator
Explore the introduction of a 15+ year cap-and-floor mechanism for large, long-term storage projects to address policy and regulatory risk, mirroring current provisions for interconnectors. A cost-benefit analysis should be conducted to assess the appropriateness of applying this mechanism to large storage projects, to ensure a level playing field across flexibility technologies.	Ofgem
Adhere to the timelines outlined by National Infrastructure Commission for addressing the regulatory and legal status of storage, to ensure clear signals about the future role of storage.	DECC and Ofgem

REVENUE INTERFACE RISKS: Storage operators cannot monetise the full range of services that their plant can deliver.

ROOT CAUSE

Revenue stacking: Revenue streams must be stacked, since each source by itself is normally too small to justify investment. This is fundamentally different to offtake solutions to renewables.

IMPACT

Storage operators tend to stack revenue streams associated with just 1-2 counterparties only, which is not normally economically optimal.

When revenues are stacked, storage operators may fail to achieve the targeted revenues due to complex interfaces, and may face heavy penalties for non-compliance with service specifications.

The economic benefit that storage provides does not just confer to one player; it is distributed across multiple players. In the UK this means that National Grid, DNOs, suppliers and consumers share the benefit; the implication is that revenue streams lack a joined-up approach.

Even when one party – the system operator – offers multiple revenue streams, the timings of tenders are rarely aligned, and bundled offers for multiple revenue streams are not possible.

In addition, revenue streams such as ancillary services have highly complex electrical specifications, meaning that ascertaining which revenue streams can be stacked together is a technical, as well as economic, challenge. Developers need to undertake techno-economic optimisation modelling to understand what revenue streams they can access, before a business case can even be established.

The complex contractual and technical interfaces between offtake counterparties can mean that storage operators tend to stack revenue streams associated with just 1-2 counterparties only, which is not normally economically optimal.

REVENUE INTERFACE RISKS: Storage operators cannot monetise the full range of services that their plant can deliver.

ADDRESS REVENUE INTERFACE RISK

DEFINITION

Revenue streams do not always match up from a timing, contractual and technical perspective.

ABILITY TO ADDRESS

MID
There are always technical challenges when stacking revenue streams – for instance around forecasting when storage is required. However, timing and contractual interfaces are fixable. Aggregators can also help package revenue streams together for smaller market participants.

RECOMMENDATIONS

ACTION	PARTY
Improve the temporal alignment of tenders to enable more complementary timescales, and/or accept bundled offers. Where this is not possible, publish a clear calendar mapping out key dates to ensure complete transparency in the temporal interfaces.	System Operator
Systematically study revenue contractual/technical interfaces from a storage perspective, recognising that these ancillary services will often form primary, rather than subsidiary, revenue basis for new storage plant.	System Operator
Consider supporting innovative aggregation business models which help to “wrap” multiple revenue streams together to manage interface risk from a private sector perspective – which go substantially beyond what is already offered on the market.	Scottish Enterprise Highlands & Islands Enterprise

LOST POTENTIAL: Storage operators cannot monetise the full range of services that their plant can deliver

ROOT CAUSE

New technical challenges: Increasing penetration of renewables and reducing role for conventional plant creates new technical challenges not previously seen on the network.

New actors: Network operators are not familiar with procuring these services from a large number of often small players.

IMPACT

Lack of value realisation means that the market for storage is smaller than it should be – both in terms of the number of accessible revenue streams, and the strength of their pricing signals.

There are various benefits or services that storage can bring which are not currently priced in the market. In other words, storage can offer functionalities which are currently not incentivised, even though these functionalities offer value.

This is particularly relevant at the network and distribution system level. Triads and red zone management do not fully capture the network investment deferral benefits that storage can offer. Distribution network operators have limited experience in procuring such services directly from third parties.

LOST POTENTIAL: Storage operators cannot monetise the full range of services that their plant can deliver

UNLOCK POTENTIAL

DEFINITION

The full breadth of potential roles that storage can offer are not fully mapped into revenue streams. This means that the size of the market for storage operators is smaller than it should be.

ABILITY TO ADDRESS

HIGH
The fundamental challenge is not technical: it is about markets and regulation.

