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A Good Practice Guide on Electrical Energy Storage:

Executive Summary

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A Good Practice Guide on Electrical Energy Storage: Executive Summary

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Aim

- To be a reference guide for those implementing Electrical Energy Storage (EES) systems in the UK.
- To disseminate the lessons learnt from UK deployments of EES and to draw out good practice from these.
- It is not intended to be used as a rigid set of guidelines for those developing or installing EES systems.

Background

- Distribution Network Operators (DNOs) in the UK have deployed 12.6 MW / 20.6 MWh of EES, mainly via the Low Carbon Network (LCN) Fund.
- These projects are delivering large amounts of learning, throughout the whole project life-cycle.
- The Energy Storage Operators' Forum (ESOF) was formed to share this learning and good practice.
- The Guide was developed in order to consolidate this learning into a reference resource for those deploying EES.
- It was supported by the Department of Energy & Climate Change's (DECC) Energy Storage Component Research and Feasibility Study Scheme.

Who is the Good Practice Guide for?

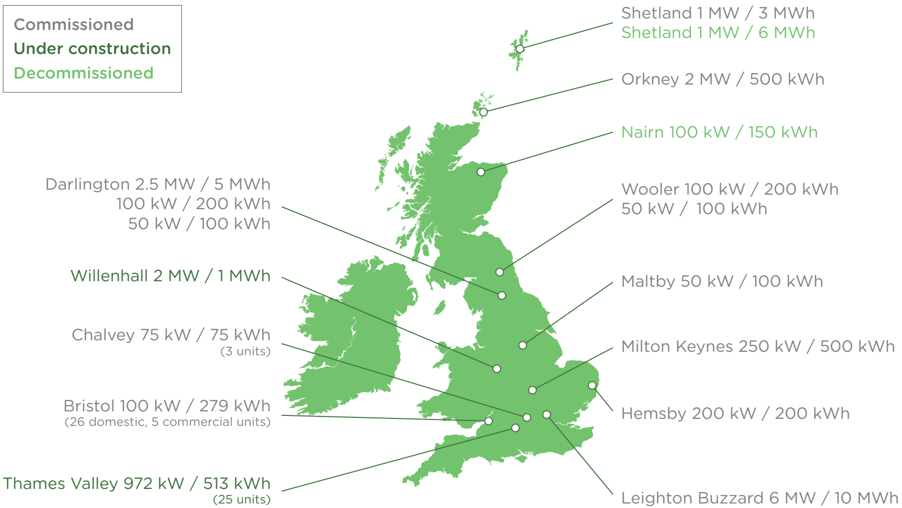
- Those involved in implementing EES systems (e.g. DNOs, Transmission System Operators, Energy Suppliers, Generators, independent Storage Service Suppliers etc.).
- EES suppliers, manufacturers and developers.
- Standards bodies.

Electrical Energy Storage in the UK

12.6 MW / 20.6 MWh of Electrical Energy Storage has been deployed by DNOs in the UK to date – representing a rapid increase in activity over the last five years.

- This increase in activity has been driven by Innovation Funding available to DNOs and a DECC funded demonstration programme.
- A range of technology options is being explored. The Guide covers battery technologies, flow batteries and thermodynamic cycle systems.
- Various applications are being trialled within DNO LCN Fund projects and the DECC demonstration projects.
- The Guide describes these applications and shows examples of the benefits achieved.
- A map of DNO storage projects is shown opposite.

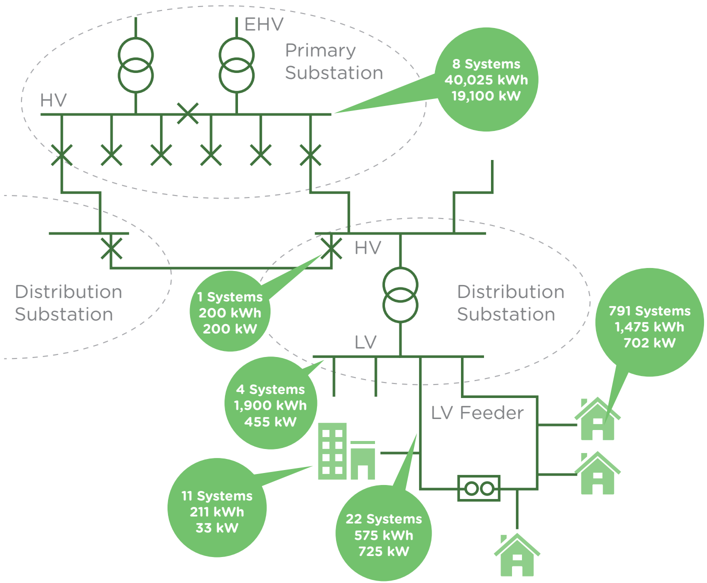
Map of DNO EES Installations (status at December 2014)



