Project Code/Version No

Low Carbon Networks Fund
Full Submission Pro-forma

Section 1: Project Summary

1.1 Project title

1.2 Funding DNO

1.3 Project Summary

1.4 Funding

Second Tier Funding request (£k)			
DNO extra contribution (k)		**External Funding (£k)**	

1.5 List of Project Partners, External Funders and Project Supporters

1.6 Timescale

Project Start Date		**Project End Date**	

1.7 Project Manager contact details

Contact name & Job title

Telephone Number

Email Address

Contact Address

Section 2: Project Description

Project Code/Version No

2: Project Description cont.

2: Project Description cont.

Project Code/Version No

2: Project Description cont.

2: Project Description cont.

2: Project Description cont.

2: Project Description cont.

2: Project Description cont.

2: Project Description Images, Charts and tables.

Project Description images

Section 3: Project Business Case

3: Project Business Case contd.

3: Project Business Case contd.

3: Project Business Case contd.

3: Project Business Case contd.

3: Project Business Case contd.

3: Project Business Case images, charts and tables.

Project Business Case images

Section 4: Evaluation Criteria

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria contd.

4: Evaluation Criteria images, charts and tables.

Evaluation Criteria Images

Section 5: Knowledge dissemination

☐ Put a cross in the box if the DNO does not intend to conform to the default IPR requirements

5: Knowledge dissemination contd.

5: Knowledge dissemination contd.

5: Knowledge dissemination images, charts and tables.

Knowledge dissemination images

Section 6: Project readiness

Requested level of protection require against cost over-runs (%).

Requested level of protection against Direct Benefits that they wish to apply for (%).

6: Project readiness contd.

6: Project readiness contd.

6: Project readiness contd.

6: Project readiness contd.

6: Project readiness contd.

6: Project readiness contd.

6: Project readiness images

Project readiness Images

Section 7: Regulatory issues

☐ Put a cross in the box if the Project may require any derogations, consents or changes to the regulatory arrangements.

7: Regulatory issues contd.

7: Regulatory issues images, charts and tables

Regulatory issues images

Regulatory issues images

Section 8: Customer impacts

8: Customer impacts contd.

8: Customer impacts contd.

8: Customer impacts contd.

8: Customer impacts images, charts and tables

Customer Impacts images

Project Code/Version No

Section 9: Succesful Delivery Reward Criteria

Criterion (9.1)

Evidence (9.1)

Criterion (9.2)

Evidence (9.2)

Project Code/Version No

9: Succesful delivery reward criteria contd.

Criterion (9.3)

Evidence (9.3)

Criterion (9.4)

Evidence (9.4)

9: Succesful delivery reward criteria contd.

Criterion (9.5)

Evidence (9.5)

Criterion (9.6)

Evidence (9.6)

9: Succesful delivery reward criteria contd.

Criterion (9.7)

Evidence (9.7)

Criterion (9.8)

Evidence (9.8)

Section 10: List of Appendices

APPENDIX B – MAPS & DIAGRAMS

List of Figures:

Figure B1 – Aerial view of Leighton Buzzard Primary Substation (Woodman Close) & Storage Facility Location

(For detailed layout see Site Plan Drawing Below)

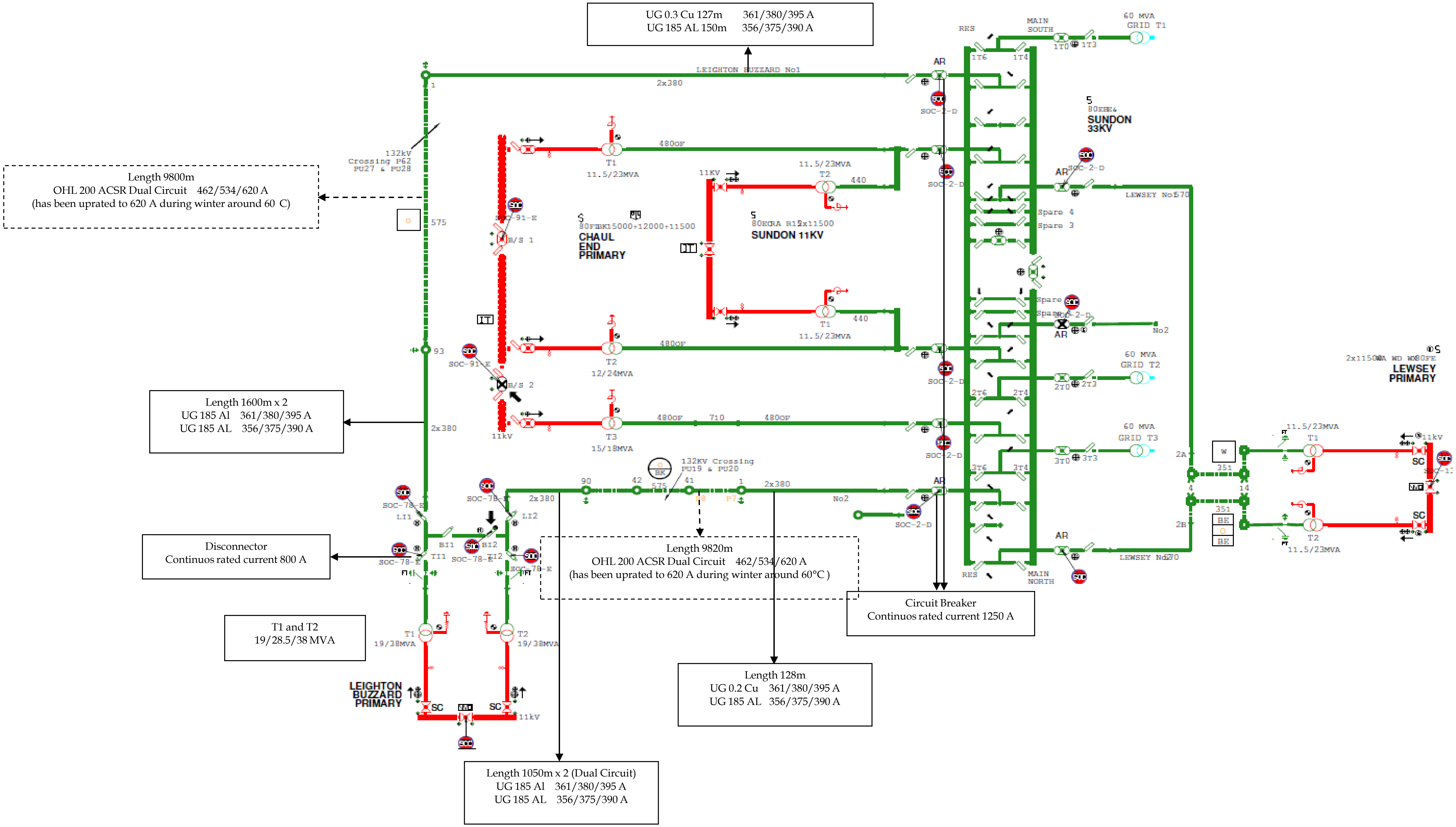
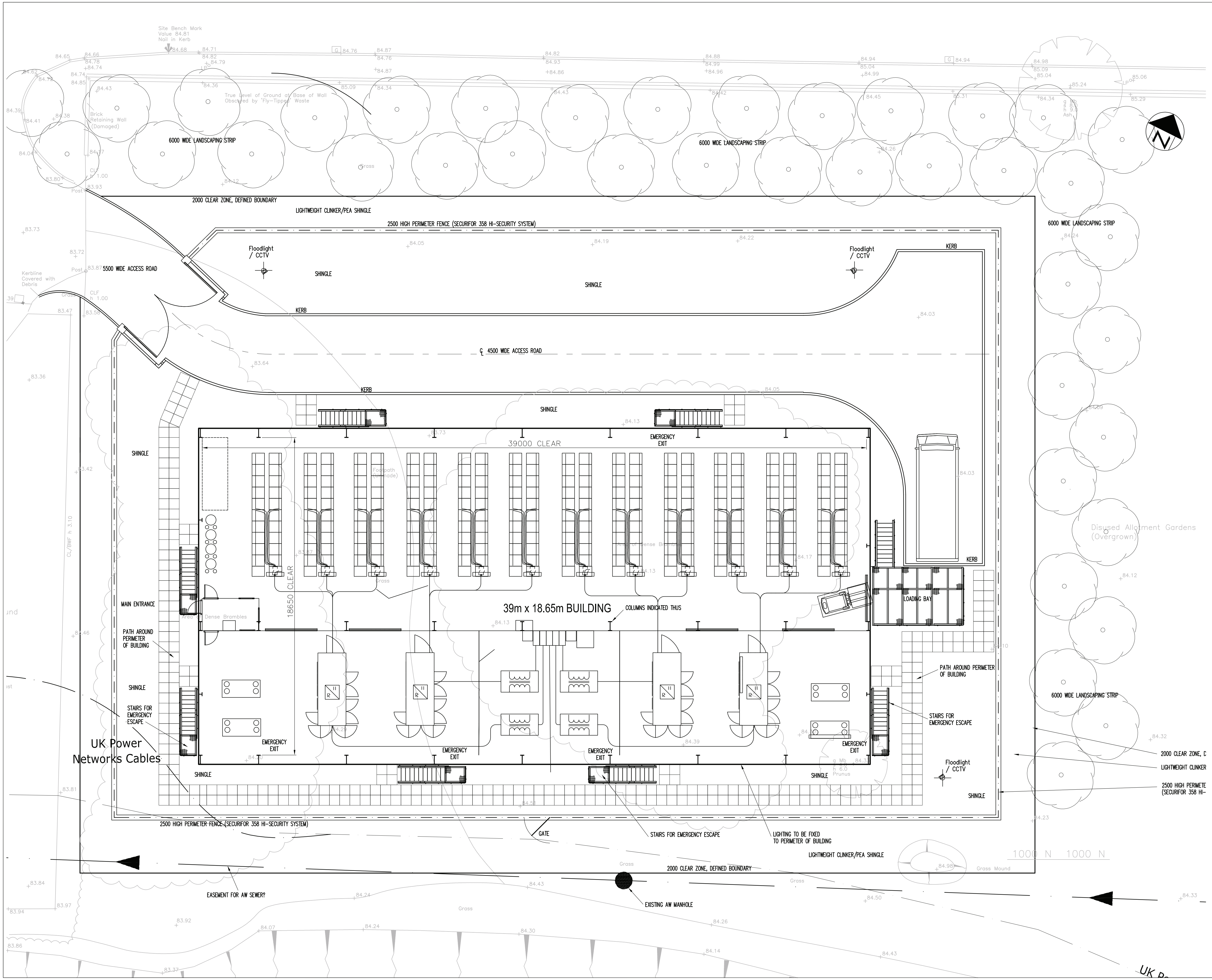


FIGURE B2 - Line Diagram of Leighton Buzzard Primary - Sundon 11kV



NOTES

1. This drawing is to be read in conjunction with all relevant Architect's, Engineers and specialist's drawings and specifications.

2. Do not scale from this drawing manually or electronically. Written permission must be obtained from MLM prior to scaling electronically or using this electronic file.

3. All dimensions are in millimetres unless noted otherwise. All levels are in metres.

4.

CONSTRUCTION (DESIGN AND MANAGEMENT) REGULATIONS 2007

DESIGNERS HAZARD INFORMATION FOR CONSTRUCTION

1. If you do not fully understand the risks involved during the construction of the items indicated on this drawing ask your manager, health & safety advisor or a member of the design team before proceeding.

The above notes refer specifically to the information shown on this drawing.

Refer to the Health and Safety plan for further information.

Version	Date	Description	Drn.
A	9/07/12	Updated to suit A123 drawing	IH

MLM
Multidisciplinary Consulting
25, London Road, Ipswich, Suffolk IP1 2HF
Tel: 01473 231100 Fax: 01473 231515
Website: www.mlm.uk.com

UK Power Networks

TITLE
SITE PLAN

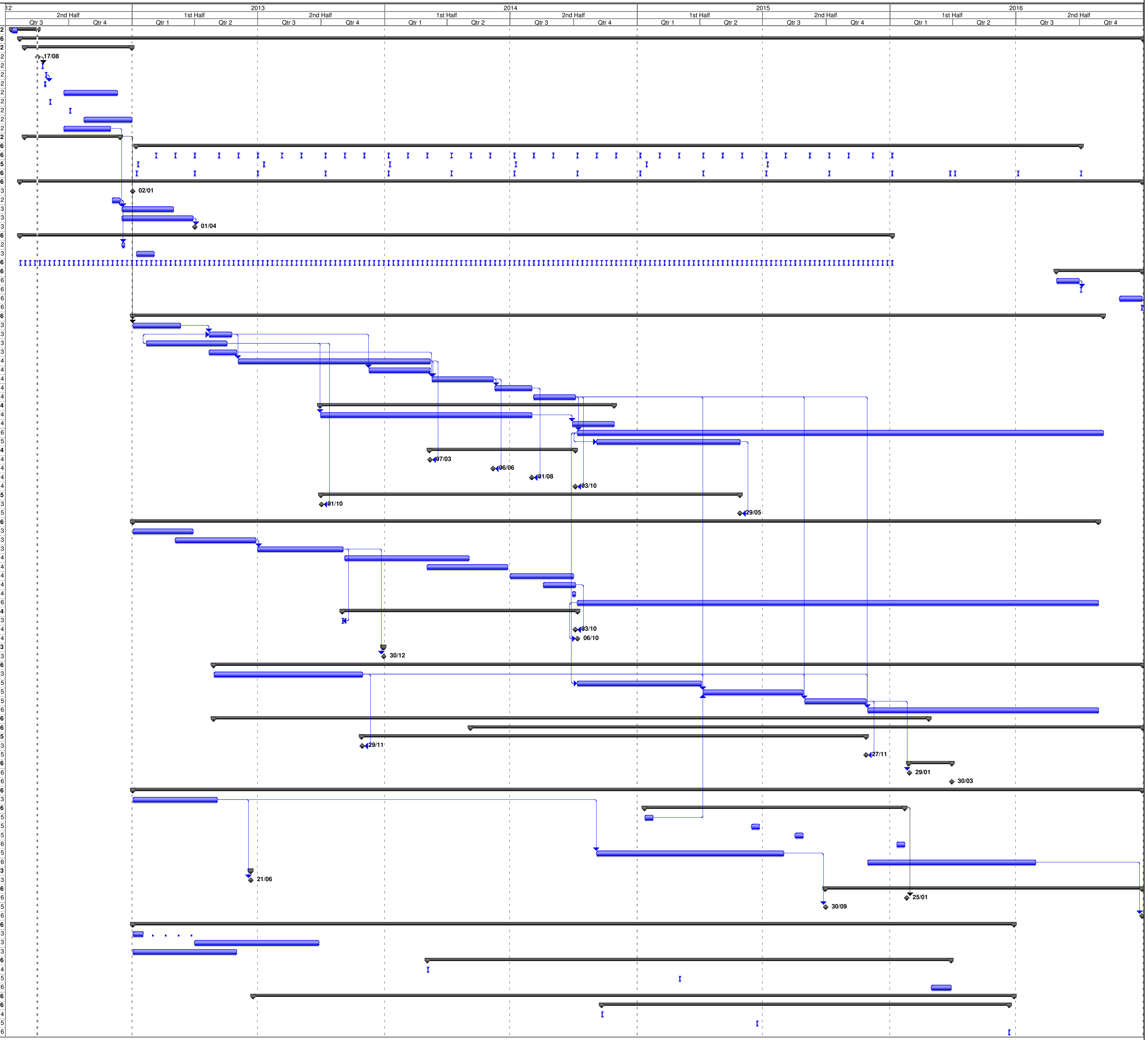
SCALE 1:100@ A1 | CONCEPT | Checked IH XX/12 | Approved IH XX/12

