Low Carbon Networks Fund First Tier Portfolio Reward

2017

SSET1001 1MW Shetland Battery

Connecting energy storage to network and integrating with ANM

SSET1002 Monitoring LV Network with Embedded PV and EV

Understanding impact on demand profiles from LCTs and feasibility of monitoring LV network

SSET1003 Trial Evaluation of DDSM

Technical interface with domestic customers, communication, engaging with domestic customers

SSET1004 Demonstrating the Functionality of ADR

Interface with I&C customers, responsiveness of customers, engagement with I&C customers

SSET1005 LV Network Modelling & Analysis

Allowing detailed modelling of LV network considering new load profiles for LCT adoption

SSET1007 Orkney Energy Storage Park (Ph 1)

Commercial arrangements, procurement, economics for large scale energy storage connections

SSET1008 LV Connected Storage

Use of storage on LV network to mitigate adoption of LCTs

SSET1009 Orkney Energy Storage Park (Ph 2)

Commercial arrangements, procurement, economics for large scale energy storage connections

SSET1010 Impact of Electrolysers on the Network

Controlling demand via ANM scheme, integration with other industry sectors, commercial relationships

SSET1011 Digital Substation Platform

Common IT platform within substation environment

- Energy Storage
- Demand Side Management
- Active Network Management
- Constraint Managed Zones
- Low Voltage Strategy
- Distribution System Operator

Scottish & Southern Electricity Networks

Contents

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Our portfolio of Tier 1 Projects:

- Has produced learning which will provide benefits for GB customers of up to **£327m** by 2050
- Provided learning to accelerate and de-risk larger scale Tier 2 projects including SSEN's New Thames Valley Vision, UKPN's Smarter Network Storage and SPEN's Accelerating Renewable Connections projects
- Will enable a further **£858m** financial benefit through Tier 2 projects by 2050
- Will create capacity increases of up to **3GW** by 2050
- Delivered exceptional learning for the industry which has led to the creation of industry wide forums including the ANM Working Group and the Energy Storage Operators Forum
- Established key learning in the sector especially around energy storage, demand side response and active network management all of which will be key factors in a future transition to DSO

First Tier Portfolio Reward – Executive Summary

At SSEN we take pride in the quality of our innovation portfolio. The exceptional learning from our projects has delivered significant benefits for customers, and enabled us to lead the industry in the development and implementation of a broad range of innovations into our Business as Usual (BAU) activities.

Our Tier 1 portfolio has been crucially important to this success, and has directly led to the implementation of pioneering initiatives such as Active Network Management (ANM) and Constraint Managed Zones (CMZ).

The learning outcomes have also helped prepare SSEN, other DNOs and the wider industry to become better prepared for the transition to Distribution System Operator Model, and facilitate the growth in Distributed Generation.

This document sets out our application for the First Tier Portfolio Reward (FTPR). At SSEN we believe that the Tier 1 projects are a key building block in the overall success of our Innovation programme.

Our Ethos

Throughout the development and delivery of our Tier 1 portfolio we have maintained a number of central principles. These principles have held us in good stead. They are directly responsible for the delivery of benefits now, and provide us with a robust framework to provide benefits going forward.

These principles are:

- Broad stakeholder engagement and horizon scanning;
- Maintaining a broad portfolio of projects;
- Identifying focus areas to achieve BAU transition and seeking early deployment opportunities;
- Recognising the value of fast following;
- Driving collaboration with key stakeholders; and
- Recognising that "the whole is greater than the sum of it's parts".

SSEN has long recognised the additional value that can be derived from adopting new methods of managing our network. With the opening of the Orkney Smart Grid in 2009 we were the first GB DNO to implement ANM as an alternative to a traditional approach of network reinforcement. This was a step change in the design, construction and operation of the network allowing significant volumes of new renewable generation to be connected providing benefits for the network, renewable developers and the local community. The success of this ground-breaking project has been widely recognised at home and abroad; most GB DNOs now offer flexible ANM-based connections whose roots can be traced back to the Orkney Smart Grid project. Similarly, SSEN has led the industry in the development of projects to enable energy storage, demand side management and network monitoring.

Our projects have produced a wide range of learning including design, construction, operation and maintenance of a wide range of technologies. Crucially, this has been supplemented by other areas such as commercial arrangements, safety, risk assessment and stakeholder engagement. The richness of our portfolio has benefited from the broad range of stakeholders who have contributed to the success of the portfolio. This includes technology providers, transport companies, community groups and housing associations, as well as industry stakeholders such as suppliers. The outputs from the portfolio have been enhanced by our success in attracting funding from a range of UK, regional and European funding bodies, allowing us to gain further value over and above the original Tier 1 investment.

Innovation is of limited value unless successful innovations are delivered and transferred to BAU. We have a strong focus on this 'last mile' stage of the innovation life cycle. Our experience has shown us that this can be the most challenging stage. Our approach to implementation has developed over time and has been significantly enhanced by the knowledge and learning we accrued during the delivery of our Tier 1 portfolio.

We have developed our portfolio in an incremental manner to validate the outcomes of earlier projects until we reach a stage where we are sufficiently confident to deploy the innovation into the business. This incremental approach has ensured that we have been able to deliver maximum value from customers' funds and ensure that we achieve best outcomes by identifying any risks at the earliest stage. The use of Tier 1 funding has allowed us to accelerate this process and deliver benefits for our customers.

We believe that our Tier 1 portfolio has delivered exceptional results and has proved to be excellent value for customer money, producing benefits which significantly exceed the value of the initial investment. The portfolio has also provided learning which will make us well prepared to deal with the wide range of challenges which we will face going forward.

Colin Nicol

Managing Director, Networks

Description of the Portfolio

The SSEN Tier 1 portfolio has delivered a broad range of learning across a wide spectrum of topics, which has allowed us to:

1. Accelerate the transition of innovation into BAU
2. De-risk and accelerate larger Tier 2 projects to produce further benefits
3. Develop knowledge to prepare for key future challenges including DSO
4. Shape the organisational structure of SSEN to allow benefits to be maximised

Delivering benefits for customers

The move to a low carbon economy will result in changes to the way we live and our approach to energy. LCN Fund Tier 1 projects have allowed SSEN to trial new technology, operating methods and commercial arrangements, and produced a comprehensive range of learning.

The learning has allowed us to bring innovations to BAU which have brought benefits to customers by reducing costs or improving network reliability. Using the industry recognised Transform Model®, EATL has estimated that the SSEN Tier 1 portfolio will produce benefits of up to £327m for consumers by 2050. Additionally, the learning has also been used to accelerate and de-risk larger scale Tier 2 projects such as NTVV.

As well as providing benefits directly to customers, the learning from our Tier 1 portfolio has increased our awareness and has helped us to prepare for a range of future challenges such as the anticipated growth in EVs. This knowledge will allow DNOs to be better prepared and make better informed decisions, which will allow the time to deploy appropriate measures to prevent the network becoming a barrier to this transition to a low carbon economy.

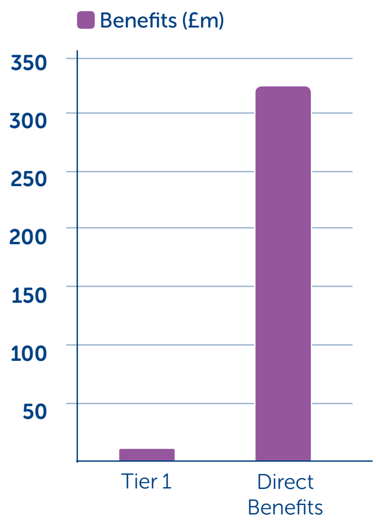


Figure 1 Benefits to GB customers

Analysis undertaken by EATL using the Transform Model® has identified that the we can attribute £327m in direct financial benefits for GB customers from the SSEN Tier 1 portfolio by 2050. If wider and indirect benefits are considered this rises to £858m.

The analysis also demonstrated that the deployment of the SSEN solutions across GB as and when appropriate can deliver a concurrent capacity increase of approximately 3GW by 2050.

The innovation and creativity demonstrated in the delivery of our Tier 1 portfolio has allowed us to move towards a more flexible, cost effective and secure electricity network. However, the Tier 1 projects are only part of the wider portfolio of SSEN innovation projects. Experience has shown that maximum value is created by combining learning from multiple innovation projects to create an outcome which is greater than the sum of all parts. Our incremental approach to network innovation has ensured that we have used the portfolio to test and validate any new innovation, until we are confident enough to deploy it into BAU. The most successful innovations are based on learning from multiple projects across the wider innovation portfolio.

This has allowed us to build on the knowledge gained and involve our stakeholders in identifying how best to develop the next stage; this helps ensure that the portfolio is aligned with our stakeholders views and needs.

Therefore, we have characterised the learning from our portfolio including the Tier 1 into five key 'Innovation Areas' which have allowed us to develop our knowledge, and future readiness:

- Demand Side Management (DSM) – showing how power flows can be used to manage network power flows and voltage limits
- Low Voltage Strategy – the move to a low carbon economy will require a greater focus on the LV network. We have developed new monitoring, modelling and operational techniques to prepare for the challenges of large scale LCT deployment
- Constraint Managed Zone (CMZ) – using commercially procured services to manage network constraints giving DNOs options beyond traditional reinforcement
- Energy Storage (ES) – energy storage has a crucial role to play in any future energy scenario. Our Tier 1 portfolio has helped develop our knowledge as we prepare for its deployment across the network
- Active Network Management (ANM) – using monitoring and real time control combined with flexible connection arrangements to improve network access for renewable generators.

These innovation areas can be viewed as the 'sum of all parts'; we have taken learning from multiple projects to deliver value for the business and our customers in each innovation area. Table 1 shows our Tier 1 projects have been integral in delivering knowledge in each of the innovation areas.

To aid the understanding of the relationship between our Tier 1 projects and Innovation Areas we have included a series of models within the project description section.

Project	DM	LV Strategy	CMZ	Energy Storage	ANM
SSET1001 1MW Shetland Battery	✔		✔	✔	✔
SSET1002 Demonstrating the benefits of monitoring Low Voltage network with embedded PV panels and EV charging point	✔	✔			
SSET1003 Trial Evaluation of Domestic Demand Side Management (DDSM)	✔	✔	✔		✔
SSET1004 Demonstrating the Functionality of Automated Demand Response			✔	✔	✔
SSET1005 Low Voltage Network Modelling and Analysis Environment		✔			
SSET1007 Orkney Energy Storage Park (Phase 1)	✔		✔	✔	✔
SSET1008 Low Voltage (LV) Network Connected Energy Storage	✔	✔		✔	
SSET1009 Trial of Orkney Energy Storage Park (Phase 2)	✔		✔	✔	✔
SSET1010 Impact of Electrolysers on the Distribution Network	✔		✔		✔
SSET1011 Digital Substation Platform – Phase 1			✔		✔

Table 1: Contribution of Tier 1 portfolio projects to SSEN's Innovation Areas

Preparing for future change

The SSEN Tier 1 portfolio began development in 2010, and progressed into a broad portfolio covering a wide spectrum of innovation areas. This recognises potential challenges that the industry may face in the future, including the uptake of EVs, energy storage, government policy on renewables, the hydrogen economy and the transition to a Distribution System Operator (DSO).

Our portfolio focused on the fundamental components of smart and flexible energy systems like energy storage, active network management and demand management which are likely to play a role in any future energy scenarios. The scenarios utilised for this analysis are based on work previously undertaken by the Smart Grid Forum.

Having a more 'flexible' energy system will not only be an essential element of the transition to a low carbon economy but also has the potential to provide significant benefits for GB consumers – The National Infrastructure Commission (NIC) report on Smart Power[1] reported that a smart system could provide gross benefits to consumers of £3bn a year in 2030. This validates our focus on the fundamentals of a smart and flexible energy system which will provide benefits for customers and allow the transition to a low carbon future.

Through our focus on smart and flexible energy systems our business has embraced potentially disruptive technology. The LCN Fund has allowed SSEN to improve our understanding of the technology, its potential impact on the network and how the technology can be utilised to provide benefits for our customers.

The **SSET1001 1MW Shetland Battery project, SSET1007,9 Orkney Energy Storage Park projects, and SSET1008 Low Voltage (LV) Network Connected Energy Storage project** laid the foundations for our understanding of network scale energy storage and its potential as a source of flexibility.

In addition, our **SSET1003 Trial Evaluation of Domestic Demand Side Management (DDSM) and SSET1004 Demonstrating the Functionality of Automated Demand Response (ADR) project**s proved the concept and de-risked the use of demand side services on the network. The cumulative learning gained from these projects gave the confidence to develop and implement the Constraint Managed Zone (CMZ). We have used a procurement exercise as BAU to source demand flexibility and storage.

We will be deploying this to avoid or defer conventional reinforcement. This service can be provided by a range of technologies including energy storage, demand side response or distributed generation. The CMZ approach gives the DNO additional optionality benefits in its investment decisions and can bring benefits for consumers as well as releasing network capacity. Our analysis has indicated that this could see over 4,300 CMZ deployments by 2050 releasing up to 1000MW simultaneous additional capacity. See Figure 12 for details.

In addition to generating deployments to BAU one of the key benefits of our Tier 1 portfolio was the ability to use these projects to de-risk and accelerate the benefits from larger scale LCN Fund Tier 2 projects, in particular New Thames Valley Vision (NTVV) and Northern Isles New Energy Solution (NINES). These Tier 2 projects represent a significant investment of customers funds (approx. £45m). The prudent use of the smaller scale Tier 1 funding, has not only protected customer funds but has also accelerated the benefits from these larger Tier 2 projects.

Our early work in Active Network Management (ANM) flexible connections has led the industry and has enabled other DNOs to further develop some of these ideas through their own Tier 2 projects (e.g. SPENs ARC project) and other trials which would not have been possible without the initial work undertaken by SSEN. The deployment of ANM allows for faster and lower cost connections to the grid for generators and increases the amount of renewable generation connected in a timely manner. Flexible ANM type connections are now offered as BAU by SSEN and most other DNOs. Analysis by EATL estimate that over the period to 2050 there will be over **1000** deployments of ANM schemes of the type pioneered by SSEN.

Traditionally, DNOs have largely operated the LV network with minimal intervention; however, the move to a low carbon economy will have a fundamental impact on the LV network. The large scale adoption of EVs, PV and heat pumps will change well understood historic demand patterns and place significant additional demands on the LV network. SSEN has developed an LV Strategy to begin to prepare for these changes by increasing the visibility of the LV network, developing new modelling techniques and identifying a range of potentially smart interventions to provide an alternative to traditional network reinforcement.

1 https://www.gov.uk/government/publications/smart-power-a-national-infrastructure-commission-report

The Tier 1 portfolio has provided an invaluable contribution to the development and implementation of the LV Strategy. **Our SSET1002 project Demonstrating the benefits of monitoring Low Voltage network with embedded PV panels and EV charging point** investigated and demonstrated appropriate substation monitoring that could be installed retrospectively to assess the network impact without interruption to supply of PV and EV uptake and has informed our EV Strategy which in turn is informing decisions and consultations undertaken by OLEV. **SSET1005 Low Voltage Network Modelling and Analysis Environment** identified, tested and demonstrated a detailed LV network modelling tool that facilitates the electrical modelling of new and emerging Low Carbon Technologies (LCT). Modelling by EATL has shown that there could be up to **182,000** instances where the use of the LV strategy innovations will defer reinforcement, leading to an additional **1,150MW** of capacity within the GB network over the period to 2050.

The SSEN portfolio delivered significantly more learning than was expected in many areas. One significant body of learning was on Energy Storage and in particular the operating safety cases for different battery technologies. This work led directly to the establishment of the Energy Storage Operators' Forum (ESOF) and contributed significantly to the ESOF Good Practice Guide. As well as establishing the body of knowledge for ESOF, projects like our **SSET1007 Orkney Energy Storage Park** encouraged the creation of the ANM working group.

Tier 1 projects have also provided SSEN with the opportunity to work with new stakeholder groups and a wider range of partners; this included social landlords, technology providers as well as other industry sectors such as transport. These projects highlighted the differences in business drivers and cultures outwith the traditional DNO operating environment.

This broader understanding of the commercial landscape will provide important learning to inform the transition to DSO, where relationships with third parties will be crucial to the successful future operation of the network.

The transition to DSO has the potential to provide significant benefits for customers by creating a more flexible system. However, this also presents DNOs with new challenges and risks. Our innovation portfolio including the Tier 1 projects has provided invaluable learning which has helped shape SSEN's views on the transition to DSO. In particular, our work on improving the visibility of the LV network, the implementation of ANM and the commercial relationships around energy storage has helped prepare SSEN for this transition.

Making change happen – supporting transition

Our Tier 1 portfolio has taught us that the greatest value from innovation can only be delivered if the learning is implemented into BAU. This strong focus on the 'last mile' stage of the innovation cycle has resulted in us creating two new business functions in SSEN to support the deployment of innovation into the business.

The Active Solutions Team are focussed on the implementation of all of SSEN smart solutions including CMZ and ANM. SSEN quickly recognised that to fully realise the benefits from these innovations would require a dedicated resource with the appropriate skill sets and tools to successfully operate these techniques.

Additionally, SSEN has created the Innovation Deployment Team to provide additional support for initiatives during the transfer from innovation to BAU. This provides a mechanism for 'fast tracking' key innovations into the business and realising benefits at the earliest opportunity. A key success of our Innovation Deployment Team is the introduction of LiDAR (Light Detection and Ranging) into BAU. This was identified through scrutiny of other DNO's project portfolios, with additional SSEN investment required to accelerate the transition into the business.

This new structure was established to ensure that the outputs from our innovation portfolio successfully move to BAU. The learning from our Tier 1 portfolio highlighted the need for this change by identifying the additional skills and knowledge required to fully benefit from new innovations.

Table 2: Summary of Tier 1 Portfolio

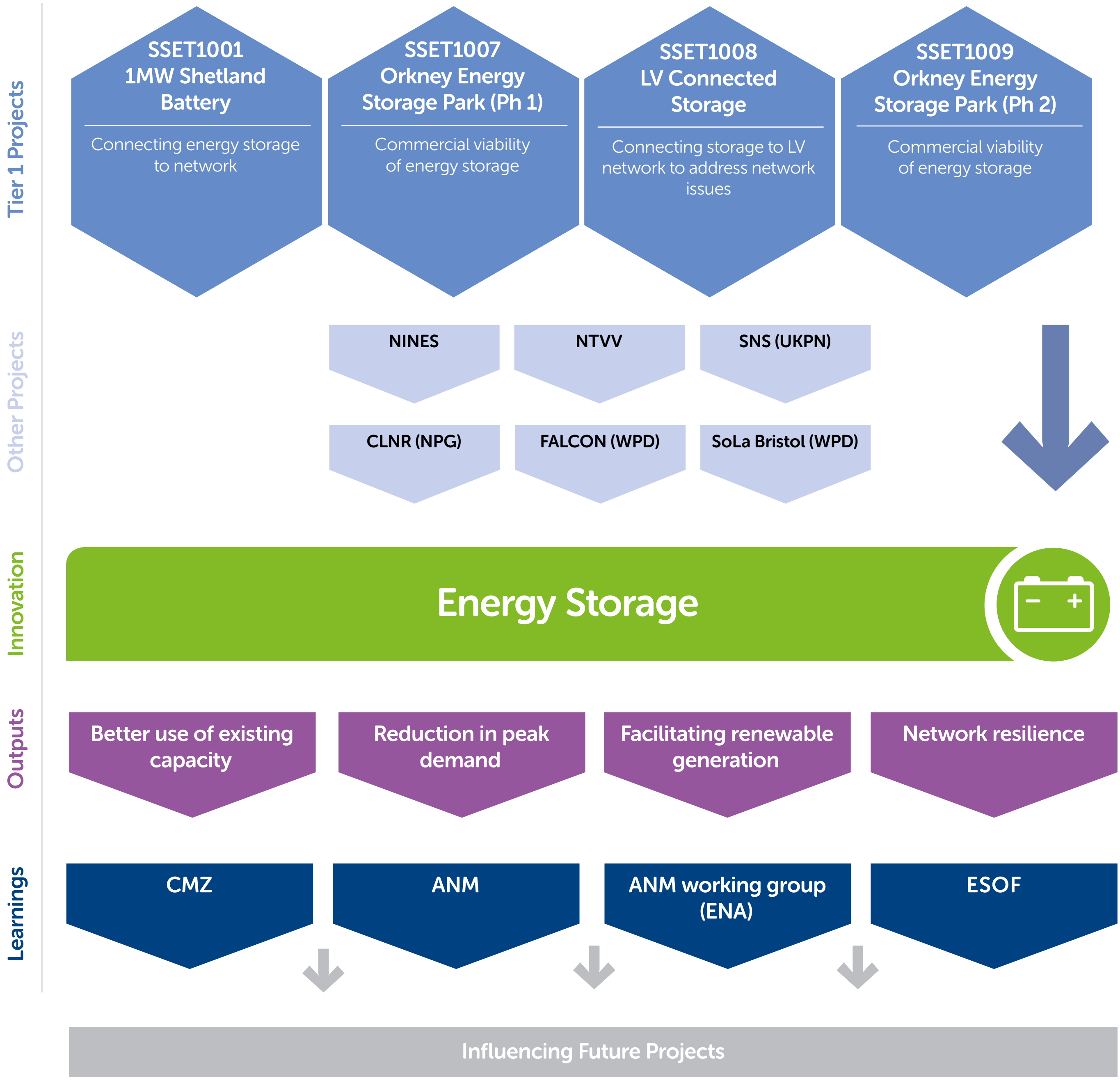
Tier 1 Project Name	Licensee	Project Summary (2 sentences)	Tier 1 funding £k	Licensee compulsory contribution £k	Other contributions £k	Link to close down report
SSET1001 1MW Shetland Battery	SHEPD	Installed a grid scale energy storage device on the SHEPD network in Shetland and integrated this with an active network management system.	960.0	96.0	1049.1	SSET1001
SSET1002 Demonstrating the benefits of monitoring Low Voltage network with embedded PV panels and EV charging point	SEPD	Demonstrated the impact of PV panels and EV charging point on the LV network by installation of an 11kV/LV substation monitoring solution. Gained insight into the actual impact on the network of PV and EVs and hence demonstrated the benefits of LV network monitoring to the operation of the Distribution Network.	191.0	19.1		SSET1002
SSET1003 Trial Evaluation of Domestic Demand Side Management (DDSM)	SHEPD	Partnered with Glen Dimplex to develop and trial a new range of domestic energy efficient storage heaters and immersion water heaters designed for grid energy storage, demand side management and frequency response.	262.0	26.2		SSET1003
SSET1004 Demonstrating the Functionality of Automated Demand Response	SEPD	Implemented and demonstrated basic ADR functionality in commercial buildings. Three building owners were recruited as trial participants, each willing to test the Honeywell ADR system.	260.2	26.0		SSET1004
SSET1005 Low Voltage Network Modelling and Analysis Environment	SEPD	Investigated the creation of a proof of concept 'Low Voltage Network Modelling Environment' that enables a GB DNO to carry out load flow analysis calculations without the need for significant user input.	320.0	32.0		SSET1005
SSET1007 Orkney Energy Storage Park (Phase 1)	SHEPD	Created a commercial and physical incentive that encouraged third party Energy Storage Providers (ESPs) to locate on a constrained network. The incentives were then tested by running a commercial tender process to identify if suitable ESPs were enticed to apply for the contract.	176.5	17.7		SSET1007
SSET1008 Low Voltage (LV) Network Connected Energy Storage	SEPD	Demonstrated the potential benefits, practicalities and costs of installing electrical energy storage (ESS) connected via four quadrant power conversion systems (PCS) on the LV network. Informed and de-risk the larger scale deployment of street batteries as detailed in the NTVV Tier 2 project.	284.5	28.5		SSET1008
SSET1009 Trial of Orkney Energy Storage Park (Phase 2)	SHEPD	Demonstrated that an Energy Storage System (ESS) could be linked to a an ANM system previously installed on Orkney. Facilitated a commercial investigation into the UK energy markets and how ESSs could interact with these markets in order to improve the business case for ESSs.	643.8	64.4		SSET1009
SSET1010 Impact of Electrolysers on the Distribution Network	SHEPD	Investigated the potential impact that hydrogen electrolysers will have on the electricity distribution network and explored the extent to which this technology can be used to manage network constraints in the future.	753.0	75.3		SSET1010
SSET1011 Digital Substation Platform – Phase 1	SHEPD	Demonstrated the feasibility of combining ANM and protection systems together to simplify IT architecture and minimise costs by rationalising both hardware and software whilst retaining the benefits and performance of both systems.	241.6	24.2		SSET1011
Total			**4,092.6**	**409.3**	**1049.1**	

Innovation Models

Our experience has shown that innovation deployment usually pulls on learning from a pool of projects; only the simplest of innovation can be enabled by one single project.