The use of EES is being trialled both at different points on the distribution network and on the customer side of the meter.

- The diagram opposite shows the point of connection for the DNO storage projects and the DECC funded demonstration projects.
- This range of projects and technologies is generating learning throughout the whole system life-cycle – from developing business cases, through procurement and installation, to system operation and network benefits.
- The aim of the Guide is to collate this information and use it to provide a reference resource for others installing electrical energy storage.

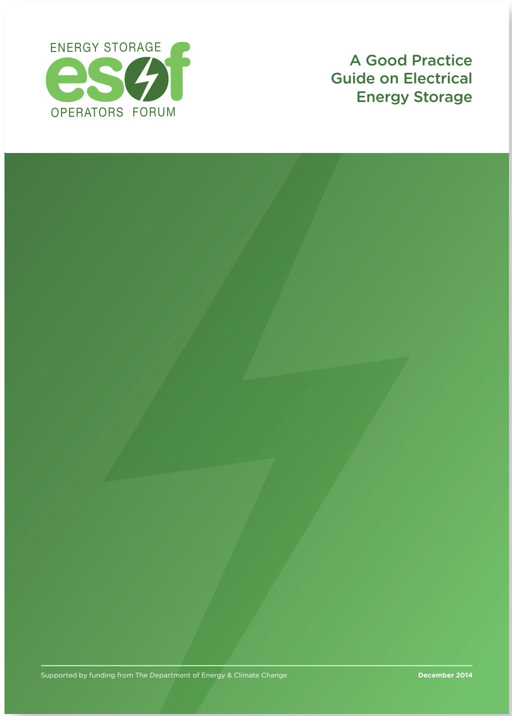
Network Connection of Proposed and Deployed storage in the UK. (DNO projects and DECC demonstrators as of 1 December 2014)



Introduction to the Good Practice Guide

The Guide is a reference document to be used through the full project life-cycle. This Executive Summary describes the Guide and shares some of the key lessons learnt.

- The Guide gives ‘good practice’ from the current storage deployments.
- It may be used to inform the development of Standards, in the future, but is not intended to form a rigid set of guidelines for those developing or installing EES.
- The following pages summarise some of the key lessons learnt, with links to the relevant chapters of the main Guide.
- The full Guide is designed as a reference document with chapters relating to each stage of the project life-cycle, as shown on the following page.



Project Lifestyle and Reference Sections of the Guide

Applications (Section 3) Costs and Revenue Streams (Section 12) Business Models (Section 12)	**1. Identify Potential Requirement for Storage:** Develop Outline Business Case, Consider suitable business models (owner operator/contracted service), 1st Stage Screening Assessment for Suitability	Cost:Benefit Analysis Approaches (Section 13) Candidate systems and technologies (Section 4 and Appendix 3)
Case Studies (Appendix 1) Installation (Section 8)	**2. Develop Procurement Specification for candidate sites and applications**	Hazards/FMEAs (Section 9) Codes, Standards and Licensing Considerations (Section 6)
Procurement rules and processes (Section 7)	**3. Initiate Procurement Process:** Issue Pre-Qualification Questionnaire, Short List, Full Submissions, Assessment and Ranking, Identify preferred bidder(s)	
Codes, Standards and Licensing Considerations (Section 6) Hazards/FMEAs (Section 9) Procurement rules and processes (Section 7)	**4. Assessment of Preferred Technologies/bidders:** Commercial, Supply, Warranty, Installation, Performance, Safety, Operations and Maintenance, Decommissioning and End of Life Disposal	Candidate systems and technologies (Section 4 and Appendix 3) Installation (Section 8) Safety Case Evaluation/Outline Risk Assessments (Section 10)
	5. Place Order(s)	
Hazards/FMEAs (Section 9)	**6. Develop Site/System Specific Risk Assessments**	Risk Assessments (Section 10)
Installation (Section 8)	**7. Installation and Commissioning**	
Scheduling (Section 11) Applications (Section 3)	**8. Operation and Maintenance:** Realising Value, Continuous Improvement, Monitoring, Maintenance, Metering, Evaluate ongoing business case	Risk Assessments (Section 10) Revenue Streams (Section 12) Cost:Benefit Analysis Approaches (Section 13)
Codes, Standards and Licensing Considerations (Section 6)	**9. Decommissioning and End of Life Disposal**	Risk Assessments (Section 10)