DRAWING NO. 614673/sk02 | Version A

SITE LEIGHTON BUZZARD ENERGY STORAGE SCHEME

APPENDIX C - PROJECT PLAN

ID	Task Name	Duration	Start	Finish
1	**Smarter Network Storage Bid Submission**	**28 days**	**Wed 11/07/12**	**Fri 17/08/12**
52	**Post Submission**	**1160 days**	**Mon 23/07/12**	**Sat 31/12/16**
53	**Pre Award Activities**	**111 days**	**Mon 30/07/12**	**Mon 31/12/12**
54	Submit Proforma to Ofgem	1 day	Fri 17/08/12	Fri 17/08/12
55	Post submission review of leasson learnt	1 day	Fri 24/08/12	Fri 24/08/12
56	Early Bilateral meeting with Expert Panel	1 day	Wed 29/08/12	Wed 29/08/12
57	Early Bilateral meeting preperation	2 days	Mon 27/08/12	Tue 28/08/12
58	Investigate further external funding channels	56 days	Mon 24/09/12	Mon 10/12/12
59	Meeting with Ofgem consultants	1 day	Tue 04/09/12	Tue 04/09/12
60	Full bilateral meeting with Expert Panel	1 day	Wed 03/10/12	Wed 03/10/12
61	Initiate drafting of delivery contracts	50 days	Tue 23/10/12	Mon 31/12/12
62	Confirm resource plan and create job descriptions	50 days	Mon 24/09/12	Fri 30/11/12
63	**Civils, Tendering and Planning Permission**	**100 days**	**Mon 30/07/12**	**Fri 14/12/12**
67	**Project Governance**	**976 days**	**Mon 07/01/13**	**Mon 03/10/16**
68	**Project Internal Steering Group (Monthly)**	**761 days**	**Mon 04/02/13**	**Mon 04/01/16**
105	**Project Progress Report (6 Monthly)**	**651 days**	**Wed 09/01/13**	**Wed 08/07/15**
112	**Project Forums (Quarterly Partner Meetings)**	**976 days**	**Mon 07/01/13**	**Mon 03/10/16**
130	**Project Management**	**1160 days**	**Mon 23/07/12**	**Fri 30/12/16**
131	Project kick off	0 days	Wed 02/01/13	Wed 02/01/13
132	Project governance and controls in place	10 days	Mon 03/12/12	Fri 14/12/12
133	Project team mobilisation & resourcing	55 days	Mon 17/12/12	Fri 01/03/13
134	Development of SNS Project Handbook	75 days	Mon 17/12/12	Fri 29/03/13
135	SNS Project Handbook Complete	1 day	Mon 01/04/13	Mon 01/04/13
136	**Project Planning**	**901 days**	**Mon 23/07/12**	**Mon 04/01/16**
137	Review of bid submission plan	4 days	Mon 17/12/12	Thu 20/12/12
138	Phase 1 Detailed Work Stream Plans	20 days	Mon 07/01/13	Fri 01/02/13
139	**Project plan review, update and creation of further stages (Weekly)**	**901 days**	**Mon 23/07/12**	**Mon 04/01/16**
321	**Project Closure**	**90 days**	**Mon 29/08/16**	**Fri 30/12/16**
322	Prepre Ofgem project close-down report	25 days	Mon 29/08/16	Fri 30/09/16
323	Ofgem project close-down report submission	1 day	Mon 03/10/16	Mon 03/10/16
324	Project closure	25 days	Mon 28/11/16	Fri 30/12/16
325	Project completed	1 day	Fri 30/12/16	Fri 30/12/16
326	**WS1 Energy Storage Hardware**	**1003 days**	**Wed 02/01/13**	**Fri 04/11/16**
327	Technology Contract Award	49 days	Wed 02/01/13	Mon 11/03/13
328	Procurement of Civils & Electricals, Long-lead time items	25 days	Mon 22/04/13	Fri 24/05/13
329	Design Finalisation & Approval	85 days	Mon 21/01/13	Fri 17/05/13
330	Site Works Phase 1 - Setup	30 days	Mon 22/04/13	Fri 31/05/13
331	Site Works Phase 1 - Civils Works	200 days	Mon 03/06/13	Fri 07/03/14
332	Site Works Phase 1 - Electricals	65 days	Mon 09/12/13	Fri 07/03/14
333	Site Works Phase 2 - A123 Installations	65 days	Mon 10/03/14	Fri 06/06/14
334	Site Works Phase 2 - A123 Testing	40 days	Mon 09/06/14	Fri 01/08/14
335	Site Works Phase 3 - Final Connections & Finishing	45 days	Mon 04/08/14	Fri 03/10/14
336	**Operational Preparedness & Training**	**305 days**	**Mon 30/09/13**	**Fri 28/11/14**
337	Engineering & Safety Documentation	220 days	Mon 30/09/13	Fri 01/08/14
338	Training	45 days	Mon 29/09/14	Fri 28/11/14
339	Operation / Maintenance Phase	545 days	Mon 06/10/14	Fri 04/11/16
340	Studies - Storage as an Asset	150 days	Mon 03/11/14	Fri 29/05/15
341	**Key Milestones**	**151 days**	**Fri 07/03/14**	**Fri 03/10/14**
342	Main civils works finished	1 day	Fri 07/03/14	Fri 07/03/14
343	Equipment Installed	1 day	Fri 06/06/14	Fri 06/06/14
344	A123 Equipment Commissioned	1 day	Fri 01/08/14	Fri 01/08/14
345	Step-up Tx commissioned and System Energised	1 day	Fri 03/10/14	Fri 03/10/14
346	**SDRC'S**	**434 days**	**Tue 01/10/13**	**Fri 29/05/15**
347	**SDRC 9.1 - Design & Planning Considerations for large-scale energy storage**	1 day	Tue 01/10/13	Tue 01/10/13
348	**SDRC 9.4 - Energy Storage as an Asset**	1 day	Fri 29/05/15	Fri 29/05/15
349	**WS2 - Smart Optimisation, Control & Integration**	**998 days**	**Wed 02/01/13**	**Fri 28/10/16**
350	Delivery contract development & award	63 days	Wed 02/01/13	Fri 29/03/13
351	Requirements Gathering and Scope 2.1	85 days	Mon 04/03/13	Fri 28/06/13
352	Design 2.2	90 days	Mon 01/07/13	Fri 01/11/13
353	Development 2.3	130 days	Mon 04/11/13	Fri 02/05/14
354	System Testing	85 days	Mon 03/03/14	Fri 27/06/14
355	Integration and Testing 2.4	66 days	Tue 01/07/14	Tue 30/09/14
356	Training 2.5	35 days	Mon 18/08/14	Fri 03/10/14
357	Go-Live Preparation 2.6	5 days	Mon 29/09/14	Fri 03/10/14
358	Operational Phase 2.7	540 days	Mon 06/10/14	Fri 28/10/16
359	**Key Milestones**	**242 days**	**Fri 01/11/13**	**Mon 06/10/14**
360	Delivery of Algorithm and Engine designs	1 day	Fri 01/11/13	Fri 01/11/13
361	Delivery of training sessions for operating Opt & Control System	1 day	Fri 03/10/14	Fri 03/10/14
362	System Go-Live Date	1 day	Mon 06/10/14	Mon 06/10/14
363	**SDRC'S**	**1 day**	**Mon 30/12/13**	**Mon 30/12/13**
364	**SDCR 9.2 - Confirmation of the Smart Optimisation & Control System design**	1 day	Mon 30/12/13	Mon 30/12/13
365	**WS3 Storage Value Streams, Services & Trials**	**960 days**	**Mon 29/04/13**	**Sat 31/12/16**
366	Identify & Assess Storage applications & Services, Trail Plans & Designs 3.1	155 days	Mon 29/04/13	Fri 29/11/13
367	DNO Service Demonstration & Validations 3.2	130 days	Mon 06/10/14	Fri 03/04/15
368	Ancillary Service Demonstrations 3.3	105 days	Mon 06/04/15	Fri 28/08/15
369	Wholesale Market Demonstrations 3.4	65 days	Mon 31/08/15	Fri 27/11/15
370	Optimised / Integrated Service Demonstrations 3.5	240 days	Mon 30/11/15	Fri 28/10/16
371	**Imperial Studies**	**740 days**	**Mon 29/04/13**	**Fri 26/02/16**
380	**STOR Seasons & Key Dates**	**695 days**	**Mon 05/05/14**	**Sat 31/12/16**
434	**Key Milestones**	**521 days**	**Fri 29/11/13**	**Fri 27/11/15**
435	Test plan, including scenario testing complete	1 day	Fri 29/11/13	Fri 29/11/13
436	Completion of individual service trials	1 day	Fri 27/11/15	Fri 27/11/15
437	**SDRC'S**	**44 days**	**Fri 29/01/16**	**Wed 30/03/16**
438	**SDRC 9.6 - Analysis of integrated energy storage contribution to security of s**	1 day	Fri 29/01/16	Fri 29/01/16
439	**SDRC 9.7 - Successful demonstrations of storage value streams**	1 day	Wed 30/03/16	Wed 30/03/16
440	**WS4 Commercial & Regulatory Frameworks**	**1043 days**	**Wed 02/01/13**	**Fri 30/12/16**
441	Project setup - Commercials Requirements 4.1	88 days	Wed 02/01/13	Fri 03/05/13
442	**Identify and Manage Commercial Arrangements 4.2**	**270 days**	**Mon 12/01/15**	**Fri 22/01/16**
443	Tender Preperation 1	10 days	Mon 12/01/15	Fri 23/01/15
444	Tender Preperation 2	10 days	Mon 15/06/15	Fri 26/06/15
445	Tender Preperation 3	10 days	Mon 17/08/15	Fri 28/08/15
446	Tender Preperation 4	10 days	Mon 11/01/16	Fri 22/01/16
447	Regulatory & Legal Review 4.3	195 days	Mon 03/11/14	Fri 31/07/15
448	Operating & Ownership Models 4.4	175 days	Mon 30/11/15	Fri 29/07/16
449	**Key Milestones**	**1 day**	**Fri 21/06/13**	**Fri 21/06/13**
450	Business case model templates shared for consultation	1 day	Fri 21/06/13	Fri 21/06/13
451	**SDRC'S**	**328 days**	**Wed 30/09/15**	**Fri 30/12/16**
452	**SDRC 9.3 - Commercial arrangements for integrated use of flexibility**	1 day	Mon 25/01/16	Mon 25/01/16
453	**SDRC 9.5 - Evolution of Regulatory and Legal Arrangements for energy stora**	1 day	Wed 30/09/15	Wed 30/09/15
454	**SDRC 9.8 - Full Evaluation of the SNS Solution**	1 day	Fri 30/12/16	Fri 30/12/16
455	**WS5 - Learning Capture, Engagement & Dissemination**	**910 days**	**Wed 02/01/13**	**Tue 28/06/16**
456	Development of Knowledge Dissemination Roadmap	11 days	Wed 02/01/13	Fri 29/03/13
457	Develop project website	130 days	Mon 01/04/13	Fri 27/09/13
458	Local Stakeholder Engagement	108 days	Wed 02/01/13	Fri 31/05/13
459	**Project Annual Seminars**	**541 days**	**Tue 04/03/14**	**Tue 29/03/16**
460	2014	1 day	Tue 04/03/14	Tue 04/03/14
461	2015	1 day	Tue 03/03/15	Tue 03/03/15
462	2016	21 days	Tue 01/03/16	Tue 29/03/16
463	**LNCF Conferences**	**786 days**	**Tue 25/06/13**	**Tue 28/06/16**
468	**Facility visits / tours**	**421 days**	**Tue 11/11/14**	**Tue 21/06/16**
469	Tour 1	1 day	Tue 11/11/14	Tue 11/11/14
470	Tour 2	1 day	Tue 23/06/15	Tue 23/06/15
471	Tour 3	1 day	Tue 21/06/16	Tue 21/06/16



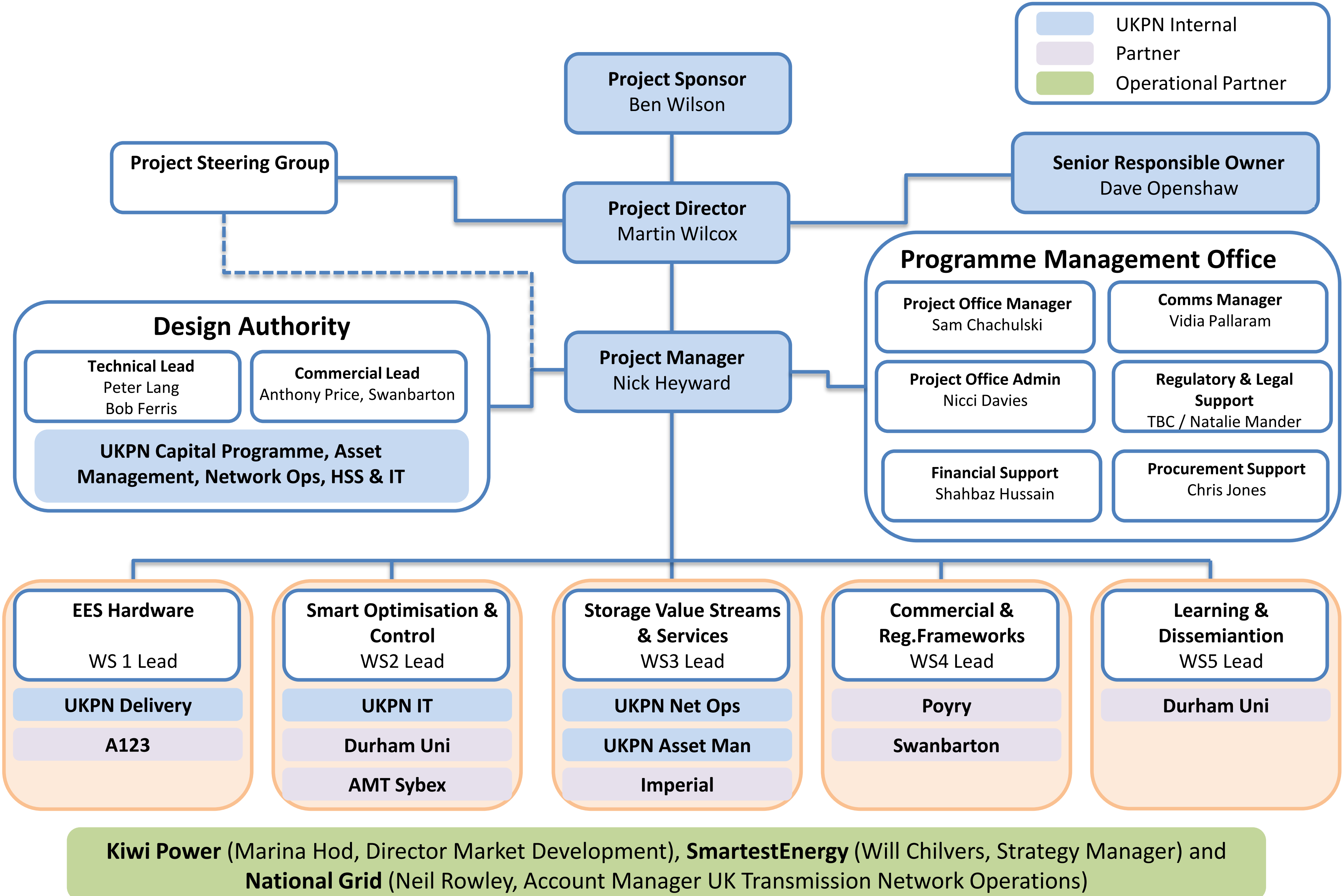
Project: &Project Plan v1.3
Date: Thu 16/08/12

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

APPENDIX D - RISK REGISTER

AREA	REF NO.	OVERALL RISK STATUS	RISK & IMPACT DESCRIPTION	DATE RAISED	RISK OWNER	PROBABILITY	MITIGATING ACTIONS	SEVERITY
CIVILS	R0001	On track	The building is not delivered on time.	25/07/12	ST	10%	Regular progress meetings/reports to track progress and highlight/remove potential issues. Use standard Networks design policies and procedures, where possible.	3
CIVILS	R0002	On track	The building is not delivered to specification resulting in rework and cause delays.	08/08/12	PL	15%	Regular design meetings/reports to ensure strict change control. Key stakeholder engagement to ensure compliance with UK Power Networks design policies and procedures. Rework to be completed at the contractors expense.	2
DESIGN	R0003	On track	A123 do not produce designs are acceptable to UKPN Asset Management, which will result in re-design and delays.	23/07/12	PL	10%	Asset Management were involved in the tendering process. Early stakeholder engagement, including A123, sessions are planned for Q3 2012 to ensure the design(s) are acceptable and meet all requirements.	2
EQUIPMENT	R0005	On track	The installed storage technology fails and needs to be disconnected from the network whilst being repaired/replaced.	04/04/12	PL	5%	Close collaboration with A123 to ensure the design meets UKPN specification and standards through robust testing (maintenance & training delivered by A123). Replacement parts are to be made easily available. With a regular maintenance cycle.	3
EQUIPMENT	R0006	On track	Operational and Health and Safety procedures are not approved for use of the Storage device, so UKPN staff are unable to operate the equipment.	24/07/11	PL	10%	Engage with UK Power Networks' Health, Safety Sustainability and Technical Training team to design suitable and approved policies and procedures.	2
EQUIPMENT	R0007	On track	The installed storage technology has a catastrophic failure, which adversely affects customers supplies and needs to be disconnected from the network resulting in project delays.	28/07/12	PL	15%	Close collaboration with A123 to ensure the design meets UKPN specification and standards through robust testing (maintenance & training delivered by A123). Carry out a full set of test to minimise the possibility failure and affect upon customers.	4
EQUIPMENT	R0008	On track	Another A123 storage battery fails with severe consequences before the device has been commissioned. Results in limited confidence in the equipment and delays whilst further testing takes place.	31/07/12	PL	10%	Monitor defects and issue reports supplied by A123 for existing installs.	3
EQUIPMENT	R0009	On track	A123 reliance on single factory source - resulting in delays in delivering of the storage device.	31/07/12	PL	20%	Through the tendering and contractual negotiations, ensure A123 are able to meet the project delivery timelines. Include penalty clauses within their contact.	3
EQUIPMENT	R0010	On track	A123 go out of business before any payment has been made for the storage device, leading to project delays.	07/08/12	MW / NH	10%	Carry out full financial diligences checks in line with approved standards of practice and the UKPN procurement procedure(s). Identify alternative supplier(s).	3
EQUIPMENT	R0011	On track	A123 go out of business after payment has been made for the storage device, but has it not been delivered, leading to project delays and lost money.	08/08/12	MW	10%	Carry out full financial diligence checks in line with approved standards of practice and the UKPN procurement procedure(s). Negotiate the transfer title of the device.	4
EQUIPMENT	R0012	On track	A123 go out of business after the storage device has been paid for and delivered, resulting in lack of continuity and covers should the unit fail.	08/08/12	PL	10%	Carry out full financial diligence checks in line with approved standards of practice and the UKPN procurement procedure(s). Arrange a software ESCROW and novation of liabilities to OEMS.	3
EQUIPMENT	R0013	On track	Another A123 storage battery fails with severe consequences after the UKPN device has been commissioned, resulting in limited confidence in the device, so it is disconnected until all test have been completed.	08/08/12	PL	10%	A full set of quality tests to be completed before installation, with the design and operation meeting the UKPN requirements. Ensuring full confidence in the equipment installed. Monitor defects and issue reports supplied by A123 for existing installs.	3
EQUIPMENT	R0014	On track	The installed storage technology causes damages UKPN Asset(s), so needs to be disconnected from the network whilst issues are resolved causing delays to the project.	08/08/12	PL	10%	Carry out a full set of test to minimise the possibility of failure. Close collaboration with A123 to ensure the design meets UKPN specification and standards through robust testing (maintenance & training delivered by A123). Replacement parts are to be made easily available. With a regular maintenance cycle.	3
EQUIPMENT	R0015	On track	Equipment is stolen or vandalised whilst on site, but not commissioned.	08/08/12	NH /MW	25%	Improve security at the site with a manned presence.	3
EQUIPMENT	R0016	On track	Equipment is stolen or vandalised after commissioning, requires repairs , so reduces the time to realise benefits.	08/08/12	NH /MW	15%	Improve security at the site with a manned presence.	3
EQUIPMENT	R0017	On track	The storage device is not commissioned on time causing project delays.	08/08/12	PL	10%	Regular progress meetings/reports to track progress against the plan.	2
EQUIPMENT	R0018	On track	The storage device does not perform to specification, so not all benefits are realised.	08/08/12	PL	10%	Regular design meetings/reports. Key stakeholder engagement to ensure specification can comply with UK Power Networks design policies and procedures.	3
EQUIPMENT	R0019	On track	When shipping the storage device from A123's factory in America to the England, the device is damaged beyond causing delays to the project.	08/08/12	NH /MW	10%	Use proven safe method's of shipping the device from America and consult with UKPN Insurance manager to ensure appropriate/adequate levels of insurance are in place.	3
EQUIPMENT	R0020	On track	Site load growth exceeds expectations, pushing peak demands beyond the spare capacity range of the battery.	08/08/12	PL	5%	Detailed load studies to understand maximum demand and future increases. Additional storage provision has been included within the design to allow for capacity to be increased to 24MWh.	4
EQUIPMENT	R0021	On track	A123 is critically dependant upon re-financing by October 2012.	10/08/12	MW	20%	Review information from ITT to identify alternative suppliers, updating them with developments on the project.	4
IT	R0022	On track	The optimisation platform can not be delivered in time , causing delays.	08/08/12	DS	10%	Regular progress meetings/reports to track progress against the plan.	2
PROJECT	R0025	On track	Final Funding may not be awarded. Therefore, the project would not be able to be carried out from 2013.	01/02/12	NH	20%	Ensure quality bid submission through regular review, clear differentiation and stakeholder engagement.	3
PROJECT	R0026	On track	The lack of available technical, commercial and project resources available , result in delays in project delivery.	24/07/11	MW	10%	Resourcing plan completed during resources within UKPN / Future Networks.	2
PROJECT	R0027	On track	Site load growth declines or extremely mild winters mean network constraint limits are not met, meaning full capabilities of the storage are not utilised.	27/07/12	PL	10%	Trials include a range of demonstrations based on artificial or future scenarios.	3
PROJECT	R0028	On track	The optimisation platform can not be developed to specification and cost , causing delays to the optimised trials.	27/07/12	DS	10%	Continued dialogue with the IT partner and UKPN IT to ensure scope and requirements are fully understood and achievable in advance of project start.	3
PROJECT	R0029	On track	Unfavourable changes in legislation or market arrangements that restricts on the usage and reduces the identified benefits.	31/07/12	NH	15%	The project has been scoped to look at multiple ownership / operational structures, so should be robust to legislative changes.	4
PROJECT	R0030	On track	Resource availability during the life cycle of the project resulting in delays.	08/08/12	MW	10%	Provide adequate notice when planning meetings, workshops and events. Resource pooling within Future Networks.	2
SITE	R0032	On track	Planning permission prevents build of storage unit at chosen site, resulting in delays.	01/02/12	PL	15%	Identified a suitable alternative site at March Grid.	2
SITE	R0033	On track	Local opposition to building the storage facility causes both delivery timescales being extended and reputational damage.	25/07/12	NH	15%	External stakeholder engagement to be conducted prior and throughout the project to ensure concerns are managed appropriately.	4
SITE	R0034	On track	The site is not fit for purpose, requires additional work i.e. high stilts causing project delivery delays.	25/07/12	PL	10%	Complete full suite of environmental surveys i.e. flood risk, archaeological, contaminated land etc.	3
SITE	R0035	On track	Planning permission prevents the building of a storage unit at March Grid, resulting in delays to contingency site.	26/07/12	PL	10%	Do not launch additional planning permission, given the cost to customers. Monitor progress regularly.	3
SITE	R0036	On track	There is significant flooding at the site whilst building works are taking place causing damage and delays.	08/08/12	PL	15%	Put temporary protection place to stop significant flooding of the site.	3
SITE	R0037	On track	Planning permission is not granted at Leighton Buzzard and the suitable alternative site(s) do not have any approved NAMP expenditure.	10/08/12	MW	10%	Complete full suite of environmental surveys i.e. flood risk, archaeological, contaminated land etc and exhaust all possible options to ensure the Leighton Buzzard Grid is used.	3
STAKEHOLDER	R0038	On track	At the bid stage the appropriate UKPN staff do not engage adequately or in a timely manner with the Project. Resulting in poor engagement and delays in getting internal buy in for the project.	24/07/11	SC	5%	All relevant governance panels informed and have authorised the work. Additional stakeholder events to be held in Q3 2012.	2
STAKEHOLDER	R0039	On track	During the project delivery stage the appropriate UKPN staff do not engaged adequately or in a timely manner with the Project. Resulting in poor engagement and delays.	25/07/12	NH	5%	Design and implement a robust internal and external stakeholder road map to identify all the key stakeholders.	2
SUPPLIERS	R0040	On track	Commercial arrangements with Smartest, National Grid and KiwiPower are not acceptable to all parties resulting in delays.	01/02/12	NH	5%	Strong engagement and collaborative working with partners. Put in place strong commercial agreements.	3
SUPPLIERS	R0041	On track	Project partner(s) withdrawing their participation in the SNS project at the start of the project, leading to delays.	24/07/11	NH	10%	Strong engagement and collaborative working with partners.	3
SUPPLIERS	R0042	On track	Delay in delivery of hardware or software from partners and contractors cause delays.	25/07/12	NH	20%	Full continual engagement with partners, with penalties clauses included for late delivery. Contingency has been built into well designed plans.	3
SUPPLIERS	R0043	On track	Key Project partner(s) withdraw their participation in the SNS project during the project has started, leading to delays.	08/08/12	NH	15%	Tender process was carried out for several projects aspects and provides alternatives therefore reduces this risk.	3

APPENDIX E - ORGANOGRAM



APPENDIX F – PROJECT PARTNER INFORMATION

Organisation	AMT SYBEX
Organisation Type / Description	Software Supplier
Relationship to DNO (if any)	AMT-SYBEX has an existing supply relationship with UK Power Networks for a range of data management and software services relating to its field force and asset management functions.
Role Summary	AMT-SYBEX has been selected to develop, deploy and test the Smart Optimisation and Control platform for the project.
What does AMT SYBEX bring to SNS?	AMT-SYBEX has over 20 years experience in providing leading-edge software solutions to the energy sector that cover a range of Generation, Transmission, Distribution and Retail requirements. They will use their Affinity Suite of data management software that is already deployed in the sector as the base for the Smart Optimisation and Control solution.
Funding	AMT SYBEX are providing preferential rates to the project for the integration and testing of the software. In addition they are providing all product development of their foundation Affinity suite of products at no cost, and a reduction in ongoing licensing costs. This equates to an overall contribution of approximately 25% to these components.
Contractual Relationship	An MoU has been signed between UK Power Networks and AMT SYBEX.
External Collaborator benefits from the Project	As a result of the involvement in this project AMT SYBEX expects to gain knowledge of the leading edge thinking around optimised dispatch and scenario modelling to build on its existing ideas in this field. AMT SYBEX hopes to develop a greater view of the detailed requirements that each user (storage owner, network operator, supplier etc.) might have in terms of visibility and control of network devices. AMT SYBEX also wish to gain a view of the monitoring, modelling and feedback required on the local electrical network for the network operator to be able to use an IT based system in an automated or semi-automated manner with absolute confidence that it would maintain security of supply.