Given the cohesive nature of our Tier 1 portfolio, we see limited value in artificially attributing benefits of each project as in reality the value is greater than the sum of the parts. Instead we have considered the benefits of the whole portfolio in terms of the five key innovation areas described previously and shown in the Innovation Models below. Each of our Tier 1 projects has contributed to one or more of these innovation areas, as shown in the learning outcomes shown in these graphics.

The true benefits of the projects are only realised when considered in conjunction with the learning outcomes of the whole.



Tier 1 Projects

SSET1001 1MW Shetland Battery
Use of battery to manage demand

SSET1002 Monitoring LV Network with Embedded PV and EV
Modelling of LCTs on LV network

SSET1003 Trial Evaluation of DDSM
Technical interface with domestic customers, communication, engaging with domestic customers

SSET1004 Demonstrating the Functionality of ADR
Interface with I&C customers, responsiveness of customers, engagement with I&C customers

SSET1007 Orkney Energy Storage Park (Ph 1)
Commercial arrangements to incentivise location of third party energy storage provider

SSET1008 LV Connected Storage
Connecting energy storage to LV network

SSET1009 Orkney Energy Storage Park (Ph 2)
Commercial arrangements to incentivise location of third party energy storage provider

SSET1010 Impact of Electrolysers on the Network
Use of ANM to control and schedule demand

Other Projects

- NINES
- NTVV
- My Electric Avenue
- C2C (ENW)
- CLASS (ENW)
- CLNR (NPG)
- LCL (UKPN)
- FALCON (WPD)
- SoLa Bristol (WPD)

Innovation

Demand Side Management

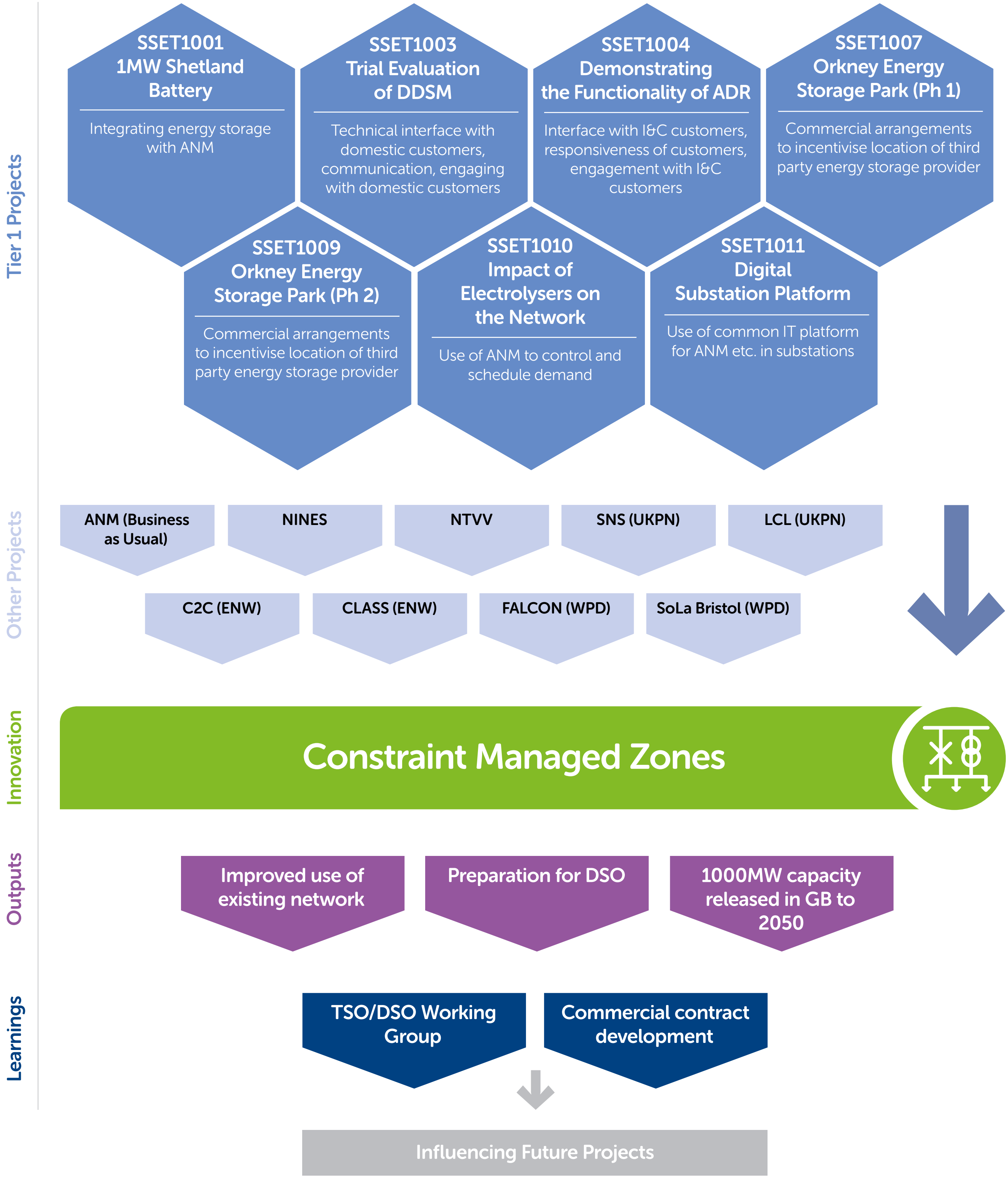
Outputs

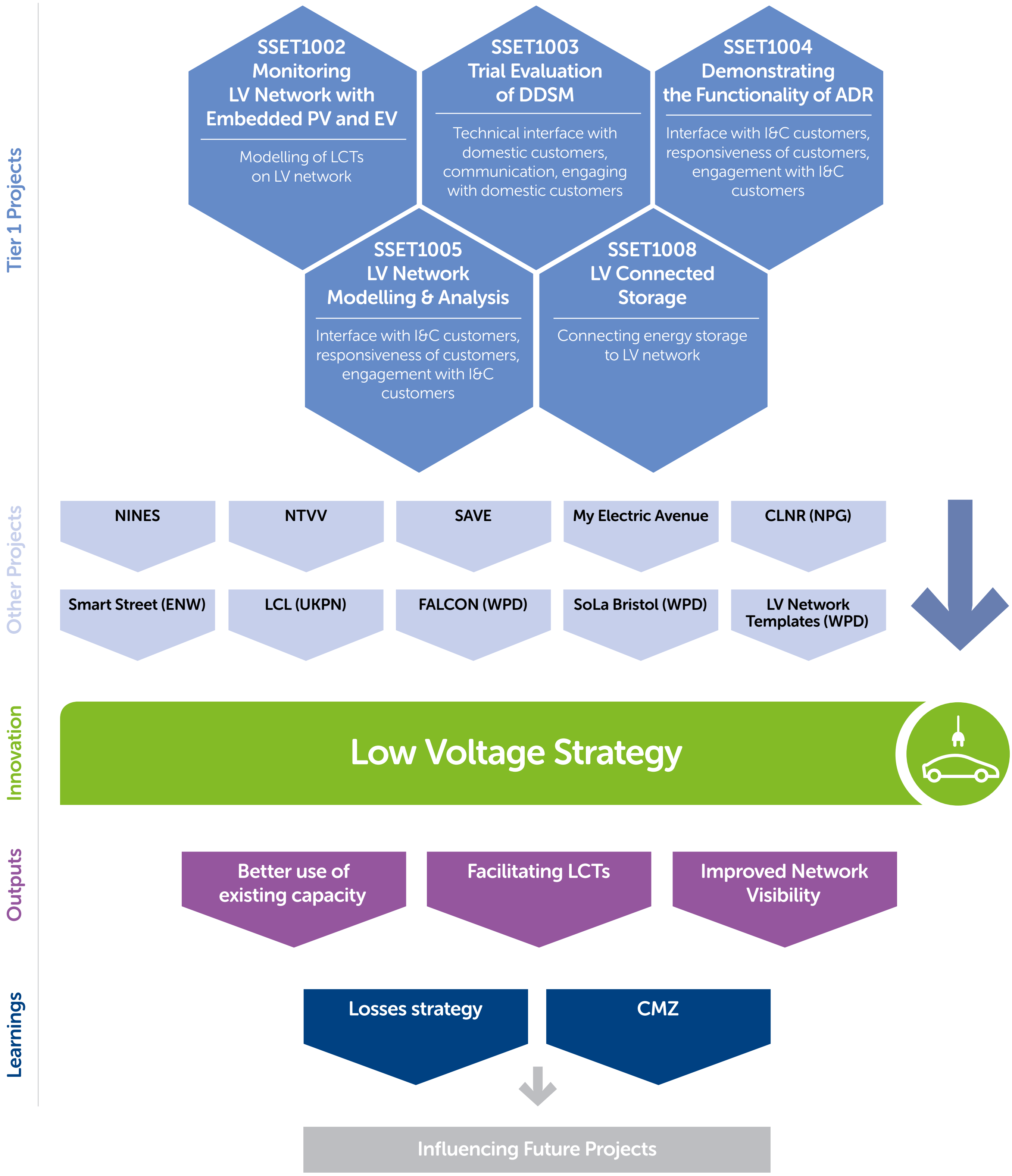
- Reduce peak demand
- Improve renewable load factor
- Inform business case

Learnings

- Community engagement
- CMZ
- ANM

Influencing Future Projects


Tier 1 Projects
SSET1001
1MW Shetland Battery
Integrating energy storage with ANM
SSET1003
Trial Evaluation of DDSM
Technical interface with domestic customers, communication, engaging with domestic customers
SSET1004
Demonstrating the Functionality of ADR
Interface with I&C customers, responsiveness of customers, engagement with I&C customers
SSET1007
Orkney Energy Storage Park (Ph 1)
Commercial arrangements to incentivise location of third party energy storage provider
SSET1009
Orkney Energy Storage Park (Ph 2)
Commercial arrangements to incentivise location of third party energy storage provider
SSET1010
Impact of Electrolysers on the Network
Use of ANM to control and schedule demand
SSET1011
Digital Substation Platform
Use of common IT platform for ANM etc. in substations
Other Projects
ANM (Business as Usual)
NINES
NTVV
SNS (UKPN)
LCL (UKPN)
C2C (ENW)
CLASS (ENW)
FALCON (WPD)
SoLa Bristol (WPD)
Innovation
Constraint Managed Zones
Outputs
Improved use of existing network
Preparation for DSO
1000MW capacity released in GB to 2050
Learnings
TSO/DSO Working Group
Commercial contract development
Influencing Future Projects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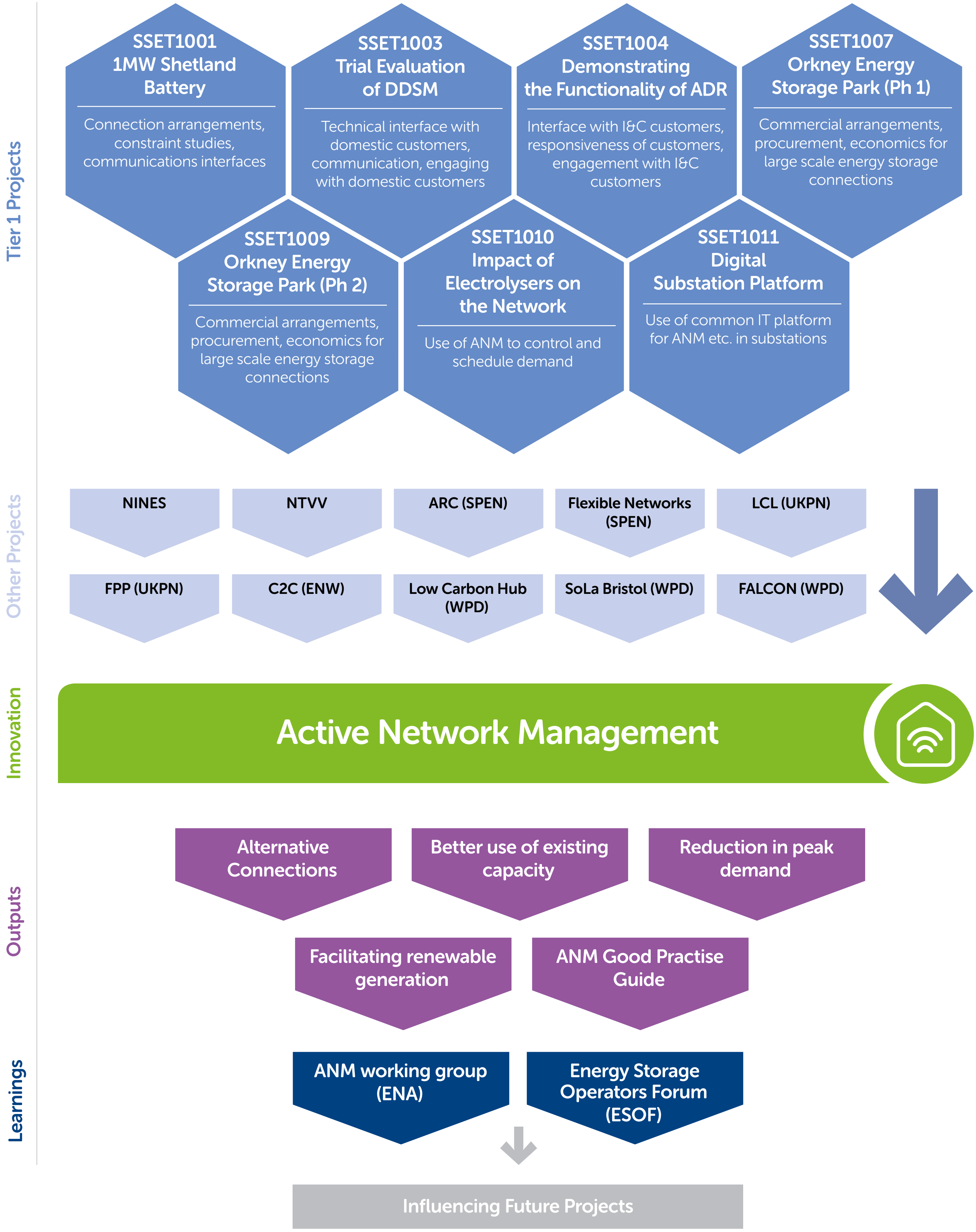
NINES
NTVV
SAVE
My Electric Avenue
CLNR (NPG)
Smart Street (ENW)
LCL (UKPN)
FALCON (WPD)
SoLa Bristol (WPD)
LV Network Templates (WPD)
Innovation
Low Voltage Strategy
Outputs
Better use of existing capacity
Facilitating LCTs
Improved Network Visibility
Learnings
Losses strategy
CMZ
Influencing Future Projects


Tier 1 Projects
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Connection arrangements, constraint studies, communications interfaces
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Use of ANM to control and schedule demand
SSET1011 Digital Substation Platform
Use of common IT platform for ANM etc. in substations
Other Projects
NINES
NTVV
ARC (SPEN)
Flexible Networks (SPEN)
LCL (UKPN)
FPP (UKPN)
C2C (ENW)
Low Carbon Hub (WPD)
SoLa Bristol (WPD)
FALCON (WPD)
Innovation
Active Network Management
Outputs
Alternative Connections
Better use of existing capacity
Reduction in peak demand
Facilitating renewable generation
ANM Good Practise Guide
Learnings
ANM working group (ENA)
Energy Storage Operators Forum (ESOF)
Influencing Future Projects

SSEN LCNF Energy Storage Projects

Building a body of knowledge surrounding the safety case, operational requirements, and commercial drivers for energy storage.

2010

SSET1001 1MW/6MWh Sodium Sulphur battery

2011

SSET1008 3 x 25kW/25kWh Lithium ion batteries

2012

SSET1007 2MW/500kWh Lithium ion battery

ENERGY STORAGE esof OPERATORS FORUM

SSEN lead the foundation of the Energy Storage Operators Forum

2013

SSET1001 1MW/3MWh Lead Acid battery

SSEN contribute to "A Good Practice Guide on Electrical Energy Storage" published by ESOF

2015

NTVV 25 x 36kW/12.5kWh Lithium ion batteries

SSET1001 1MW Shetland Battery

Tier 1 Funding: £960,000
2010–2014

NINES

Introduction

This project was funded by a combination of both Tier 1 and a £1m award from the Department of Energy and Climate Change (DECC) Smart Grid Demonstration Capital Grant Programme. This was the first time that a GB DNO had undertaken a large scale energy storage project.

The project commenced in 2010 with the aim of installing a grid scale energy storage device on the SSEN network in Shetland and integrating this with an active management system. The goal was to: "reduce the peak demand on Lerwick Power Station"; for the battery to "cycle efficiently to meet the needs and profiles of the islands' generation and demand"; and to increase the knowledge and understanding of "battery operation within a network environment".

The project procured the first grid-scale battery for the UK. Three tenders were submitted, each proposing a different battery technology: Sodium Sulphur (NAS); Vanadium Redox; and Zinc Bromide. Following a robust technical and commercial review for a 1MW, 6MWh NAS battery provided by S&C Electric was selected. Civil works for a dedicated battery building commenced in February 2011 and in August the battery modules were installed using a bespoke insertion tool. Two weeks prior to the scheduled energisation of the battery, SSEN was notified by S&C Electric of a battery fire at a similar NAS battery installation in Japan. The energisation of the battery was then delayed until a full review of the safety case was concluded; this included an independent review by external technical experts.

The outputs from the review were received late in 2012 and after consideration of the residual risk, SSEN and our external consultants EA Technology concluded that the fundamental safety case had changed and decided that the NAS battery technology originally proposed was no longer fit for purpose in this application. In consultation with the principle contractor, an alternative solution was sought which had a more established safety case, which was deliverable within an appropriate timescale to allow suitable learning to be obtained, and could be delivered without any increase in cost to customers.

Figure 2 Building housing Shetland Battery.

A 3MWh valve regulated lead-acid battery was selected as an alternative. Installation of all 3168 cells was completed in December 2013. Battery commissioning to allow initial operation of the system was completed in February 2014 with full commissioning and integration with the Active Network Management (ANM) system completed in June 2014. An optimal battery operating schedule was determined and implemented to prove the battery could provide a reduction in peak demand and cycle efficiently according to the network requirements. This project has generated significant learning in key areas including: procurement, design, construction, installation, commissioning and safety.

Figure 3 Shetland Battery.

This experience gained by SSEN in implanting the Shetland Battery led directly to the development of the Energy Storage Operators' Forum (ESOF) during the course of the project. This is an exclusive forum whose membership comprises all of the GB DNOs and the Transmission System Operator. ESOF facilitates open and honest sharing of information and experience (including any failures or challenges encountered) between members on the practical aspects of Electrical Energy Storage systems through the whole project life-cycle. Further details can be found on the ESOF website[2].

The battery energy storage system will continue to be trialled and evaluated under the Northern Isles New Energy Solutions (NINES) project. Full details of the NINES smart grid project can be found on the NINES website[3].

Aspects of the Carbon Plan that have been facilitated

This project was funded by a combination of both Tier 1 and a £1m award from the Department of Energy and Climate Change Smart Grid Demonstration Capital Grant Programme. This was the first time that a GB DNO had undertaken a large scale energy storage project.