RECOMMENDATIONS

ACTION	PARTY
Explore how storage might be able to provide additional services, which could form a subsidiary part of the revenue stack. Examples to explore include: • Network investment deferral: Avoiding or delaying investments in distribution infrastructure. This is one of the higher value opportunities to be monetised. • Islanding networks: Islanding networks to enable maintenance/repair work to be conducted upstream while keeping customers powered up. • Phase rebalancing: A location-dependent (due to the dispersion effect of a larger number of customers) requirement to enable the load to become more balanced across phases. • Harmonics mitigation: Addressing the expectation for increased challenges with harmonics on the grid, which can mitigated by additional functionality in the converter interface of storage. • Voltage regulation: at point of connection • Providing reactive power: to improve power factor and reduce losses • Localised grid balancing: Working under an active network management scheme to maintain the power flow through the transformer to a defined constraint. Many of these issues have already been pioneered via innovation funds such as the Low Carbon Network Fund: the challenge is rolling them out: the challenge is dissemination.	Distribution Network Operators Ofgem (in design of innovation incentives)

Scottish opportunities

Scottish storage projects operate in distinct circumstances, differing from the rest of the UK. This stems from locational grid charging and the status of Scotland as a net energy exporter.

The three major issues of low bankability, lost potential and revenue interface risk are common across the whole UK. However, whilst the challenges may be common, Scotland faces a distinct opportunity on storage.

Long duration storage
Compared with some other parts of the UK, Scottish renewable energy projects can incur specific challenges such as high incidence of grid constraint and high transmission charges. This creates unique opportunities for storage to alleviate these issues, and is likely to favour storage technologies such as flow batteries suitable for longer duration storage (rather than high power applications such as frequency response). "Longer duration" in this context means storing energy for hours or even days, rather than for seconds or minutes. Such longer duration storage options are often less commercially mature than some high power alternatives such as li-ion batteries, but Scotland is well-positioned to continue to pioneer their research, demonstration and commercialisation.

RECOMMENDATIONS

ACTION	PARTY
Support new storage technologies – both hardware and software. Consider an emphasis on longer duration storage, supporting research, development, demonstration and commercialisation.	Scottish Government and relevant agencies, including the Scottish Funding Council, Scottish Enterprise, Highlands and Islands Enterprise, SEPA, SNH

SUMMARY OF RECOMMENDATIONS

	Low bankability	Revenue interface risk	Lost potential	Scottish opportunities
CHALLENGE	Revenue streams are not easily bankable from a private sector perspective	Revenue streams do not always match up from a timing, contractual and technical perspective	Storage operators cannot monetise the full range of services that their plant can deliver	Longer duration storage applications, and pumped hydro, may be particular opportunities in Scotland
RECOMMENDATIONS	**System operator:** Increase contract length of ancillary services. **System operator:** Provide greater clarity on the timelines and volumes of future tenders. **Ofgem:** Provide clarity on the future approach to network charging. **Ofgem:** Explore the introduction of a cap-and-floor mechanism for large storage projects. **DECC and Ofgem:** Adhere to the timelines outlined by National Infrastructure Commission for addressing regulatory and legal status of storage.	**System operator:** Improve the temporal alignment of tenders, and potentially allowing bundled offers. **System operator:** Consider publishing a calendar of ancillary services contracts, visually mapping the temporal interfaces. **Transmission and distribution system operator:** Pay careful attention to the transmission/distribution counterparty interface as DSOs offer new revenue streams. **Scottish Government and relevant agencies:** Support innovative aggregation business models which help to "wrap" revenue streams together to manage interface risk from a private sector perspective.	**Distribution system operators:** Explore how storage might be able to provide additional services, which could form a subsidiary part of the revenue stack.	**Scottish Government and relevant agencies:** Support new storage technologies – both hardware and software, with an emphasis on longer duration storage.

3 APPLICATIONS

- How do risks manifest themselves in real life?
- How might our policy recommendations help?