Organisation	Imperial College London
Organisation Type / Description	University
Relationship to DNO (if any)	Imperial College provide a number of academic research services for a range of innovation and load forecasting projects at UK Power Networks.
Role Summary	Imperial College will design and deliver a number of studies and models to assess the long-term technical and commercial benefits of storage within a distribution network including: • Development of recommendations on how energy storage could be included in future network design methodologies and future versions of P2/6. • Modelling and assessment of the conflicts and synergies in the use of storage for multiple applications. The model will be validated and informed by operational trials. • Modelling and analysis of strategic approaches to managing storage for multiple applications. • Design and development of tools to facilitate the optimum sizing of storage for distribution network planners.
What does Imperial College London bring to SNS?	Imperial College's research group has extensive, internationally recognised experience in analysing, modelling and optimising electricity systems, with particular emphasis on future systems characterised by intermittent renewable generation, electrified transport and heat demand, and high penetrations of distributed generation. Imperial has been involved in a number of UK and EU projects looking at various aspects of flexible balancing technologies and their impact on the performance of future low-carbon systems, most recently in reports to the Carbon Trust and DECC.
Funding	Imperial will provide preferential rates for the project that equate to a contribution of 35% towards the costs of this aspect of the project.
Contractual Relationship	An MoU has been signed between UK Power Networks and Imperial College
External Collaborator	Imperial College will benefit from this project through enhancing its understanding of how distribution connected storage can impact future

benefits from the Project	networks. Imperial will enhance its reputation as an organisation that provides first class analysis and modelling of future networks and the impact that new low-carbon technologies may have upon them.

Organisation	KiWi Power Limited
Organisation Type / Description	Storage Operator
Relationship to DNO (if any)	Previous discussions relating to aggregator services to the Low Carbon London LCNF project.
Role Summary	KiWi Power will provide ancillary services management for UKPN, being the main interface with National Grid when the storage device is providing ancillary services and completing the necessary reporting and management of delivery.
What does KiWiPower bring to SNS?	KiWi Power will build upon experience as a leading aggregator of demand response flexibility.
Funding	KiwiPower will provide time and resources into the project at no cost, but will recover costs through a proportion of ancillary income.
Contractual Relationship	An MoU has been signed between UK Power Networks and KiWi Power.
External Collaborator benefits from the Project	KiWi Power is focused on providing aggregator services mainly to Demand Side Response in the form of turndown or distributed generation. This will be a unique opportunity for KiWi Power to gain valuable experience working with another technology (storage), and learning what it would take to operate this technology in multiple markets. This could help KiWi Power offer new products and services, and expand its presence in the UK energy markets.

Organisation	National Grid
Organisation Type / Description	System Operator
Relationship to DNO (if any)	UK Power Networks and National Grid have many statutory and consultative interfaces; however no existing relationship in respect of Leighton Buzzard or SNS.
Role Summary	National Grid will provide guidance and advice in identifying ancillary service opportunities for storage, in so far as is consistent with non-discrimination policies. National Grid will also be one of the potential buyers of services from the network storage device (Short-term Operating Reserve, Frequency Support etc.) with any such procurement occurring as part of their normal activities in balancing the GB system. National Grid will also support the development of proposals to suggest modifications to future service design, and the relevant industry codes to facilitate a larger role for distribution connected storage.
What does National Grid bring to SNS?	National Grid is a key operational partner. As a potential purchaser of several services, National Grid will be pivotal in helping the project manage the potential conflicts between shared usage between National Grid, the DNO and the energy market. In addition National Grid will assist in the design of appropriate commercial conditions whose aim would be to facilitate the entry of distribution connected storage into the GB electricity market, whilst ensuring a non-discriminatory approach to existing providers.
Funding	National Grid will provide all time and resources involved in providing guidance and advice towards the project at no cost.
Contractual Relationship	A Partner Agreement has been signed between UK Power Networks and National Grid, agreeing principles of collaboration for the project.
External Collaborator benefits from the Project	National Grid will benefit from the success of this project by having the opportunity to experience a new type of balancing service provider. Currently there is no storage-based ancillary services provider, apart from hydro-electric plant. The project will help National Grid understand the capabilities and benefits of energy storage and how future arrangements could be designed to facilitate the shared utilisation of assets for the benefit of customers.

Organisation	Pöyry Management Consulting
Organisation Type / Description	Specialist Engineering and Management Consultancy
Relationship to DNO (if any)	None
Role Summary	Pöyry Management Consulting will deliver market and regulatory expertise to assess what changes will be needed to the regulatory framework(s) to allow the large scale adoption of storage technologies by DNOs. Pöyry will also assist with the provision of analytical and modelling services to assess the potential of each of the commercial models being trialled as part of this project.
What does Pöyry Management Consulting bring to SNS?	Pöyry offers in-depth modelling capability for the full electricity sector value chain, including networks and storage, which enables modelling of future energy scenarios taking into account the impact of intermittency among other economic factors. Pöyry brings significant market design expertise with a deep understanding of the market arrangements in GB, covering legislation, licences, industry codes and subsidiary documents.
Funding	Pöyry will be providing services to the project at rates markedly below standard government and private sector client rates, fixed at 2012 prices for the duration of the project. This represents a contribution of around 15% towards this aspect of the project.
Contractual Relationship	A framework contract for consultancy services is in place between UK Power Networks and Pöyry Management Consulting and an MoU extending the services throughout the bid phase and into project delivery has been signed.
External Collaborator benefits from the Project	Participation in the Smarter Network Storage consortium will provide Pöyry with an excellent storage project implementation case study to validate and build upon its existing thought leading analysis of storage benefits and issues within a future 'smart' UK energy sector. As a thought-leader on smart energy issues, Pöyry is engaged with a range of stakeholders across Europe to deliver insights which directly affect policy frameworks, and market developments at national and pan-European levels, so this project will provide unique best practice insights which can be disseminated in both the UK and across other EU countries. Thus overall Pöyry can use the insights from this project to provide validated clear and detailed practical insights to policy makers and industry stakeholders, enabling greater benefits to be realised for end customers in UK and Europe from decarbonisation of the energy sector.

Organisation Name	SmartestEnergy
Organisation Type / Description	Independent Energy Supplier (non 'Big-6')
Relationship to DNO (if any)	No prior relationship
Role Summary	SmartestEnergy will provide the route to wholesale markets, providing pricing information to allow service decisions to be made and reconciliation in the market. SmartestEnergy will offer a number of innovative commercial routes to the market for energy from the network storage device.
What does SmartestEnergy bring to SNS?	Smartest Energy is the leading purchaser of renewable energy from the independent sector and supplies electricity to a range of business and industrial customers. As an independent company, SmartestEnergy play an increasingly important role in providing choice and flexibility in a market traditionally dominated by major energy producers and suppliers. SmartestEnergy also brings detailed first-hand experience of previous proposed storage installations which floundered due to the Problems highlighted in Section 2.
Funding	SmartestEnergy will provide direct investment of all time and resources into the project at no cost.
Contractual Relationship	An MoU has been signed between UK Power Networks and SmartestEnergy
External Collaborator benefits from the Project	SmartestEnergy will benefit by gaining an insight into the commercial potential and market based optimisation of a storage asset

Organisation	Swanbarton Limited
Organisation Type / Description	Consultancy specialising in electricity storage
Relationship to DNO (if any)	None
Role Summary	General support to the overall development of the project and specialist support in energy storage concepts, design, hardware and operation.
What does Swanbarton Limited bring to SNS?	Swanbarton Limited is a specialist electrical energy storage consultancy services provider and has been active in the electricity storage arena for twenty years. Swanbarton has experience in market analysis, energy storage applications, costs, planning, contractual and regulatory frameworks gained from its own research and from participation in many projects of various sizes in the UK and overseas. The company therefore brings first-hand experience of previous proposed installations and the business case challenges that will be analysed and tackled in the project.
Funding	Swanbarton is providing services to the project at a significantly discounted consultancy rate, equating to a contribution of approximately 33% towards this compenent.
Contractual Relationship	A framework contract for consultancy services is in place between UK Power Networks and Swanbarton, and an MoU extending the services throughout the bid phase and into project delivery has been signed.
External Collaborator benefits from the Project	This project matches Swanbarton's skills and experience in the planning and delivery of large scale grid connected electricity storage, with the requirements of the DNO to initiate, plan and install an electrical energy storage system in conjunction with a novel application and new commercial and regulatory structures. Swanbarton aims to develop its consultancy business further within the concept of the "smarter power network" and will be able to learn from the direct experience of this large scale project, which involves a number of participants across the electricity value chain. In the constantly evolving world of network development, contact with project teams will bring benefits through knowledge transfer and exchange.

Organisation	University of Durham
Organisation Type / Description	Academic Instituiton
Relationship to DNO (if any)	Currently providing research services to UK Power Networks related to distribution network connected energy storage and other innovation projects since 2007.
Role Summary	Durham will provide development of algorithms to determine optimum use of the storage device, data analysis and learning capture throughout the operational phase of the project and coordination and audit of the knowledge dissemination.
What does University of Durham bring to SNS?	Durham has developed modelling and simulation tools to research the network impact of UKPN operating the small-scale storage installed as part of LCNF project UKPNT1001. This work has led the development of a testing programme that is being implemented in the field to explore the network support services that storage can provide. Durham researchers are also currently undertaking several other projects with a storage element; including Customer Led Network Revolution with Northern Power Grid and EPSRC projects that provide channels for wider dissemination, comparison and review.
Funding	A contribution equating to a 20% reduction in the costs of resources and overheads has been provided to the project.
Contractual Relationship	An MoU has been signed between UK Power Networks and Durham University.
External Collaborator benefits from the Project	As a research organisation, Durham University will benefit from collaboration because we will be working on a project that will produce novel, internationally leading research outputs. First access to project data and the expertise of our collaborators will stimulate the ongoing research process and allow us to develop our research strengths further.

APPENDIX G – COST BENEFIT ANALYSIS

This appendix outlines in greater detail the methodology and assumptions which have been used to calculate the costs and benefits at a project-scale, and for a wider GB roll out.

1. Project Benefits

The benefits of applying the Method have been determined by quantifying the projected costs of the SNS Method once proven successful. The additional benefits that are unlocked through leveraging storage flexibility to benefit other areas of the electricity system are also then quantified, and the net costs compared with the baseline (namely, the 'Base Case' costs).

A key aim of the SNS project is to facilitate least cost decarbonisation by ensuring the value of storage is leveraged to benefit multiple layers of the electricity system. From a customer perspective, therefore, the Method costs must take into account the wider system benefits which the storage facility provides and which reduce costs elsewhere in the system once the Method has been proven successful.

These additional benefits have assumed to be:
- Benefits from the provision of reserve services to support the transmission system;
- Benefits from the provision of response services to support the transmission system;
- Benefits from the displacement of high-carbon generation capacity and associated carbon emissions
- Benefits the DNO brings to bear in the business case for storage over third-party operators (although these were excluded to account for alternative business models where storage may be owned and operated by third-parties)

The calculations relating to financial benefits therefore considered the following components:
- Base Case costs (Ct)
- Method costs (Cm)
- Method benefits - DNO perspective (Bd)
- Method benefits - Customer perspective (Bc)

Ultimately, over a given time period (assumed 10 years throughout this analysis), if:
$\mathbf{C_m - (B_d + B_c) \leq C_t}$ **;** then the Method is projected to be beneficial over that time period from a customer's perspective. This section discusses the methodology and assumptions behind each of the components listed above.

1.1.1 Base Case costs (Ct)

Leighton Buzzard primary substation has had a relatively static load demand for several years at its full capacity of 38 MVA. The organic load growth is however now increasing, and would be exacerbated by uptake of low-carbon technologies in the area such that reinforcement is required to prevent delays in accommodating this growth. The capacity available at Leighton Buzzard Primary is restricted by the rating of the 33 kV overhead lines which are rated at 33.5 MVA.

A number of potential investment options have been considered as follows:
1) Do nothing: rejected on the basis that it is not acceptable to do nothing as demand on the substation would ultimately increase beyond its EREC P2/6 capability;
2) Rebuild the overhead lines to remove the constraint: New overhead routes have been explored with landowners, but consents would not be obtainable;
3) Retain existing overhead circuits and install cable transformer feeder from Sundon Grid to a third transformer; This is currently the preferred traditional method that would be chosen by UK Power Networks; and
4) Install 132/11 kV 60 MVA Grid Substation to replace the existing Primary; This would involve expanding the existing substation, but is rejected on the grounds that it is currently a more expensive than option 3.

Option 3 is currently the most efficient method that would be chosen today and the costs of this reinforcement are calculated to be £ 8.6 million. This includes installation of an additional 18/30/40MVA 33/11kV transformer connected directly to Sundon 33kV through a new 630mm²Al underground circuit approximately 20km in length. Figure B2 in Appendix B below shows the line diagram and approximate lengths of the existing overhead line and cable routes between Sundon Grid and Leighton Buzzard.

A new 3-section 11kV board would also need to be installed in a new switchroom, as existing buildings are not large enough to accommodate a longer switchboard.

Projects such as Low Carbon London and other LCNF projects continue to explore the use of demand response as an alternative means of mitigating constraints. However further trials and learning are required to develop this solution to a point where it could be considered as a viable solution at Leighton Buzzard.

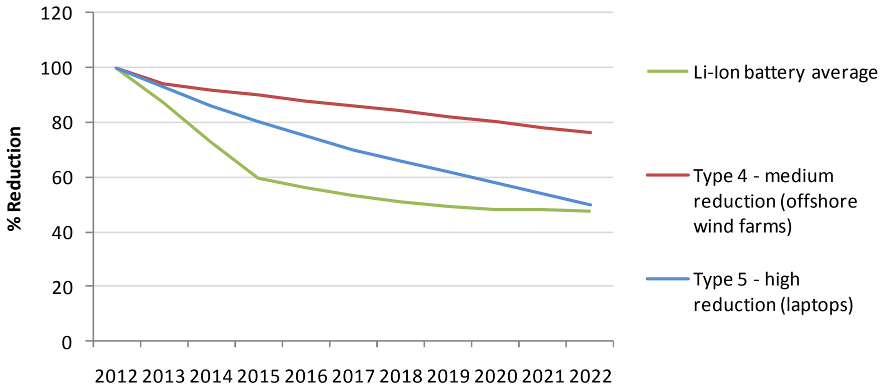
The customer mix in this area is predominantly residential and there remains uncertainty as to the magnitude and reliability of demand response achievable across this profile, which means that traditional reinforcement remains the business-as-usual solution chosen.

1.1.2 Method costs (C_m)

The Method costs represent the costs of replicating the SNS Method once the trials and concepts have been proven successful. In order to derive these it has been assumed there are savings made across the following areas:

- A significant reduction in the cost of implementing contractual frameworks for the application of the Method, as these will be a key learning outcome from the project;
- Reduced operational and maintenance costs, reflecting greater operational experience and knowledge of asset management methodologies
- No additional development costs would be required for the Smart Optimisation and Control System required to leverage multiple value streams;
- No costs for the research studies and learning and dissemination activities are required for roll-out;
- Reductions in technology costs due to continued investment in storage technology, especially within the electric vehicles industry, and additional UK deployments of energy storage;

A number of sources were used to estimate the likely technology cost reduction curves for storage, including forecasts from iSupply, Bloomberg New Energy Finance and Lux Research. The chart below shows expected reductions in price specifically for Lithium Ion technology based on blended data from these sources, in addition to two generic cost curves as used in EA Technology's recent work for WS3 of the Smart Grids Forum that are deemed appropriate for storage. Whilst there are a wide range of different storage technologies and types which will follow different cost reduction curves, we have conservatively assumed a Type-4 trajectory which is appropriate for 'new solutions, but where volumes are expected to be moderate'.



Assuming therefore a total present SNS solution cost of c.£14m; after applying the above conservative technology cost reduction curve and incorporating future estimated costs of Smart Optimisation & Control Systems and operational costs, **the estimated costs of installing and operating equivalent sized storage facilities in future deployments is £11.3 million**.

1.1.3 Method benefits - DNO perspective (B_d)

It is the intention of the SNS project to understand and validate the range of differing business models that may support energy storage. However, our hypothesis is that the nature of core activities of DNOs today means that there are a number of additional benefits that support the business case for DNOs being the owners of storage rather than third-party developers. The Method benefits from a DNO perspective include:

- the project management and efficiency savings which can be generated from having a common supply chain and not purchasing the turn-key solution;
- incorporation of enhanced knowledge and experience in the operational and maintenance requirements of battery storage into existing asset management processes and systems, leading to reduced inspection and maintenance costs; and
- no profit margin on the connection costs.

These are all benefits which would accrue to the end customer from having the DNO being the owner and operator of the storage facility. The end customer effectively makes a saving on all the asset management requirements as well as from reduced connection costs. These savings would not be available if a third-party were to own and operate the storage facility.

These operating cost savings accrued from the DNO owning and operating the asset are estimated to amount to around £3.39m over a 10 year period. However, reflecting the fact that this may not be the sole business model adopted in the future, these benefits are not included in the final calculation of the net benefit.

1.1.4 Income from Short Term Operating Reserve (STOR, B_c)

One of the services which the storage facility can provide to the system is STOR. STOR helps the TSO manage increasing real time uncertainty it faces in generation output and demand behaviour, particularly the former as driven by wind, focusing on timeframes out to four hours ahead of real time. STOR service retains flexibility providers on stand-by during certain hours of the day (typically periods when demand is changing rapidly). STOR technical delivery requirements include a 3 MW minimum of delivery, a reaction time of less than 240 minutes, a delivery period of greater than 2 hours and the ability to provide the service at least three times a week.

To estimate the revenues available for a plant contracted under STOR requires the development of future scenarios for both STOR utilisation and STOR capacity. The key inputs to the STOR utilisation scenario are:

- Future demand projection: We have based our projection of electricity demand on the National Grid's 'Gone Green' scenario.
- The future level of wind capacity: We have based our predictions on Pöyry's latest 'Central' scenario for the deployment of future wind capacity.
- A measure of the average wind forecast error, which is taken from National Grid until 2025/26 and kept constant beyond this (50% falling to 32%[1]).
- A measure of the average demand forecast error during STOR windows. We have taken a 5 year average value based on 2007-2011 data and assumed that this error remains constant in future years (580 MW[2]).

The key inputs in the calculation of the value of STOR to the Method are:

- the value of STOR on the basis of current market prices; in this case we assume £9/MW/h for availability payments and £220/MWh for utilisation payments. We assume that the Method has average utilisation based on its technical characteristics. This would set out absolute minimum expectation of revenue potential for the Method.
- an increase in STOR market prices based on an assessment of historic market price and future trends in STOR requirements as well as loss of a substantial proportion of existing providers due to the Large Combustion Plant Directive (LCPD) and Industrial Emissions (IED) obligations. In this assessment we examine a potential increase of 30% reflecting both historically higher price levels seen and future STOR trends. As above we assume the Method has above average utilisation based on its technical characteristics. These growth rate assumptions are taken as more conservative than those predicted by National Grid under different decarbonisation scenarios[3].

We have assumed that the storage capacity can be used for non-DNO applications 60% of the time whilst at the same time deferring the investment required on the network for the lifetime of the storage facility. This is based on an analysis of the specific load profile pattern at the Leighton Buzzard substation site over the course of two years which shows, even on a conservative basis, there would be sufficient headroom across at least 60% of the year where full capacity of the storage device to be used for the benefit of the wider system.