Successful Operation of EES Systems

> **EES is delivering benefits at all points on the distribution network, using a range of technologies.**

A range of applications is being trialled, offering benefits to DNOs, the System Operator and customers.

Section 11 of the Guide describes the applications being studied and demonstrates some of the benefits achieved, via six case studies covering:

- Peak shaving (1 MW/3 MWh Lead-Acid battery, SSEPD's NINES project);
- Peak shaving (2.5 MVA/5 MWh Li-Ion battery, Northern Powergrid's CLNR project);
- Voltage regulation using real and reactive power (200 kW/200 kWh Li-Ion battery, UK Power Network's Hemsby project);
- Voltage control on an LV feeder using real and reactive power (50 kW/100 kWh Li-Ion battery, Northern Powergrid's CLNR project);
- Reduction in losses by reducing neutral current (SSEPD's LV Connected Batteries project); and
- Operation based on frequency by a 50 kW/100 kWh high temperature sodium battery system (WPD's FALCON project).

An example, the NINES project, is briefly expanded upon on the following page.

Successful Operation of EES Systems: A Case Study

Project Name: Northern Isles New Energy Solutions

DNO: SSE Power Distribution

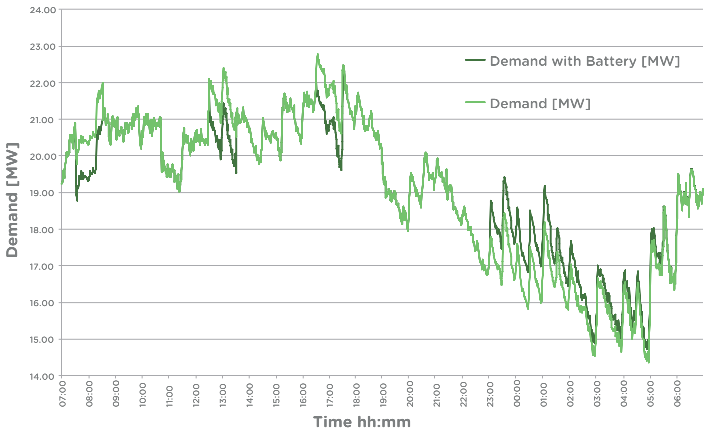
Storage Installation: 1 MW/ 3 MWh Lead-Acid system connected to 11kV at a primary substation in Lerwick, Shetland Isles.

Project Description: A 1 MW/3 MWh battery deployed as part of a wider Smart Grid trial. The system is intended to inform the strategy to replace Lerwick power station. It will provide peak shaving, frequency response (on Shetland's island network), voltage support and allow the connection of additional renewable generation.

Case Study: Peak Shaving

Explanation: A charge/discharge schedule was developed based on network demand. The graph opposite shows operation during the summer. The system discharges to support higher demand during peak times (1MWh each during 07:30 to 08:30, 12:30 to 13:30 and 16:30 to 17:30). Charging then occurs overnight, when demand is low. The impact of this charge/discharge cycle is shown on the demand curve opposite. This shows a reduction in demand during peak hours (when thermal generation output would otherwise have been ramped up) and a small increase overnight. Analysis of winter demand indicates that the battery will be able to reduce the peak lunchtime demand by 1MW for the duration of the peak.