The combination of a large scale energy storage device integrated with an ANM scheme provided additional flexibility into the operation of the Shetland network. This, combined with the **SSET1003** Trial Evaluation of Domestic Demand Side Management, has enabled additional renewable generation to be connected. This has almost trebled the volume of renewable generation produced on the islands. This includes several new wind turbines and one of the first tidal energy systems in the UK[4].

This Tier 1 project embodies the Carbon Plan intention to deliver "secure and sustainable low carbon energy paving the way towards a 'smarter' electricity grid in the UK, which will increase the efficiency and reliability of the network, enable flexible demand management and support integration of more local and wind-powered generation."

Changing the way we generate our electricity

The project integrated a grid-scale battery energy storage system with an ANM system. This enabled the battery to be scheduled to charge when new non-firm renewable generation would otherwise be constrained. This is the direct enablement of flexible demand management and wholly supports the integration of more local wind generation.

Demonstrating the use of flexible demand and energy storage

The battery can discharge 3MWh during the peak demand which reduces the generation requirement the system operator must provide through conventional generation sources and releases an additional 1MW demand capacity. To date, the battery has completed over 450 operational cycles.

2 https://www.eatechnology.com/products-and-services/create-smarter-grids/electrical-energy-storage/energy-storage-operators-forum
3 http://www.ninessmartgrid.co.uk/
4 https://www.novainnovation.com/

Releasing network capacity

With a rated power of 1MW, an additional 1MW of demand capacity has been released.

With an energy storage capacity of 3MWh the battery can discharge 3MWh across the daily peaks in demand.

To date the battery has discharged 1.45GWh to the Shetland network.

The charging requirement of the battery is 4MWh which can be scheduled at times when renewable generation would otherwise be constrained. To date, the battery – acting as a controllable demand on the Shetland network – has imported 1.92GWh, and completed around 450 duty cycles.

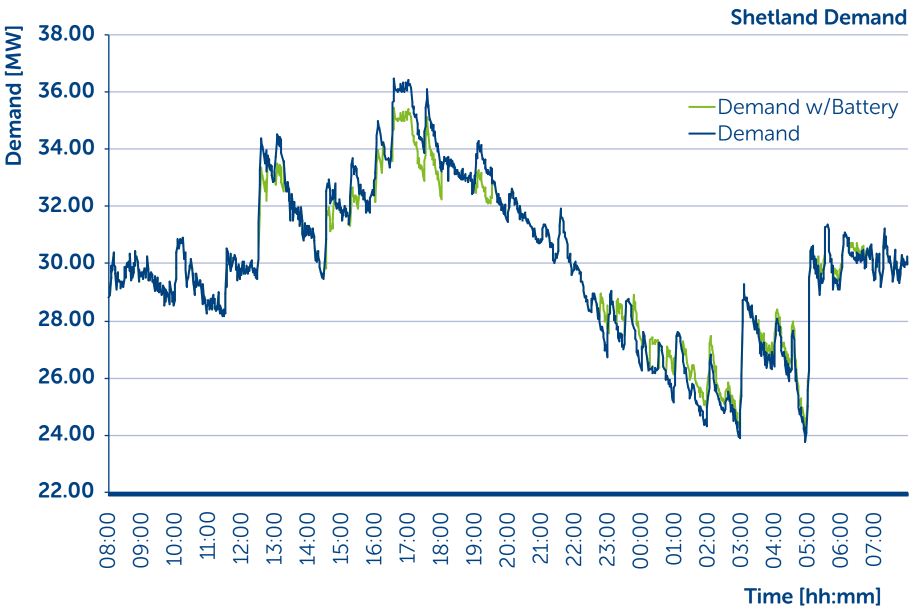


Figure 4 Battery providing a reduction in peak demand

Delivering financial benefits

The Shetland Battery project fed key learnings around operation of storage into our innovation areas such as ANM, Demand Management, CMZ, and Energy Storage.

Modelling by EA Technology Ltd has shown that these initiatives could deliver benefits of up to £327m by 2050 – see Section A3 for further details.

Roll out across the DNOs' systems and across GB

The Shetland Battery project was the first MW scale battery energy storage system to be tendered in the UK. The Energy Storage Operators' Forum published the Good Practice Guide on Electrical Energy Storage in December 2014. The learning from the outputs of the project were shared by SSEN via ESOF and informed a number of other DNOs' energy storage projects including UKPNs Smarter Network Storage, and Northern Powergrid's Customer Led Network Revolution. Despite these trials, there are regulatory barriers which prevent DNOs from owning and operating energy storage.

However, there is little doubt that Energy Storage will play an increasing role in the future of the GB network. In the last year DNOs across GB received multiple connection applications (totalling nearly 10GW) as storage developers responded to an NGET tender for Enhanced Frequency Response. The learning from our Tier 1 projects has helped inform DNOs on how to assess and respond to these applications.

Learning Delivered

Due to unforeseen circumstances[5] the project gained experience of two different battery technologies: sodium-sulphur (NAS) and lead-acid. It is a testament to the good working relationship between SSEN and the principal contractor, the perseverance of SSEN staff, and their desire to make this project a success that the Shetland Battery project was fully realised, with the replacement solution being delivered with no additional cost to customers.

The scale of this project was significantly larger than any previous trial of battery systems in the UK. This highlighted the extent to which there should be collaboration between DNOs and the need for an accessible forum to discuss, question and transfer learning between projects. To this end, in early 2012, SSEN along with EA Technology Ltd jointly instigated the Energy Storage Operators' Forum (ESOF). The forum disseminated learning by presenting collaboratively at the 2013 LCNI conference in Brighton[6] and 2014 LCNI conference in Aberdeen[7].

The seventh meeting of the group was held in Shetland in June 2014 and included a technical tour of the 1MW valve regulated lead-acid battery energy storage system and control systems at Lerwick Power Station.

The most significant achievement of the forum was the publication of the Good Practice Guide on Electrical Energy Storage in December 2014[8] which disseminates the key lessons learnt including:

- Current deployment of electrical energy storage
- Policy announcements
- Technology descriptions
- Relevant codes, standards and legislation
- The approach taken and lessons learnt regarding: procurement, installation and safety case
- Applications, scheduling and benefits obtained
- Costs and potential revenue streams
- Methodologies for analysing the cost benefit case including examples

The Shetland Battery project contributed two case studies to the guide.

5 https://www.ofgem.gov.uk/ofgem-publications/43523/nines-change-request-decision-letter-24-05-2013-pdf
6 http://www.smarternetworks.org/Files/Low_Carbon_Network_(LCN)_Fund_131203110442.pdf
7 http://www.smarternetworks.org/Files/Low_Carbon_Network_(LCN)_Fund_141111144928.pdf
8 https://www.eatechnology.com/products-and-services/create-smarter-grids/electrical-energy-storage/energy-storage-operators-forum/esof-good-practice-guide

SSET1002 Demonstrating the benefits of monitoring Low Voltage network with embedded PV panels and EV charging point

Tier 1 Funding: £191,000
2010–2011

Introduction

Electric vehicles (EVs) and photovoltaic (PV) panels are increasingly being adopted by consumers, and are generally connected to a Distribution Network Operator's (DNO's) low voltage (LV) network via existing connection points without need for permission, and likely without prior notification.

The potential impacts of these low carbon technologies (LCTs) on the LV network are of some concern; to understand these impacts, if any, additional network monitoring is required. As increasing quantities of LCTs are connected, consideration needs to be given to the potential requirement for large scale deployment of monitoring to enable DNOs to make better informed decisions on how best to intervene and to ensure that sufficient capacity is available to prevent the network becoming a barrier to the adoption of LCTs.

Monitoring of distribution substations already occurs on LV networks elsewhere in the world, but at the start of this project, had not been deployed by GB DNOs. Today, typical DNO distribution substation monitoring is still limited to a low cost low-accuracy Maximum Demand Indicator (MDI) capable of recording the peak current, aggregated over a 30 minute period, on each of the transformer's three LV phases.

The MDI does not include any communications options and requires a manual reading or reset. If planning, investment or operational decisions are to be made effectively when the LV network is undergoing pressure to allow connection of LCTs, more accurate data is required. At least in part, this data will need to come from detailed, accurate substation monitoring.

The scope of this project was to demonstrate that appropriate substation monitoring can be installed retrospectively and provide meaningful electrical information, and to assess the network impacts of PV and EV uptake at a development of ten low carbon homes, built by SSE at Chalvey, near Slough.

This project introduced distribution substation monitoring to obtain detailed and accurate current, voltage, power and directional energy usage data, and to develop an understanding of how DNOs might pursue such deployments in the future using monitoring devices installed at substations. It provided the opportunity to monitor the LV feeder circuit to which SSE's Low Carbon Homes are connected to gain insight into the impact on the low voltage network. This trial project identified and resolved a number of design, installation and commissioning issues on the installation of LV monitors in secondary substations.

The learning from this project provided key learning on the practical requirements for retrofitting LV monitoring in existing substations. This was used to develop specification and requirements document which was used to in the larger scale Tier 2 New Thames Valley Vision (NTVV). The NTVV project successfully installed monitoring in nearly 300 substations in the Bracknell area – this Tier 1 project ensured that this deployment was undertaken efficiently and effectively without interruption to customers' supplies.

Figure 5 Flexible Rogowski coils 'live installed' at two LV feeders

Aspects of the Carbon Plan that have been facilitated

The move to a low carbon energy system will place additional demands on the network, in particular the growth of photovoltaics and the move toward EVs will place additional demands on the LV network, At the start of the project there was little data available for assessment of the impact of the connection of PV and EV charging on the LV network

The project has resulted in data being available that can allow a full assessment of the network at the monitored location, so that the impact of PV and EV charging can be understood. Being able to understand the impact on the network is key to being able to make better informed choices about the need for, and urgency of, any potential intervention, whether this is traditional reinforcement or an alternative smart solution.

This improved understanding of the impact that low carbon technologies (LCT) have on the network will help DNOs to become a facilitator of LCT uptake and avoid network issues becoming a 'blocker' to their progress, thus enabling smoother progression towards the goals of the Carbon Plan.

Releasing network capacity

Being able to accurately monitor load profiles and peaks on the LV network does not in itself provide any additional capacity. However, the traditional combination of existing MDI data and conventional LV network planning do not allow DNOs to maximise the use of capacity which already exists within the network. However, the ability to accurately monitor power LV feeder data allows DNOs to utilise this potential or make any other appropriate intervention. Substation monitoring is one of a range of functions which contribute towards our revised strategy for the LV network. The potential roll out and the capacity released from our LV Strategy has been modelled by EATL using the Transform Model®, with full details available in Section A2.

Delivering financial benefits

The project provided a clear set of requirements for substation monitoring which, combined with standardisation, allows multiple manufacturers to supply equivalent equipment providing a competitive market for the DNOs and ultimately reducing the cost of monitoring equipment.

The ability to install monitoring equipment without requiring a shutdown has the benefit of avoiding disruption to customers, and also reducing the burden of work on the DNO to complete the work. This is estimated at a minimum of four hours of saved labour including production of letters and identification of affected customers, and electrical isolation and restoration.

The installation of monitoring equipment gives DNOs an opportunity to benefit from enhanced reliability and security of supply resulting from a proactive approach to Power Quality issues (as an alternative to being driven by customer complaints after significant problems arise), and allowing targeted investment in the low voltage network.

This ability to make better use of the existing network, deploy smarter interventions (such as storage) or deferring traditional network investment all have the potential to deliver benefits for customers. An analysis of the potential benefits has been carried out by EATL using the Transform Model®; the financial benefits have been outlined in Section A3. The ability to deploy low cost substation monitoring is key to being able to realise these benefits.

The potential for phase balancing to avoid reinforcement has a potentially extremely large financial benefit; this is also being further explored in the NTVV project.

Roll out across the DNOs' systems and across GB

Other DNOs have already procured equipment configured by manufacturers on this project for deployment for Business as Usual (BAU) activities. This may be considered a medium scale deployment (hundreds) rather than large scale deployment (thousands), but the manufacturer will undoubtedly gain further experience leading to product improvements and cost reductions.

The requirements specification developed during this project and implemented at scale in the Tier 2 NTVV project, should facilitate the roll out of substation monitoring across GB. The equipment proposed should be compatible with the vast majority of substations and LV cabinets in use across the GB network.

Figure 6 GridKey MCU520 Data Aggregator

Project learning contribution

At the start of the project, no manufacturer was able to offer a complete monitoring system that could be installed as required and integrated with a DNO's information management system to provide a DNO with a full suite of electrical parameters as specified. The project involved work with three manufacturers to help them fully understand the requirement (they understand how to make products, but lack awareness of how a DNO interacts with products) and allow them the opportunity to configure their solutions for trial on the network. This served to de-risk the larger scale installation as part of the Tier 2 NTVV project.

While not a major focus of the project, the ability of the monitoring systems to transmit data back to a DNO was considered, and mainstream GPRS communications used.

The project developed a method statement by which monitoring equipment can be installed safely and efficiently without taking customers off supply.

The data obtained was reviewed and particular observations were made about the performance of the LV network. In particular, significant feeder phase current imbalance was observed; busbar voltages were seen to exceed the specified voltage limits that would apply at the point of connection, real and reactive power flows were measured on the circuit to which PV is connected, and the harmonic content of the same feeder was observed to be low. At this level of PV connection to a low voltage feeder (10 houses) in an urban environment, no net detrimental impact on the LV network was observed.

This project has demonstrated that substation monitoring can be done and provides real value in terms of information gained about the LV network. The Tier 2 NTVV project deployed monitoring at more than 300 substations from which further direct learning will be derived, and then develop a much deeper understanding about the ways in which the data can be used to bring value to a DNO. It is the outcome of this Tier 2 project that will much more directly influence the justification for a true large scale deployment.

SSEN shared learning from this project with other DNOs via one-to-one site visits, including demonstrations of data transfer capabilities. The learning relating to retrofitting monitoring with zero customer interruptions was identified as new knowledge relevant to the industry and the method of dissemination was chosen following initial discussion of learning from the project with Ofgem, as an efficient, relatively low-cost method which would enable in-depth discussion of the technical aspects.

Initial discussions with other DNOs indicated that dissemination on the monitoring project was not sufficient alone to attract significant interest – a site visit including tour of SSE's Low Carbon Homes as well as the monitoring systems at Chalvey Local substation was therefore offered. One-to-one visits were arranged with UK Power Networks, ScottishPower, and Electricity North West. Most participants were Future Networks/ Low Carbon team members.

The Energy Storage Operators' Forum (ESOF) was also used as a dissemination channel.

SSET1003 Trial Evaluation of Domestic Demand Side Management

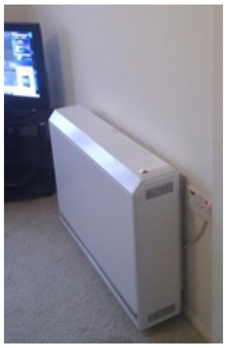
£262,000
2010–2012

Introduction

The project has contributed to the development of ANM systems, network resilience, and a key learning outcome: how a distribution system can be securely operated with a high penetration of renewable generation.

The project trialled a Domestic Demand Side Management (DSM) solution in six houses with suitable control and signalling back to a central control hub, the aim being to control domestic electrical heat demand during times of network strain such as at times of exceptionally low or high demand.

Heat storage devices (immersion water heaters and space storage heaters) were installed with control systems, enabling them to become inertial energy storage devices on the electrical network. This provided the DNO with a degree of control over local demand response and frequency response.



Aspects of the Carbon Plan that have been facilitated

Demonstrating the use of flexible demand and energy storage

Shetland has no access to mains gas therefore up to 50% of homes have electric heating compared to just 8% of homes in the UK[9]. The majority of these are controlled by a radio teleswitching system[10] providing fixed charging times for space heating and hot water appliances. The consequence of hundreds of devices switching on at the same time is a large load rise and peak demand periods as shown in Figure 7.

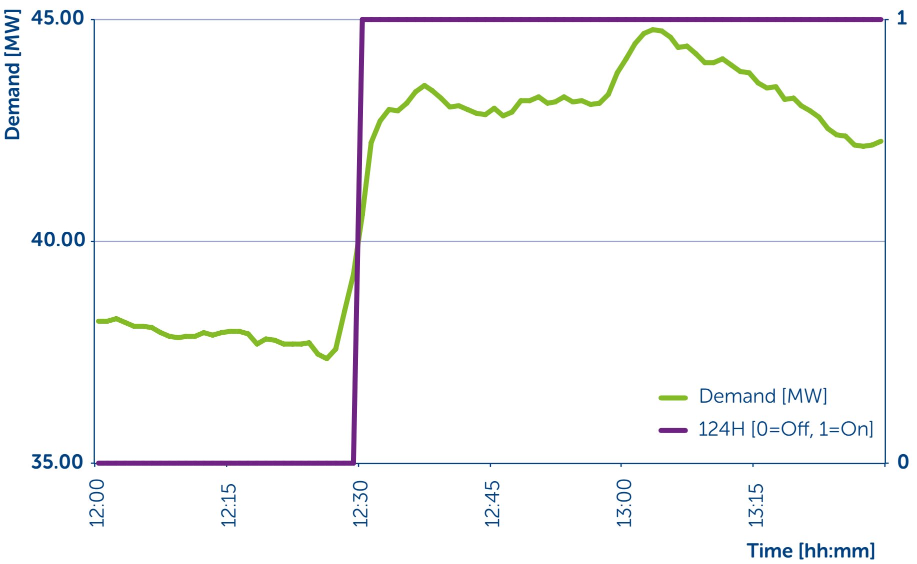


Figure 7 Scheduled switching time of a single teleswitch code on Shetland, and the impact on local demand

9 https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf
10 http://www.radioteleswitch.org.uk/

Figure 7 shows the scheduled switching time of a single teleswitch code on Shetland. GB teleswitch meters contain a random offset of up to +/- 3.5 minutes to prevent a sudden load rise. The load rises from 37.4MW at 12:26 to 43.0MW at 12:33, an increase of 5.6MW which is equivalent to 14.7% of the average demand that day. This is further emphasised when four teleswitch code 'ON' times are shown against a full day's demand, as seen in Figure 8.

The graph clearly shows the majority of large load rises can be attributed to these four teleswitch codes.

SSEN partnered with Glen Dimplex and the Hjaltland Housing Association (HHA) to develop and trial a domestic demand side management (DSM) solution. The solution demonstrated that it was possible to shift demand away from peak times. Initially as a proof of concept this was a time shift of just one hour, then two, then four; however the aim in the subsequent NINES project was the full integration of a large number of domestic properties with an ANM system capable of autonomously scheduling demand either at times where intermittent renewable generation would otherwise be constrained, or when demand was low.

This Tier 1 project trialled the installation in six homes, and allowed a range of different communication and control solutions to be tested and interfaces to be validated prior to the larger scale role out. The trial also allowed Glen Dimplex to resolve a number of similar issues within the properties; additional monitoring was fitted to monitor comfort levels for users and to ensure that the installations were responding as anticipated.

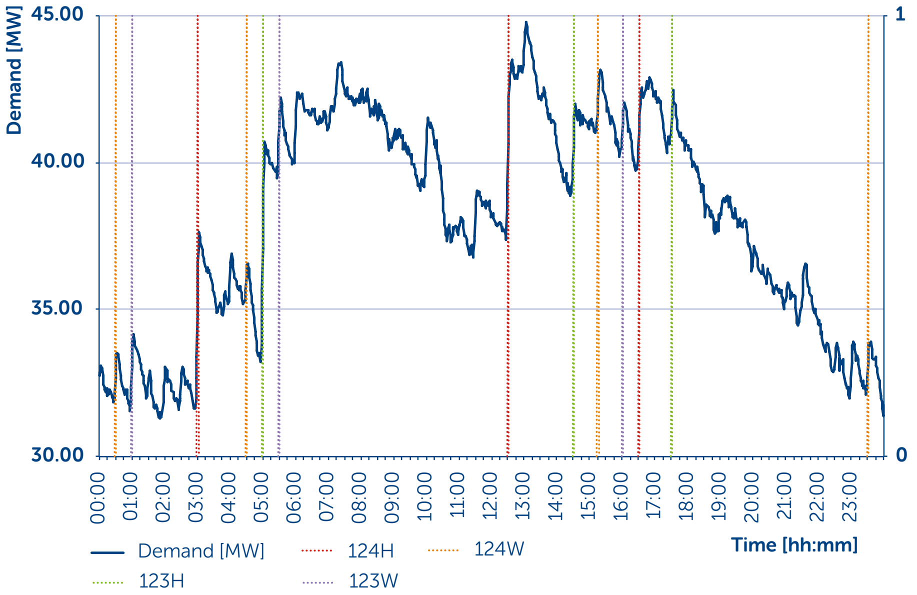


Figure 8 Demand over one day in Shetland, with four scheduled teleswitches.

This project has shown the potential for demand to be time shifted to utilise the output from an increased availability of renewable generation across Shetland. This has not only served to reduce peak demand on Shetland but has allowed a higher utilisation of renewable energy.

Saving energy in homes and communities: Low carbon heating/lighting – support ways of heating buildings without emitting carbon. Delivery of heat from low carbon sources

The (DSM) devices that have been installed can be scheduled to charge at times of high renewable generation output. Without this DSM controllable demand, there would often be times where renewable generation would have to be curtailed due to lack of demand in Shetland. The heaters and hot water cylinders can therefore be charged when low carbon sources are available. In addition, the development of a new generation of storage heaters which offer greater control and efficiency help customers save energy with Glen Dimplex calculating this to be as high as 27%[11].

This is particularly important as an insights paper[12] published by Ofgem on households with electric heating identified that a third of households with this form of heating have a low income increasing the likelihood of fuel poverty.

11 http://www.dimplex.co.uk/products/domestic_heating/installed_heating/quantum/index.htm
12 https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf

Releasing network capacity

The six homes trial was a small pilot project in advance of a larger roll out under the NINES project[13]. The network capacity released by shifting demand away from peak periods for the six homes was:

- Power – 44kW
- Energy Storage – 270kWh

Note – These are maximum values which will be affected seasonally.