The ancillary services revenues were calculated on the basis that 20% of the overall usage time of the storage device is dedicated to STOR while 20% of the time, the storage facility is used to provide Frequency Response services. This leads to conservative benefit estimates as we are excluding potential additional value from the provision of additional services such as fast reserve, black start support, reactive power and wholesale balancing.

We have also assumed that for an additional 20% of the time, the storage facility is able to provide a combination of these services, reflecting future more flexible arrangements that we aim to demonstrate within the project. During this time, reflecting the increased value to the system, the benefits across STOR and frequency response are assumed to be additive. This leads to a conservative estimate, based on the provision of multiple applications for a limited period of time.

Based on these assumptions, the model estimates the present value of these additional benefits to be approximately £520k.

1 50% of the total MW wind on the system. For example for 4000 MW of wind with a 28% load factor the error would be 560 MW.

2 This is equivalent to 2 per cent of average daily demand on the system during this period.

3 Future Balancing Services requirements - http://www.nationalgrid.com/uk/Electricity/Balancing/services/FutureRequirements/

1.1.5 Income from Frequency Response (B_c)

Frequency Response is the automatic provision of increased generation or demand reduction in response to a drop, or increase in system frequency.

Firm Frequency Response (FFR) is the firm provision of Dynamic or Non-Dynamic Response to changes in frequency. Unlike Mandatory Frequency Response, FFR is open to Balancing Mechanism Units and non-Balancing Mechanism Unit providers, existing Mandatory Frequency Response providers and new providers alike. National Grid procures the services through a competitive tender process, where tenders can bid for low frequency events, high frequency events or both. National Grid will accept the most economical tenders. A successful tender then becomes contractually binding.

The calculation for Frequency Response revenue involves using the monthly spend on commercial holding payments and energy payments as well as the volume requirements from National Grid. We then formulated an assumption of how these figures would change over time. We have used the growth of intermittent generation capacity in the system to account for an increase in the level of frequency response services needed in the future. This increase in requirements is also due to base load coal and gas plants coming off the system and being replaced by larger windfarms connecting offshore and nuclear facilities.

The same growth rates in revenue as for STOR were applied to the Frequency Response calculations. We have again assumed that 30% of the capacity of the plant is dedicated to Frequency Response requirements.

The battery unit would be grid code[4] exempt and thus is not obliged to provide 'mandatory' frequency response, consequently, only 'commercial' frequency response revenue applies (it is assumed that the unit will obtain revenue from both 'Holding' and 'Energy' charges).

The following raw data was obtained from National Grid's 'Balancing Services Monthly Reports':

- total monthly electricity volume used in commercial 'Holding' (Hv) ;
- total monthly spend on commercial 'Holding' payments (Hs); and
- total monthly spend on commercial 'Energy' payments (Es).

From the above an annual commercial 'Holding Charge' (H_c in £/MWh) was calculated. Given the absence of volume data for commercial 'Energy' utilisation we inferred the Energy charge from the relationship between H_s and E_s.
We have not included a net cost of purchase of electricity. Given a current annual figure for Holding charge and Energy charge (in £/MWh), we formulated an assumption on how these figures would change through time.
The growth in frequency response requirement we have used is in line with the methodology outlined for STOR as we believe that the same factors (growth in intermittent generation and therefore wind forecast error and EU legislation such as the LCPD and IED) will result in an increase in requirement for Frequency Response.

As previously, we have assumed that the storage capacity can be used for non-DNO applications 60% of the time whilst at the same time deferring the investment required on the network for the lifetime of the storage facility.

The ancillary services revenues were calculated on the basis that 20% of the overall usage time of the storage device is dedicated to STOR while 20% of the time, the storage facility is used to provide Frequency Response services to National Grid. This leads to conservative benefit estimates as we are excluding potential additional value from the provision of additional services such as fast reserve, black start support, reactive power and wholesale balancing.

We have also assumed that for an additional 20% of the time, the storage facility is able to provide a combination of these services, reflecting future more flexible arrangements that we aim to demonstrate within the project. During this time, reflecting the increased value to the system, the benefits across STOR and frequency response are assumed to be additive. This leads to a conservative estimate, based on the provision of only two applications for a limited period of time.

Based on these assumptions, the model estimates the present value of these additional benefits to be approximately £3.3 million.

4 Not a Balancing Market Unit – Commercial Frequency response can be provided by Non-Balancing Market Units (Non-BMUs)

1.1.6 *Displacement of generation capacity and carbon emissions (B_c)*

Savings are also accrued through displaced peak generation capacity, including a reduction in the requirement for new OCGTs and CCGTs and reduced CO_2 emissions.
Storage facilities will typically be charged when prices are low, when lower carbon generation capacity is at the margin, (wind, nuclear, gas). The discharge will typically occur at peak times, thus displacing the need for additional high carbon generation capacity. In the future, with a large penetration of electricity storage facilities, strategically placed where demand is most significant, losses could be reduced significantly as the generation does not need to travel over long distances.

We have calculated a financial benefit relating to the level of carbon emissions reduction which can be expected from a 6 MW storage facility, as installed in the project.

The Method provides two sources of savings as far as the wholesale market is concerned through:
- displaced capacity (CCGTs and OCGTs); and
- reduced CO2 emissions.

Our assumptions in this case are based on a published study conducted by Pöyry for DECC in April 2011[5], the study modelled a scenario containing a hypothetical storage facility and compared it with a baseline scenario where no such facility existed. The Zephyr modelling tool was used for these studies, which is described in further detail at the end of Section 3 of the full submission.

The study measured the following effects:
- displaced capacity;
- CO2 emissions;
- curtailment costs;
- load factors and GWh provided by plant and flexibility type;
- wholesale price cost;
- trends for use of interconnection and storage;
- implications for low carbon generation; and
- plant IRRs.

The study assessed the above effects in the context of a single year (2030), and for a 7.2 GW storage facility. For the purposes of the model we have scaled down these figures to represent a 6 MW facility, likewise, we assume that 2030 is representative annual figure for any given year.

Based on these assumptions, the model estimates the value of these additional benefits to be approximately £1.9 million, which incorporates an annual CO2 emissions saving of approximately 1.7 k.tonnes of carbon dioxide.

The main assumptions of the study are summarised in Table 1, and described further in 1.2.7 and 1.2.8.

Assumption	Source
Baseline generation mix	DECC assumptions / Pathways Alpha
Interconnection	
Exchange rate	
Carbon price	
Fuel price	
Demand Profiles	Work done by Pöyry for the CCC
Heat pump profiles	
Residential profiles	
Asset costs	Work done for DECC (Mott MacDonald)

Table 1 – Main assumptions in DECC Modelling Methodology

5 http://www.decc.gov.uk/publications/basket.aspx?filetype=4&filepath=11%2fmeeting- energy-demand%2ffuture-elec-network%2f2356-poyry-research-annex-d-nov- 2010.pdf#basket

1.1.7 *Savings through displaced capacity (CCGTs and OCGTs)*

The cost saving manifested through displaced capacity is calculated on the basis of reduction in wholesale electricity price. A reduction in wholesale electricity price is observed because expensive 'peaking' plants are displaced (i.e. not built) in the storage scenario.
The wholesale electricity price (in a given year) multiplied by the demand (in a given year) generates a total cost of electricity for a given year. The reduction in this cost (relative to the baseline scenario) was incorporated into the model as an annual consumer benefit.

1.1.8 *Savings through reduced CO_2 emissions*

Savings as a result of CO_2 emissions were calculated by multiplying projected CO_2 price in any given year by the observed reduction in CO_2 emissions (in the storage scenario).

A figure for reduced CO_2 emissions (as a result of displaced capacity) was generated from the same DECC study described above. The figure for emissions is based on the generation profiles (including start-up and loading) of all plants within the modelling dataset.

Cost savings as a result of these emissions were calculated using carbon price projections generated by Pöyry's carbon model (updated in the second quarter of 2012). Pöyry's carbon model is used to derive projections of European Union Allowance (EUA) prices that are consistent with the fuel prices and electricity demand projections in each of our electricity price scenarios.

2. Potential For Replication - Determining the number of potential primary substations suitable for battery storage

In order to determine the number of substations[6] across GB for which battery storage may be a viable alternative to traditional reinforcement we undertook five stages of analysis:

1. Filtering UK Power Networks substations;
2. Margin analysis of potential UK Power Networks substations;
3. Applying UK Power Networks results to the whole of GB;
4. Considering the impact of demand response; and
5. Determining the potential for battery storage in GB out to 2040.

Assumptions underlying our analysis are presented throughout this section where appropriate, with additional assumptions presented at the conclusion of this section.

1. Filtering UK Power Networks substations
The first stage involved a filtering process of all substations within the UK Power Networks licensed area. The aim of this filter was to determine how many substations were candidates for flexible solutions, such as battery storage or demand response, as an alternative to traditional reinforcement. The following figure presents a description of our filtering process.

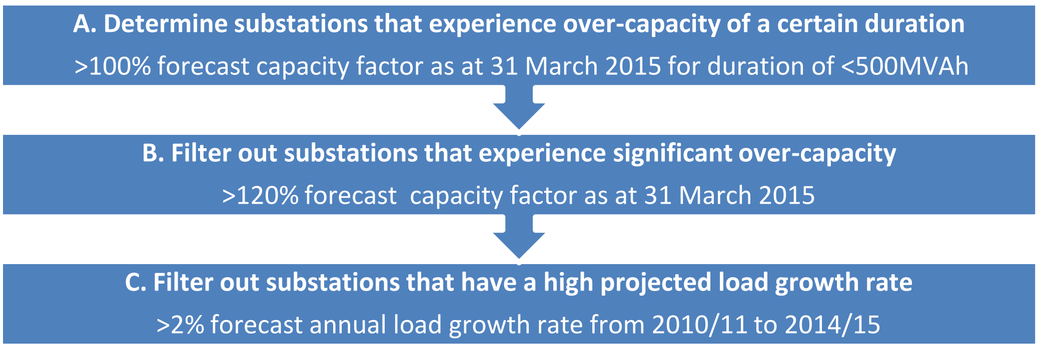


Figure 1 – Substation Filtering Process

The following table presents in more detail the filtering steps as illustrated above, the rationale for the filter and its results. We begin with 802 primary substations in the UK Power Networks licensed area (446 in EPN, 118 in LPN and 238 in SPN).

6 The term 'substations' here refers to active primary substations (EHV-HV and 132kV-HV) and does not include grid substations (132kV-EHV and EHV-EHV).

Filtering step	Rationale	Result
A) Determine substations that experience over-capacity of a certain duration >100% forecast capacity factor as at 31 March 2015 for duration of <500MVAh	A substation is forecast to be exceeding its capacity for certain periods during the year and therefore some form of investment is likely to be required. However, the substation is not running over capacity for such significant periods that reinforcement is imperative	This filter reduced potential sites for a flexible solution from 802 to 117: 66 in EPN 13 in LPN 38 in SPN
B) Filter out substations that experience significant over-capacity >120% forecast capacity factor as at 31 March 2015	A substation with a relatively high level of over-capacity is likely to be a candidate for reinforcement rather than alternative flexible solutions, as such solutions provide relatively less future-proofing.	This filter reduced potential sites for a flexible solution from 117 to 110: 60 in EPN 13 in LPN 37 in SPN
C) Filter out substations that have a high projected load growth rate >2% forecast annual load growth rate from 2010/11 to 2014/15	A substation with relatively high forecast growth rates from 2010/11 to 2014/15 is a likely candidate for reinforcement rather than alternative flexible solutions as such solutions are likely to provide a shorter deferral duration	This filter reduced potential sites for a flexible solution from 110 to 87: 45 in EPN 10 in LPN 32 in SPN

Table 2 – Substation Filtering Rationale & Results

Our filtering process returned 87 substations out of 802 (10.8%) within the UK Power Networks licensed area for which flexible solutions might be a legitimate alternative to traditional reinforcement.

2. Margin analysis of potential UK Power Networks substations

Having identified 87 potential substations for flexible solutions we then conducted analysis on substations near the 'margin' i.e. those substations forecast to be near 120% capacity factor as at 31 March 2015 and/or with a 2% annual growth figure from 2010/11 to 2014/15. The aim of this analysis was to see whether the capacity factor and growth parameters used in the filtering process above were appropriate.

Two substations were identified as being near the margin, as below, with comparable information for project trial-site Leighton Buzzard also presented.

Substation	Forecast capacity factor as at 31 March 2015	Forecast annual growth 2010/11 – 2014/15
Ashford Central (SPN)	117.8%	1.92%
Croydon (SPN)	120.0%	2.55%
Leighton Buzzard (EPN)	108.6%	1.29%

Table 3 – Substations for Margin Analysis

The filter identified Ashford Central in SPN as being a substation where flexible solutions might offer an alternative to traditional reinforcement, as it has a forecast capacity factor of 117.8% and a forecast annual growth rate of 1.92%. Further analysis of the substation verified this view. Currently substation reinforcement to 36 MVA is planned that could potentially have been deferred with an alternative flexible solution[7].

On the other hand, the filter eliminated Croydon as a potential substation site for an alternative flexible solution based on both forecast capacity factor (120%) and forecast annual growth (2.55%) parameters. Further analysis of the substation in fact suggested that, similarly to Ashford Central, a flexible alternative could potentially assist in deferring the reinforcement that is planned for 2018.

This margin analysis confirmed that the filters adopted are conservative and will underestimate the number of potential substations for which flexible solutions would be beneficial. Nonetheless we have maintained the filters as above in the interest of prudence in our forecasts.

3. Applying UK Power Networks results to the whole of GB

Our analysis above suggested conservatively that 10.8% of substations within UK Power Networks licensed area could be candidates for flexible solutions to defer investment in reinforcement. The following table presents the information broken down by individual network.

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7 This conclusion was reached based on similar analysis to that undertaken in identifying Leighton Buzzard as the test site, considering the load characteristics of the substation and the planned investment in the short to medium-term as outlined in the Portfolio Investment Management System.

Network	Analysis by substations
EPN	10.1% (45/446)
LPN	8.5% (10/118)
SPN	13.4% (32/238)
Overall	10.8% (87/802)

Table 4 – Filtering Results by Substation Numbers

The three networks within UK Power Networks have differing characteristics. For example, while LPN covers a highly urban area, EPN and SPN both include rural and lower density areas. These characteristics are reflected in the number of substations that are identified as having potential for flexible solutions.

Taken together we assume that the three networks are a sample of typical GB networks[8]. UK Power Networks accounts for a sixth of the 4,800 primary substations in GB[9] and, given its relative size, it is reasonable to apply the results from UK Power Networks across GB. In other words, 10.8% of substations across GB could potentially benefit from flexible solutions deferring investment in traditional reinforcement. **This 10.8% figure equates to approximately 520 substations across GB, as of 31 March 2015.**

4. Considering the impact of demand response

Battery storage is one form of flexible solution that could be adopted to defer traditional substation reinforcement, while demand response is another. Levels of demand response are expected to grow alongside storage, as learning and demonstrations from other LCNF projects begin to inform future business plans. However, there remains uncertainty over the level of uptake due to the significant consumer education and behavioural change required to facilitate adoption at a large scale.

Recent estimates[10] suggest the following potential for peak shifting in GB:

Consumer group	Potential peak shifting
Households	5-15%
Industrial and commercial[11]	5%

Table 5 – Potential for DSR in GB

The suitability of sites for demand response versus storage will depend on a wide range of factors such as customer mix, response required, network constraints and logistical constraints making predictions over the relative levels of demand response versus energy storage challenging.

We have taken the conservative assumption that 50% of the 520 substations across GB that we have identified as candidates for flexible solutions are able to have their peak demand sufficiently reduced via demand response approaches. Furthermore we conservatively assume that any substation that benefits from demand response does not require any further investment in the future i.e. demand response meets all of the future load growth.

Applying our demand response assumptions therefore reduces the number of potential substations for battery storage technology from 520 to 260.

5. Determining the potential for battery storage in GB out to 2040

The following assumptions underlie our analysis to determine the potential for battery storage out to 2040:

- **Initial investment rate:** Investment in battery storage for the 260 substations identified in our analysis is assumed to take place based on an innovation adoption S-curve[12] over a ten year period from 2015/16 whilst the solution moves from successful demonstration to business-as-usual approach. The S-curve sees the following adoption rates:

8 While the characteristics of LPN are unlikely to be mirrored elsewhere in GB we have retained it in our analysis in the interest of conservatism, with LPN having a lower percentage of substations with the potential for a flexible solution relative to EPN and SPN.

9 Energy Networks Association 'Electricity Networks Climate Change Adaptation Report', 2011.

10 OFGEM, 'Demand Side Reponse: A Discussion Paper', 15 July 2010.

11 Excluding those industrial and commercial customers that are already interruptible.

12 The S-curve comes from 'diffusion of innovations' literature, which analyses the process by which an innovation is communicated through society over time.

Group	% of population	Substation #	Period
Innovators	2.5%	7	2015/16 – 2016/17
Early adopters	13.5%	35	2017/18 – 2018/19
Early majority	34%	88	2019/20 – 2020/21
Late majority	34%	88	2021/22 – 2022/23
Laggards	16%	42	2023/24 – 2024/25
Total	100%	260	2015/16 – 2024/25

Table 6 – Innovation Adoption Curve S-Model

- **Long term growth rate:** Between 2010/11 and 2014/15, 4.5% of all UK Power Networks substations moved from being outside of our filters (described earlier) to inside the filters. This aggregate growth rate amounts to an annual growth rate of approximately 1.1%, which has been applied to the total GB substation figure to determine how many substations become candidates for battery storage each year, over the longer term. These growth figures are also subject to the technology adoption S-curve discussed above from 2015/16 to 2024/25.

- **Demand response:** Any additional forecast growth in applicable substations is subject to the same demand response assumption as presented earlier in the report, with a 50% reduction in potential substations.

Overall our analysis suggests that from 2014/15 to 2039/40 there are 671 substations cumulatively across GB that could potentially benefit from battery storage technology to defer investment in traditional reinforcement, as illustrated in Figure 4.1 (Page 28) of the full submission.

In practice, storage technologies can be deployed in flexible configurations to meet any necessary power and energy duration to support the local network. However, in order to conservatively estimate an overall MW installed capacity, we use an estimated average MW of battery storage capacity for the 671 GB substations. To arrive at this figure we calculated the average annual level of overcapacity in MW for the 87 filtered UKPN substations from the period 2011/12 to 2014/2015.

Assuming an eight year lifespan for the technology[13], the typical scale of storage capacity that would benefit each substation is in the order of 3 MW.[14] Some substations are likely to require larger installations, while for others smaller installations would be sufficient to defer reinforcement. Based on an average of 3MW, **total battery storage potential is therefore estimated at approximately 2,000 MW out to 31 March 2040**.

6. Additional assumptions underlying our analysis

The following additional assumptions support the above analysis.

- **Applying the filter on 31 March 2015:** This was taken as the date for the filtering process to be applied for two reasons. Firstly, the trial installation of battery storage at Leighton Buzzard is due to be undertaken in the 2014/15 period and naturally any wider adoption of the technology would follow the trial. Secondly, load forecasts for DPCR5 are provided out to this date.

- **Load growth from 2010/11 to 2014/15:** Load growth is assumed to be that forecast for the purposes of DPCR5. Such load growth does not take into account energy efficiencies or factors such as demand response, which is why potential demand response is subsequently applied to these figures.

- **The forecast capacity factor as of 31 March 2015:** The forecast capacity factor for each substation was taken assuming no further DPCR5 intervention, such as reinforcement, between 2010/11 and 2014/15. This assumption is based on the fact that flexible solutions could potentially have been used during this period to defer such reinforcement.

- **Assumption on substation space**: We have assumed away space as a factor that might limit the deployment of battery storage technology for two reasons. Firstly, substation reinforcement frequently also requires space at the substation. Secondly, storage systems could potentially be located at a range of network locations, subject to network arrangement. Fundamentally the DNO need not own the battery storage technology and its associated assets, such as land and buildings.

- **'Peakiness' of demand**: Over time it is expected that demand for electricity will increase in peakiness. In other words, the profile of electricity demand will have higher periods of maximum demand relative

13 Following this eight year period traditional substation reinforcement is assumed to take place.

14 Note that the proposed investment in battery storage at Leighton Buzzard at 6 MW is larger than the 3 MW average due to the substation being one of the largest in the filtered group (7th out of 87).

to the average level of electricity demand. The chart below provides a forecast of GB electricity demand profiles in 2030 and 2050 compared to an actual demand profile in 2009 to illustrate this phenomenon.