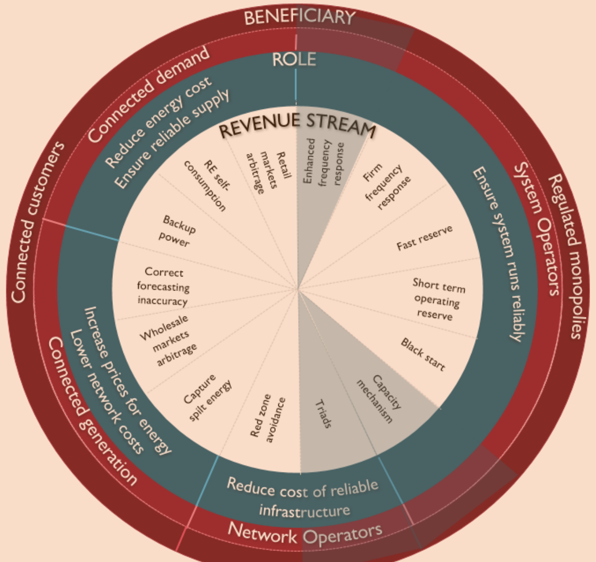
From theory to real-life applications

Revenue risks and recommendations are best viewed through examples

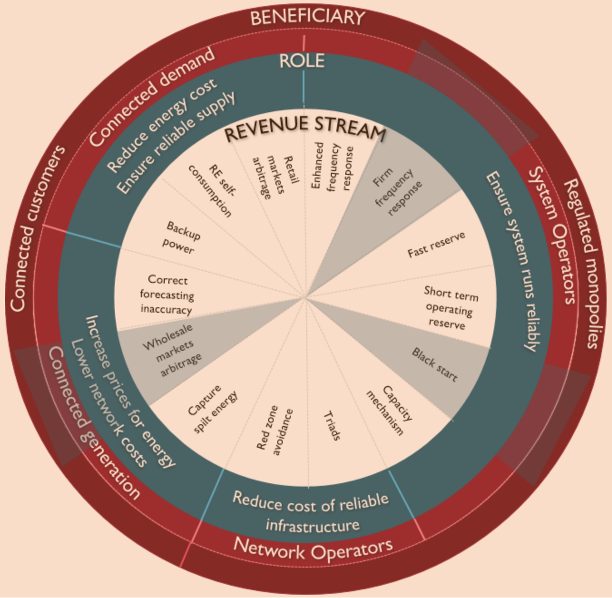
Let's be clear: there is no one-size-fits-all revenue stack. A key finding of the World Energy Council's report *Energy storage: from cost to value* was this: storage economics vary widely both by technology and application. As a result, we've applied our analysis of risk and recommendations to three specific applications.

These sample revenue stacks are put together based on consideration of what is possible from a technical and regulatory perspective, and what is economically attractive. It is possible that projects could procure more services. However, in the interests of simplicity we have used three as a means of illustrating the challenges that projects will typically face.

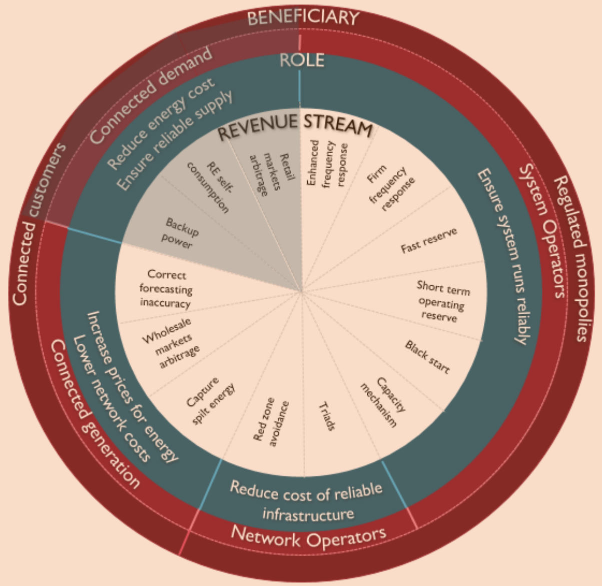
SAMPLE STACK 1
UTILITY-SCALE BATTERIES
FOR FREQUENCY RESPONSE & PEAK AVOIDANCE



SAMPLE STACK 2
PUMPED HYDRO
FOR ANCILLARY SERVICES & ARBITRAGE



SAMPLE STACK 3
RESIDENTIAL BATTERY+THERMAL
FOR ENERGY BILL REDUCTION



Utility-scale batteries

Most recent commercial activity in storage in the UK has been on large battery deployments for frequency response.

Battery technologies such as li-ion batteries are well placed to providing quick responses (<1 second), making them suitable for targeting frequency response as a primary revenue stream. Enhanced Frequency Response (EFR) in particular has attracted substantial interest to offering 4 year contracts, though there are also battery projects being developed targeting firm frequency response. Triads and the capacity mechanism stack well with (EFR) from both a technical perspective (eg EFR tends to have low value during triad events) and because they require a comparatively low number of hours of operation per year.