Although new renewable generation was only connected in November 2014 – after the SSET1003 project end date – a theoretical increase in renewable generation capacity could be claimed by charging the devices at times where renewable generation would otherwise be curtailed.

The maximum increase in generation would be equal to the maximum demand available from the six homes – 44kW, 270kWh. Crucially, this Tier 1 project significantly de-risked and accelerated the larger scale roll out of DSM heating and hot water systems in approximately 240 homes across the island. This combined with the 1MW battery and importantly the ANM scheme along with the other elements of the follow on NINES project has enabled additional renewable generation to be connected on Shetland. These flexible connections have allowed an additional 8MW of new renewable energy developments to proceed, taking the total connected on Shetland from 4MW to 12MW.

Delivering financial benefits

The learning from the project established that domestic properties can provide a useful source of demand side response for DNOs. In future, it is likely that any domestic demand side response will be provided to DNOs via an aggregator or supplier.

Our experience has shown that this can be used as part of a CMZ type DSM service. Modelling by EA Technology Ltd has shown that CMZ deployment will deliver benefits of £52.7m in GB to 2050.

Roll out across the DNOs' systems and across GB

The prototypes were developed into a commercial product – Dimplex Quantum. A further trial took place under the NINES project with 700 devices, installed in 234 homes. This equates to a maximum of 1.4MW power and 9.6MWh energy storage available across the island.

There is significant roll out potential in the UK with over 2.2 million homes currently using electrical heating systems. This could provide significant benefits in balancing the GB network in future. As stated above this will in part be driven by aggregators and suppliers as the develop products which include these services.

13 https://www.ninessmartgrid.co.uk/

Project learning contribution

The project advanced the Technology Readiness Level (TRL) level from 6 to 7, as an actual system prototype has been demonstrated in a working environment. The six homes trial delivered extensive learning including:

- Developing the functionality required in a commercial DSM heating system
- Requirements for a communications solution
- Resource requirements
- Understanding of customer perceptions
- Skills development and safe working procedures
- Input to further academic work on modelling household energy use to forecast customer demand
- Understanding the protection that is required for the larger scale roll out to avoid unintended impact on participants' bills.

The project fulfilled all the objectives required to prove the integration of the technologies, scheduling of the devices and automatic frequency response.

During initial power quality testing, flicker measurements out with BS EN 61000-3-3:2008 limits were observed due to the rapid operation of a pulse width modulation heating element. SSEN worked closely with Glen Dimplex and defined a simple switching strategy that maintained load control within 2% steps. This was successfully tested on the SSET1003 project and carried forward to NINES.

The comprehensive close down report[14] set the standard for all future Scottish and Southern Electricity Network Tier one reports. The project learning log identified learning across a number of innovation themes including: energy storage, communications, low carbon technology integration, construction, environment, network stability and power quality, customer engagement, asset utilisation, and network security.

There were a number of lessons learned that are directly applicable to the NINES project. These include:

- Functional and non-functional requirements for the NINES project's invitation to tender for a DSM communications solution specifying reliability, scheduling, security, physical dimensions, data storage, service level agreements and safety testing
- A wireless communication solution within the home which would considerably reduce installation time from four and a half hours to two hours.
- Resource requirements for the NINES roll out
- A standards group to define minimum functionality and characteristics of the heating systems to prevent negative impacts to the distribution network

Hjaltland Housing Association is an organisation actively involved in the provision of high quality housing throughout the Shetland Isles. The location we operate in poses some significant challenges due to its remoteness and climatic conditions and with very high levels of fuel poverty the Association is always looking at ways to improve things, not only for its tenants, but also for the wider community. Being a part of the NINES project gave us the opportunity to do both by improving the energy efficiency of our housing stock and also making the local grid more responsive, which in turn allowed more renewables to connect. This project has enabled the Association to meet the Scottish Government's Energy Efficiency Standards for Social Housing (EESSH) well in advance of the compliance year of 2020 and has provided our tenants with the opportunity to reduce their energy bills with more controllable heating and hot water systems. The Association is delighted to be a partner in this project and hopes the learning disseminated from it can be applied at a national level and ultimately allow more renewables onto the national grid.

Paul Leask
Head of Investment & Asset Management
Hjaltland Housing Association Ltd

14 https://www.ofgem.gov.uk/ofgem-publications/45829/sset1003-closedown-report.pdf

SSET1004 Demonstrating the Functionality of Automated Demand Response

Tier 1 Funding: £260,200
2011–2012

Introduction

Automated Demand Response (ADR) technologies, implemented in commercial buildings, have been shown to be able to support DNOs in managing a range of network issues and will help smooth the transition to a low carbon future.

The Honeywell ADR system trialled in this project enables a reduction or shift of electricity load from buildings through their existing building management systems (BMS). Honeywell are industry leaders in installing BMS in the UK and as such were well placed to participate in this trial. This project was developed to demonstrate, for the first time in GB, an end-to-end solution and functionality for building owners to automate load shedding in response to a signal from the DNO.

This project implemented and demonstrated basic ADR functionality in commercial buildings. Three building owners were recruited as trial participants, each willing to test the Honeywell ADR system. A framework for customer engagement was developed iteratively during the project to identify potential participants, engage with them to obtain sign up to the trial and manage their participation. The ADR system was installed and tested by carrying out individual and aggregated load shed events.

The aim was to advance the system's TRL level from 8 to 9 through a small scale trial and to define a working process for customer engagement. The results indicate ADR has considerable potential to reduce load and provide wider benefits to DNOs. However, conclusions are very tentative due to the small sample size and require validation through further trials. This trial has been an essential first step in creating a platform for systematically testing:

- the cost, effectiveness and value for money of stages in the customer engagement process
- ADR's technical potential
- The commercial/social limits on exploiting this potential

Further testing of these aspects of ADR was then carried out under the Tier 2 New Thames Valley Vision project on a wider sample (30 buildings) to provide a more robust evaluation of the commercial viability of ADR.

Aspects of the Carbon Plan that have been facilitated

Enabling a move towards low carbon generation requires a more flexible network, by using new smarter approaches to shift demand from peak times and free up capacity which exists within the network.

This project has developed experience and knowledge to reduce the peak demand which is most likely to be supplied via carbon-intensive peaking plant.

Furthermore, the ability to shift and flex demand offers more options for dealing with intermittency issues caused by renewables.

This should allow renewable output to be maximised, avoid generation constraints and associated constraint payments. This ability to flex demand will be an essential element of a network with significant volumes of renewable energy generation.

Releasing network capacity

Technical demonstration of load shed was achieved for each building, with an absolute maximum aggregated load shed of 188kW from all three sites, achieved by a manual signal via the ADR Gateway at a time specified by SSEN. The load available for shedding in any building changes for any given time of day/year, since load reduction is primarily based on control of Heating Ventilation and Air Conditioning (HVAC) systems.

Modelling by Imperial College London based on trial results estimated an aggregated peak load shed of at least 460kW (summer) and 100kW (winter) could be expected from the three buildings studied, indicating that ADR at these study sites will be most effective in managing constraints in peak periods during the summer.

Results from the trial highlighted that the real time demand profile data available for buildings with ADR can be used with existing network data to improve the accuracy of estimated power flows in HV feeder sections and corresponding network voltage profiles.

Delivering financial benefits

The net present value of the cost of ADR was estimated at between £56,700 and £97,000 per building over 30 years. Estimates of network reinforcement costs were used to calculate the minimum levels of demand reduction that ADR in this cost range must achieve to make it a financially viable alternative to reinforcement. Minimum levels were then compared to forecast summer and winter load shed from the buildings studied as above.

This indicated that the expected reductions in summer load from the three individual buildings studied would exceed the minimum, making ADR viable if network reinforcement is driven by demand peaks in summer, rather than winter. These types of installation are likely to be one of a range of future flexibility options available to DNOs in the future, the benefits from these have been estimated using the Transform Model®, and the financial benefits have been outlined in Section A3.

Roll out across the DNOs' systems and across GB

The results of this project informed the use of ADR in the LCNF Tier 2 NTVV project which saw the deployment of ADR in 30 premises in the Bracknell area. The learning from this Tier 1 and the follow on NTVV project have helped SSEN implement demand side solutions such as CMZ.

Analysis by EATL has shown that there could be a large number of CMZ deployments by 2050 – full details are provided in Section A2.

Project learning contribution

A framework for customer engagement was developed which can be used and evaluated in future trials. The framework covers engagement required from the first meeting through to agreement of load shed strategies. Work after this can be deemed as the technical integration/installation and performance of the equipment.

As a result of this trial, the documentation provided to participants on ADR in the NTVV project was simplified and the sign up process was streamlined so only one contractual agreement is now required instead of a two-step process with separate agreements to authorise ADR site surveys and ADR event participation.

The trial project identified and resolved initial concerns from participants regarding cyber security and firewall access. It was identified at an early stage that this was a key concern from IT Departments within the customer organisation. Resolving this in a mutually acceptable manner, allowed the system to be approved in a relatively short timescale with less concerns over cyber security. This was crucial in preparing for the larger scale roll out in NTVV

The project has specifically:

- Proven that the ADR Hardware is capable of shedding load in commercial properties by communicating with the existing building management system
- Shown that this load shed can be triggered simultaneously to perform an aggregated load shed
- Identified that data can be easily and securely stored on the ADR Gateway
- Delivered improved understanding of the cost of ADR
- Identified safety risks and issues and appropriate controls associated with implementing ADR in commercial buildings, detailed in Risk Assessments and Method statements
- Developed understanding of the potential range of load shed and factors affecting load shed from three typical UK commercial buildings
- Provided greater understanding of the additional observability of network provided by ADR system

Most importantly this project provided learning which allowed the larger scale deployment of ADR within the Tier 2 NTVV project to progress quickly and efficiently. This project is on course to complete in March 2017 and is anticipated to provide significant future benefits for customers.

SSET1005 Low Voltage Network Modelling and Analysis Environment

Tier 1 Funding £320,000
2011–2012

Introduction

This project recognised the opportunity of the prospect of having, for the first time, large amounts of data relating to the status of our low voltage networks.

This data will come from Smart Meters, network embedded monitoring devices (see SSENT1001) and information extrapolated using advanced modelling and forecasting tools. The existing systems, interfaces and methodologies adopted in the industry are currently not able to take full advantage of this new source of data. Similarly the wealth of new energy sources and demands on the network are changing traditional usage profiles, again leaving the industry potentially 'blind' to the changing demand patterns on the low voltage network.

This project, a precursor to the New Thames Valley Vision (NTVV) project, aimed to source, integrate and evaluate the tools and data that will be both available and needed to help face this challenge going forward.

The project investigated the creation of a proof of concept 'Low Voltage Network Modelling Environment' that would enable a GB Distribution Network Operator (DNO) to carry out load flow analysis calculations without the need for significant user input. It was anticipated that this analysis would facilitate the DNO being able to identify where and under what conditions the LV network would need to be reinforced. The main driver behind this was the accelerating change towards a low carbon economy and the unknown impact this would have on a network historically designed for consumer load, with no consideration for the recent emergence of embedded generation or other LCTs.

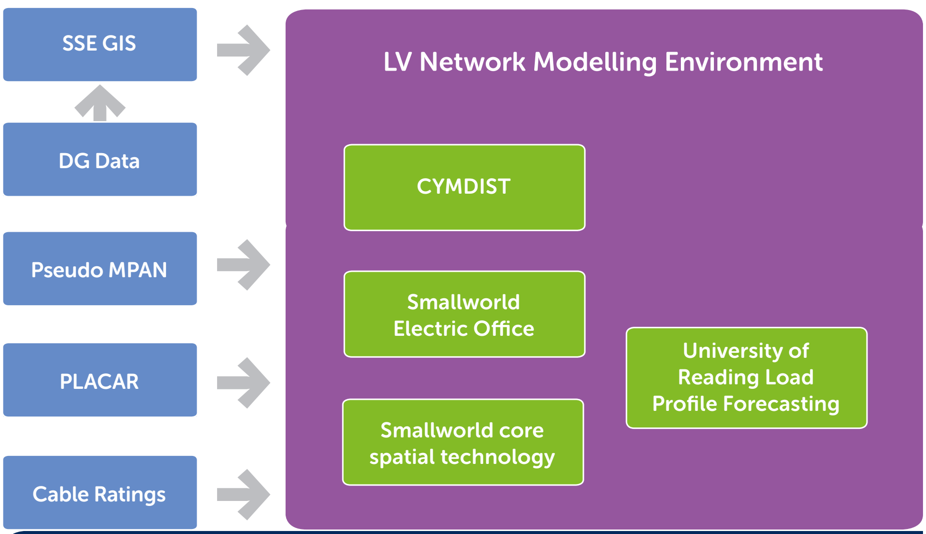


Figure 9 Low Voltage Network Modelling Environment data sources and components

SSEN partnered with GE Digital Energy to demonstrate the capability of electrically modelling the low voltage network. The proof of concept was required to be capable of re-creating network topology from existing SSEN information systems to avoid the need for significant user interaction to input network connectivity data. The tool was also intended to facilitate the modelling of new and emerging low carbon technologies such as solar PV, heat pumps, electric vehicles, etc. GE Digital Energy are ideally placed to support this project as they provide SSEN and four other DNOs with 'Power On Fusion' which is used for control of the higher voltage networks.

An additional key requirement of this Tier 1 project was to de-risk our Low Carbon Networks Fund (LCNF) Tier 2 project, New Thames Valley Vision, by laying the foundations for a fully automated Network Modelling Environment. This would provide SSEN with a small, but representative, example low voltage network derived from the company's actual data and enable SSEN staff to interact with the selected power analysis tool. This built on the work carried out in the other Tier 1 projects which helped to prepare for the larger scale NTVV project.

Aspects of the Carbon Plan that have been facilitated

The project demonstrated a proof of concept 'Low Voltage Network Modelling Environment' that would enable a GB Distribution Network Operator (DNO) to carry out load flow analysis calculations without the need for significant user input.

The analysis facilitates the DNO to identify where and under what conditions the electricity network would need to be reinforced in order to operate effectively under new load demands.

This improved understanding of the impact of low carbon technologies (LCTs) aims to avoid DNOs being a 'blocker' to new LCTs connecting to the network, thus enabling faster progression towards the goals of the Carbon Plan.

Releasing network capacity

Using Distributed Generation (DG) and Load Profiles, the integrated geographical information system and network analysis tool can identify network reinforcement requirements, and provide more accurate modelling of low voltage networks. This in turn allows us to better understand where additional capacity can be sited on the network without the need for reinforcement. Similar to the SSET1002, enhanced monitoring and more sophisticated modelling will allow DNOs' to make better use of the existing capacity of the LV network. This allows DNOs' to make better informed decisions on the extent and timing of any network intervention. The ability to better model the LV network using a combination of new data sources (such as smart meters) and substation monitoring is a key element of our LV Strategy. The potential roll out and the capacity released from our LV Strategy has been modelled by EATL using the Transform Model®, with full details available in Section A2.

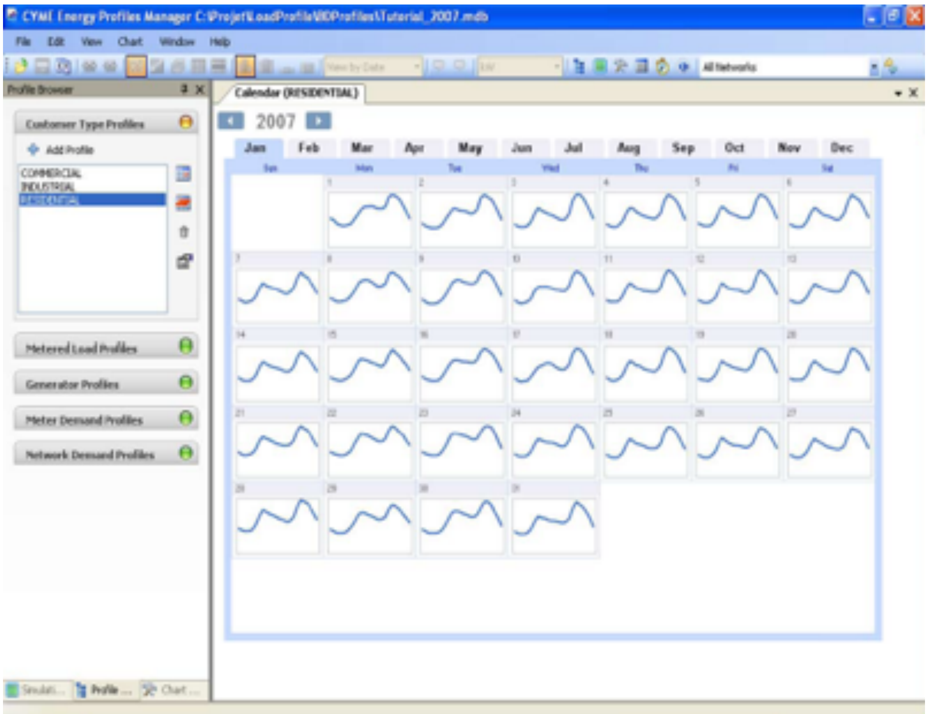


Figure 10 CYMDIST – Energy Profile Manager – Calendar View

Delivering financial benefits

This ability to make better use of the existing network, deploy smarted interventions (such as storage) or deferring traditional network investment all have the potential to deliver benefits for customers. An analysis of the potential benefits has been carried out by EATL using the Transform Model®; the financial benefits have been outlined in Section A3. The ability to better model the LV network and the impact of LCTs is a key component of this strategy.

The ability to better model potential smarter interventions such as phase balancing or storage to avoid reinforcement has a potentially extremely large financial benefit; this is also being further explored in the NTVV project. The NTVV project is approaching closure and is on course to provide significant benefits for customers.

Roll out across the DNOs' systems and across GB

The system has been used as part of the LCNF Tier 2 NTVV project to perform detailed modelling on 20 substations in Bracknell. There is little doubt that the move to a lower carbon economy will produce a new set of challenges for the LV network. Rather than the traditional 'fit and forget' approach to managing the LV network DNOs will need to adopt a much more proactive approach.

The ability to identify networks likely to be subject to stress due to LCT deployment and then to be able to readily model a range of interventions will be crucial to DNOs going forward. The potential roll out and the capacity released from our LV Strategy has been modelled by EATL using the Transform Model®, with full details available in Section A4.

Project learning contribution

This trial project evaluated a number of approaches to how best to transfer data and information from existing sources to the new modelling environment. It also considered the best approach for integration of new data sources such as substation monitors. At that time the capability of the modelling tools and information 'standards' such as Common Interface Model (CIM) had not fully evolved. This project identified many of these issues at an early stage and proposed potential solutions. This allowed the project to proceed on a limited basis but more importantly ensured that the large scale deployment in NTVV was as well informed as possible. This allowed the modelling work packages in NTVV to proceed in a cost effective and efficient manner.

The project has brought the issue of low carbon devices on the low voltage network to the attention of multiple parts of the distribution business. This has led to the intention to integrate distributed generation within our existing GIS system – this will make it much simpler to understand the number of devices connected to our network in the future.

Un-metered load exists on the low voltage network. Street furniture is the most obvious, but there are also sewerage pumps, and other local authority/public service usages that have become evident during the Tier 1 project. Whilst SSEN's current GIS records identify locations of these un-metered supplies, there is limited visibility of the actual consumption profiles.

Our current approach to cable rating is possibly too simplistic. It was recognised during the showcase that the cable ratings stated in TGPS-123 or Engineering Recommendation P17, are quoted in Amps per phase, and that this may not be sufficient since neutral current caused by phase imbalance may put the cable outside its thermal rating without exceeding the rating of the phases. A more sophisticated modelling tool will help with this analysis.

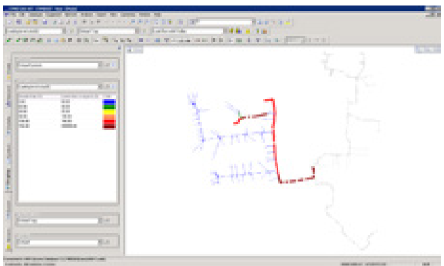
Integration of data from SSEN's existing GIS with Smallworld Electric Office was completed successfully, mapping all necessary data objects and matching with a geographical referencing system 'Address Layer 2'. The completion of this activity allowed users to select a network area of interest and migrate the relevant data into Smallworld Electric Office autonomously.

In carrying out the evaluation it became apparent that low voltage load flow analysis appears to be an emerging requirement to the vendors of power analysis tools, so caution is required when evaluating the capabilities of the products. In some cases the analysis appears to be inherited from that used for higher voltages, which may not be exactly what is required at low voltage where the construction of the network may be different (e.g. the presence of a neutral cable).

All of the above helped contribute to the requirements definition for the modelling environment implemented and validated in the NTVV project.

Previous GIS system

Smallworld Electric Office



CYMDIST

SSET1007 Orkney Energy Storage Park (Phase 1)

Tier 1 Funding: £176,500

SSET1009 Trial of Orkney Energy Storage Park (Phase 2)

Tier 1 Funding: £643.794
2011–2015

Introduction

The challenge that led to these projects was that the 33kV network on Orkney had reached its generation connection limit based on traditional network planning methods.

Previously, a Registered Power Zone (RPZ) had been established on Orkney in 2009, using Active Network Management (ANM) to facilitate the connection of new renewable generation on to a constrained, or technically 'full', 33kV network. ANM was used to monitor the network constraint points and to control those generators connected through ANM to keep the network within operational limits. This allowed more generators to connect but meant that their export capability was subject to constraint actions by the ANM.

The Orkney Energy Storage Park projects aimed to use the ANM functionality to instruct a third party to provide a service by importing excess renewable energy to reduce constraints on ANM connected generators.

The Orkney Energy Storage Park Project Phase 1 involved the creation of a new commercial incentive to encourage an Energy Storage Provider (ESP) to locate an Energy Storage System (ESS) where it would provide real benefits to a Distribution Network Operator (DNO).