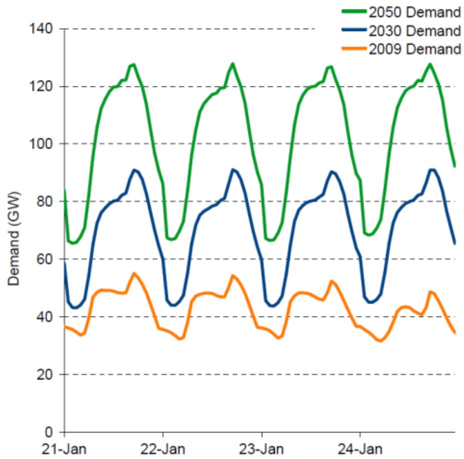

Figure 2 – Forecast Electricity Demand Profile and Peakiness[15]

Increased peakiness implies that relatively more network locations will need to be considered for reinforcement in the future, therefore the opportunity for flexible solutions such as battery storage may be even greater than presented in this paper. Nonetheless we have not included any increased peakiness in our forecasts in order to keep our estimates as prudent as possible.

- **Battery storage versatility**: Battery storage has the potential to be relocated between different network areas based on need. For example, if traditional reinforcement was deemed necessary at a substation due to an unforeseen increase in demand, the battery storage technology could be deployed elsewhere, subject to the lifetime constraints of the battery.

3. GB-wide Benefits

The GB wide business case estimates the overall benefits of the wider deployment of electricity storage capacity, and is based on results of the repeatability study described in the previous section out to 2040. We have used the same Poyry Zephyr model, which is described in more detail in Section 3 of the submission template, and used the recent paper published by Goran Strbac[15] of Imperial College London on the strategic benefits of bulk and distributed electricity storage in the future to determine the distribution and transmission network savings at the GB-scale.

A discount rate of 7.2%, which is lower than an expected market rate, has been used throughout the analysis.

3.1 Benefits

Resulting from the roll out of 2GW of storage capacity through to 2040, the following benefits were calculating using the same modelling framework:

Reserve and Frequency Response

We have used the same methodology as per our project specific business case to define the value of 2GW of distributed electricity storage capacity for STOR and Frequency Response. We have taken into account the forecast for STOR capacity carried out by National Grid through its Gone Green Scenario and expanded on these. The key inputs to the STOR utilisation scenario are the future demand projection including the demand forecast error as well as the wind capacity projection and the wind forecast error.

With regards to Frequency Response, we again used the same methodology as per the project specific business case described in part 1 of this Appendix. We have again assumed a relationship with the growth in renewable capacity and an increase in requirement due to the closures of plants through the Industrial Emissions Directive (IED) and the Large Combustion Plant Directive (LCPD).

The same growth rates in revenue as for STOR were applied to the Frequency Response calculations. We have again assumed that 20% of the capacity is dedicated to Frequency Response requirements and 20% of the capacity dedicated to STOR. In addition, we have also assumed that for an additional 20% of the time, the storage facility starts off by providing Frequency Response and then moves on to providing STOR

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15 Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low Carbon Energy Future, June 2012, Strbac, Aunedi, Pudjianto, Djapic, Teng, Sturt, Jackravut, Sansom, Yufit, Brandon

sequentially. We have assumed that the storage facility earns availability as well as energy payments for both the provision of STOR and Frequency Response during that time. It is anticipated storage could provide a much more flexible combination of these services in the future, and hence these benefits have been estimated conservatively.

The present value benefits of provision of balancing services to the TSO or to the Distribution System Operator in the future are then calculated as approximately £630m.

Transmission and Distribution network capacity cost and benefit
In this instance, we have used the analysis carried out by Imperial College mentioned above. We have used approximate values relating to the annual system benefits obtained by deploying storage facilities of lower duration. The value of annual system benefits was taken as an average of the modelled results when the cost of storage was £200/kW/yr and £150/kW/yr, reflecting the nearest corresponding price point to that assumed in the Method costs.

The savings from a distribution network perspective were as expected, much greater with the deployment of distributed electricity storage. **These benefits are calculated to be between £0.5bn to £0.6bn in terms of deferral of distribution network reinforcement** out to 2040.

In terms of transmission benefits, the distributed capacity is however estimated to add **an additional cost to the Transmission Network Operator of between £15m to £17m** which is subtracted from the overall net benefits.

OCGT displacement, carbon emissions reduction and reduced system costs
As previously described, savings from the deployment of storage are also accrued through displaced peak generation capacity, including a reduction in the requirement for new OCGTs and CCGTs, reduced CO2 emissions and lower system costs due to reduced wind curtailment and better overall plant utilisation.

Based on 2GW of storage integrated on the electricity system by 2040, **the displacement of OCGTs on the system is calculated to provide savings of approximately £0.53bn**. Total **emission savings are estimated to be 588 k.tonnes of carbon dioxide, which equates to an associated financial saving of £13.1m in present terms**.

The additional associated savings with regards to system costs which occur due to the **reduction in wind curtailment and better utilisation of remaining plants on the system are calculated as £170m**.

3.2 Costs

Based on the estimated costs of the SNS Solution once proven successful and the profile of roll out previously described, the **cost of wide scale deployment of 2GW of distributed storage capacity by 2040 on the system is estimated at £1.32bn** at present value.

We have then compared all the present values of benefits outlined above against this cost to determine the overall net benefit to the end consumer of the wider roll out of the SNS Solution. The result is **net benefits of approximately £0.6bn** for the 25 year period under consideration, which is illustrated further in the Figure below.

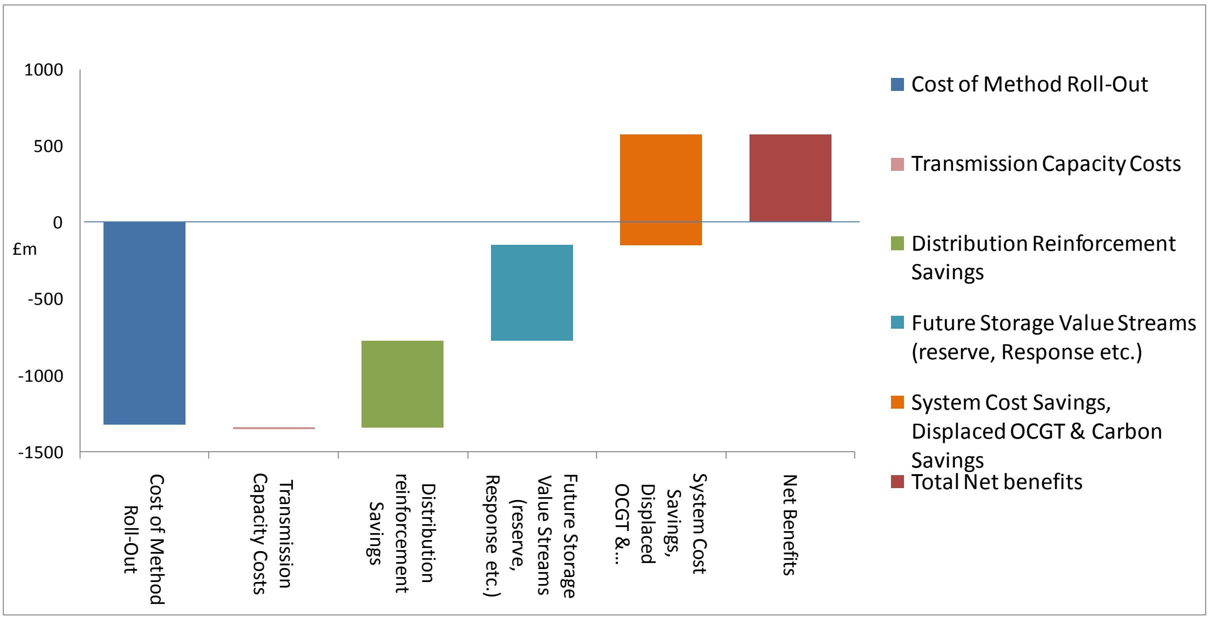

Figure 3 – Costs (Negative) and Benefits of Roll out of the SNS Method

APPENDIX H – SUMMARY WORKSTREAM DESCRIPTIONS

Work stream 1: Energy Storage Hardware

Work stream Summary
This work stream will be responsible for the overall design approval, building and commissioning of the energy storage device to facilitate the demonstration of potential services. This work stream will also be responsible for the production of all necessary operational procedures to ensure the energy storage device meets safety requirements and providing additional industry learning around the ownership and operation of large-scale energy storage. Staff will be appropriately trained to carry out routine maintenance to ensure that the storage asset lifecycle is maximised.

This work stream will benefit from lessons learnt from the 200 kW / 200 kWh energy storage device installed at Hemsby near Great Yarmouth, which has served to de-risk elements of the planning already undertaken and activities to be carried out within this area.

WS 1.1 – Procurement and Design Approval

This work area will finalise the procurement and design approval activities around the storage technology. In order to facilitate a timely start of the project, during the bid phase UK Power Networks has undertaken significant design work and activities to reduce the risks associated with the physical components of the energy storage device and develop a "value for money" solution.

UK Power Networks has carried out a number of surveys, including a topographical survey of the proposed site, Flood Risk Assessment (FRA) and geotechnical investigation to confirm the suitability of the site to accommodate an energy storage device. The geotechnical investigation confirmed suitable ground conditions and allowed design and costing of appropriate foundations to support the building.

The Leighton Buzzard trial area lies within a flood plain, and therefore flood water displaced by the building was an important consideration for the design. The building has been specially designed to avoid any impact on flood waters, whilst supporting the weight of the equipment and a letter from the Environment Agency supporting the proposed design is shown in Section 6 of the submission. UK Power Networks continues to develop materials necessary for a full planning application in order to make a formal application prior to the end of 2012.

Following a competitive supplier selection process, the preferred supplier, A123 Systems, has assisted UK Power Networks in developing a "value for money" solution that meets the needs of the network and will satisfy local planning considerations. A123 will supply UK Power Networks with a 6 MW / 15 MWh device with the option to expand either the power capacity or energy storage or both up to an 8 MW / 24 MWh device.

Within this work area, the designs will be finalised and approval sought through UK Power Networks' internal design review panel to ensure robust governance and internal stakeholder engagement. This will include agreeing the level of co-ordination of interface protection. For example, installing an EREC G59/2[1] relay on the primary substation 11 kV circuit breaker will not be appropriate as the energy storage device is intended to provide voltage support on the 11 kV busbars at Leighton Buzzard.

The construction of the building to house the energy storage device will also be put out to tender to ensure value for money is obtained. Detailed plans of the foundations and building structure have already been produced and will provide the detail necessary to invite tenders from building contractors. Details of these plans are shown in Appendix B.

Whilst Leighton Buzzard is the preferred site, due to the significant benefits that could be realised through the deployment of energy storage, a contingency 132/33 kV substation site has also been identified adjacent to March Grid. This mitigates the risk that UK Power Networks was unsuccessful in obtaining planning consent at Leighton Buzzard. Storage applied at this site will benefit the network by mitigating a number of issues associated with the high number of connected wind farms at March which can lead to reverse power at any time. The storage device would be expected to absorb the energy produced by the wind farms and reduce the number of times that they are constrained.

UK Power Networks owns the land adjacent to the substation and the more rural location will likely present few planning issues in the contingency situation. UK Power Networks will continue to develop a planning application for March Grid, in parallel with Leighton Buzzard, to avoid delays in commencing the project. Should it be necessary to

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[1] ENA Engineering Recommendation G59/2 – Recommendations for the Connection of Generating Plant to the Distribution Systems of Licensed DNOs.

move to March Grid, only minor design changes will be required e.g. the design of the step-up transformer and protection settings.

Key Components
Contract with A123 for the supply, delivery, installation and commissioning of a 6 MW/15 MWh storage device.
Finalisation of any remaining issues raised from the Environmental Agency and Local Planning Authority to obtain planning consent.
Detailed final designs approved by UK Power Networks' Asset Management to allow connection to the distribution network.

Dependencies
This work stream is dependent on UK Power Networks being successful in obtaining planning consent.
A123 must produce detailed designs acceptable to UK Power Networks' Asset Management function.

High-level roles and responsibilities
UK Power Networks will be responsible for finalising the planning approval from the Environment Agency and Local Planning Authority.
A123 will be responsible for collaborating with the UK Power Networks' Asset Management function to produce detailed designs compliant with current network design policies and procedures.
UK Power Networks will select a building contractor to construct the building.

Key Reports / Dissemination Activities
A summary report will be produced, describing the preferred supplier selection process and the considerations and novel solutions relating to the planning processes around large-scale energy storage.

WS 1.2 – Building and Commissioning

This work stream will undertake all the activities to prepare the Leighton Buzzard site to be ready to accommodate the energy storage device and the installation and commissioning of the storage technology. Overall this phase is expected to last around 16 months, the outcome of which will be one of the largest operational and energised storage facilities in the UK, providing valuable learning opportunities for UK and international network operators. UK Power Networks has mobilised internal Capital Programme delivery teams to support this area in order to leverage the experience in project management and delivery of large construction projects of this nature.

The geotechnical investigation already completed determined the ground conditions to inform the type of foundations necessary to support a building two metres above the EA flood design level and house approximately 300 tonnes of equipment. Further information on these plans is shown in Appendix B.

Key Components
- Foundations to support the building
- Building to house the storage equipment, PCS and other auxiliary equipment
- Delivery and installation of the Energy Storage Device including PCS & control systems
- 11 kV network connection and monitoring between the Energy Storage Device and Leighton Buzzard primary substation
- Import and export metering
- IT communications, including redundant communications links, IT security and virtual private network links to project partners

Dependencies
- A123 delivering an energy storage device that meets UK Power Networks' design review approval
- The building contractor constructing the building to specification.

High-level roles and responsibilities
A123 will deliver, install and commission the Energy Storage Device, and carry out the commissioning tests with UK Power Networks which will include a full charge and discharge cycle at rated power.
UK Power Networks will provide the connection to the 11kV busbar at Leighton Buzzard
A meter operator will be appointed to install the import and export meters
UK Power Networks' IT department will manage the communications required

Key Reports / Dissemination Activities
- Experience of the type of buildings required to accommodate Energy Storage to meet Environmental Agency and local planning authorities requirements
- Interface protection settings to co-ordinate with existing primary substation settings
- Suitability of designs to be replicated in other areas

WS 1.3 – Operational preparedness

This work stream area covers the preparation of all Safety and Training documentation necessary to introduce a new technology into the distribution network and the delivery of training to all field personnel likely to come into contact with the storage device. Engineering documents e.g. Engineering Operating Procedures, Engineering Design Standards, maintenance schedules, etc. will be written and approved by UK Power Networks' Asset Management and Health, Safety, Sustainability and Technical Training and will provide valuable learning towards the incorporation of storage as a more common asset for DNOs.

Infrastructure planners will need to understand what the impact of an energy storage device is on a distribution network; when it is appropriate to consider it as an alternative to traditional reinforcement but also be able to inform third party developers of areas where their proposed development would provide a benefit to UK Power Networks.

Training will be provided by A123 to control room staff and local field staff will be trained to carry out operations and routine maintenance.

Key Components
Energy Storage Device documentation
Safety documents
Control systems
Distribution Planning tools adapted to assess the impact of energy storage

Dependencies
Approved Engineering Operating Procedures

High-level roles and responsibilities
A123 will provide the Training
UK Power Networks will write and approve the necessary Engineering documents.

Key Reports / Dissemination Activities
- Copies of the Approved Engineering documents will be made available to other DNOs
- Generic training material syllabus

WS 1.4 – Storage as an Asset

This work stream area covers studies on the operational performance and lifecycle of storage assets and considerations for asset management to help inform industry best practice.

Methodologies to assess the condition of storage assets will be developed, along with maintenance and inspection regimes that would need to be implemented to ensure assets are kept functioning safely and optimally.

Key Components
Assessments and workshops on asset management considerations
Field experience and operational data

Dependencies
Fully operational storage device
Data around the lifecycle impact and operation of the device

High-level roles and responsibilities
UK Power Networks will be responsible for these studies, with the support of A123 Systems.
Durham University will be responsible for the capture of operational data around the use and cycling of the asset

Key Reports / Dissemination Activities
- A report around the considerations for asset management of a large scale energy storage device
- Best practice guidance on inspection and maintenance regimes for energy storage, based on field experience and operational data

Work stream 2: Smart Optimisation and Control System

Work stream Summary
Work stream 2 will deliver the design, development and integration of a novel optimisation and control system that will enable the energy storage device to provide wider system benefits, over and above those provided to the DNO. The system will schedule the user of the device depending on a number of inputs and predictions, attempting to maximise the value of the storage capacity within the constraints of the network.

Interfaces with relevant other industry parties will be designed and developed to provide a blueprint for systems required to allow storage and other forms of flexibility to be made visible and controllable by multiple system participants. The platform will take a variety of price signals, future load predictions and network state information to provide automated dispatch and control of the storage device. Dispatch will be prioritised to ensure that the device is available to the DNO in periods where it is predicted that the network will exceed its maximum capacity. Furthermore, the DNO will have the ability to override dispatch instructions to the storage device to help resolve real time issues on the network. An optimisation system will consider any additional capacity on the storage device and the range of options available to UK Power Networks to dispatch that capacity.

New business processes will need to be designed and implemented around the platform and storage device, that will provide valuable learning and experience into the types of business change and new activities a future, more active 'Distribution System Operator' (DSO) might undertake as we transition to a low carbon electricity sector.

Figure 1 demonstrates how the optimisation and control system will sit between the storage device control system and the three parties potentially receiving benefits from the device.

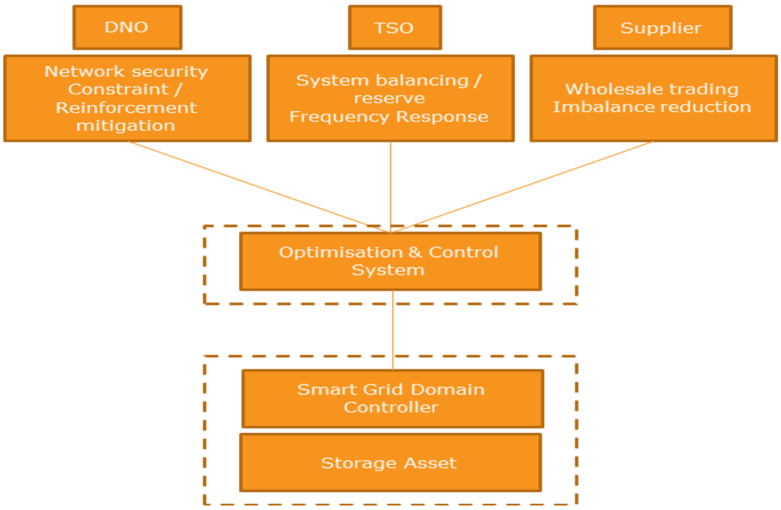


Figure 1 – High-level Architecture

AMT SYBEX has been selected as the partner to design, develop and supply the optimisation system. A second partner in the Smarter Network Storage project, Durham University will also be supporting the design and specification of the optimisation algorithms based on experience with a previous UK Power Networks' storage project.

WS 2.1 Requirements and Scope
The Requirements and Scope phase of the project will lay the foundations for the success of the work stream. The team will gather the business and technical requirements for the Smart Optimisation & Control System (SOCS), such that the end-to-end scope of the work stream can be described to all project partners. The control algorithms will be central to the overall operation of the storage device during the trials and will be a major point of focus during this phase.

Overview of Control Algorithms
Energy storage systems cannot be considered as a straightforward generation asset or demand-side response, because power can only be imported or exported if the device's charge is at a suitable level ahead of time. This brings a requirement to anticipate the particular service that will be asked of the device and to ensure that the state-of-charge is adjusted in time, while minimising negative technical or commercial consequences.

The situation under investigation in the Smarter Network Storage project leads to the existence of periods when the DNO has an absolute and exclusive requirement for the storage device to be available. The periods of requirement are well understood from historical data, which allows a high-level design to be completed. However, on operational timescales, a planning and control algorithm is needed to schedule the resources provided by the network storage device between system participants. As the operation period approaches, the algorithm will respond to updated conditions by revising the schedule, supervising real-time operations and initiating corrective actions when required.