1MW/3MWh peak shaving operation (source: SSEPD)

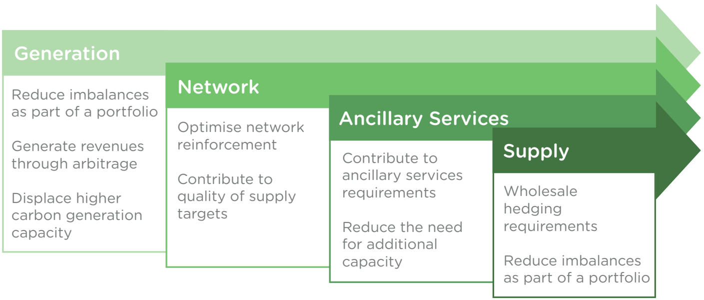


Developing the Business Case

EES systems have multiple potential applications within the electricity system – combining these benefits is often crucial to the business case.

- The business case for an installation is formed by comparing the total revenue which can be obtained (e.g. from combining multiple revenue streams) against the lifetime system costs.
- Different business models are being evaluated within the current LCN Fund projects, including: DNO owner/operator, DNO ownership/3rd party operation and a contracted services model.
- Section 12 of the Good Practice Guide outlines the costs of various EES technologies, the revenue streams available and three different business models.
- Section 13 shows the way in which this information can be combined into a Cost:Benefit Analysis. This is demonstrated using a number of case studies.
- An example of these case studies is shown on the following page.

EES Applications Across the Value Chain (source: UK Power Networks)



Developing the Business Case: A Case Study

Project Name: Smarter Network Storage

DNO: UK Power Networks

Storage Installation: 6 MW/10 MWh Li-Ion system connected at a primary substation.

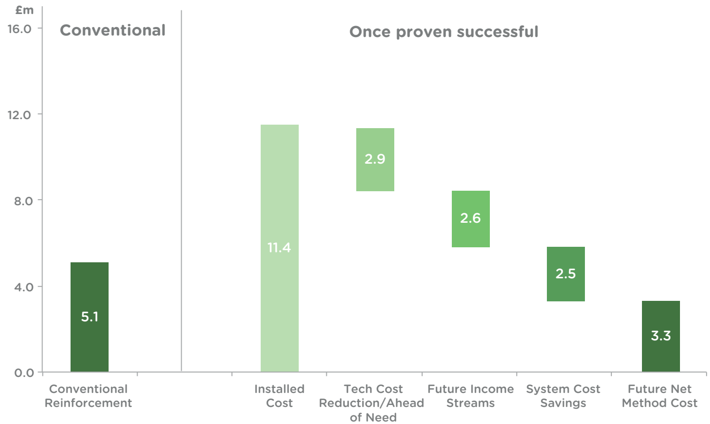
Project Description: This project is deploying a large EES system to avoid the installation of a 3rd overhead line circuit in Leighton Buzzard. It is combining multiple revenue streams by allowing a 3rd party to operate the EES system, and is exploring the commercial and regulatory barriers to this type of operation.

Cost:Benefit Modelling: The lifetime system costs have been compared to lifetime revenues to show the remaining 'net method cost' (i.e. cost of the storage solution). This can be compared against the conventional reinforcement solution. Benefits are included for:

- **'Tech Cost Reduction'** – this adjustment accounts for the fact that, strictly, the system for Smarter Network Storage was procured two years ahead of need, and the technology cost is likely to reduce during this period.
- **'Future Income Streams'** – the revenues available from providing ancillary services over the life of the project.
- **'System Cost Savings'** – the value of the wider benefits generated as a result of a reduction in peak demand, displaced peaking generation and carbon savings.

Results: This analysis shows that, when the likely reduction in the cost of EES technologies is taken into account, this type of installation has potential net benefits of £1.8 million.