The project aimed to create a commercial and physical incentive that encouraged third party ESPs to locate on a constrained network. The incentives were then tested by running a commercial tender process to identify if suitable ESPs were enticed to apply for the contract.

Following the early success of Phase 1, the second stage of the project progressed to allow SSEN to fund the implementation of the commercial arrangements developed in Phase 1. The ESS was provided with signals by the existing ANM scheme instructing absorption of excess renewable energy that would otherwise be stopped from generating onto the network.

The contract allows the ESS to run their system commercially with the emphasis placed on them to increase their operating income by targeting other revenue streams, i.e. STOR and arbitrage, at times when their services are not required by the DNO.

The Orkney project demonstrates an example of where we have employed disruptive technology for our business in the form of energy storage to provide benefits to customers and generators in the form of increased renewable generation.

Aspects of the Carbon Plan that have been facilitated

These projects demonstrated the technical and commercial case for energy storage, supporting the integration of more local and low carbon generation – a key aim of the Carbon Plan. The projects enhanced the understanding of the energy markets open to distribution network connected ESSs through the deployment of a physical ESS. This assisted in the facilitation of securing low carbon electricity by addressing intermittency issues associated with renewables by establishing a new market which will have wider UK business benefits.

This same market could also be exploited by existing I&C customers with flexible demand or on site standby generation that could bid to provide network services allowing better local and national balancing. This learning has been fundamental to the development of the CMZ.

Figure 11 Spurness windfarm Orkney

Releasing network capacity

The Orkney Energy Storage Park developed, trialled and validated a commercial mechanism for the deployment of energy storage devices to provide a service to DNOs. This directly enabled the further development of the Constraint Managed Zone (CMZ) project – a business as usual tool which SSEN has deployed to contract with third parties as a new way to meet network security of supply standards.

Modelling by EA Technology Ltd has shown that CMZ can be expected to simultaneously release **1,000MW** in GB to 2050.

The actual capacity released fluctuates due to the relatively short contract period, which means some contracts are renewed while others are replaced by other innovations or reinforcement over time. See Section A2 for further details.

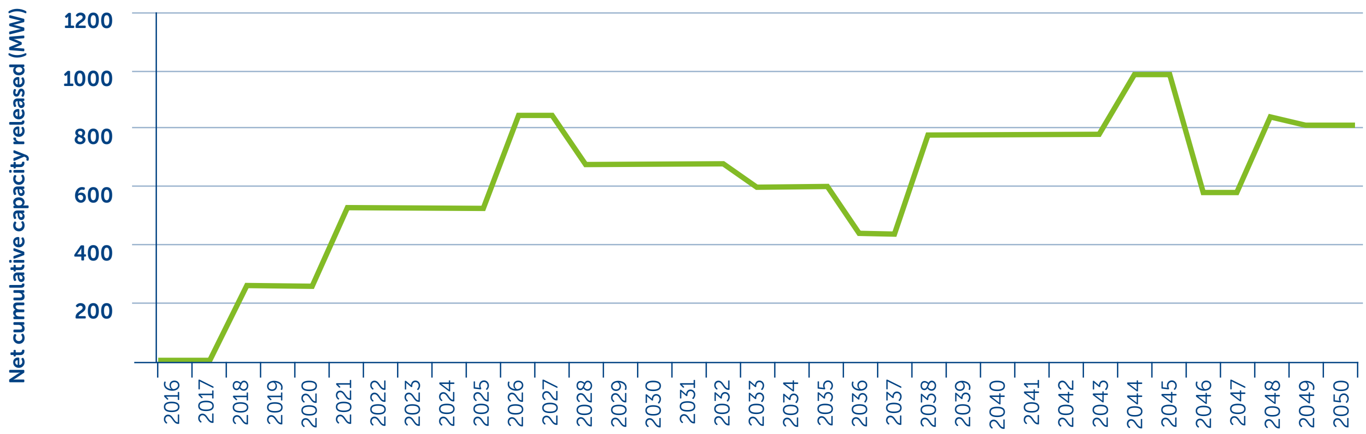


Figure 12 Cumulative capacity released through CMZ deployment across Great Britain

Delivering financial benefits

The Orkney Energy Storage Park projects informed the future business case for EES by investigating multiple scenarios of reducing battery capital cost, increasing curtailment volumes, changing ancillary markets and alternative battery capacities. These scenarios show improving economics for small to medium sized EES assets installed on the GB network in the medium to long term (5 to 10 years).

In developing a commercial mechanism for third parties to provide network services to DNOs, the Orkney Energy Storage Park projects directly enabled the development of Constraint Managed Zone. Modelling by EA Technology Ltd has shown that CMZ deployment will result in benefits of **£52.7m** in GB to 2050.

Roll out across the DNOs' systems and across GB

The main uses to date of the principles and the knowledge gained during this project has been to inform the creation of Constraint Managed Zones (CMZ) in the SSEN area. EA Technology analysis has shown there will be potentially 4.300 CMZ type deployments across GB by 2050.

In addition UKPN were aided in their development of the Tier 2 Smarter Network Storage Project through commercial knowledge shared by SSEN as part of ESOF.

A number of dissemination activities took place to raise awareness of the project outcomes, including presenting at major conferences and a dissemination event on Orkney that included a tour of the facilities.

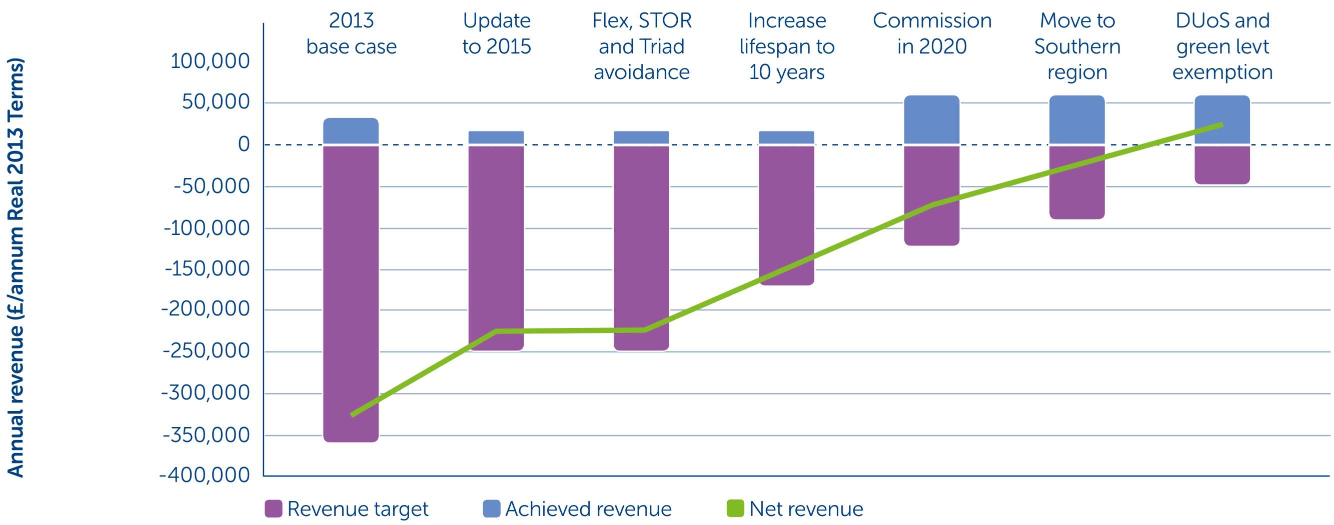


Figure 13 The business case for batteries as developed by the Orkney Energy Storage Park projects

One of the key project learning outcomes from the Orkney projects was their contribution to the setting up of the Energy Storage Operators' Forum (ESOF) and the development of the ESOF Good Practice Guide on Electrical Energy Storage.

ESOF was created as a direct result of project like the Orkney Energy Storage Park that produced large amounts of learning on storage projects.

The business models use case and contracts developed through the Orkney projects were shared with members of ESOF and other working groups such as the Distributed Generation and Storage working group.

SSET1008 Low Voltage (LV) Network Connected Energy Storage

Tier 1 Funding: £284,500
2012–2014

Introduction

Three Community Energy Storage (CES) units were installed and tested on the Low Voltage (LV) network in Chalvey, Berkshire.

The units were installed to investigate their ability to mitigate the effect of traditional load increases or from the adoption of Low Carbon Technologies (LCTs), such as solar photovoltaic (PV) generation and Electric Vehicles (EV). The batteries were installed on the same feeder as the SSE 'Zero Carbon Homes' which includes 65kW of solar PV generation.

The project work has successfully taken the system from TRL 5 up to TRL 7. It has aided the larger roll out of 25 units as part of the NTVV project.

Aspects of the Carbon Plan that have been facilitated

Increasing uptake of low carbon technologies such as solar PV and electric vehicles (identified in the Low Carbon Transition Plan) is likely to cause power quality issues and problems with voltage and thermal constraint, with the issues most likely to appear first on the LV network. The present solution, of network reinforcement, has high capital outlay, causes significant disruption to customers, requires full excavation and has long lead times.

In order to understand the operation of an energy storage system with relevant low carbon technologies such as solar PV and EVs, SSEN trialled this technology at a site with established solar generation and electric vehicle charging points.

The energy storage units with associated power conversion systems have been proven to aid power quality, to manage reactive power flows and to reduce the peak demand/peak generation real power flows, through peak lopping. This can delay or reduce the need for traditional network reinforcement, thereby preventing the local DNO network from becoming a barrier to the deployment of low carbon technologies.

This is the direct enablement of flexible demand management and wholly supports the integration of more renewable generation. It also supports the "step change" identified in the Carbon Plan which is needed to "move away from oil-based fuels and towards ultra-low carbon alternatives", by ensuring the distribution network does not unnecessarily limit the uptake of electric vehicles.

Releasing network capacity

Community Energy Storage units along with their associated power conversion systems can achieve similar benefits as a cable or plant upgrade:

- Through reducing the peak demand/generation to keep the cable within thermal limits
- Employing a combination of real/ reactive power to buck or boost voltage
- Managing network issues such as phase imbalance and power quality

Fully automated peak shaving cycles have been completed successfully with a maximum reduction of up to 100 amps over a 24 hour period.

The phase balancing testing demonstrated that it is functionally possible to use energy storage devices to balance power flows between phases on the LV network. The trials confirmed that the theoretical benefits from balancing LV networks can be achieved in practice, and has highlighted the practical limitations.

The SSET1008 project has directly informed our LV Strategy through increased understanding of the operation of community-scale storage to manage local demand. Modelling by EA Technology Ltd has shown that the LV Strategy will enable the release of **1,150MW** by 2050.

Delivering financial benefits

The cost for the battery system in this trial was of the order of 2.5 times more expensive than the traditional cable overlay alternative. In addition the traditional solution will potentially last three times longer than this energy storage solution. However, the costs of lithium ion batteries are falling sharply and there is also the potential to earn additional revenue from energy storage systems outside of the core network requirements that has not been accounted for.

There are a number of additional benefits that are difficult to put a monetary figure on:

- Reduced customer inconvenience as street excavation works can be avoided;
- Customers do not need to go off supply to be reconnected;
- Limited traffic management requirements, without need for a permit to complete works from local council; and
- Solution can be re-redeployed in a new location easily if the network problem is no longer present.
- Importantly, the use of the CES solution can allow a DNO to defer a reinforcement, and allows time to gather better information on any predicted load increase – thus retaining options for the DNO.

Additionally, the learning from this project has directly enabled our LV Strategy through increased understanding of the operation of community-scale storage to manage local demand. Modelling by EA Technology Ltd has shown that the LV Strategy will deliver benefits of **£189.9m** in GB to 2050.

Roll out across the DNOs' systems and across GB

The work has de-risked and supported the larger roll out of 25 similar units under the Tier 2 New Thames Valley Vision project, by validating the technical specification for the units, and defining and testing the communications and data transfer requirements for the array.

The contribution of this project to informing our LV Strategy will lead to 182,000 instances of delivering benefit across GB to 2050.

Project learning contribution

The main benefits and knowledge delivered by the project relate to the implementation of lithium ion CES connected to the LV network, however much of the learning on the operation of the units is relevant to all battery projects.

This project has proven that batteries and power conversion units can operate as intended on an LV network to deliver benefits. It has informed the safety case and the operational procedures including installation, maintenance and operational work on a network which has storage connected to it.

The system has been successfully connected to the distribution network and proven to comply with the requirements of Engineering Recommendation G59/2:

- An Operational Risk Assessment has been prepared which shows that the residual risk from the system has been reduced to an acceptable level
- Efficiency of the units has been tested in detail, with figures of around 80-85%, in line with expectations at the start of the project
- Fully automated peak shaving cycles have been completed successfully with a maximum reduction of up to 100 amps over a 24 hour period
- Manipulation of network voltage has been achieved up to +/- 7V utilising both real and reactive power
- A detailed estimate of the lifetime costs of implementing the units on business as usual basis has been completed over a 15 year period

An opportunity to deliver additional learning was identified as the substation that supplies the CES units has advanced monitoring equipment, supplied by Current Group, from a previous SSEN Tier 1 project SSET1002 (Demonstrating the benefits of monitoring Low Voltage network with embedded PV panels and EV charging point).

In order to utilise the real time data from this monitoring equipment it was decided that it would be integrated with the control unit. This required some significant modifications and a number of meetings between S&C and Current Group IT staff. The end result was that the control unit can now record real power and reactive power values for all three phases in real time. This allows these real time values to be used as set points in demand limiting algorithm. Without this feature it would not be possible to automatically run the peak lopping

Figure 14 Finished site – 3 CES units and auxiliary transformers

SSET1010 Impact of Electrolysers on the Distribution Network

Tier 1 Funding £753,000
2013–2015

Introduction

The UK Government-led H2 Mobility[15] study identifies that there could be **1.6 million** hydrogen fuel cell electric vehicles (FCEV) on the road by 2030 and that 51% of the hydrogen demand of these vehicles could be met by electrolysers. This could add an estimated 9,000GWh to UK annual consumption, and 1GW to peak demand.

This project investigated the capability of electrolysers to act as a flexible demand on the distribution network in response to a number of potential network scenarios. The set points issued related to a range of variables including pricing signals, local demand constraints, and renewable generation availability. The trials controlled the operation of a new hydrogen refuelling station (HRS) established as part of the wider Aberdeen Hydrogen Project. The £20m Aberdeen Hydrogen has been funded by a mix of EU, UK and Scottish Government funds combined with direct investment by industrial partners to see the successful operation of ten fuel cell electric vehicles (FCEV) buses in the city.

Project partners include Stagecoach, First Group and BOC Linde. The HRS includes three electrolysers, compressors and a hydrogen storage facility and has a peak electrical demand of 1MW.

The potential for hydrogen to be produced from renewable energy sources offers an opportunity to decarbonise both commercial and domestic transport. In addition, the inherent flexibility of the HRS offers the potential to use it as a responsive demand, which can be used to address a number of potential network issues including those associated with intermittent renewables. This flexibility should also allow electrolysers to be connected in high demand networks (such as city centres) without the need for system reinforcement. This will not only reduce the cost of future HRS construction but will provide benefits to customers by avoiding future network reinforcement costs.

Figure 15 Kittybrewster Hydrogen Refuelling Station, Aberdeen

15 UK H2 Mobility Project: http://www.ukh2mobility.co.uk/the-project/

Aspects of the Carbon Plan that have been facilitated

The Carbon Plan recognises that a "step change is needed over the coming decades to move away from oil-based fuels and towards ultra-low carbon alternatives". In 2009 road transport accounted for 20% of UK greenhouse gas emissions[16]. The Plan also notes that the European Renewable Energy Directive (RED) requires the UK to source 10% of transport energy from renewable sources by 2020.

The SSET1010 project has facilitated this aspect of the Carbon Plan in two ways:

i. Understanding the potential impact of a roll out of FCEV on the distribution network

ii. Demonstrating the potential to maximise the contribution of renewables to the generation of electricity for hydrogen production

The project demonstrated electrolyser operation as a flexible demand, and their capability to follow both local demand and the output from a wind or solar farm. This showed that electrolysers have the capability to generate hydrogen without negatively impacting on the distribution network, and could be used to help alleviate network constraints. The project estimated that actively managing electrolysers could avoid adding 1GW to peak demand by 2030 (based on H2 Mobility estimated FCEV uptake[17]).

The analysis undertaken in this project may facilitate the development of hydrogen refuelling stations which are capable of helping to reduce renewable curtailment, while simultaneously decarbonising both domestic and commercial vehicles, which will impact on local air quality as FCEV emit only oxygen and water as exhaust.

Releasing network capacity

Analysis undertaken during this project has shown that HRS deployment could add more than 9,000GWh to UK annual consumption, and more than 1GW to peak demand. Electrolysers connecting to the distribution network could trigger reinforcement in a number of areas, unless they can be operated flexibly to avoid exceeding network limits.

Trials undertaken with the Kittybrewster HRS have shown that the electrolyser can be operated as a controllable demand to maintain network levels below a simulated demand constraint. This was achieved while still delivering sufficient hydrogen to fuel vehicles by increasing production during low-demand times such as overnight. As such the outputs of this project can allow design of HRS to avoid network reinforcement and make better use of existing capacity during off-peak times.

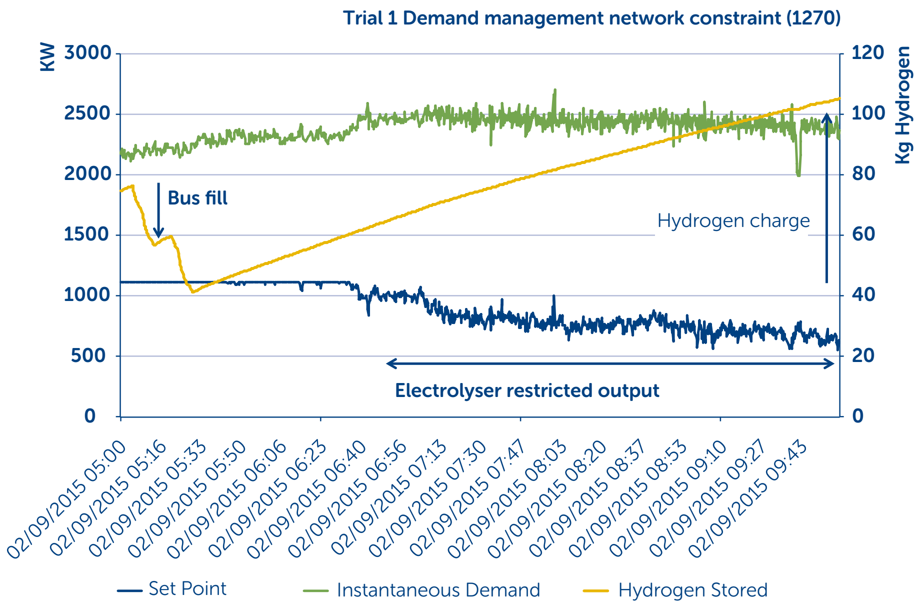


Figure 16 Trial results showing an instance of electrolyser constrained output to avoid breaching local demand constraint

16 The 2009 final UK greenhouse gas emissions figures, available at: www.decc.gov.uk/en/content/cms/statistics/climate_change/gg_emissions/uk_emissions/2009_final/2009_final.aspx. UK domestic emissions only.
17 UK H2 Mobility Project: http://www.ukh2mobility.co.uk/the-project/refuelling-infrastructure/

As outlined in the section above, the project has also shown the electrolyser can increase production when renewable output is high to avoid curtailment of renewables.

Figure 17 shows the results from Trial 4 – Maximise net wind. During this trial, power from the wind farm is used to fulfil the local demand, and any excess power from the wind farm (the 'spill') is used to operate the electrolyser. This graph shows operation during the night (23:00 to 02:00) when local demand is low. It is clear from the figure that the electrolyser is acting as responsive load as it is changing it's electrical demand to follow the output from the wind farm.

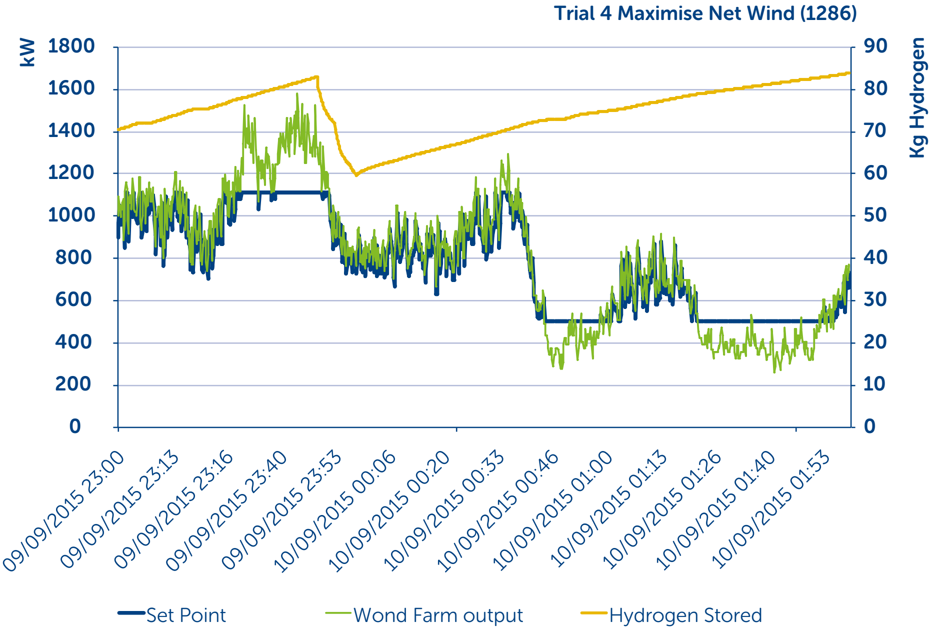


Figure 17 Trial results showing electrolyser using 'spill' wind generation

Delivering financial benefits

Where HRS are designed to operate as flexible demand as demonstrated by this project, financial benefits can accrue to several parties.