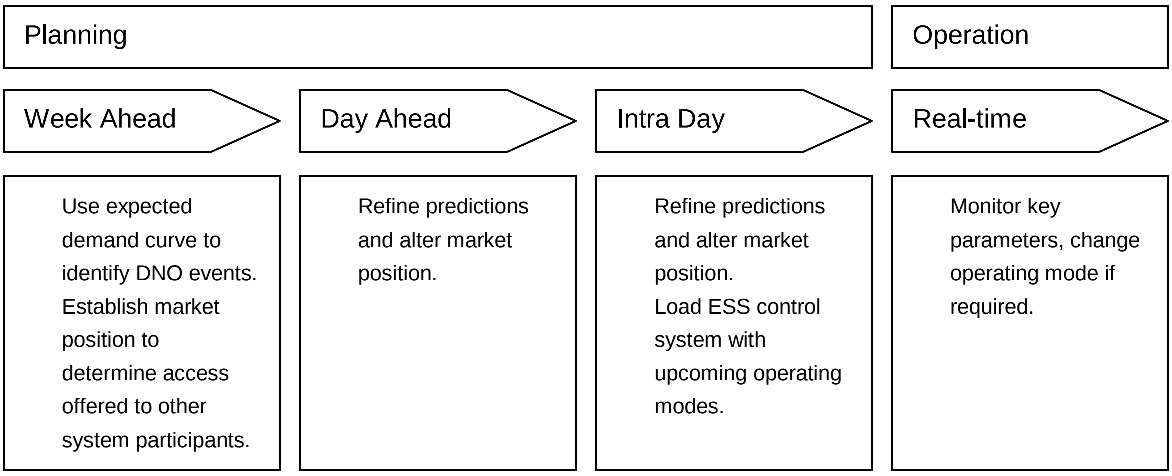


Figure 2 - Overview of planning and operation process

However, there will be many interacting technical and commercial components of the overall solution and the requirements for each of these components will be captured during this phase. Comprehensive requirements will be collected from all relevant sources including:
- Business requirements from UK Power Networks' control & commercial staff
- Business requirements from the battery provider A123 Systems
- Business requirements from the operators of the storage device, KiWi Power and SmartestEnergy
- Business requirements from the Transmission System Operator, National Grid
- Technical and non-functional requirements from UK Power Networks' internal IT operation and AMT SYBEX

Key deliverables from this phase will be:
- A baseline set of functional, non-functional, technical and interface requirements
- A baseline functional specification for the forecasting and optimisation algorithms to be produced by Durham University
- A baseline functional specification for the SOCS to be produced by AMT SYBEX
- Baseline integration specification documents
- Detailed plans for the Design phase of the project.

High-level roles and responsibilities
- Durham University will be responsible for delivering the functional specification for the algorithms for forecasting overfirm network events and commercial optimisation of the use of the energy storage device.

UK Power Networks' Future Networks team will be responsible for:
- Overall work stream management, including progress tracking, risk monitoring and mitigation, issue resolution, planning, resource management and financial management;
- Detailed planning for the Design phase, supported by AMT SYBEX and Durham University;
- Defining the interfaces that will be needed between each of the project partners to ensure the developed solution is capable of compliance with each party's need; and
- Defining the historic site data, pricing data and weather data upon which the forecasting and optimisation algorithms will be developed.

AMT SYBEX will be responsible for:
- delivering the functional specification of the forecasting and optimisation system that will employ the algorithms.
- UK Power Networks' IT team will be responsible for defining the full range of technical and non-functional requirements for the system, in respect of all touch points with UK Power Networks' IT infrastructure.

Dependencies
Availability of the commercial and technical resources that each partner has committed to the project

Key Reports / Dissemination Activities

Dissemination of the functional requirements for the forecasting and optimisation algorithms

WS 2.2 Design Phase

This phase will deliver all of the activities required to understand the characteristics and functions that should be built in to the forecasting and optimisation algorithms and the SOCS. Furthermore, this phase of the project will also examine the requirements for interfaces between project partners and determine the required technical design of such interfaces. This will allow UK Power Networks to conduct relevant trials of the network storage device and to make the technical and commercial decisions on how to deploy the capacity of the device to support DNO activities and exploit commercial opportunities. This phase will ensure that a comprehensive technical design is created and agreed by all parties, such that software and business processes can be developed to ensure that the trials of the storage device can be conducted efficiently and effectively.

The design will build upon experience gained in developing the control algorithm in the LCNF Tier 1, UKPNT1001 project that determines storage device set-points from measured network variables to meet multiple concurrent technical requirements. The Design Phase will also build on the preparatory work that has already been laid down between the project partners. To date this has established the data inputs, processing requirements of the control algorithm and the resulting outputs.

Key deliverables from this phase will be:
- A baseline Technical Architecture, Technical Specification, and Technical Integration specifications
- Algorithm design specifications
- High-level business process design
- Testing Strategy
- Detailed plans for the Build phase of the project.

Key Components:

AMT SYBEX Optimisation System
The SOCS will be built upon the existing Affinity Suite of products, which is in widespread use across the GB and Ireland energy markets. The SOCS will implement the algorithms developed by Durham University to manage the forecasting of potential overfirm network events and to optimise the use of the storage device for commercial purposes. The SOCS will orchestrate and integrate the requisite data from the relevant parties and manage the flow of messages between parties and to/from the storage device itself. Data may be consumed or disseminated in real time e.g. instructions to the storage device to provide a particular type of service or may be processed in batch mode e.g. market prices used to determine potential deployment options in the week ahead.

Durham University algorithms; forecasting and optimisation

Forecasting
A major part of the planning process is to forecast the expected duty of the energy storage device. This means that the value that can be realised from selling services to the aggregator or contracting power exchanges with the supplier can be bounded to periods outside those in which the DNO requires exclusive use of the device.
The demand forecasting process is seeking the loading on the specific substation to which the energy storage device is connected. Several factors will be combined to produce demand predictions for each settlement period in the upcoming planning window:
- Historical demand
- Meteorological conditions
- Unusual events, e.g. those leading to TV pickup
- Planned maintenance/outages
- Load-growth, e.g. linked to GDP
- Distributed Generation installations

It is noted that there is a body of work available on load prediction and this area is advancing, current best practice will be sought to inform this process.

The output of the first stage of the planning process will be a matrix of availability, such as in Table 1, consisting of periods that are not required by the DNO. The identified periods of energy storage device availability are then offered to the supplier and aggregator to determine the value they can realise in each period.

Table 1. Planning by Settlement Period for one day

Participant	SP1	…	SP16	SP17	SP18	SP19	…	SP36	SP37	SP38	SP39	…	SP48
DNO		…					…					…	
Supplier		…	Unavailable			Available	…		Unavailable			…	
Aggregator		…					…					…	

Optimisation

The optimisation algorithm will be used to determine the energy market value by offering the available periods to the supplier or through the provision of ancillary services to National Grid. The potential revenue streams will be compared to understand the best commercial return that can be expected from the asset. Any value that the DNO can extract through modified network operation is also factored in at this stage, such as reduced peak power flows through transformers, loss minimisation and tap-changer operation count reduction.

There are instances where a number of services can be delivered concurrently, this raises questions on whether one or several system participants should be charged for the provision of the resource. The issue of concurrence will be addressed, both on a technical level—to identify when it is feasible, and on a commercial and regulatory level in the 'Optimised & Integrated Service Demonstrations' operational phase, described further in WS3.

High-level Business Processes

UK Power Networks will work with all partners to develop the high-level business processes that will need to be developed to ensure the effective operation of the network storage device and the ability to deploy the device in the desired manner, whilst ensuring compliance with industry processes (e.g. National Grid processes for Short-Term Operating Reserve, etc.) and to ensure that adequate consideration has been given to the needs of each party in performing its role in relation to the optimisation of the network storage device.

Testing Strategy

The testing strategy will determine the overall approach to testing the SOCS at each phase prior to the project going live. The strategy will lay the foundations for each level of testing from ensuring that individual modules of the system function as expected to ensuring that the business processes can be operated end-to-end by all parties and that the core system and its interfaces support effective operation. The strategy will also lay the foundations for technical testing of the system to ensure that the IT staff that support the business have sufficient technical information to support the system under normal circumstances and are well-prepared for unusual events. The strategy will also address how Business Continuity will be maintained if parts of the application or the communications infrastructure are unavailable. Finally, the testing strategy will ensure that adequate plans are in place to ensure clarity in a disaster recovery situation. The purpose of the testing strategy is to identify, at a high-level, the stages of testing that will be undertaken and the purpose of each stage. Further plans, scenarios and data will be determined in subsequent phases and be related to the individual testing phase to which they refer.

Dependencies

Availability of the commercial and technical resources that each partner has committed to the project
Operational site data from the Leighton Buzzard site
Pricing and weather data
Technical information on interfaces and formats from all partners
Business Process information from all partners

High-level roles and responsibilities

- Durham University will be responsible for designing the algorithms for forecasting overfirm network events and optimising the use of the storage device for other commercial purposes.
- UK Power Networks will be responsible for supplying historic site data, pricing data and weather data upon which the forecasting and optimisation algorithms will be developed.
- AMT SYBEX will be responsible for delivering the technical architecture, technical specification and interface specifications, supported by the UK Power Networks' IT team and by each partner for relevant interfaces.
- UK Power Networks' IT team, working with AMT SYBEX, will be responsible for defining the full range of technical and non-functional requirements for the system.
- UK Power Networks' Future Networks team will be responsible for developing high-level business processes, supported by each partner organisation, as appropriate.

Key Reports / Dissemination Activities

- Dissemination of the design specification for the forecasting and optimisation algorithms
- A summary report on the key business processes required for the operation of the storage asset across multiple markets, and how this will impact the control rooms and activities of future DNOs

WS 2.3 Development Phase

This phase will deliver the core software and algorithms in accordance with the design agreed in WS2.2. The software will be tested in a standalone environment, and these tests will need to complete successfully prior to entry into the formal testing and integration phase (WS2.4). This phase will also deliver the detailed business processes and procedures that each of the partners will need to follow, in order for the trials to be conducted effectively and successfully. Any remaining hardware, software or other project infrastructure will be procured.

Key deliverables from this phase will be:

- Completed SOCS
- Standalone Testing in accordance with IT best practise, and including Simulation Testing (modelled algorithms)
- Site Acceptance Testing at UK Power Networks' chosen site
- Detailed business process and procedure design
- Preparation for Integration and Testing Phase, down to the level of test data, scripts and expected results
- Preparation of test system(s) at KiWi Power and SmartestEnergy

High level roles and responsibilities

- AMT SYBEX will build the system in accordance with the functional and technical specifications that were developed in earlier project phases and will carry out a range of technical tests
- Durham University will develop a model of the trial network power system and energy storage system. Historical data will be passed through this in a simulation that will test the behaviour of the control algorithm in controlled conditions.

Dependencies

Availability of the commercial and technical resources that each partner has committed to the project
Agreed and approved technical and integration specifications

WS 2.4 Testing and Integration Phase

The phase will ensure that new business processes operate end-to-end. Interfaces between parties and to and from the storage device will be tested.

Key Components:

In addition to testing, a cutover plan and business readiness plan will be prepared, training materials will be prepared, training participants will be identified and training courses scheduled. Testing will be split into:

Integration Testing

A series of use-cases will be developed to define and test each of the integration points between systems and partners. Each partner will be expected to have a test system/process in place and to be able to process messages and make appropriate responses.

User Acceptance Testing

The testing phase will be structured around 'Use Cases' that describe the involvement of participants, objectives to be met, actions required of the storage device and configuration of the control system to provide running in this mode. Users will be expected to review and agree that the objectives have been met in each case.

Technical Testing

A range of compliance testing to ensure the robustness and integrity of the solutions to be deployed will be carried out, such as volume testing, performance testing and disaster recovery testing.

Dependencies

Availability of the commercial and technical resources that each partner has committed to the project

High-level roles and responsibilities

- AMT SYBEX will be responsible for Integration and Technical Testing and the preparation of cutover plans
- AMT SYBEX will be responsible for the development and delivery of training
- Durham University will be responsible for the development of use-cases and the preparation of tailored test data
- UK Power Networks, KiWi Power and SmartestEnergy will be responsible for the provision of realistic network and market data from which the data used in the testing phase will be derived

Key Reports / Dissemination Activities

- Testing Reports
- Use Case documents capturing the learning from analysing existing business processes in the partners

WS 2.5 Training Phase

This phase sees the delivery of training courses to the personnel identified in the previous phase. Training will comprise both business training in the use of the applications and business processes and technical training on the Optimisation System. User training will take the form of 'train the trainer' to ensure that new staff can be trained easily within their own organisation. Technical training will adopt a 'hands on' approach.

Dependencies

Availability of designated personnel to undertake training
Integrated Training System(s)
Course Materials
Test Data

High-level roles and responsibilities

AMT SYBEX will be responsible for designing and delivering the overall business and technical training scheme.
UK Power Networks will provide training facilities

Key Reports / Dissemination Activities

- Document for field staff detailing and explaining the operation of the storage device and safety related data
- Training documentation for control staff detailing the operation of the device remotely, including changing set points, understanding the data available

WS 2.6 Go-Live

Execution of the implementation plan, cutover plan and business readiness plans leading to approval for the Smarter Network Storage project to enter into the live phase of trials.
Deployment of AMT SYBEX functional and technical resources to provide an initial period of four-weeks on-site support.

WS 2.7 Operational Phase

During the operational phase, the storage device will be trialled in several different ways to test the efficacy of the optimisation algorithms and to determine the commercial models that offer the best value in terms of security of supply and value for customers. Stand-alone trials are envisaged to trial the use of the storage device independently with each of the commercial models within Work stream 3. Ultimately there will be a trial based upon the full system functionality, predicting potential overfirm events and reserving the use of the storage device for UK Power Networks operations and optimising the remaining availability of the device to receive the best commercial returns.

Durham University will capture and analyse a large quantity of data to understand the real impact of the storage operations on both technical and commercial terms. Operational results will inform modifications to use-cases, which will ultimately inform the studies around the business models for network-scale energy storage carried out in Work stream 4.

Time series data will be collected during trials so that technical and financial performance can be reported robustly. Reports will detail the operating regime, storage device service, changes in power flows, effect on voltage regulation and financial exchanges that have taken place.
Through the simulation tool developed within WS2.3, results will be extended by considering future scenarios such as:

- a greater degree of fluctuation in the electricity market price;
- changing load patterns due to increased adoption of low-carbon technologies (supply and demand)

Learning outcomes

Learning from the operational phase relating to the Optimisation & Control System will include:

- The requirements for interactions between system participants and the success of the system in facilitating these interactions
- Changes that project partners can make to their practises or commercial offerings in order to increase the utility of an ESS within the electricity distribution system
- Level of visibility and control capability required at the DNO control room

Dependencies

Successful completion of the design and development activities and integration into the UK Power Networks IT infrastructure.
Agreed business process around the SOCS to facilitate the shared utilisation of storage

Work stream 3: Storage Value Streams, Services and Modelling

Work stream Summary

Storage capacity has the potential to provide a range of system-wide services and applications. The suitability of differing storage technologies varies depending on their individual characteristics. It is therefore useful to understand the requirements of a range of system applications, and the relative suitability of a range of storage technologies. The purpose of this work stream is to explore the capabilities and suitability of the chosen storage technology for a number of system applications, identifying the requirements, potential value and benefits to the electricity system.

This work stream encapsulates the design and execution of the real-world trials of the use of storage for a range of services and applications. The system value of storage, and particularly that to the DNO, in terms of contribution to network security, will be assessed and used to inform revisions of core network design standards, such as P2/6.

Key Components

- Storage device
- Contractual arrangements with operational partners
- Control systems
- Business processes defining operational procedures
- Reporting and payment mechanisms

WS 3.1 - Storage Applications and Services – Detailed Trial Design and Planning

This work stream will assess appropriate system-wide services and applications that storage can potentially provide. The work will be undertaken using meetings with key stakeholders, as well as reviews of literature and publicly available information on current ancillary service products and storage characteristics.

The potential value in each application area will be evaluated and estimated, and details trials planned for the operational phases of the project.

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Assessment of full range of applications and services	In-depth desktop studies of the possible range of system-wide network and market applications for storage flexibility including (i) use of energy storage to enhance the utilisation of transmission network; (ii) energy storage based provision of frequency regulation, various forms of reserves and balancing services (markets operated by National Grid); (iii) energy storage resource used for energy trading and the ability to displace the need for conventional generation capacity, particularly in peak demand periods	Understanding of the current range of applications, market products and services that are served by flexibility. Understanding of the key future applications of flexibility for network operators and which could storage serve.
Identify key applications and services to be demonstrated within the project	Assessment of specific network, market and system services and suitability for chosen storage technology, and identify appropriate and key value services.	Understanding of the specific applications and services demonstrable by specific storage technology. What are the potential applications of storage for a transmission operator? What are the potential applications of storage for a supplier?
Value Modelling	The value of certain applications and services to system participants will be estimated and modelled, based on availability and constraints of the storage device.	Understanding of the value of storage from a range of system-wide applications. Development of methods and tools to estimate the value of storage from a range of current system-wide applications.
Detailed Trial Planning	Detailed planning and coordination of individual service demonstrations across: - DNO Service Demonstrations - Ancillary Service Demonstrations - Wholesale Service Demonstrations	Understanding of the integration, information flow and business processes required for the system-wide utilisation of storage flexibility

Dependencies

This work stream will inform and support the design and planning of the operational service demonstrations and validations (WS 3.2)

High-level roles and responsibilities

UK Power Networks will be responsible for developing the materials and assessment for this work stream in conjunction with Imperial College who will feed the outcomes into subsequent analysis work. Guidance and support will be provided by National Grid, Swanbarton, KiWi Power and SmartestEnergy.

Key Reports / Dissemination Activities

- A summary report will be produced, describing the range of applicable services and network applications for storage.
- Services and applications to be demonstrated within the operational phase of the project will be identified and indicative value estimates produced that shall be validated in the project.
- Detailed service trial plans to support the phased demonstration of individual applications of the storage flexibility will be produced, covering DNO service demonstrations, ancillary service demonstrations and wholesale service demonstrations

WS 3.2 – DNO Service Demonstrations and Validation

This work stream area will undertake a range of distribution network based operational demonstrations of the various services and applications of storage capacity for the distribution network operator. The work stream will identify the capabilities of storage in supporting distribution network operation. Key learning will include the potential range of products or services that may be procured by DNOs in the future as they become more active in seeking alternatives to reinforcement and influencing demand and generation profiles in their role as a ‘DSO’.

One of the primary responsibilities of a distribution network operator is to ensure security of supply and that demand does not overload assets on the network. Future low-carbon technologies, such as heat pumps and electric vehicles, will however create peakier and less predictable demand profiles. Storage has a key role to play in allowing peak demands to be met without significant increases in firm capacity, improving the utilisation of existing assets and reducing the need for costly reinforcement.

Storage can also be used by network operators to maintain voltage within a tightly controlled range by dynamically feeding in or storing both reactive and active power to support the voltage. This can be a highly effective means of supporting fluctuations in voltage caused by renewable generation on the network, such as PV clusters with intermittent output.

Power factor correction is another application of storage that can be used to improve the capability of network assets, such as overhead lines. Poor power factor increases distribution losses, reducing the real power that can be delivered to customers. Battery energy storage has the capability to provide reactive power simultaneously to real power, which can be used to correct the power factor and reduce losses.

The unique flexibility of storage in providing both generation support, load/demand support and reactive power allows storage to be applied to local networks resolve a wide combination of distribution network challenges such as thermal, voltage and fault-level constraints. Additionally, this flexibility can also be leveraged to provide a wider range of benefits for the wider electricity system. Within Smarter Network Storage, the storage will primarily serve to mitigate thermal constraints of the overhead lines at Leighton Buzzard, and also provides a unique test bed to improve capacity, reduce losses and demonstrate range of other system-wide applications.

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Security of Supply / Load smoothing	Trials of the capabilities of storage for supporting the distribution network through peak-shaving, reducing maximum load and contributing to security of supply. The ability of the storage facility to reduce peak loads at the chosen site will be trialled. These trials will be best performed throughout the winter period, when peak loads are at higher levels.	What are the capabilities of storage in providing benefits to the distribution network? What is the potential range of ancillary services that a ‘DSO’ might require from a storage operator? What are the operational safety considerations in dispatching storage to support distribution networks?
Power factor support	Improving power-factor through reactive power support to increase capacity. The power conversion system (PCS) component of storage can be used to provide reactive power that can increase the real power delivered by the network, reducing losses and improving capacity. The capabilities of the storage facility in correcting power factor to improve utilisation and reduce losses on the overhead lines will be trialled and assessed.	
Voltage Support	Voltage support of the local network using both reactive and active power. Clustering of low-carbon technologies could result in voltage issues for distribution networks that can be corrected by storage acting in a dynamic, real-time mode of operation. Operation of the storage in this way will be trialled, and the capabilities in stabilising voltage shall be assessed.	

Dependencies
This work stream is dependent on the delivery of operational storage hardware (WS1) and integration of the control system (WS2).
The detailed plans for the execution of these tests will be carried out within WS3.1.
The work stream is also dependent on communications to support the data capture and control of the storage facility (WS1 & 2).
The practical experiments performed will inform and support the studies carried out in WS3.6 and other studies.

High-level roles and responsibilities
A123 will provide technical and operational support for the trials.
UK Power Networks will be responsible for designing and carrying out the tests, ensuring safety standards and operational procedures are adhered to.
Durham University will be responsible for data capture from operational tests and analysis of that data.

Key Reports / Dissemination Activities
- Report summarising the trials carried out and results achieved, incorporating the applications that could be translated to ancillary services or products that future active DSOs may procure
- Contribution to learning and dissemination events for other DNOs

WS 3.3 – Ancillary Service Demonstrations and Validation

This work stream area covers operational demonstrations of the use of storage capacity for providing ancillary services as an additional benefit of distribution-connected storage.