Projected Future Business Case for Smarter Network Storage (source: UK Power Networks)



Procurement

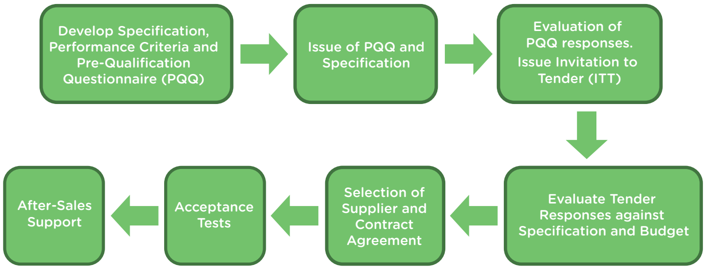
Section 7 of the Good Practice Guide describes: the approaches taken to procurement, factors to consider and lessons learnt.

The LCN Fund energy storage projects have utilised a range of procurement processes, each broadly following the order shown in the diagram opposite.

The key lessons learnt in relation to procurement are:

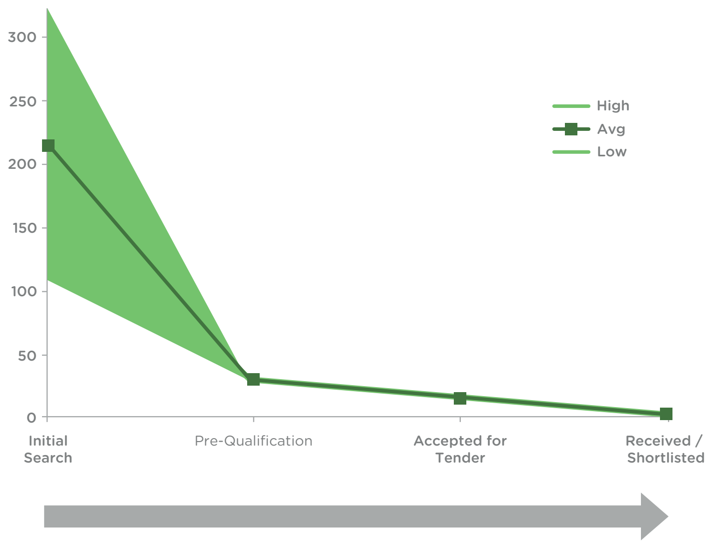
- There are a wide variety of factors (e.g. functionality, reliability, physical constraints etc.) which can be included within system specifications. However, due to the relatively immature nature of the market some flexibility should be included in the requirements.
- Current supplier management systems do not include a dedicated code for utility scale EES systems. This makes targeting the issue of PQQs and specifications to potential suppliers more difficult.
- Only a limited number of codes and standards are directly applicable for utility scale systems in the UK. This limits the extent to which codes and standards can be utilised for specification purposes during the procurement process.

Procurement Process



- The tender exercises to date have shown a relatively sharp ‘cliff edge’ in the number of potential suppliers at each stage of the procurement process (shown in the diagram opposite).
- The experience of various projects has shown the importance of Factory and Site Acceptance Tests to minimise potential delays in the commissioning process.
- These tests should be designed to accurately reflect the operating conditions on site. Testing prior to installation/assembly should be maximised, ideally using all the relevant sub-systems.
- In the majority of the case studies the deployment was a “first” of some kind (e.g. a specific technology), and the experience base of EES owners/operators in the UK is still developing. Close interaction between the owner/operator and the supplier in the after-sales period has therefore proved valuable.

Number of Potential Suppliers during Procurement Stages



Installation

Section 8 of the Guide describes the installation process, approaches taken in the case studies and lessons learnt.

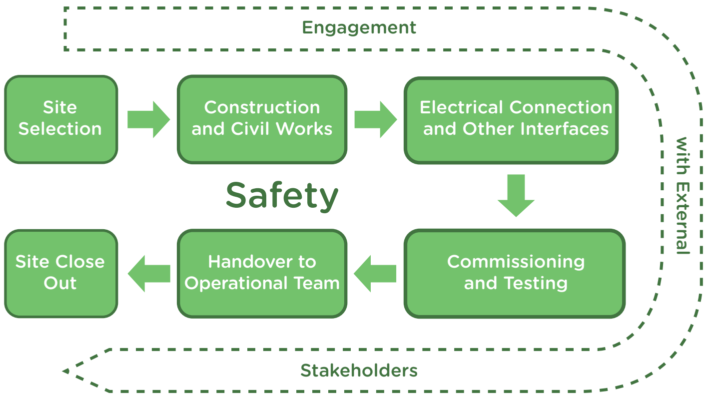
The process is shown by the diagram opposite.