SAMPLE PROJECT

Project initiator: Private sector developer

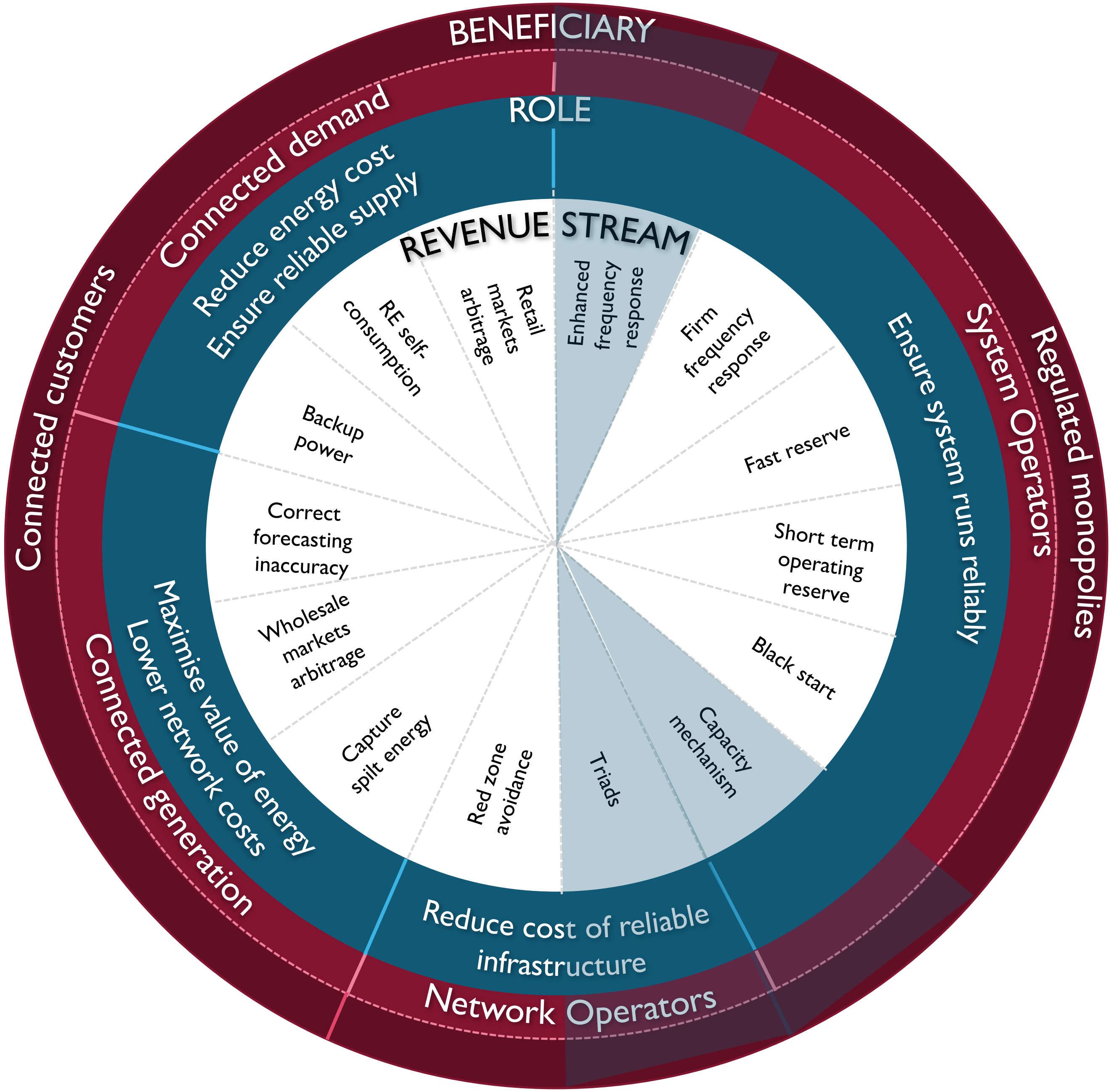
Technology: Lithium-ion battery

Rating: 20MW/ 11MWh

Revenue streams: Enhanced Frequency Response, triad avoidance and capacity mechanism