The transmission system operator (TSO) is currently responsible for balancing supply and demand on the electricity system, ensuring the frequency remains within statutory limits and maintaining security of supply. A range of services are currently procured by the TSO to meet these requirements, summarised below:

Reserve Services:
Short-Term Operating Reserve (STOR), also referred to as a positive reserve service, provides additional active power by way of instructing increased generation and/or demand reduction. This helps to deal with actual demand being greater than forecast, or unforeseen generation unavailability.

Negative reserve is also occasionally required to deal with an unexpected demand decrease, or increase in embedded generation output. This can typically happen in high-wind, low-demand situations such as summer evenings.

Fast Reserve, is a service typically provided by large generators, and provides a means for the TSO to instruct (either manually or electronically) a rapid change in active power output or demand. Fast Reserve is used, in addition to other energy balancing services, to control frequency changes that might arise from sudden, and sometimes unpredictable, changes in generation or demand.

Response Services:
System frequency is a continuously changing variable that is determined and controlled by the second-by-second (real time) balance between system demand and total generation. If demand is greater than generation, the frequency falls while if generation is greater than demand, the frequency rises. Dynamic frequency response is a continuously provided service that is used to manage the real-time variations in system frequency, whereas non-dynamic frequency response is a discrete service, provided only when system frequency hits a specific threshold.

Firm Frequency Response is a balancing service under which both dynamic and/or non-dynamic frequency response can be provided.
Frequency Control by Demand Management (FCDM) is a service designed to allow the provision of non-dynamic frequency response through the interruption of demand customers.

Each of these services have different sets of requirements, currently tailored to the generating sets or aggregated demand customers currently providing the majority of these services. Storage has the capabilities to provide several of these services, alongside the distribution-network requirements and the extent to which storage can contribute to supporting the wider system will be explored in this work area. The value in providing these services will be captured to help inform the viability of business models for storage that is able to perform multiple applications.

Learning from individual demonstrations of the storage ability to provide reserve and response services will be used to help inform the design and demonstration of trials of more simultaneous provision of system-wide supporting services, as trialled in WS3.5.

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Frequency Response Services	Trial demonstration of the capability of the storage device to provide high and low frequency response. This will involve committing the availability of the storage capacity to be in the correct state of charge to provide response as contracted. Initially, this will be most suitable during low demand periods (summer months) and will be underpinned by a bilateral contract with National Grid.	The requirements and capabilities of storage in providing frequency response services. What internal business processes are required to ensure alignment with DNO requirements and post-fault scenarios? What are the technical, regulatory and commercial barriers in doing so?
Reserve Support	Trials of the capabilities of storage for providing operating reserve through wider system ancillary services through existing mechanisms such as STOR and Fast-Reserve and new bilateral agreements. This will involve committing the availability of the storage capacity to be in the correct state of charge for providing reserve as required.	What are the capabilities of storage in providing reserve balancing services for the transmission system? What internal business processes required to ensure alignment with DNO requirements and post-fault scenarios? What are the technical, regulatory and commercial barriers in doing so?

Dependencies

This work stream is dependent on the delivery of operational storage hardware (WS1) and integration of the control system (WS2).
The work stream is also dependent on communications to support the data capture and control of the storage facility as well as integration and communications between UK Power Networks' control centre and the operational partners (WS1&2).
The work stream is also dependent on contractual arrangements being developed and put in place between UK Power Networks, the operational partners KiWi Power, and National Grid (WS4).

High-level roles and responsibilities

KiWi Power will be responsible for managing the trials of the storage device for ancillary service purposes, including for example, managing the incorporation of the storage capacity in any tender rounds and handling notifications and dispatch from National Grid.
Guidance and support from National Grid will be necessary to accommodate and participate in the trials.
UK Power Networks will be responsible for designing necessary business processes to notify storage availability and network conditions, and ultimately validating proposed actions.

Key Reports / Dissemination Activities

- Report summarising the trials carried out and results achieved, including the benefits in providing additional ancillary services and potential scope for simultaneously providing these services in tandem with alternative activities
- Contribution to learning and dissemination events for other DNOs

WS 3.4 – Wholesale Market Service Demonstrations and Validations

This work stream area covers operational demonstrations of the various services and applications of storage capacity for wholesale market purposes that an 'energy storage operator' may undertake, including arbitrage and imbalance risk mitigation. Learning from these individual service demonstrations will be used to help design and demonstrate trials of simultaneous provision of system-wide supporting services, as trialled in WS3.5

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Supplier storage demonstrations – Short-term optimisation	Trials of the capabilities of storage for providing energy management services and arbitrage to ensure visibility of the use of storage in the markets, and optimise the costs of know operations of the storage device to support the network.	Understanding of the capabilities of storage in providing additional benefits through wholesale markets. Understanding of the key the technical, regulatory and commercial barriers in the use of distribution-connected storage by Suppliers.
Supplier storage demonstrations – Tolling	Trials of the ability of third-party energy-storage operators to optimise and make efficient use of storage capacity within the constraints of distribution requirements.	Understanding of the potential for optimising the storage capacity around the Distribution constraints of storage Insight into the additional benefits realisable, to support the business model for a system-wide energy storage operator.

Dependencies

This work stream is dependent on the delivery of operational storage hardware (WS1) and integration of the control system (WS2).

The work stream is also dependent on communications to support the data capture and control of the storage facility as well as integration and communications between UK Power Networks control centre and the operational partners (WS2).
The work stream is also dependent on contractual arrangements being in place between UK Power Networks and SmartestEnergy (WS4).

High-level roles and responsibilities
A123 will provide technical and operational support for the trials.
SmartestEnergy will be responsible for management of the trial demonstrations and communicating proposed dispatch patterns.
UK Power Networks will be responsible for designing necessary business processes to notify storage availability and network conditions, and ultimately validating proposed actions.
Durham University will be responsible for data capture from operational tests.

Key Reports / Dissemination Activities
Results from these trials will generate learning around the potential to maximise the economic potential of storage and how it can support third party operators, such as suppliers, in managing wholesale activities and imbalance risk. This will further help to inform the business case for storage and the value in optimising energy storage within wholesale markets.

- Report summarising the trials carried out and results achieved, including the high-level value generated and potential scope for simultaneously providing these services in tandem with alternative activities
- Contribution to learning and dissemination events for other DNOs

WS 3.5 – Optimised / Simultaneous Service Demonstrations and Validations

This work stream area covers optimised operational demonstrations of the use of storage capacity for providing simultaneous system-wide benefits, including distribution network support, arbitrage and reserve and response services.

The previous experience in preparing and despatching the storage capacity for a range of individual purposes will provide the foundation for further development and understanding of the opportunities, risks and limits of optimising the use of the storage to maximise the efficiency and economics of the installation. This work area will build on these trials to identify synergistic modes of operation and identify how the value in storage capacity can be maximised for the benefit of the DNO and wider system. These demonstrations will serve to provide DNOs and TSOs with new insights into how future market services and products may be designed to best accommodate the flexibility of distribution-connected storage.

The business processes developed will be tested to demonstrate the operation of the storage facility in a more integrated, efficient system manner providing greater understanding of how the future activities of a Distribution System Operator might need to develop to support additional flexibility and management of demand and generation flows on the networks.

Innovative new service structures will be designed and tested collaboratively with National Grid, allowing the storage to provide a range of benefits in a more flexible fashion. This may necessarily be undertaken on a no fee basis, in order not to be discriminatory to other providers and so as not to impose additional Balancing Services use of System (BSUoS) charges. Estimates of the potential value to the system will be estimated and used to further understand the business models for storage that may evolve as market structures evolve to accommodate storage flexibility.

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Optimised operation of integrated storage trial	The capabilities of the storage device will be demonstrated when providing multiple applications to the full electricity system. Integrated, simultaneous operation across a range of timescales will rely on new business processes and the full capabilities of the optimisation platform will be used to perform trials demonstrating a combination of approaches to optimisation on a more granular basis.	The capabilities of storage in providing multiple, integrated system-wide services. The economic potential for storage for system-wide operators and how this will support the business model for energy-storage operators. The availability and reliability of storage in providing distribution security of supply, whilst also providing integrated, system-wide benefits

Dependencies
These trials will be dependent on successful demonstrations of individual service demonstrations of the storage facility (WS3.2, WS3.3, WS3.4).

The work stream is also dependent on contractual arrangements being in place between UK Power Networks, the operational partners, and National Grid (WS4) – these may be flexible enough to incorporate simultaneous service provision from the early stages of the project, or may require new contractual frameworks to support alternative operating arrangements. These will be determined during the initial contractual framework design and implementation stages.

High-level roles and responsibilities
A123 will provide technical and operational support for the trials.
SmartestEnergy and KiWi Power will be responsible for managing submission of required information to support the optimisation within the designed business process.
UK Power Networks will be responsible for validating the optimisation platform algorithms and proposed operating schedules.
Durham University will be responsible for data capture from operational tests.

Key Reports / Dissemination Activities
- A report summarising the trials carried out and results achieved, including the high-level value generated, and how this may be realised in the context of different business models.
- Contribution to learning and dissemination events

WS 3.6 - Distribution Network design in the presence of storage facilities

This work stream relates to technical studies by Imperial College around the use of storage for contributing to distribution network security, and how the use of storage for multiple applications affects the way in which storage can be incorporated into network design principles.

The ability of energy storage to displace network reinforcement by reducing network loading during peak demand conditions will be quantified. Appropriate methods to assess the contribution of energy storage to security of supply over various time scales will be designed. Particular emphasis will be on quantifying the supply risks when network is supported by energy storage with limited amount of energy, taking also into account that storage may be used to provide other services. The basis for determining the capacity value of energy storage units will be the requirement that security performance of the network with storage is the same as the network reinforced through traditional network solutions.

The outcome of this work, incorporating analysis of the storage performance along with engagement with other DNOs, will help inform reviews of Engineering Recommendation P2/6 and provide recommendations for the incorporation of integrated storage into revised network design standards.

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Analysis of distribution network security contribution from energy storage	Quantification of the ability of energy storage to displace network reinforcement. A number of key factors will be considered: (i) load profiles characteristics, which will include an analysis of different mixes of customer types (industrial, commercial, and residential) and different voltage levels to take into account diversity effects; this will be carried out in close collaboration with UK Power Networks and other interested DNOs; (ii) number of energy storage units of different technologies and different characteristics (iii) storage design parameters (power and energy rating, efficiency) including technical and commercial availability.	The overall ability and performance of storage to displace network reinforcement. Methods to assess the contribution of storage towards network security. Recommendations on how energy storage could be included in future network design standards.

Dependencies
This work stream will be informed by data captured during operational service demonstrations, in particular the DNO Service demonstrations in WS3.2.

High-level roles and responsibilities
Imperial College is responsible for the studies in this work stream, leading the activities to design methodologies to assess the contribution of energy storage and generate recommendations with the support of UK Power Networks and other DNOs.

Key Reports / Dissemination Activities
- Technical report describing the analysis of contribution of energy storage to distribution network security;
- Recommendations on how energy storage could be included in future network design standards;

WS 3.7 - Quantifying the value of energy storage against alternatives, and assessing conflicts and synergies across multiple markets

In this set of studies Imperial College will quantify the value of energy storage when providing support to distribution network management and analyse its competitiveness against alternative technologies such as demand response and advanced network technologies. We will apply Imperial College's whole-electricity system modelling framework and explicitly consider synergies and conflicts of storage resources being used in multiple markets in relation to the benefits it may provide to the distribution networks.

Based on the studies in WS3.1, analysis will be conducted to assess possible conflicts and synergies that may exist between the storage applications for managing the distribution network and providing services in other markets. This will involve consideration of the specific location of storage installation within GB, as storage connected to distribution networks in the north and south of the country may be associated with different operating patterns.

Validated and informed by the operational trials carried out in WS3.2 and leveraging Imperial College's Dynamic Investment System Model, we will assess the economic and CO_2 benefits that storage application could bring, against a range of future development scenarios.

Finally, leveraging results from Low-Carbon-London and other LCNF projects, studies will be undertaken to consider alternative technologies that can compete with energy storage, including in particular, various forms of demand side response, conventional and advanced distribution network technologies. Sets of cost and performance targets for energy storage technologies when competing with alternatives to support distribution network management will be established. The impact of storage design parameters, such as power and energy ratings and efficiency on its competitiveness will be considered in depth.

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Benefits of energy storage technologies to distribution networks	Analysis of the benefits of energy storage in enhancing the capability and utilisation of existing networks to facilitate cost effective integration of distributed generation and load growth including the impact of electrification of heat and transport sectors. This will be applied at the project-scale and at the UK scale by applying using representative distribution networks analysis. This will involve consideration of connections of energy storage to all voltage levels in the GB distribution networks, including LV, HV and EHV networks.	The value of energy storage services for the particular installation in the UK Power Networks system considering different future development scenarios The value of the economic benefits across all distribution network types at UK scale Cost targets for energy storage and the volume of the market potentially available to storage in GB, under different future development scenarios The impact of storage design characteristics on benefits
Synergies and conflicts in the application of energy storage distribution network connected in multiple markets	Analysis of possible conflicts and synergies that may exist between the storage applications for managing distribution network and providing services in other markets. Assessments of the economic and CO_2 benefits that storage application could bring, against a range of future development scenarios, including investigation into the impacts that storage power and energy ratings and efficiency may have on the portfolio of services that storage can deliver. The modelling will be validated and informed by operational trials.	How storage can be leveraged for distribution network and wider system benefit, whilst managing conflicts and synergies in requirements. The overall value and carbon benefits that can be realised by storage, and how the characteristics determine the ability to provide services
Understanding competition to energy storage	Analysis of alternative technologies that can compete with energy storage, including in particular, various forms of demand side response, conventional and advanced distribution network technologies.	Cost and performance targets for energy storage technologies when competing with alternatives to support distribution network management The impact of storage design parameters on the relative benefit of storage against other options

Dependencies

This work stream will be informed by data captured during operational service demonstrations, in particular the DNO Service demonstrations in WS3.2.
Learning generated from other LCNF projects, including Low-Carbon London, will be leveraged to help assess energy storage against competing solutions to network challenges.

High-level roles and responsibilities

Imperial College is responsible for the studies in this work stream, with the support of the data captured by Durham University and UK Power Networks.

Key Reports / Dissemination Activities
A research report will be produced covering analysis of:

- The benefits of energy storage to distribution networks under different future development scenarios
- The synergies and conflicts in the application of storage for multiple services
- The relative costs and benefits of storage against other sources of flexibility and considerations of cost/performance targets

WS 3.8 Energy Storage Commercial Strategy

In this activity the key focus of the analysis will be to understand how the resource of a single energy storage device can be optimally allocated between distribution network support, system balancing including management of wind, energy arbitrage, supporting transmission network and providing backup, while considering the constraints associated with the amount of energy that can be stored.

This analysis will involve development of commercial strategies for energy storage that will allow aggregation of multiple revenue streams of electricity storage in a systematic way to meet the needs of distribution network operators. This will be based on a model that can coordinate a series of auctions in which the right to utilise the storage unit is advertised, which can include different time horizons. The model derives optimal strategy for alternative markets in terms how best to use the available storage capacities in a certain auction, and then ensures that non-conflicting uses of storage in different markets are coordinated.

This work will help inform the approach to developing more flexible and optimal commercial arrangements to maximise the value of storage flexibility in the later phases of operational demonstrations.

Trials Envisaged

Area	Sample of envisaged experiments	Learning Points
Auction approach to allocating storage resource to multiple markets	Identification and development of auction approaches to the use of flexibility	Approaches to the commercial use of energy storage and other flexibility across the system, and how these can inform future market and regulatory frameworks

Dependencies
The work in this area will involve the interaction of all operational partners in the project as stakeholders in the electricity system.

High-level roles and responsibilities
Imperial College is responsible for leading the studies in this work stream, which will feed in to the development and implementation of commercial arrangements in WS4.

Key Reports / Dissemination Activities
A report will be produced that will help inform the activities across WS4, and include:

- Energy storage commercial strategies involving an auction approach to optimally allocating storage and how this might inform future market services

Work stream 4: Commercial & Regulatory Frameworks

Work stream Summary

Work stream 4 is responsible for managing the commercial and regulatory aspects of the project. It will ensure that all necessary enabling partner agreements are initially placed and that all further commercial arrangements are set up to ensure that the project can participate in desired services provision trials with the transmission system operator (TSO) and other operational partners. Any legal and regulatory barriers that would otherwise prevent the wider adoption of this type of storage facility connecting to Distribution Networks will be identified and proposals for overcoming these will be documented and disseminated. The various ownership arrangements will be considered and the learning that is gained from the trials will be made available to inform and develop the potential of network storage across the UK.

WS 4.1 – Project Set up - Commercial Requirements

This work stream encompasses the initial implementation of collaboration agreements with all project Partners at the start of the project. All such agreements will be co-ordinated and concluded in conjunction with each of the work stream leads and project partner key contacts. Note the procurement and purchase of the SOCS and storage system, enabling civil and other engineering works required to connect the storage device to the network will be managed and coordinated within the technical branches of the project undertaken within Work streams 1 and 2, leveraging UK Power Network's own Capital Programme and Procurement functions for assets of this nature.

Collaboration agreements will be established with the following operational partners to ensure the delivery of the project learning objectives:

- National Grid: National Grid will provide guidance and advice in identifying ancillary service opportunities for storage, be one of the potential buyers of services from the network storage device, and facilitate a larger role for distribution connected storage in the future.
- KiWi Power: will provide management of the provision of ancillary services to National Grid; and
- SmartestEnergy: will provide access to the wholesale electricity market and settlement activities including purchase and sales price information to allow service decisions to be made. SmartestEnergy will ensure appropriate import and export meters are installed and registered for the facility.

Collaboration agreements will also be implemented with the following research and learning partners:

- Pöyry Management Consulting: Pöyry will deliver market and regulatory expertise, provide analytical and modelling services, and assess various ownership models;
- Imperial College: Imperial College will undertake studies relating to the integration of storage into electricity systems, and the value against alternatives;
- Swanbarton Limited: Swanbarton will support the overall development of the project and provide specialist support in energy storage commercials, design, hardware and operation; and
- Durham University: Durham University will provide research services specifically related to distribution network connected energy storage and will provide specific support to ensure maximum learning is captured and disseminated for the industry.

Key components: Partner Collaboration Agreements

Dependencies
This Work stream will be reliant on both partner and work stream resource being available to respond quickly during the period of these contract negotiations. In order to help mitigate risks of delays during this process, IPR provisions have been included in the pre-project phase Memorandums of Understanding entered into with each intended project partner and discussions to progress the delivery contracts will continue in the months following submission.

High level roles and responsibilities
UK Power Networks has specific legal resource identified for the project to undertake and support these activities, with the remaining resources being accounted for in the Project Management Office and Delivery function. These activities will also involve the input of each of the project Partners.

Key reports / dissemination activities
The outcome of this work area will be established collaboration agreements with partners for the duration of the project.

WS 4.2 – Identify and Manage Smart Commercial Arrangements

This work area involves the identification and development of the necessary commercial arrangements to enable the range of services demonstrated within the project to be provided.

A number of these arrangements are relatively well developed, but have not yet been applied in the context of energy storage; whereas others will require new arrangements to be established. This work will provide significant learning around the risks, responsibilities and considerations of novel commercial arrangements to support the integrated use of flexibility and the arrangements will be developed into templates that can be shared for the benefit of other DNOs and industry.

For existing services offered by the TSO e.g. short term reserve or other ancillary services, the commercial arrangements required are already well specified, and the new business processes developed will enable participation in the necessary mechanisms required to tender and commence the services provision. Contractual arrangements will be developed to allow demonstration of the following services:

- Short-term operating reserve (Flexible)
- Short-term operating reserve (Committed)
- Frequency Response (Dynamic)
- Frequency Response (Static)

In exploring the ability of the storage device to provide a more flexible and optimised set of services, for example a combination of short term reserve at the same time as offering frequency response services, new commercial arrangements will need to be developed that balance the constraints and benefits in the provision of multiple services with one asset.

Commercial arrangements will also need to be established with SmartestEnergy to allow the pricing and procurement of energy required for the storage device on the wholesale markets. Contractual arrangements that will be trialled with SmartestEnergy include:

- Energy Trading Service Agreement – to enable the energy costs of the storage device to be reconciled in the wholesale markets, providing a known price against a known despatch profile as well as enabling short-term positions for supporting the network
- Tolling Agreement – to enable the storage capacity to be released to SmartestEnergy for a fixed capacity payment, which is then optimised to best meet the supplier's requirements

Key components
Commercial arrangements underpinning each operational service trial

Dependencies
In order to participate in the ancillary services market providing transmission services to the TSO will require the support and co-operation of KiWi Power and National Grid.
Resources from SmartestEnergy to support the development of commercial arrangements.