The DNO will avoid reinforcement costs associated with connecting new electrolysers. Where electrolysers have connected in a network which becomes constrained at a later date, the electrolysers will be able to offer demand reduction services which may allow reinforcement to be avoided or deferred.

These types of installation are likely to be one of a range of future flexibility options available to DNOs in the future, the benefits from these have been estimated using the Transform Model®, and the financial benefits have been outlined in Section A3.

The HRS developer will also benefit from faster connection to the network (where reinforcement would otherwise have been required), access to payments for ancillary services such as demand reduction (where the electrolyser connection preceded the network constraint) and reduced electricity charges by avoiding operation during peak periods. All of which should help ensure that the network doesn't become a barrier to the large scale adoption of FCEVs.

Roll out across the DNOs' systems and across GB

The H2 Mobility Project report states that 1,150 HRS will be required in the UK by 2030 and that 51% of the hydrogen will be derived from electrolysis. The stations will be in areas of high car densities throughout the UK, which coincides with urban distribution networks.

The outputs from the trials demonstrate how the impact of electrolysers on the distribution network can be managed and minimised.

The learnings provide confidence to DNOs that electrolysers can be considered responsive load and could be offered non-firm connections where appropriate.

The trial also successfully demonstrated active network management which linked a controllable demand with local demand and renewable generation. Both of these 'tools' could become essential elements of a future DSO model.

Project learning contribution

The knowledge generated in the project will help DNOs to prepare and understand the potential impact of the wide-spread adoption of hydrogen vehicles including the potential impact of a roll out of HRS and the alternative operational modes. This could avoid adding to local peak demand, reducing generation constraints, and also help avoid reinforcement. It could allow more renewable generation on to the grid and improve the amount of 'green' hydrogen which could be produced. More generally, this has helped SSEN's body of knowledge on demand side services and the ability to interact with them via ANM; this has helped us to develop the CMZ concept toward BAU.

During the project further commercial modelling was undertaken by the University of Strathclyde to determine the impact of flexible operation on both the capex and 10-year cost of a HRS. An additional level of modelling was added to this analysis to examine the impact of electricity price on the configuration of the HRS, and the indicative 10-year cost. This showed that even if the operation of the electrolyser was constrained to follow an erratic renewable output, the resulting cost of the HRS was significantly lower than for a standard DUoS model.

This has shown that electrolysers co-located with renewable sites with a low electricity price could produce hydrogen at a lower cost than those which operate in a base-load or simple off-peak model.

Figure 18 Hydrogen fuelled bus in operation in Aberdeen

SSET1011 Digital Substation Platform – Phase 1

Tier 1 Funding: £241,600
2015–2015

Introduction

The Digital Substation project looks at the feasibility of running an Active Network Management (ANM) control system on a digital substation protection system.

The project was not to produce a fully functional system, but rather to confirm the possibility of the two systems working as an integrated system, and assess the potential business benefits. The aim of the project was to prove that software developed for a standalone platform can be re-coded for another platform, and maintain its integrity and functionality, without causing any adverse effects on the new host platform.

Aspects of the Carbon Plan that have been facilitated

The Digital Substation project is a key enabler for ANM in some areas, which allows for the connection of more renewable distributed generation without reinforcement. The project demonstrated that small scale ANM could be run on the same platform as the substation protection system.

Whilst ANM schemes offer the potential to reduce the cost of connection for generators they can often still entail significant capital cost. Therefore, even with an ANM solution the cost of connection may make some renewable developments unviable. By attempting to combine some of the infrastructure required for ANM with that used for protection and control this should reduce the overall cost of connection.

In particular, savings in terms of the purchase of additional equipment and hardware for running the ANM, in turn reduce the cooling requirements of the hardware and the environmental footprint of the substation. There would also be savings in the physical space required in the substation, which reduces the impact on the local built environment.

This will help reduce the cost of connection which should allow further renewable development to proceed.

Releasing network capacity

As a key enabler for ANM in some areas, the Digital Substation project can help with managing local loads so that additional distributed generation can be allowed onto the network.

By allowing an ANM control system to run on the same platform as the substation protection systems, ANM can be placed in areas that previously would not have been suitable due to constraints on the physical size of the substation.

Using the Transform Model® EATL identified that ANM solutions of the type developed by SSEN have the potential to be widely rolled out freeing significant capacity on the network; see section A2 for further details.

Delivering financial benefits

This project delivers savings in a number of areas including the reduction in ANM hardware costs and reducing the need for additional ancillaries within the substation. The project also proved the capability of platforms to run software from multiple suppliers without negative interaction, and without objection from the suppliers. It thus established a basis for open procurement of these systems without being 'tied in' to one supplier. The financial benefits of an open, competitive procurement process are difficult to quantify but will ensure the best possible value for customers.

In addition, it was found that savings could be made on cyber security through the application of one firewall, as opposed to two.

These types of measures should help continue to see the development of further ANM based solutions. Most DNOs now offer flexible connections for generation, and EATL have modelled the benefits using the Transform Model® – full details can be found in Section A3.

Roll out across the DNOs' systems and across GB

This project showed that the idea of using a common digital platform for several differing applications within a substation context would work. As such it would work in any substation across the UK, and allows the substation equipment to be used more efficiently by adding a dual purpose, where this is beneficial to the network. This adds to the options available to a DNO when considering implementation of ANM or reinforcement of the network.

The project also identified the potential for future application of condition monitoring to realise benefits, for example Real Time Thermal Ratings fed into an ANM system could release headroom available to a generator.

As identified above the EATL analysis showed that ANM could be deployed over 1000 times by 2050. Further details are provided in Section A4.

Project learning contribution

The project showed that it was possible to use ANM control software on a proprietary platform, which can prioritise protection mechanisms over the generation control algorithms. The key learning from the project can be demonstrated in the following areas:

- Reduction of hardware requirements – It was found that a reduction in hardware costs can be achieved by running both ANM and Protection software on the same system.
- Improved performance of data – The integration of the two platforms has identified a resulting benefit of reduction in curtailment through sharing data.
- Event capture – The system has the capability to capture an ANM event at a higher granularity than is possible with ANM functionality in isolation.
- Cyber security – It was found that savings could be made on cyber security through the application of one firewall, as opposed to two. Also operating a dual operating system also makes the system more secure.
- Potential integration of condition monitoring – Additional learning from the project was achieved in the form of the potential for condition monitoring to realise benefits, for example Real Time Thermal Ratings fed into an ANM system could release headroom and reduce curtailment.

The project also demonstrated that:

- The Locamation platform used in the trial could provide protection of High Voltage network assets;
- It is possible to manage the voltage on a network through automated control of the generator output;
- Both network protection and voltage control can be integrated onto the same platform.

The project was just a first stage, and further development of the ANM software would be required in order to provide the full confidence needed in order to bring the integrated system into BAU.

Reward Criterion A

SSEN set out to be leaders in a number of key innovations, not only in trialling but also in deploying. We believe we have been successful in this and have had a significant impact on developments in the UK and our Tier 1 portfolio has been a pivotal enabler to this progress.

SSEN has led the industry in implementing many key innovation areas, with pioneering deployments of Active Network Management (ANM) and Constraint Managed Zones (CMZ). The learning, knowledge and confidence gained from across our innovation portfolio has allowed these developments to proceed, including a significant contribution from our Tier 1 projects.

Our Innovation Models on page 9 show the flow of learning from our Tier 1 projects to our innovations.

The outstanding learning gained from our early Tier 1 projects in Shetland and the Thames Valley derisked and accelerated the flagship NINES and NTVV projects – both of which are on course to deliver significant benefits to customers. In a similar fashion our other projects have helped to address not only current network problems, but will also make us better prepared for future challenges including transition to DSO.

SSEN's leading work in the areas of storage, and engagement with third party providers of demand and generation services will be crucial to the development of any DSO model over the next decade and will act as a sound base for the developing a business model that is likely to be adopted by distribution companies.

How we have quantified benefits

Our experience has shown that innovation deployment usually pulls on learning from a pool of projects, only the simplest of innovation can be enabled by one single project. Given the cohesive nature of our Tier 1 portfolio, we see limited value in artificially attributing benefits of each project as in reality the value is greater than the sum of the parts. Instead we have considered the benefits of the whole portfolio in terms of the five key innovation areas described previously. Each of our Tier 1 projects has contributed to one or more of these innovation areas.

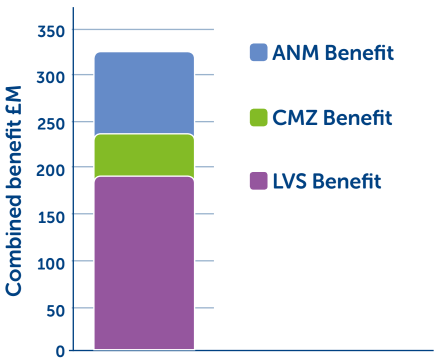


Figure 19 Network benefits of portfolio in GB to 2050 future network

We engaged EA Technology Ltd (EATL) to help us to quantify the benefits from these five innovation areas using the Transform Model®. Transform was originally developed, and has been maintained, to represent the whole of GB's distribution network (from 33kV to LV). Its output has been used by Ofgem and the DNOs to inform the benefit case for Smart Deployments. EATL tailored this model to represent the two licence areas using network data provided by SSEN.

Network scenarios

The Transform Model® contains the latest "best" view from central government (including BEIS and OLEV) regarding the projected uptake of distributed generation (DG), electric vehicles (EVs) and heat pumps (HPs). For each of these technologies, government has provided three potential uptake scenarios (which for simplicity will be referred to here as 'high', 'central' and 'low').

Considering the current and expected level of uptake on our network we have modelled a central case as shown in Table 3, and included sensitivity analysis against a high and low case. The volumes are suitably scaled down to each of SSEN's licence areas, using the scaling factors that were agreed with Ofgem for the RIIO-ED1 business planning process.

	DG	EV	HP
Low	Low	Low	Low
Central	Central	Central	Low
High	High	High	Central

Table 3 Scenarios used to model future network

Considering other solutions

The Transform Model® will choose the best solution for each network issue from all available solutions; this includes traditional and innovative (for example the FUN-LV Meshing technique first trialled by UKPN, or Real Time Thermal Rating of Assets first trialled by NPG as part of the CLNR Project). In order to establish the benefit associated with the SSEN innovation portfolio, we compared the default baseline results for investment (where the

SSEN Tier 1 innovations are not available, but other innovations are), to the revised outputs where the SSEN innovations can be selected in place of alternative solutions. As the model includes all BAU innovations it intrinsically avoids double-counting of benefits, as each network issue is solved only once, and by the most efficient method available for that specific case – be it traditional, BAU, or from any other DNO innovations. The Transform Model® was successfully used to calculate the benefits from recently completed innovation projects including My Electric Avenue and CLNR.

We recognise that these innovations are complementary, rather than competing, and have all added to the body of evidence which will help the GB network face the challenges of the future network. The Transform Model® looks at the long term cost of managing the network and over time may choose to use different innovations on the same network.

This approach has allowed us to consider the use of other alternative innovations and where appropriate these have been deployed rather than the SSEN approach.

A1 Aspects of the Carbon Plan that have been facilitated

The Carbon Plan identifies three critical areas of change to enable the transition to a low carbon economy:

1. In the way we **generate our electricity**, where we must see a dramatic shift away from fossil fuels and towards low carbon alternatives
2. In the way we **heat our homes and businesses**, where a step change is needed in how well our homes are insulated and in the use of low carbon energy
3. In the **way we travel**. This means better public transport, reducing emissions from petrol and diesel engines and moving towards alternative technologies such as electric vehicles

The outputs from the SSEN portfolio has directly addressed each of the above elements of the Carbon Plan including understanding a "connect and manage" regime, and "paving the way towards a 'smarter' electricity grid in the UK, which will increase the efficiency and reliability of the network, enable flexible demand management and support integration of more local and wind-powered generation."

Changing the way we generate our electricity

Enabling a move towards low carbon generation requires a more flexible network. By using new smarter approaches such as ANM we have been able to create additional headroom for the connection of renewables by freeing up the "latent unused" capacity which exists within the network. The learning from many of our Tier 1 projects has allowed us to move ANM from innovation to BAU; SSEN now offer a range of flexible connection options to customers[18].

We have further leveraged this by developing the knowledge to shift demand to times of high renewable availability, which improves the commercial case for renewable developments and increases the proportion of energy that is supplied by renewables.

Crucially, this also helps to reduce peak demand which is most likely to be supplied via the most carbon-intensive peaking plant.

The SSEN portfolio has facilitated a move towards this 'smarter' electricity grid in GB by enabling flexible demand management **(SSET003,4,10)** and demonstrating the technical and commercial case for energy storage **(SSET001,7,9)** to support integration of more local and low carbon generation.

Key to changing the way we generate our electricity will be the widespread adoption of LCTs; learning from across our portfolio has helped us to improve our knowledge and understanding of the impact of LCTs on the network.

a) Understanding the uptake and characteristics of LCTs

Our projects **SSET1002,5** developed tools to enable collection and detailed analysis of LV network data including load flow analysis calculations. This allows the impact of PV and EV charging to be better understood, which is crucial to being able to make informed choices about the need for, and urgency of reinforcement, or alternative smart solutions. This has allowed DNOs to become a facilitator of LCT uptake, enabling smoother progression towards the goals of the Carbon Plan.

b) Understanding the commercial environment to enable LCT uptake

Projects SSET1007 & 9 enhanced the understanding of the energy markets open to distribution network connected Energy Storage Systems (ESSs) through the deployment of a physical ESS. This commercial learning has been fundamental to the development of the CMZ innovation.

18 https://www.ssepd.co.uk/AlternativeGenerationConnections/

c) Demonstrating the use of flexible demand and energy storage

The **SSET1001,3,4** projects demonstrated flexible demand and energy storage through control of a grid-scale battery integrated with ANM, domestic heat and water tanks, and I&C building management systems. This enabled a shift in demand to times of peak renewable generation, or away from times of peak demand.

Another storage model was trialled in **SSET1008** for networks with higher levels of PV and EV adoption. The uptake of these LCTs (identified in the Carbon Plan) may cause power quality issues on LV feeder circuits. SSEN trialled energy storage units with associated control systems to improve power quality. This can defer the need for traditional network reinforcement, thereby preventing the local DNO network from becoming a barrier to the deployment of LCTs.

These projects directly enable flexible demand management and wholly support the integration of more renewable generation.

Changing the way we heat our homes

The **SSET1003** project trialled domestic DSM in six homes. This innovation releases network capacity by shifting demand away from peak periods or to periods of high renewable generation, enabling a reduction in the carbon intensity of this heat. The project deployed a new generation of storage heaters which offer greater control and efficiency, helping customers save energy and reduce energy costs, providing benefits for customers and for the network. This is particularly important as an insights paper[1] published by Ofgem identified that a third of households with electric heating have low incomes and may suffer from fuel poverty. The DSM solution trialled by **SSET1003** enables these customers to contribute to the Carbon Plan whilst also reducing their energy consumption.

This project also enabled the development of a further 1.5MW of flexible demand and successful trialling of Frequency Responsive Domestic DSM.

Changing the way we travel

The SSEN Tier 1 portfolio has facilitated this aspect of The Carbon Plan in three areas:

i. **SSET1010** Understanding the potential impact of a roll-out of hydrogen vehicles on the distribution network.
ii. **SSET1002,5** Improving visibility of potential stresses to the network caused by increased demand due to EV uptake.
iii. **SSET1002,8,10** Demonstrating the potential to maximise the contribution of renewables to the generation of electricity for either hydrogen production or EV recharging.

The SSET1010 project installed a network management system to manage hydrogen production from an electrolyser. The project demonstrated electrolyser operation as a flexible load, and their capability to follow both local demand and the output from a wind or solar farm. The hydrogen produced fuelled a fleet of ten fuel cell buses in Aberdeen. The project estimated that actively managing electrolysers could avoid adding 1GW to peak demand by 2030.

The network monitoring, modelling, and demonstration of control of storage devices already outlined in this document all enable an increased use of renewable generation to generate hydrogen or recharge EVs, both of which can contribute to the future decarbonisation of transport.

A2 Releasing network capacity

As described previously, SSEN has established five innovation areas to model, which have resulted directly from our Tier 1 projects.

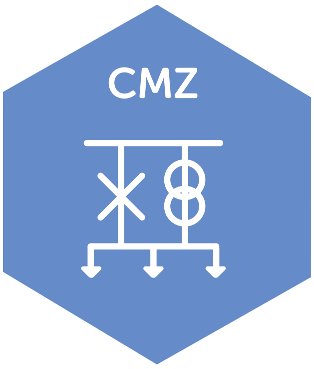
This approach recognises the complementary nature of our innovations and avoids any risk of double-counting benefits from projects. From the EATL analysis, we have identified that at least 3GW of network capacity due to the SSEN portfolio could be released from the Innovation areas we have identified; these are described overleaf:

Constraint Managed Zones

Commercial arrangements with energy Storage Providers
SSET1007 Orkney Energy Storage Park phase 1
SSET1009 Orkney Energy Storage Park phase 2

Operational characteristics and reliability of energy storage
SSET1001 1MW Shetland Battery

Contracts and operation of demand side response
SSET1003 Trial Evaluation of DDSM
SSET1004 Demonstrating the Functionality of ADR



1,000MW
capacity released in GB to 2050

The use of the CMZ approach to defer the need to install additional assets and instead manage demand locally releases additional capacity. By engaging with third party providers of services in generation, storage and DSM, it is be possible to connect additional demand without upgrading the existing infrastructure. The learning from the Tier 1 projects identified above allowed us to develop and progress the CMZ concept. It is possible to estimate the capacity released by each installed scheme by limiting the engagement of third parties to provide no more than 10% of the rating of the asset that is at risk of being overloaded.

The calculation found that there could be up to 269 deployments of CMZ on the SSEN networks over the period to 2050, and 4,300 across GB. By examining the nature of the assets involved in the SSEN network area it was identified that a capacity of approximately 74MW is **simultaneously** released in SSEN to 2050.

In GB the largest simultaneous release is **1,000MW in GB** as shown in Figure 12 in our description of SSET1007 Orkney Energy Storage Park.

It is important to recognise that this figure is based only on the bottom-up analysis and there may well be additional benefits at higher voltages that can be realised through application of the CMZ approach dependent on the specific network details.

Additionally, this figure does not include benefits which could be realised on the Transmission network. The exact nature and value of these will be heavily influenced by the final arrangements for DSO-TSO service sharing. The reason that the capacity released fluctuates in Figure 12 is that each CMZ contract is anticipated to last for up to five years. At the end of the five years, a decision is taken as to whether the CMZ should remain in place or whether some other form of intervention is required. In the event that a different intervention is recommended (such as a conventional reinforcement scheme, then the capacity released by that CMZ is subtracted from the total CMZ capacity being provided in that year. Hence in Figure 12 there are some instances when the CMZ capacity contribution falls.

Over time CMZ schemes contribute a large amount of capacity, we have quoted 1GW as being the largest amount that is simultaneously available.

LV Strategy

Develop low cost monitoring tools
SSET1005 LV Network Modelling and Analysis

Understand flexibility of demand and commercial contracts
SSET1004 Demonstrating the Functionality of ADR
SSET1003 Trial Evaluation of DDSM

Understand Operation of storage to manage local demand
SSET1001 1MW Shetland Battery
SSET1008 LV Connected Energy Storage

1,150MW
capacity released in GB to 2050

Historically, the network operated on a 'fit and forget' model, where assets could be installed with a high degree of certainty around an established demand profile. As the use of DG and EVs increases, it will become more challenging for the DNO to manage local demand and to plan for future investment. In addition the introduction of smart meters and dynamic tariffs will disrupt traditional energy use patterns. There is a risk of over-investment if DNOs attempt to cater for the theoretical peak demand in all networks where demand is forecast to grow. Previous work by EATL for the ENA and Smart Grid Forum has shown across GB that some 72% of the reinforcement due to the uptake of LCTs would be required on the secondary network (LV up to 11kV).

This comes about as the connection of such technologies occurs at the customer-side and hence the lower voltages are where the effects are first felt as they 'trickle-up' the network. This is the primary reason that innovation at lower voltages are likely to produce significant benefits. Several projects in our portfolio have reduced uncertainty by improving our understanding of the impact of LCTs, the potential for storage to smooth demand profiles, and methods to monitor demand in a cost efficient manner.

This strategy is concerned with having a greater understanding of the LV network, and being able to make better informed investment decisions. Within the Transform Model®, all of the various asset types have an 'intervention threshold'. This is the point at which a network operator decides that a network investment of some sort must be made. As shown above and in the Innovation Models, the outputs from our Tier 1 portfolio have helped us to develop the capability to better monitor and model the LV network, as well as identifying new smart interventions.

At low voltage, this intervention threshold is ordinarily set to 100%, meaning that the load can grow on these assets until they reach their rating before reinforcement is considered. By having better monitoring to understand in more detail the load profile, a DNO can improve its decision-making ability. Within the Transform environment, this is modelled as an increase to the 'intervention threshold' from 100% to 105% to reflect this greater visibility and utilisation.

We have only applied this to the network types studied in the Tier 1 trials. It is, of course, perfectly possible that the technique could be rolled out to a wider sample of assets. Equally, however, there will be numerous cases whereby the investment is still required. It was therefore felt that a 5% increase in threshold for all assets of this particular class was a conservative compromise, rather than potentially overstating the benefits. Modelling completed by EATL has shown 12,000 instances in the SSEN network where the use of the LV strategy innovations successfully releases capacity and defers reinforcement, leading to an additional 75MW of capacity released within the SSEN network over the period to 2050. This is calculated as each instance releases somewhere between 5 and 8kW depending on the LV assets involved.

Across GB there will be some 182,000 instances of the LV Strategy delivering benefits; this indicates interventions in just over 30% of the LV feeders in GB, permitting a capacity release of approximately 1,150MW over the period to 2050.