Location: Distribution connected

Start of operations: 2018



UTILITY-SCALE BATTERIES STACK: EFR + TRIADS + CAPACITY MECHANISM

CHALLENGES	RECOMMENDATIONS
Low bankability • EFR contract lengths are considered short at 4 years; this is a significant barrier to securing meaningful debt gearing. • Non-EFR revenue streams are substantially discounted by financiers, particularly post year 5, due to lack of long-term visibility. For instance on triads, storage operators are not guaranteed to hit all three triad alerts (due to forecasting limitations and limited delivery duration), and the long-term regulatory outlook is unclear.	**Improve bankability** • Consider increasing EFR contract length; even a 1yr extension would aid financing, and ultimately reduce costs to consumers. • Clarify network charging regimes going forward
Revenue interface risk • The timelines of EFR and capacity mechanism tenders are not aligned. • There has been lack of clarity in the rules on stacking EFR + triads, with information amended in the run-up to the tender.	**Address revenue interface risk** • Allow bundled bids and/or better align timelines of EFR and capacity mechanism. • Anticipate and address revenue interface risk upfront when designing new ancillary services schemes.
Lost potential • The bid structure of EFR is highly constrained; for instance, bidders must bid in four-hour blocks, and it is not possible to differentiate between weekends and weekdays. This limits the potential to optimise revenue stacks. • National Grid's EFR "value" calculation is complex and not transparent to new entrants.	**Unlock potential** • Enable greater flexibility in bid structures in the service specification for EFR, and more granular time windows for bidding. • Provide clearer, quantified breakdown of the value of EFR to market participants, at a half-hourly resolution.

Pumped storage

Scotland's topography is particularly well suited to the development of utility-scale pumped storage projects.

Pumped storage is a highly flexible and mature technology well suited to providing support over multiple timelines. Today, most pumped storage assets operate on a daily cycle or shorter; however, since MWh capacity can be scaled at comparatively low incremental cost, in future pumped storage might operate over longer cycles. A typical revenue stack for pumped hydro might target ancillary services from National Grid, supplemented by playing the "buy low, sell high" game of wholesale markets arbitrage.