The responsibilities of various parties (e.g. the owner/operator of the EES system, contractors and system suppliers) under the Construction (Design & Management) Regulations are outlined.

The key lessons learnt in relation to installation are:

- The selection of a site is complex and involves an assessment of the applications which can be addressed and the suitability of each potential location. Factors to consider are outlined in the Guide.
- Some applications are location specific and this limits the number of potential sites.
- Where possible, interfaces and procedures within an EES system should be familiar to staff (e.g. comparable to those for existing assets). This helps to facilitate fast, effective and safe resolution of any faults.

Installation Process



- The importance of engaging with external stakeholders throughout the installation process has been demonstrated across many projects. These stakeholders could include Local Authorities, emergency services, the Environment Agency, the relevant DNO and the local community.
- Auxiliary loads (e.g. battery heating, ventilation or air conditioning) should be proportionate to the battery size, and their operation should be minimised. Large auxiliary loads have the potential to decrease the round-trip efficiency of the system and erode some of the system's benefit.

Example EES Installations

6MW/10MWh in a purpose built building, UK Power Networks

2MW/0.5MWh containerised system, SSEPD

50kW/100kWh in an existing substation, Northern Powergrid

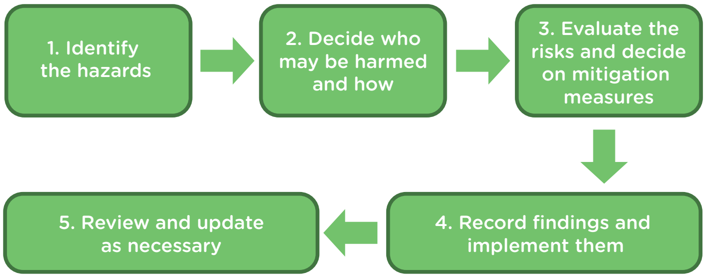
2kW/4kWh in domestic attic, Western Power Distribution

Developing the Safety Case

> **The DNO/TSO sector has an excellent safety record for deploying and operating existing distribution/transmission equipment. However EES systems present a new range of technologies and challenges.**

- Members of ESOF have worked with manufacturers to understand any new hazards which EES systems can present, their failure modes and mitigation measures.
- This has allowed EES systems to be deployed on distribution networks safely, and to be integrated into DNO safety procedures.
- Section 9 of the Guide describes some of the hazards associated with EES, in general, and how these can be mitigated. The particular hazards of each technology are then reviewed separately, alongside potential mitigation measures.
- Section 10 of the Guide reviews the approaches to hazard evaluation taken by the various projects and how Risk Assessments and Method Statements can be prepared. It also discusses the importance of engaging with external stakeholders and training staff who will work with EES devices.

HSE 5 Steps to Rise Assessment (source: HSE)



Conclusion

This Executive Summary provides an introduction to the Good Practice Guide on Electrical Energy Storage.

It shows:

- The activity in the UK in relation to Electrical Energy Storage
- The contents of the full Good Practice Guide
- The key lessons learnt from the DNO and DECC funded demonstration case studies.

The Good Practice Guide is designed to be used as a reference document for those deploying energy storage.

Different sections of the Guide will be relevant to different readers, at the various stages of a project, and ‘signposts’ to relevant sections are given in Section 1 of the Guide.

The Good Practice Guide can be downloaded from:

www.eatechnology.com

Acknowledgements

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- The funding support provided by DECC, without which the production of the Guide would not be possible;
- Members of ESOF for their contribution to the development and review of the Guide, and provision of case study material;
- Other parties deploying EES as part of DECC/ETI funded demonstration projects for the provision of case study material; and
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This Executive Summary of the Good Practice Guide on Electrical Energy Storage (EES) summarises key learning from storage projects in the UK and provides an introduction to the main Guide. The Guide is a reference document for those implementing EES in the UK.

The Good Practice Guide has been produced by EA Technology, working with the Energy Storage Operators' Forum. Its production was supported by the DECC Energy Storage Research and Feasibility Competition.