ANM, DSM and Energy Storage

Develop network management system
SSET1009 Orkney Energy Storage Park phase 1
SSET1007 Orkney Energy Storage Park phase 2
SSET1010 Impact of Electrolysers on the Network

Investigate interactions and least-cost operating systems
SSET1011 Digital Substation Platform

Understand Operation of storage to manage local demand
SSET1001 Shetland 1MW Battery
SSET1008 LV Connected Energy Storage

1039MW capacity released in GB to 2050

Faster connection of new generation, and better use of existing capacity

The wide-scale deployment of ANM allows for flexible access for generators to the network. In itself, it does not necessarily constitute a 'release' of capacity, but it does increase the amount of generation that can be connected.

Similarly, DSM and Energy Storage improve the utilisation of existing capacity by 'moving' demand from peak times.

We did not explicitly model the capacity release under these three innovations, as DSM and Energy Storage are likely to be deployed alongside ANM in the future. For example, in Orkney and Shetland, the combined implementation of these three innovations enabled the connection of an additional 36MW of renewable generation. Modelling by EATL shows an expected 1,039 deployments in GB to 2050 of ANM schemes of the type pioneered by SSEN. If we imagine that each deployment allows even a modest 1MW of additional capacity to connect, this would equate to a capacity release of over 1GW.

A3 Delivering financial benefits

As with the capacity released, the Transform Model® selects the most economically efficient solution for any network issue.

When considering the cost of implementing these innovations EATL used cost curves as agreed for use in the Transform Model®.

The increased visibility and improved modelling that are gained through our LV Strategy enables better informed decisions regarding the need or otherwise to make LV interventions. This creates up to 182,000 instances across GB in the period to 2050 which will result in either intervention being deferred or a different intervention being deployed.

It does not mean that these 182,000 assets never require any further intervention, but it does result in the deferral of investments and therefore represents a financial saving and benefit to customers.

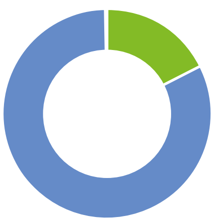


Figure 21 ANM GB Benefit

In calculating the benefits from our portfolio, we have not included benefits associated with energy storage, as current policy is unclear about the future ownership and location of storage. However, the learning from our portfolio of storage and DSM projects has helped us to develop the CMZ concept, EATL estimate that there will be up to 4,300 deployments of CMZ in GB by 2050. The benefits described above all accrue to network customers and exclude wider benefits. The benefits from ANM deployment are shared between the DNO and generation developers. For example the Orkney ANM system enabled by our Tier 1 portfolio delivered an estimated £4m benefit to the local economy in 2013 by enabling it to be a net exporter of electricity[19]. To look at the ANM example more widely, EATL estimate that there will be over 1,000 ANM deployments across GB by 2050, and they have estimated the **gross** benefit of ANM on the SSEN network as £127.8m, and on the GB network as £423.5m to 2050. However, the majority off this benefit accrues to the generator directly through reduced connection costs. We have therefore taken a conservative approach to net benefit calculation by assuming only 20% of the gross benefit flows to the network.

The results of the analysis are presented below and show the necessary expenditure expressed in cumulative discounted totex terms to 2020, 2030, 2040 and 2050. We have already begun to implement these solutions via our BAU activities for example the ANM scheme deployed on the Isle of Wight has deferred £2.3m of network reinforcement and released 45MVA of network capacity.

Benefits to the SSEN network

In Figure 22 overleaf, it can be seen that across the period to 2050, there is a benefit of £48m in avoided expenditure (an 11% saving). Initially, over the period to 2020, there is no saving as the costs of installing the monitoring necessary to facilitate the LV strategy approach outweigh the benefits realised. Over the 2020s and 2030s, a benefit in excess of £20m is experienced and this benefit grows in the latter part of the modelled period to a total of £48m by 2050.

19 http://www.smartergridsolutions.com/resources/case-studies/ssepd-anm-saves-ssepd-30m-by-preventing-grid-reinforcement/

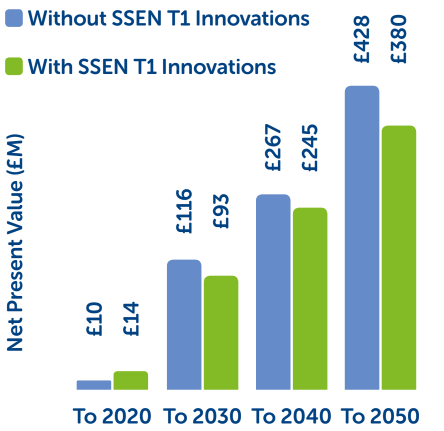


Figure 22 Cumulative discounted totex investment with and without Tier 1 innovations across SSEN network area

The figures below are based on the central scenario. We have also investigated the level of benefits that accrue if the uptake of customer technologies is higher or lower (thereby making the demands experienced on the network higher or lower).

In the high case the benefit realised to 2050 is some £40m, or 3.4% of investment, while in the low case it is approximately £4m or 2.4% of investment.

Benefits to the GB network

The results indicate a strong level of benefit that can be realised through the adoption of the SSEN innovations. The payback time is very short, even accounting for the fact that there is significant investment in the early years to install monitoring that will facilitate the LV Strategy approach. Even accounting for this level of investment in the pre-2020 period, there is still a net benefit of £50m achieved through utilising the CMZ and ANM approaches.

For example the investment of approximately £1m for the ANM scheme on Orkney deferred a £30m network reinforcement cost. Over the longer term, the level of benefits realised is some £327m to 2050, or 4.3% of the projected investment.

The benefits for the higher and lower cases (as described previously) were also considered. In a world where customer uptake of technologies is higher, the initial benefit to 2020 is constant in comparison to the central case but over time the level of benefit that can be realised through deployment of the SSEN innovations begins to increase. Over the longer term to 2050 the benefit increases from £327m to £429m. If considered in relative terms, the benefit for the central study case was a reduction in investment of 4.3% over the period to 2050, and though the benefits for the high scenario increase in financial terms, it corresponds to a reduction in relative terms to a saving of 4.0% in the high case.

When considering the low case, the benefits continue to hold up well given that there is much lower demand growth. Now over the period to 2050 there is a net benefit of £169m, but this equates to a higher relative saving of 11%.

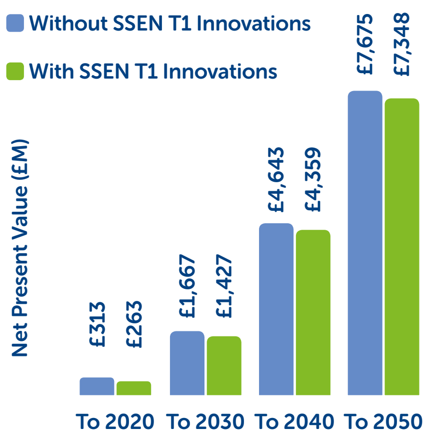


Figure 23 Cumulative discounted totex investment with and without SSEN's Tier 1 innovations across GB

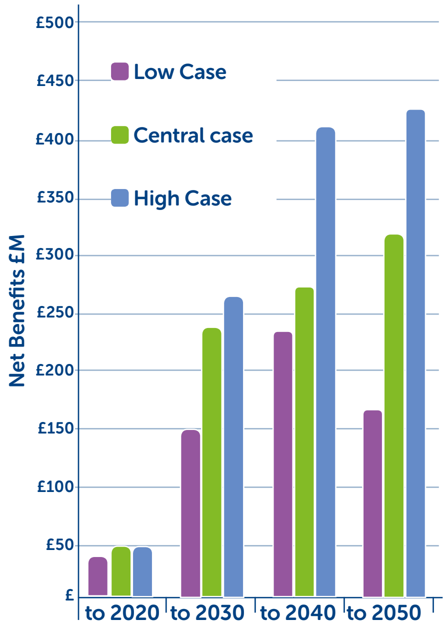


Figure 24 Net benefits (in terms of avoided expenditure) for Low, Central and High scenarios

It is important to note in all of these cases, only the benefits associated with changing customer demands in a bottom-up way were considered. As identified previously, there will be additional benefits at higher voltage levels. However, these will depend on the local network conditions and will be very specific in nature, making accurate modeling very difficult, therefore we have excluded them.

The fact that under all of these cases there are significant savings from the implementation of the SSEN Tier 1 innovations provides a clear indication that the approaches are valid and appropriate irrespective of the level of uptake of customer technologies that manifests. They therefore represent a low risk route to providing savings over the longer term as their efficacy is not predicated on any particular customer trends.

Carbon/environmental benefits

Based on the capacity release figures presented in Section A2 for CMZ, LV Strategy and ANM, we find the total capacity release from our innovations is up to 3.1GW in GB to 2050. The capacity released by CMZ and LV Strategy will primarily be in response to demand constraints caused by the increasing electrical load. Although this is primarily envisaged to be due to LCTs, there will be other factors which will drive this load increase. Therefore, we have not attempted to attribute any carbon savings with these innovation areas. However, ANM will produce capacity for generation to connect. Our experience has shown that this is likely to be renewable generation which will displace carbon fuelled plants. Therefore, we have calculated the following carbon benefits associated with the 1,039MW of capacity released by ANM.

By apportioning the capacity released between PV and onshore wind, and estimating the load factors[20] we have been able to estimate the additional volume of renewable energy produced.

We further apply the UK Government GHG Conversion Factor[21] to find tonnes CO_2e as follows:

Tonnes equivalent of carbon dioxide avoided by ANM

	2020	2030	2040	2050
SSEN	0.06m	0.06m	1.7m	3.5m
GB	0.2m	2m	5.7m	11.4m

Additional and indirect financial benefits

There are some additional benefits that should also be considered. For example, the LV Strategy approach could be deployed to other types of LV networks, such as those in village locations, or different types of domestic customers. This could be done with minimal additional work as it would build entirely upon the approach of the existing LV Strategy innovation.

Modelling this and the increased cost associated with additional monitoring on a wider selection of LV network assets, **the level of benefit across GB to 2050 is found to increase by £632m.** In determining the level of this benefit that can be apportioned to the Tier 1 portfolio, we believe that it is virtually all attributable as it is merely applying the same philosophy to a wider set of assets. Hence in calculating the additional benefit that can be claimed, we have taken 60% of this figure.

Additionally, the work carried out in the Tier 1 portfolio has directly influenced SSEN's Tier 2 projects. Most notably, there is strong correlation between the Tier 1 activity and the New Thames Valley Vision (NTVV) project. Based on the bid documentation for this project, the anticipated financial benefit to 2050 was shown to be £5,000m.

In determining what proportion of this is owed to the foundation work set out in the Tier 1 activity, we have taken the view that a modest 2% should be referenced as being attributable to the Tier 1 portfolio. This amounts to an indirect benefit of £100m. Similarly, our learning has influenced a number of Tier 2 projects by other DNOs listed below.

Tier 2 Project
NTVV (SSEN)
MEA (SSEN)
NINES (SSEN)
C2C (ENWL)
CLASS (ENWL)
CLNR (NPg)
Flexible Networks (SPEN)
ARC (SPEN)
LCL (UKPN)
LV Network Template (WPD)
FPP (UKPN)
SNS (UKPN)
FALCON (WPD)
LCH (WPD)

Most notable in this are the ANM projects Accelerating Renewable Connections (SPEN) and Flexible Plug and Play (UKPN); and the energy storage project Smarter Network Storage (UKPN). The level of benefit that these three projects deliver across GB to 2050 is some £5,100m in total. In making an assessment of the level of benefit that can be attributed to the original work conducted by SSEN in Tier 1, we have assumed a conservative 1% of the benefits released by these three projects, giving a further indirect benefit of £51m.

When all of these benefits are collated, the overall net financial benefit to GB over the period to 2050 attributable to the SSEN Tier 1 innovations is a total of £858m. This is illustrated in Figure 25 below.

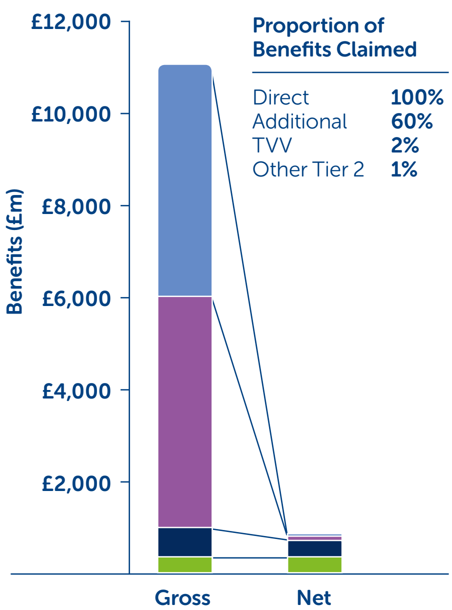


Figure 25 Total gross benefits and the subsequent net benefit from these activities across GB to 2050 attributable to SSEN's Tier 1 portfolio

20 Taken from the Digest of United Kingdom Energy Statistics (DUKES)

21 UK Government GHG Conversion Factors for Company Reporting: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/526957/ghg-conversion-factors-2016update_MASTER__links_removed__DECC_Standard_Set.xls

A4 Roll-out across the DNOs' system and across GB

The work carried out by SSEN has led the way in some areas of innovation such as energy storage and ANM. This enabled other DNOs to further develop these ideas through their own projects, and trial technologies and processes that would not have been possible without the initial work undertaken by SSEN.

To date, there has been limited deployment of trialled innovations in BAU situations due to the relatively recent completion of trials (in contrast to network asset life cycles) or lack of agency on the part of DNOs to deploy the innovation in question.

Specifically, whilst the Energy Storage related projects provided strong learning relating to the procurement, installation and operation of network connected battery systems, DNOs are not able to directly operate such systems within the current regulatory regime. Instead, third party providers are making use of such systems to provide network services, building on the learning produced by SSEN's Tier 1 portfolio.

We have described the anticipated uptake of these technologies based on the latest best view from central government of future scenarios. SSEN intend to deploy the technologies and commercial approaches when deemed to provide best value to the network.

As described earlier, the Transform Model® includes other innovations which could be used instead of the SSEN innovations. As such the model automatically controls for other innovations.

Deployments to 2050	SSEN	GB
CMZ	269	4,300
ANM	315	1,039
LVS	12,000	182,000

A5 Other benefits

Due to the nature of the SSEN network in Scotland, we experienced many network issues earlier than elsewhere in GB; this allowed us to lead the way with inception of ANM and energy storage projects.

This has allowed us to validate the learning and then share it, to prepare the industry for wider uptake in GB. In undertaking these projects we have gained additional learning which has provided wider benefits to the energy sector:

- Experience gained during SSET1003 Trial Evaluation of DDSM gave us greater insight into methods for engaging customers and understanding their requirements. This proved invaluable in the development and implementation of the SSEN Tier 2 SAVE project.
- The SSET1001 1MW Shetland Battery project encountered unprecedented challenges in sourcing and operating a battery.
- The development by SSEN of the CMZ mechanism has added a new tool for meeting security of supply conditions. The roll out of CMZ will help develop and stimulate a new market for third parties to provide services to DNOs. This comes at a time when there is an increasing demand for other ancillary services such as EFR. By adding additional market opportunities for service providers this may help to drive down the overall cost for customers. We have received several requests for detailed information and one-to-one meetings with other DNOs who wish to roll out this mechanism on their networks.
- Our experience in implementing innovations as BAU has led to the creation of the Active Solutions Team and the Innovation Deployment Team. This is a change to our operating structure and these teams have a specific remit to drive uptake of our innovations within our business.

The Tier 1 portfolio also helped us to identify a number of potential "unintended consequences". Our Tier 1 portfolio has delivered learning which has built our competence in five key innovation areas which are all essential ingredients in the future transition to DSO. In understanding the potential future operating scenarios and disruptive technologies on the distribution network (such as EVs and domestic PV installations), SSEN's Tier 1 portfolio has positioned us to understand the challenges, communicate effectively with industry, customers, and other DNOs, share best practise through fora such as Energy Storage Operators Forum, and deliver a network which is capable of facilitating the transition toward a low carbon economy.

A6 Portfolio Management

SSEN does not view our Tier 1 projects in isolation; each project has fed key learning into a larger body of evidence.

In our Innovation Models, we show graphically the cumulative effect of these projects and their contribution to our understanding in each area.

To allow any innovation to move into BAU a range of questions need to be answered, typically:

- Can it perform technically?
- Have the risks been identified?
- Have the mitigations for these risks been defined and tested?
- Have the ongoing support requirements and costs been identified?
- Has the business case, costs and benefits been validated?
- Have any un-intended consequences been identified?
- Are the impacts on customers positive and understood?
- Have we tested customer and stakeholder perception?

We have structured and evolved our portfolio to answer these questions and others building towards an informed decision to deploy new solutions based on the cumulative learning from our portfolio and from other sources.

There are some clear examples where our Tier 1 projects have de-risked larger projects, such as the SSET1003 project, which trialled domestic DSM in six homes to de-risk a larger roll-out of the technology during the NINES project, or the SSET1004 project which investigated the use of ADR, and allowed the sign-up process to be improved before a wider roll out as part of the Tier 2 NTVV project.

This prudent use of the Tier 1 Funding has de-risked the development and implementation of both of these Tier 2 projects (which have a combined value of £45m), and has helped to ensure that these projects deliver their anticipated benefits.

Across our portfolio we have developed learning which is focused on the fundamental aspects of operating the network. These have been categorised in our five key innovation areas, which address many of the challenges which will exist across a wide range of future network scenarios and operating models which will ensure that SSEN can deliver benefits for customers and be as well prepared as possible for any future challenges.

Reward Criterion B – Additional Funding

Whilst SSEN has not directly contributed any additional funding beyond the 10% compulsory contribution, we did take significant steps to maximise the value of external funding either as contributions from other project partners or by accessing funding from other sources. This is illustrated by the examples set out below. We have continued to try and maximise the use of external funding throughout our portfolio.

External investment has either been in the form of a direct financial contribution or by combining the Tier 1 funding with other funds to deliver a larger scale project. In developing our innovation portfolio, SSEN has deliberately set out to take advantage of external funding where we can provide benefits for the networks and deliver additional learning.

In part our success in this area is due to our proactive approach to stakeholder engagement when developing our innovation projects. This approach has allowed us to involve a wide range of third party interest/participation in our projects and has enabled us to access significant external funding.

B1 Details and significance of DNOs' additional contribution

As identified above, SSEN did not directly make any significant additional contribution to any of the Tier 1 projects, however, we did secure additional external funding to support the delivery of the projects, including:

SSET1001 1MW Shetland Battery

SSEN had recognised that energy storage was likely to be a component of any future energy system and that it was an area in which there was a lack of knowledge in the UK. It is important that as a DNO we understood the potential implications of the deployment of energy storage on the network.

Therefore the Shetland Battery project was developed; however, the capital cost of the battery system was identified as a potential barrier for the project. To overcome this SSEN decided to look for additional funding mechanisms to allow the project to progress. The Department of Energy and Climate Change (DECC) Smart Grid Demonstration Capital Grant Programme was identified and an application was developed. The project was awarded a grant of £1m which was crucial in making the project's progress viable.

SSET1003 Trial Evaluation of Domestic Demand Side Management

This project established that it was possible to use domestic heating and hot water systems as a means of providing demand side management. The project developed a greater understanding of the needs of the householders, the technical interface between the ANM system and the home as well as allowing equipment providers Glen Dimplex and Smarter Grid Solutions to fine tune their products prior to the larger scale roll out in the NINES project.

After the success of this initial trial Hjaltland Housing Association (HHA), supported by SSEN, made an application to the European Regional Development Fund (ERDF) to support the installation of the new heating systems across approximately 240 homes. This application was successful and resulted in HHA being awarded approximately £460k toward the cost of the new heating systems. This new flexible demand was key to the success of the NINES project. The learning from the SSET1003 project was crucial in developing the successful ERDF application as it gave a certainty to the funders that the project could be delivered on time and on budget.

SSET1010 – Impact of Electrolysers on the Distribution Network

This project was a component of a much larger project to support the long term operation of a fleet of ten hydrogen fuel cell buses in Aberdeen. This Aberdeen Hydrogen Project was funded by a combination of funding from multiple EU (via the Fuel Cell and Hydrogen Joint Undertaking), UK (via Technology Strategy Board), and Scottish governments as well as funding from industrial partners including Stagecoach, First Group and BOC.

The total funding awarded to the project was in excess of £20m. The Tier 1 funding of £750k was used solely to fund costs directly associated with the impact on the network, but it formed a crucial element of the overall funding package to ensure the successful delivery of the overarching Aberdeen Hydrogen Project.

In general all of the SSEN Tier 1 projects were delivered within scope and budget, with only minimal departures from the original project submissions.

The only project which was subject to a significant change was the Shetland Battery project due to a change in the safety case of the initial NAS technology.

However, adhering to timescales and budgets did not mean that the projects were not without challenges nor required additional work to ensure the projects were delivered. Across the Tier 1 portfolio this has involved significant additional input from a wide range of staff across SSEN, which has been provided at no additional cost to the Tier 1 fund.

B2 Issues that justified the additional contribution

There are a number of different reasons why SSEN sought additional contributions toward the cost of our portfolio. In general we were aiming to ensure best value for electricity customers by maximising use of external spend but in many cases the projects would not have been able to proceed without the external funding.

Project Scope

SSEN has a very broad scope of innovation projects and to be successful we have had to encourage participation from across the energy supply chain from generation to end consumer. In some of the projects additional contributions were required to fund elements of the project as the activities were either outwith the scope of LCNF or were not appropriate to be funded by Tier 1. For example, upgrades to domestic heating systems in Shetland were not appropriate for Tier 1 funding, and HHA would not have been able to fund all of the upgrades within the project timeframe, but the injection of ERDF funds allowed the project to proceed.

Risk

The use of external funding has been used to reduce project risk to a level where industrial partners felt confident to invest. This was crucial to the involvement of Stagecoach and First Group in the SSET1010 project; without this they would not have been able to make the step change from a traditional fossil fuelled bus to a Fuel Cell Electric Vehicle. Without the full range of partners this project would not have been able to proceed.