SAMPLE PROJECT

Project initiator: Private sector developer

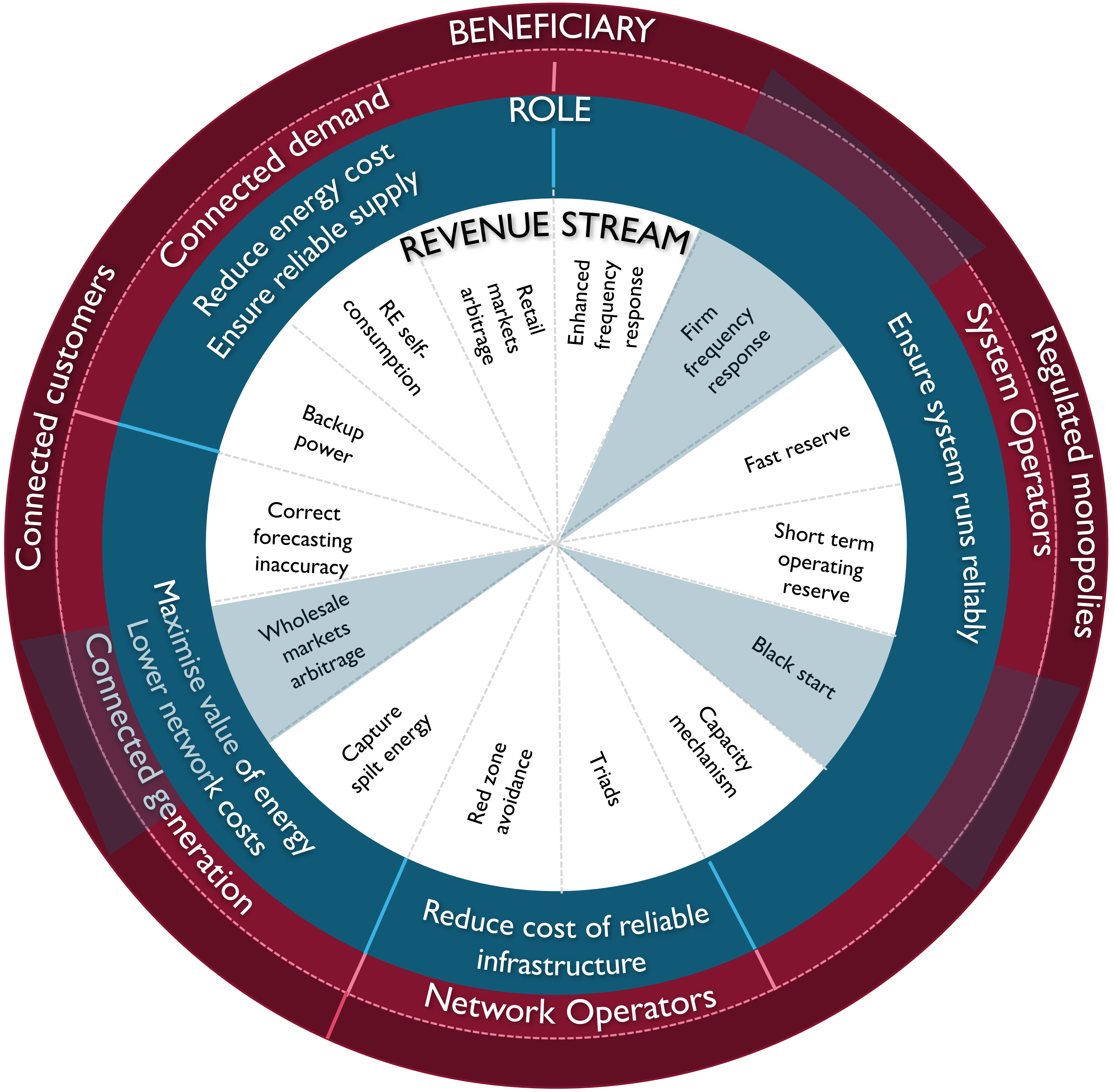
Technology: Pumped storage

Rating: 250 MW / up to 3 GWh

Revenue streams: firm frequency response, supplemented with wholesale energy market arbitrage and black start

Location: Transmission connected

Start of operations: Mid-2020s



PUMPED HYDRO STACK: FFR + BLACK START + ARBITRAGE

CHALLENGES

Low bankability
There is a fundamental mismatch between the long asset lifetimes and lead times of pumped hydro development, and limited longer-term market visibility. Investors lack clarity on the future structure of flexibility markets, and the value that will be assigned to each revenue stream.

Revenue interface risk
Revenue interfaces are difficult to model during the feasibility stage – since the rules around the revenue streams themselves could well have changed by the time that the project is operational.

Lost potential
There is potential for pumped hydro to substantially offer support in the deferral of transmission investments, and to help maximise the utilisation of existing transmission assets. Such services are not yet fully priced in the market.

RECOMMENDATIONS

Improve bankability
A "cap-and-floor" regime similar to that adopted to interconnectors may help to derisk long term storage projects, addressing long-term policy and regulatory risks. This merits further investigation to better understand the benefits and costs, and how this might need to be tailored to long term storage projects without prejudice to other flexibility solutions.

Address revenue interface risk
Provide greater visibility and clarity on revenue streams – see *Bankability* point above.

Unlock potential
Ensure that the full range of services provided, such as the deferral of transmission investment, is properly priced in the market.

Residential packages

Small can be beautiful too. Homes with PV systems can make the most of this microgeneration through hybrid battery+heat storage applications.

At present, residential applications focus on straightforward revenue streams which can be provided via energy suppliers, rather than requiring additional counterparties such as National Grid. As a result, revenue streams such as "making the most" of onsite renewables and retail markets arbitrage are the most common, plus possible backup power benefits if this is important to consumers.

SAMPLE PROJECT

Project initiator: Residential energy user

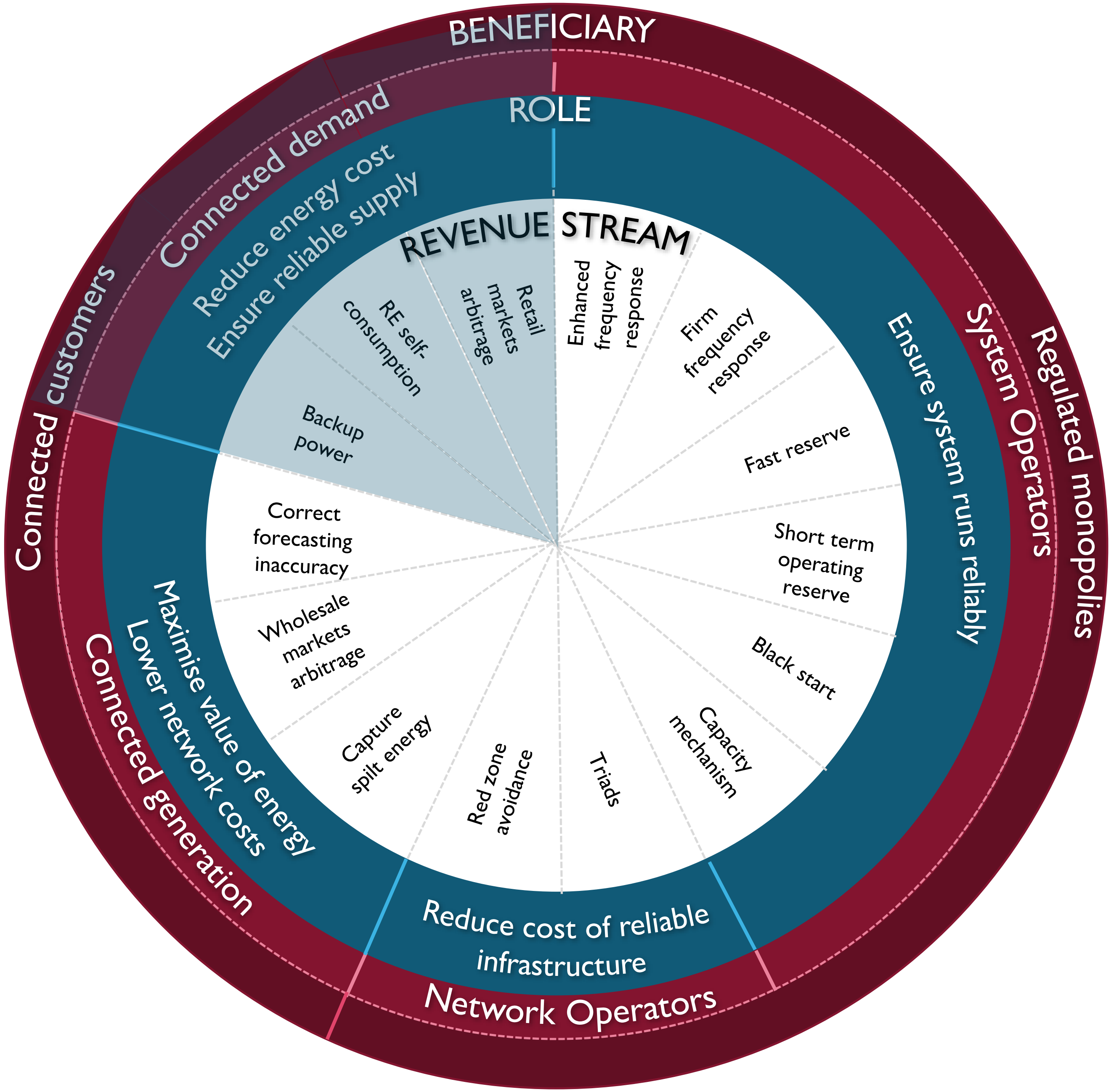
Technology: Li-ion battery plus heat storage, on a site with rooftop PV

Rating: 6-10kW

Revenue streams: Renewables self-consumption, retail price arbitrage and backup power

Location: Behind the meter

Start of operations: 2020



RESIDENTIAL STACK: BACKUP POWER + RE CONSUMPTION + RETAIL MARKETS ARBITRAGE

CHALLENGES	RECOMMENDATIONS
Low bankability This may not be such an immediate problem for residential deployment; experience from PV has shown that there is a substantial number of "early adopters" prepared to finance their own systems if the returns are clear	**Improve bankability** N/A
Revenue interface risk There are key revenue interface risks from a technical perspective – in particular, the challenge of forecasting both load and onsite renewables generation, which in turn causes challenges in optimising the usage of the storage unit.	**Address revenue interface risk** Funding to support modelling and predictive analytics capability would help to reduce technical revenue interface risk through optimised control algorithms.
Lost potential There is substantial potential for residential systems to access additional revenue streams from the system operator. The major barrier here is the complexity of those system operator markets from a consumer perspective.	**Unlock potential** Due to technical complexities, there is a limit to how far National Grid can simplify its products. As a result, there is need for aggregators to innovatively package up National Grid products for residential consumers in a simple way. Funding to support innovation and pilot schemes in aggregation are a key stepping stone to achieving this.