Value

In some instances whilst the future benefits from a particular technology may be widely recognised, the first time deployment costs may be too high to warrant a deployment. Without the support from DECC, the SSET1001 1MW Shetland Battery project would not have progressed as the high capital cost could not have been provided by the SSEN Tier 1 allowance. Since then the cost of battery technology has fallen sharply with numerous commercial deployments currently being installed across GB. The learning from the Shetland Battery project has helped DNOs to be better prepared for this roll out.

Commitment

Being able to secure financial commitment from project partners commits them to remain involved in the project to ensure successful delivery. By its very nature innovation is uncertain and challenges and risks will develop during the course of a project which could not have been reasonably foreseen. If project partners had not had a direct financial or reputational stake in the delivery of these projects it would have added a risk of them ceasing their involvement in the projects.

In general, none of the projects described above would have been possible without additional funding, or the project scope, scale or duration would have had to have been significantly reduced. This would have had a corresponding impact on the quality of the learning outcomes potentially rendering them statistically invalid.

SSEN has always considered that projects need to be undertaken at the correct scale to ensure learning outcomes are relevant and meaningful and can de-risk further investments.

Applying for and securing additional external funding is not an easy task and requires significant time and effort to complete a successful application. Along with the funding there comes an additional obligation to comply with the funders governance rules and to disseminate the learning which places a significant burden on the DNO to ensure compliance. However, in our experience this has been a worthwhile and valuable process.

B3 Demonstrable benefits to customers

The key benefits from our ability to secure additional funds have been that customers have been able to access knowledge from a bigger pool of projects with a much wider range of partners. This has allowed us to develop our knowledge in key areas such as energy storage more quickly and robustly. For example the additional funding from DECC allowed SSEN to procure a large scale battery for the SSET1001 1MW Shetland Battery project; due to the scale of the project it attracted attention from large multinational equipment providers. This allowed SSEN to gain key insights into the experience of installation and operation of batteries across the globe. This would not have happened had we set out to procure a much smaller installation.

The ERDF funding secured following the completion of SSET1003, allowed the Domestic DSM solution to be rolled out to 240 homes across Shetland. This represents a statistically significant element of the island's population and gives confidence in the ability of domestic customers to participate in demand side management. Without the support of ERDF the larger scale roll out may never have happened or would have been restricted to a much lower number.

In general, the external funding we have attracted has allowed us to do larger scale trials, across a broader range of topics with a larger range of partners to improve the quality of the learning outcomes for customers.

Reward Criterion C

C1 Demonstrate where the portfolio has delivered more learning than was expected

The SSEN portfolio has delivered more learning than expected in several ways. As we have progressed the delivery of our innovation portfolio we have developed and refined our learning capture processes to ensure that they become an integral element of project delivery.

This is possibly best demonstrated by our experience in Energy Storage, where the learning outcomes from the SSEN portfolio have delivered additional learning which has benefited the whole industry. SSEN was the first GB DNO to undertake a large scale energy storage project with the SSET1001 1MW Shetland Battery. The original battery was a Sodium Sulphur (NAS) battery.

Prior to energisation we were informed of a battery fire at a NAS installation in Japan. This delayed energisation while a comprehensive review was carried out, including the fundamental safety case, and we, in conjunction with the supplier, concluded that the NAS battery technology originally proposed was no longer appropriate for deployment at this location.

The knowledge and learning gained during this process made SSEN a better informed buyer when selecting the replacement technology. In particular, we gained knowledge in the design, risk assessment and construction of energy storage technology. Following a robust technical and commercial evaluation of a number of potential storage technologies, a 1MW 3MWh Lead-Acid battery was selected as a replacement.

Thus the Shetland Battery project delivered significantly more learning than expected by delivering the safety case for two battery chemistries (Sodium-Sulphur and Lead-Acid) as well as the process for installation and commissioning. This additional case was delivered at no extra cost due to the outstanding efforts of the project team to manage delivery by the suppliers and the co-operation of our main supplier, S&C Electric. This work significantly de-risked the larger NINES project.

This learning was again utilised in the development and delivery of both the SSET1007 Orkney Energy Storage Park project and SSET1008 Low Voltage (LV) Network Connected Energy Storage in Chalvey, Berkshire. These projects also significantly de-risked the larger Tier 2 project New Thames Valley Vision and were fundamental in SSEN developing the CMZ concept.

These projects were amongst the first energy storage projects in the UK. This was an entirely new technology for GB DNOs with a completely new set of technical, operational and commercial challenges unlike any established DNO asset type.

The delivery of our first batch of energy storage projects provided SSEN with a very steep learning curve in this new field and we were keen to share this experience, 'warts and all', with the other DNOs. This led directly to the establishment of the Energy Storage Operators' Forum (ESOF). SSEN developed the concept and approached EA Technology Ltd to help manage the forum. SSEN held the first chair of the forum and hosted learning events in Shetland, Chalvey and Orkney. In addition SSEN paid a membership to the forum and contributed financially to the creation of the ESOF Good Practice Guide. In addition to financial support SSEN contributed to the content of the guide in terms of the learning from our energy storage projects, due to the robustness and breadth of the experience gained during the delivery of our energy storage projects.

> "SSEN played a significant role in ESOF and shared the learning from their portfolio of Tier 1 EES projects (Chalvey, Orkney and Shetland), both with other DNOs, the TSO and the wider industry via the GPG. As one of the first DNOs to install EES using Tier 1 and IFI funding this enabled SSEN to assist others as the volume of DNO storage projects increased. SSEN hosted technical visits to their Chalvey and Shetland installations through the ESOF meetings, and these were attended by representatives from all the DNOs, the TSO and the ENA. To date the Good Practice Guide has been downloaded over a thousand times and continues to act as a resource for the energy storage industry."
> – EA Technology

In addition, we gained valuable learning on the operation of ANM. The Orkney Smart Grid, delivered in 2009 by Smarter Grid Solutions for SSEN, was the UK's first Smart Grid. We consolidated this knowledge by integrating the Orkney Energy Storage Park under projects SSET1007 and SSET1009 into the real time operation of the ANM system. This created significant learning on both of these emergent technologies.

The learning from the Orkney Smart Grid provided a foundation of knowledge and was a catalyst for the establishment of the Energy Networks Association's ANM Working Group. SSEN proposed the establishment of this group based on our experience of ANM and energy storage and the foresight from our Tier 1 projects which identified that this was an area that required industry collaboration. Our Tier 1 portfolio also contributed significantly to the ANM Good Practice Guide that was created by this group particularly in the structuring of connection and commercial arrangements.

Preparation for DSO

At the outset of the SSEN Tier 1 portfolio there was a degree of uncertainty on the future requirements of the networks and the structure of the industry. Whilst the move to a DSO model was not directly identified at the outset of the Tier 1 process, SSEN did recognise that in almost all of the future scenarios there was a need for the DNO to be more flexible and more directly engaged in managing energy flows on the network. Our Tier 1 portfolio provided early indicators and insight into the complex technical, commercial and regulatory matters associated with the democratisation of energy production and management at a local community level. The breadth of the SSEN project portfolio has ensured that we have delivered a rich seam of validated learning beyond the scope of the original projects, which will help future preparedness for DSO.

Key areas of learning about future DSO readiness in relation to data from Tier 1 portfolios relate to data exchange between parties, communication system failure and cyber-security. The SSET1003 Trial Evaluation of Domestic DSM generated significant learning on communication requirements for reliability scheduling, security, physical dimensions of equipment, data storage service level agreements and safety testing.

Learning in these areas has fed into the larger NINES project however the significance and relevance of this learning is key for future preparedness for DSO.

Our project in Bracknell SSET1004 Demonstrating the Functionality of Automated Demand Response (ADR) provided additional and unexpected learning that developed our understanding of the appetite amongst I&C customers to participate in ADR services. Specifically this informed DNOs around the data sharing issues that integration of our systems and customers' system would have to overcome.

Our DSM project in Shetland was initially targeted at the technical aspects of integrating the DSM equipment with the customers' domestic heating systems. However, the trial also identified how important the individual behaviours, lifestyle and "needs" of individual customers were going to be to the success of the trial. This included their concerns around equipment installation, concerns around future energy costs, how long trials would last, and arrangements for support if there were any issues. This allowed SSEN and the social landlord (HHA) to improve the communication materials and prepare appropriate mitigations for the larger scale roll out across the islands. By addressing these concerns and providing the appropriate materials, the customers' registration rate for the NINES project was extremely high. This was maintained beyond the initial project sign up period as tenants changed.

Working with third parties – speaking the same language?

Several SSEN Tier 1 projects have involved working closely with third-party project partners and service providers. This type of interaction is expected to become an essential element of the move to a more flexible DSO network, where more and more network services will be procured from non-traditional providers.

In many instances our Tier 1 projects have offered our first chance to really engage with these providers, and the learning from this experience has been at times unexpected, and very relevant.

During our SSET1003 project, and continuing through our NINES project we engaged with Hjaltland Housing Association (HHA). We were able to modify our approach to domestic customers based on the experience of HHA to better reflect their priorities.

Similarly, when planning our SSET1010 Impact of Electrolysers project, we had to design the control system to meet the needs of BOC (the plant operator) and the bus operators (First Group and Stagecoach). The time margins they were willing to accept for fuel availability were unfortunately much more stringent than we had anticipated, and required us to redesign many of our trials to ensure these were met. This experience highlighted that while a few minutes' delay in refuelling may not seem important to us, it can have a large impact on the running schedule of the buses.

The SSET1007 and SSET1004 projects in Orkney and Bracknell provided unexpected learning in the form of the interaction between a DNO and a third-party commercial service provider. It was recognised that for a DNO to obtain a service at the right prices then they need to recognise the consumer perspective. Learning was established that demonstrated that SSEN were required to tailor our commercial criteria so the third- party could optimise the services they provided to allow them to participate in other markets. This provided an understanding of what third-party service provider's needs are so SSEN could access a cost effective service. This was learning that was unexpected as it was not anticipated how important commercial considerations are for third-party service providers and in particular from the perspective of a developer being able to have sufficient information to be able to develop a 'bankable' business case to enable them to secure financial backing.

Maximising and embedding the learning

In recognition of the importance of effective knowledge management and learning capture, SSEN appointed the first dedicated knowledge manager in this sector, followed by the appointment of a second knowledge manager to develop and deliver an outstanding approach to knowledge management to ensure maximum value was achieved from our portfolio of Tier 1 projects. This led to a framework for knowledge management which is now used as a platform for knowledge management across our innovation portfolio including Tier 2, NIA and NIC projects.

This framework ensures we capture all learning outcomes from our projects, and recognise connections/synergies with other projects as they arise.

As well as new approaches to knowledge management the learning from our Tier 1 projects had a significant impact on the way in which we engage with other parts of the business. This shaped the creation of our Active Solutions and Innovation Deployment teams.

Our Active Solutions is a new team, appointed to roll out certain proven innovations that require more support once they have been installed and commissioned.

Our Active Solutions team is currently responsible for rolling out ANM and other types of flexible connections based on the consolidated and proven learning from our Tier 1 portfolio. Our Innovation Deployment team was developed through our Tier 1 portfolio to ensure the successful delivery of innovations from business case justification to implementation and handover to BAU.

C2 Additional learning as a result of exceptional effort of the DNO

SSEN made an exceptional effort to deliver robust safety cases for battery technology for our energy storage projects. Due to the change from the initial battery technology on our SSET1001 1MW Shetland Battery project, we made an exceptional effort to get the technology independently reviewed to create a robust safety case for battery technology.

This was then adopted by our other energy storage projects and presented to the industry to ensure all future projects were subject to the same rigorous analysis. Due to the robust commercial arrangements that SSEN had in place on this project, SSEN was able to minimise the exposure to the customer and the costs of this additional work were met within the original budget.

The SSEN involvement, through our SSET1010 project, in the Aberdeen Hydrogen Project minimised the exposure for our customers and maximised the learning by joining our Tier 1 project to the larger project which has external funding from the EU, Scottish Government and Innovate UK. During the project it became clear that some of the benefits of electrolyser flexible operation (which can avoid network reinforcement) could only be borne if the third party developers invested in additional capital equipment such as storage and control systems.

SSEN engaged the University of Strathclyde to complete some commercial modelling to establish a business case for third party developers to invest in this flexibility. This work was not envisaged at the project outset and was undertaken through exceptional effort by our team who were determined to deliver benefits to customers, even though the ability to do so (by building flexible electrolysers) lay with third parties rather than DNOs.

SSEN has further developed the case for energy storage and flexible solutions through our deployment of CMZ. This identified potential revenue stacking opportunities for energy storage providers. This was based on the learning from SSET1007 Orkney Energy Storage Park, which SSEN extended to demonstrate the feasibility of this future market for energy storage providers.

The development of CMZ was undertaken without any innovation funding, as SSEN recognised that we could build on the wealth of knowledge gained through our Tier 1 and wider innovation portfolio. However delivering this commercial option required a huge internal resource and effort, which was borne by the business to ensure the benefits could be passed to customers as quickly as possible. Additional effort was made to host two interactive webinars on CMZ in order to educate, inform and develop the supply chain and identify additional learning on the commercial drivers of the supply chain. Over 160 individuals registered for these webinars which demonstrates the level of interest that CMZ created. Similar CMZ schemes are being replicated throughout the industry.

C3 Exceptional capture and dissemination of learning in a way that maximises value for all customers

Identifying cross-sector benefits

SSEN recognise that sometimes customer benefits can best be realised by engaging with other industry partners. For example, the SSET1010 project involved partners in gas distribution, road transport, and the city council. Recognising hydrogen use as a potentially disruptive technology, with potential to necessitate network reinforcement in mature urban environments, SSEN undertook to lead this project to ensure any potential to reduce cost to customers would be investigated.

SSEN has continued to develop and disseminate outcomes of the Tier 1 project through involvement in the larger Aberdeen Hydrogen Project. We led a dissemination event in Aberdeen on 16 February 2017 to present the learning from this project with non-electrical utilities which will influence potential hydrogen refuelling station developers and highlight the benefits to them of investing more CAPEX to allow flexible operation of the HRS. This can reduce lifetime cost for the developer, but crucially can avoid network reinforcement costs.

Encouraging collaboration

Elsewhere in this document we have described our role in creating the Energy Storage Operators Forum (ESOF). This first forum proved the benefits of DNO collaboration and sharing of best practice, resulting in the publication of the Good Practice Guide on Electrical Energy Storage[22]. We continued this proactive approach and were also a founding member of the ANM Working Group which developed the ANM Good Practice Guide.

These guides provide an invaluable resource of technical best practice to any user who is designing an energy storage or ANM system.

ENERGY STORAGE esof OPERATORS FORUM

Supporting the innovation pipeline

As described throughout this document, the SSEN Tier 1 projects have each added a new layer to our knowledge base and allowed SSEN to build our competence in the emerging smart network, and prepare our business for future transition to Distribution System Operator.

Energy Innovation Centre

We recognise the importance of supporting projects and engaging smaller companies which feed into early stage innovations, and of developing a pipeline of implementable innovations and skilled researchers to deliver this future smarter network. For these reasons, SSEN has spent over £600,000 with the Energy Innovation Centre (EIC)[23] since 2012, £150,000 annually with the Power Networks Demonstration Centre (PNDC)[24] (of which we were a founding supporter), as well as providing a significant amount of our time, skilled support, and industry insight to several academic groups including the Centre for Doctoral Training (CDT) in Future Power Networks and Smart Grids[25], the CDT Power Networks[26], and the CDT Energy Storage[27].

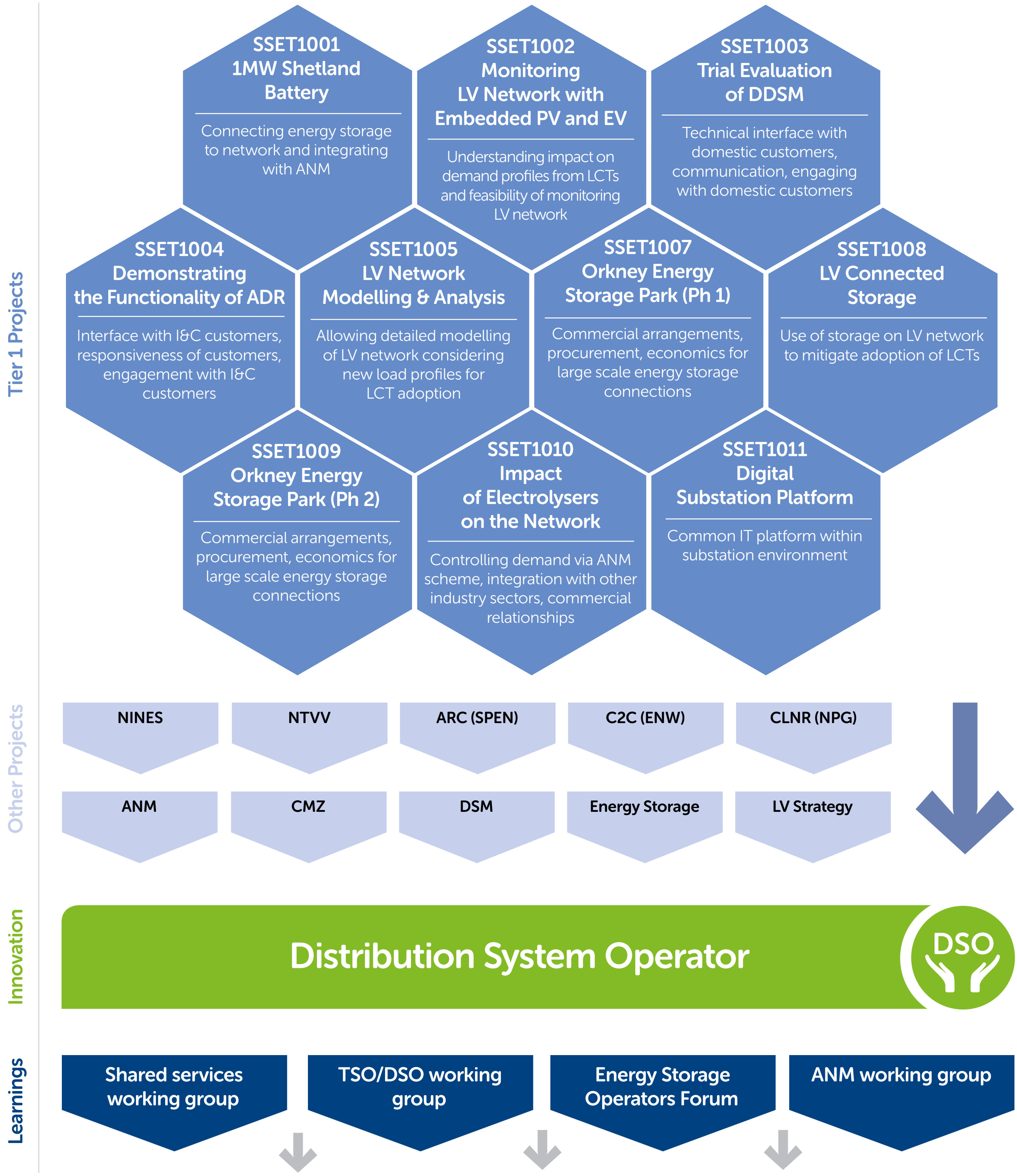
Through these avenues we have ensured the learning and expertise of our team, built up through the portfolio of Tier 1 projects, is being passed on to those working on the innovations of the future in a meaningful way. We believe our input at these early stages improves the quality of this early research and ensures a steady flow of new innovation ideas which are not repeating any of the lessons which we have already learned.

We do not attempt to quantify this support, but wish to recognise the extraordinary effort made by our most skilled colleagues to deliver this meaningful support and feed into the future of networks innovation.

Denise Massey, Energy Innovation Centre:
"Delivering innovation in this sector can sometimes feel like pushing water uphill. SSEN has been instrumental in our success, and has consistently supported the EIC since our creation."

As described throughout this document, each of our projects has fed into a body of knowledge which delivers benefits far outweighing the sum of the whole. Learning outcomes from our Tier 1 Portfolio have enabled further projects and delivered learning directly relevant to the future of DNOs. We have shown a snapshot of some of these relationships on our final cover page.

22 https://www.eatechnology.com/products-and-services/create-smarter-grids/electrical-energy-storage/energy-storage-operators-forum
23 http://energyinnovationcentre.com/
24 http://pndc.co.uk/research/
25 https://www.strath.ac.uk/dtcs/futurepowernetworksandsmartgrids/
26 http://www.power-networks-cdt.manchester.ac.uk/programme/
27 https://www.sheffield.ac.uk/energy-storage-cdt


Tier 1 Projects
SSET1001
1MW Shetland Battery
Connecting energy storage to network and integrating with ANM
SSET1002
Monitoring LV Network with Embedded PV and EV
Understanding impact on demand profiles from LCTs and feasibility of monitoring LV network
SSET1003
Trial Evaluation of DDSM
Technical interface with domestic customers, communication, engaging with domestic customers
SSET1004
Demonstrating the Functionality of ADR
Interface with I&C customers, responsiveness of customers, engagement with I&C customers
SSET1005
LV Network Modelling & Analysis
Allowing detailed modelling of LV network considering new load profiles for LCT adoption
SSET1007
Orkney Energy Storage Park (Ph 1)
Commercial arrangements, procurement, economics for large scale energy storage connections
SSET1008
LV Connected Storage
Use of storage on LV network to mitigate adoption of LCTs
SSET1009
Orkney Energy Storage Park (Ph 2)
Commercial arrangements, procurement, economics for large scale energy storage connections
SSET1010
Impact of Electrolysers on the Network
Controlling demand via ANM scheme, integration with other industry sectors, commercial relationships
SSET1011
Digital Substation Platform
Common IT platform within substation environment
Other Projects
NINES
NTVV
ARC (SPEN)
C2C (ENW)
CLNR (NPG)
ANM
CMZ
DSM
Energy Storage
LV Strategy
Innovation
Distribution System Operator
DSO
Learnings
Shared services working group
TSO/DSO working group
Energy Storage Operators Forum
ANM working group