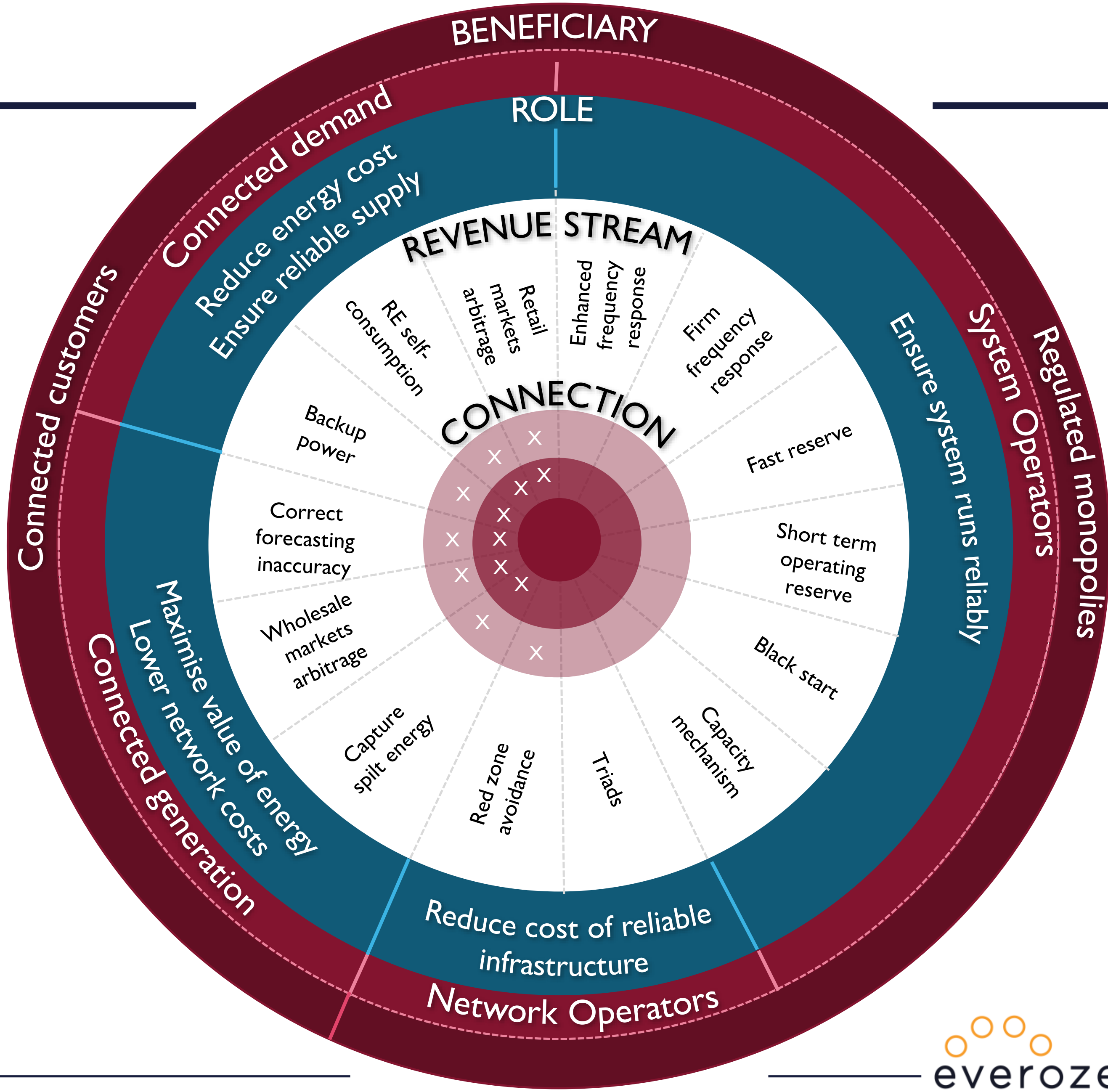
CONCLUSIONS

Cracking the code

Can we unleash the benefits of storage in Scotland, and the wider £2.4bn of benefits across the UK? The choice is up to us. The technical ability of storage technologies to deliver a wide range of services is proven. But our flexibility markets are still largely designed with conventional generators in mind.

The financeability of revenue streams is critical to cracking the code. We need to take action to improve bankability, address revenue interface risk and unlock market potential.

This will not just help storage compete – but also give the boost needed to a wider set of flexibility technologies too, and ultimately enable us to connect even more renewables to our electricity system.



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Disclaimer: This report has been prepared and is issued in accordance with contract document SR001-P-01 dated 8 April 2016, which governs how and by whom this report should be read and used.

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