High level roles and responsibilities
UK Power Networks has specific legal resource identified for the project to undertake and support these activities. Identifying and managing commercial arrangements will take place from May 2013-September 2014 in the lead up to the technology becoming operational, with further support as and when framework agreements are set and tendering processes occur.
Imperial College's work on Commercial Strategies for storage (WS3.8) will support and inform these activities.

Input from the operational project Partners will be provided at their own cost from National Grid, KiWi Power and SmartestEnergy. Swanbarton will provide commercial support when exploring these new innovative commercial arrangements, based on previous experience and expertise.

Key reports / dissemination activities
The outcome of this work will be a significant level of learning around the necessary commercial arrangements to support the system-wide use of storage.
Contract templates will be produced that provide frameworks for other DNOs to implement the shared use of flexibility and provide learning around the key risks, roles and considerations in ensuring network constraints are met whilst maximising additional value for customers.

WS 4.3 – Regulatory and Legal Arrangements

This Work stream will undertake studies to further identify any legal and regulatory barriers to developing the wider introduction of storage facilities on DNO networks. The main objective of this work stream will be to provide recommendations for the removal of regulatory constraints that will need to be achieved in order to optimise the use of storage connected to a distribution network which is also providing additional system-wide services.

This review will test the existing commercial and regulatory arrangements in light of the arrangements implemented in WS4.2 and identify changes which would better enable storage to support a decarbonised GB electricity system.

Understanding how larger-scale deployment would affect the current market codes, licences and technical protocols will be a significant element of the project; UK Power Networks expects that the learning generated from this element of the project will be of significant interest to Ofgem and all DNOs and will help inform the on-going dialogue around the development of market arrangements that support smarter grids and the low carbon economy.

Dependencies
This study will be informed by the learning generated from WS4.2, following the implementation of real commercial frameworks that enable the provision of a range of services.

Key components
Learning from implementation of storage commercial arrangements.
Assessment and research into regulatory documents.

High level roles and responsibilities
Poyry will lead on this activity however input from UK Power Networks legal and regulatory functions and support from other partners will also be required.
The regulatory and legal review will take place following the storage becoming operational in October 2014 and is expected to run for 8 months.

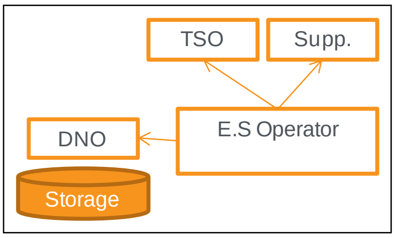
Key reports / dissemination activities
Based on experience and knowledge of the frameworks within which electricity markets operate, Poyry will provide an in-depth review and research report including:
- Identification of the specific areas across existing regulation that poses a threat to the future adoption of energy storage, across distribution, transmission and generation
- Analysis of the potential for ancillary benefits of integrated storage to exceed current regulatory limits on supplementary income for DNOs
- Evaluation of changes required to regulatory and commercial frameworks to enable distributed energy resources to participate in the wholesale market and offer services to both transmission and distribution system operators
- The potential impact of EMR developments on the potential for maximising the value of flexibility

WS 4.4 –Operating and Ownership Business Models for Storage

This work stream will explore and assess the various future business models available for such storage facilities, detailing the benefits and opportunities of each and looking at how these may change over time.

Although there are obviously derivatives of each, two core models will be evaluated in the project:

(i) Regulated Asset (DNO-owned / operated)



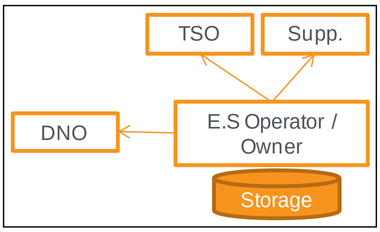
The simplest business model to implement would be that of a regulated asset. Albeit a higher risk option than a conventional network solution, investment in Electrical Energy Storage (EES) would attract the same regulated cost of capital as established network asset-based solutions. However the current cost of EES compared with typical conventional network reinforcement can be relatively high. In order for the investment to be cost-effective, it would therefore generally be necessary to identify further cost-offsetting benefits; for example by providing balancing services to the TSO or supporting wholesale market participants in managing their out-of-balance risks. These activities, provided by the 'energy storage operator', would be managed either by the DNO or a third-party service provider as illustrated above. Such ancillary and risk mitigation services, efficiently and competitively procured by the relevant stakeholders, would generate an additional income stream that would enhance the business case for investment in EES. A further potential opportunity arising from EMR proposals is that of using EES to access the capacity market.

By deploying EES in this way, consumers would benefit directly through reduced DUoS charges as well as from reduced 'pass through' costs of balancing services and generation capacity, and ultimately therefore reduced electricity energy bills. In terms of funding EES, while it might seem feasible to apportion contributions from relevant stakeholders to investment, and divide revenue streams accordingly, there might be practical difficulties in reaching consensus as to apportionment of costs, risks and benefits. In this 'regulated asset' model, the DNO can retain some higher level of control over the storage capacity to provide the required level of network security for consumers, whilst also leveraging existing expertise in capital project delivery and asset management. The question then becomes whether sufficient value is then still realisable to the rest of the system to make it worthwhile leveraging additional applications, and hence improving the overall efficiency and economics of operation.

We do not see major impediments to the regulated asset model. The equalisation of incentives (TOTEX) approach to treatment of regulated asset value (RAV) and operational expenditure allowances (fast and slow money) would seem to hold up well given that, like conventional network reinforcement, EES solutions have a capital cost and relatively small maintenance cost, albeit differentiated by also being revenue generating and having a shorter life expectancy than conventional network assets. The current Information Quality Incentive (IQI) mechanism would provide an incentive to invest in EES where the overall net cost (i.e. net of revenue income) represented a saving over conventional reinforcement, albeit potentially at a higher risk (i.e. in terms of certainty of revenue income generating services competitively bid for).

A derivative of this particular model could be ownership/operation of the asset by the TSO, although in this case it would be more challenging to realise distribution network benefits from strategic positioning of the storage.

(ii) Non-regulated Asset (Leased-regulated or Third-party owned / operated)



An alternative business model is that of a 3rd party operating the EES. In this case, the 3rd party (for example an Aggregator or Supplier) might invest in the facility and the DNO (as with other customers of ancillary services) would strike a contract with the 3rd party operator for provision of capacity for network support, as illustrated below. However a DNO investing in the facility would potentially have access to a lower cost of capital and there might therefore be merit in the DNO procuring the device as a 'regulated asset' but then leasing the facility to a 3rd party operator. In-house analysis is available which enables us to calculate the value we would attribute to services from an EES device in order to defer reinforcement. This is based on the present value of the alternative traditional investment option, but somewhat complicated by the fact that EES (as with DSR) could be described as a bridging solution pending eventual traditional reinforcement of a substation or circuit. Hence the present value is adjusted to take into account that work might still be required at a later date (though, equally, the EES device might then be redeployed to address a network constraint elsewhere).

In this model, the utilisation of the storage capacity is driven more freely by commercial terms (i.e. an unconstrained market). The question around the model then becomes whether in some circumstances the DNO valuation of the required services is sufficiently high to command priority over other applications, and how security of supply could be guaranteed in the event of near-coincident and mutually exclusive calls for utilisation. We believe this matter could be resolved as part of the planned review of ERP2/6 by (as with distributed generation) assigning a probability of availability to EES which will form part of the other studies and learning that the Smarter Network Storage project will undertake.

The specific costs and value associated with real use of the device in performing additional services will be captured across the operational demonstrations and provide real commercial data that can inform this analysis.

Key Components
Analysis of value streams realised and how these support the possible business models for storage.

Dependencies
This work stream will be informed by the economic value and revenue streams captured as part of the learning from the operational trials.

High level roles and responsibilities
Work on the activity will be lead by Pöyry, however it is anticipated input and support from other partners (Imperial College, Swanbarton Limited and Durham University) may be required.
UK Power networks will provide input to the analyses based on experience and value realised from the operational demonstrations.

Key reports / dissemination activities
Pöyry will provide an in-depth review of the possible business models around storage, and analysis that will validate the business cases for each of these models based on operational trial data/ Key learning outcomes will include:

- Identification and assessment of the range of potential business models for storage
- Development of frameworks to assess the different models for energy storage
- Development of case studies based on the value realised during the project to assess the validity of business models
- Assessment of the impact on different future market scenarios on the business cases, for example varying carbon prices, high versus low wind penetration and demand side response

APPENDIX I – STORAGE TECHNICAL DETAILS

The proposed solution uses A123's Long Duration Product. Information is provided for a 6MVA/15MWh configuration that can be expanded to an 8MVA/24MWh configuration within the allocated space. This Appendix contains further information on the technical solution, and more detailed information is also available on request.

1.1. Long Duration Solution – 6MVA, 15MWh

A123 will supply a Long Duration solution that consists of nine battery zones (six installed, three spare for expansion) with a capacity of 15MWh, three enclosed power conversion units, three step-up transformers, medium voltage protection circuitry, auxiliary equipment, and a control system. The 'Site Layout' drawing in Appendix B shows the proposed site layout for the configuration.

1.1.1. Long Duration Solution – 6MVA, 15MWh – Overall System Specification

Long Duration ESS System Specifications		
Description	**Specification**	**Note**
Power Capability	6 MVA	
Energy storage	15 MWh	Not affected by charge/discharge rate
Reactive Power Capability	≥80% of active power	100% capability optional
Voltage at connection point	11 kV AC Nominal	
Maximum Depth of Discharge	100%	
Maximum Charge Rate	6 MVA	Over Entire State of Charge range
Maximum Discharge Rate	6 MVA	
Minimum Charge Rate	0 MVA	
Minimum Discharge Rate	0 MVA	
Battery Type	Lithium Ion Nanophosphate® (LFP based)	
AC-AC Nominal Round Trip Efficiency at C/2.5, excluding transformer.	90%	Excludes Auxiliary Consumption
AC-AC Nominal Round Trip Efficiency at C/2.5 including transformer.	87%	Excludes Auxiliary Consumption
Estimated Auxiliary Consumption No cycling (Standby Power)	9.9 kW	Summer Day
Estimated Auxiliary Consumption 1 cycle per day	29.2 kW	Summer Day
Self Discharge Rate	≤5% in 6 months	At 100% SOC
Charge Recovery Time	None	
Discharge Recovery Time	None	
System Audible Noise	50dB - 77dB	
Operating Temperature Range	-30 to 50 °C	
Storage Temperature Range	-30 to 60 °C	
DC Voltage Level	750 V – 1050 V	
Usable State of Charge	0% - 100%	
Cycle lifetime @ 1C/23°C	>3500 cycles @ 100% DOD	To 80% BOL Energy
Maximum altitude	1000 metres	Without de-rating
Relative Humidity	0% - 100%	

The complete system will be housed in a purpose built building that consists of two major compartments. The compartment containing the battery storage will be closed to the outside and actively cooled while the compartment containing the Power Conversion System, Transformers and Switchgear will be open to the outside air and enclosed using slat walls. A section plan of the building is shown in Figure 8.1 (Page 48) of the full submission.

1.2. Power Conversion System (PCS) with integrated protection and measurement

The system will include three Power Conversion Systems (PCS's) housed in their own enclosures. A summary of specifications is provided below:

Inverter Specifications		
Description	**Specification**	**Note**
Power Rating	6 MVA	
Active Power Rating	6 MW	
Reactive Power Capability	4.8 MVAR (6 MVAR optional)	
Frequency	50 Hz	
Operational Frequency Range	47 Hz – 53 Hz	Programmable
Phases	3	
AC Voltage Level (before step-up Transformer)	480 V AC	
AC Voltage Level (after step-up transformer)	11 kV AC	
600V 3-pole AC breakers	9600 A	(total all breakers)
DC Voltage Level	750 V – 1050 V	
One-way efficiency	97%	
Ramp-up time to full power (excludes communication latency)	20 msec	
Operating Temperature Range	-30 to 50 °C	
Humidity Range	0% - 100%	
System Noise	50dB - 77dB	
Maximum Voltage for continuous operation	1.10 pu Full Power	
Minimum Voltage for continuous operation	0.9 pu Full Power	
Overpower Capability	120% - 10 minutes 150% - 30 seconds 200% - 3 seconds	
Harmonics	IEEE 1547 compliant	

1.2.1. Auxiliary Equipment

The proposed solution includes all required auxiliary equipment including:

- Auxiliary feed from protection cabinets
- 200 kVA Auxiliary transformer 110 kV to 400/230 V
- Auxiliary PDU to distribute power to all system components
- AC to DC power system for powering the protection relays
- All auxiliary cables

1.3. Electrical System Diagram

A representative Electrical System Diagram showing the configuration of the storage solution including the Battery System, Power Conversion System protection circuitry and Auxiliary Power Distribution has been developed and can be provided upon request.

1.4. Product Lifetime

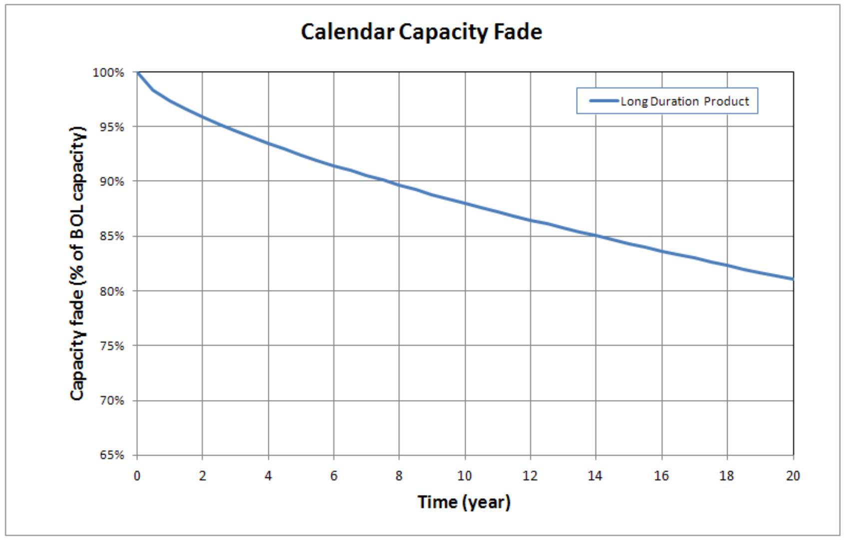
Battery system components are designed for a 20 year life provided that proper preventative maintenance is executed on a regular basis (Note other equipment, including switchgear, and transformers will have lifetimes closer to 40 years, similar to other typical network assets). Separately, the battery life will depend on two factors: Cycle Life and Calendar Life. The effects of the two are cumulative and define the total life of the batteries. The capacity will gradually decrease over time until it reaches approximately 65% of its beginning of life capacity. At this point the batteries are considered at their end of life.

A123 batteries have an exceptional long life compared to other technologies including other lithium ion technologies. One unique property of A123 cells is that they will continue to have significant cycle and calendar life even when the capacity has decreased well below 80%.

1.4.1. Calendar Life

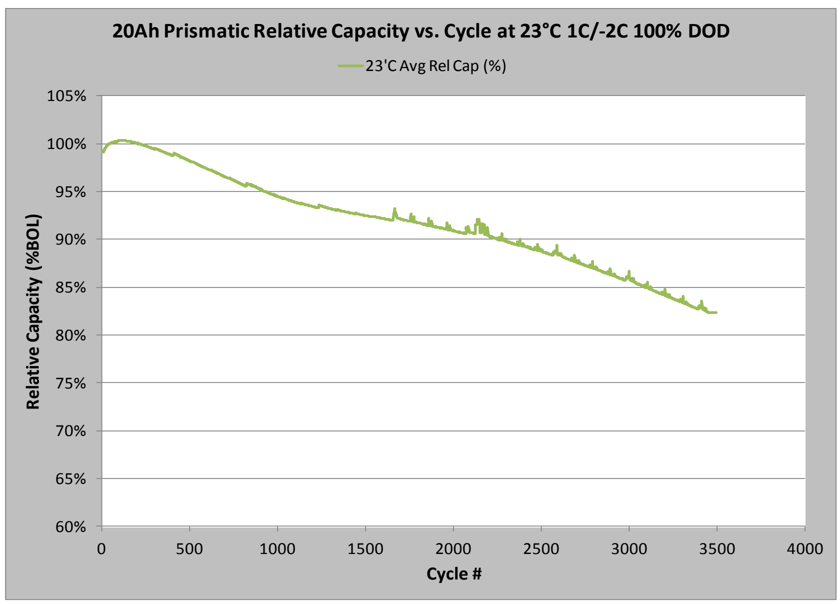
All batteries will lose capacity over time not related to the cycling of the batteries. The primary factor that affects calendar life is the average temperature at which the batteries operate.

The Calendar Life Graph for the Long Duration system is shown to the right.



1.4.2. Cycle Life

The available capacity of the storage system is affected by the number of cycles that the system experiences. Cycles are not cumulative so a 100% cycle has a greater effect on cycle life than two 50% cycles. The following graph shows test data for A123 cells cycled with full 100% depth of discharge (DOD) cycles.



1.4.3. Product Recycling

All components of the Storage Solution are highly recyclable. The batteries contain no heavy metals, lead, rare-earth metals or other chemicals that complicate recycling or disposal. A123 has all the capabilities to recycle the storage solution in compliance with the EU Batteries Directive. A123 current works with Xstrata in North America and Umicor in Europe who have specialised recycling processes for lithium ion batteries. A123 will also leverage experience gained from other UK, LCNF projects.

APPENDIX J - LETTERS OF SUPPORT

nationalgrid

National Grid House
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CV34 6DA

Richard Smith
Future Transmission Networks Manager

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www.nationalgrid.com

10th August 2012

Dear Sir/Madam,

UK Power Networks, Smarter Network Storage (SNS) LCNF Tier 2 Project

National Grid is pleased to be a proposed partner for the Smarter Network Storage (SNS) LCNF Tier 2 project. Projects such as this are an important part of how we respond to market changes, possibly paving the way for national benefits and savings.

By 2020 our electricity transmission system will have evolved to connect extensive renewable generation to achieve UK renewable and carbon targets. Beyond 2020 the requirements on the UK on electricity networks will dramatically increase with rising levels of variable wind generation, new larger nuclear power stations and increased electricity demand. Managing the transmission system and balancing electricity supply and demand will become more complex; with this the opportunity for the market to provide new roles and services will likely grow. This could include the growth of electricity storage.

The SNS project aims to trial the installation and use of storage technology on the UK Power Networks distribution network. If successful, the project will demonstrate how such a device could defer network reinforcement, whilst also contributing to meeting Great Britain's energy needs in the form of participation in the electricity wholesale market and within the balancing service markets.

National Grid has been actively involved in the LCNF for the last two years participating in several projects from both; previous rounds of the competition and current projects bidding. This includes already being a partner with UKPN on the existing Low Carbon London project. I wish to reemphasise our support to the LCNF and SNS project and our commitment to work with UKPN towards making this a successful project.

Yours Sincerely,

Richard Smith
Future Transmission Networks Manager

Full Copies of Letters of Support can be provided on request.

"It has been evident for some time that cost-effective electricity storage is a key enabler for many of the proposed future electricity supply architectures, and so may well become an important means of supporting the UK's electricity system transformation as it seeks to decarbonise. Many studies have shown that as more intermittent renewable energy, and local generation devices, connect to the power network, storage can become critically important as a means of ensuring network stability and economic control of its operation.

We are now at the stage where a multiplicity of studies have shown the potential technical and economic value of storage, notably those from the Energy Research Partnership and the Carbon Trust in recent months. However, a dearth a prototypes and demonstrations mean we remain unsure of how the various technology options will actually perform, in technical, operational, and economic terms, and whether our simulations have overlooked what could be critical operational and material limitations.
I would therefore endorse the importance of demonstration of electricity storage at scales typical of network operation, as described in your project, and hope you are successful in your application."
Professor John LOUGHHEAD OBE, FREng, FTSE, Executive Director, UK Energy Research Centre

"…..We believe that the role of electricity storage in our power system is important and would commend your proposal which seeks to investigate the technical and commercial challenges of using electricity storage as an alternative solution to conventional network reinforcement. It is particularly pleasing that you are addressing the project at a large scale and this will demonstrate some of the true system value that storage offers. The information derived from this project will be extremely valuable in supporting further deployment of storage throughout the UK. Electricity storage is a major component in the necessary transition towards a more sustainable power network ….."
Dr Jill Cainey Scientific and Technical Consultant

"…..The Institute of Mechanical Engineers are very keen to support the use of storage as a means of increasing the efficient utilisation of assets on the electricity network in Great Britain. In addition to maximising the use of output from renewable-based electricity generation technology, storage enables an increased return on investment for base load plant through enabling longer periods of operation at higher output. Electricity distribution infrastructure, such as transformers, cables and overhead lines can also be installed to meet peak loads, thereby avoiding unnecessary expenditure on power infrastructure….."
Dr Tim Fox CEng FIMechE CEnv

"…..In spite of not being selected as the preferred supplier of the energy storage solution I was pleased to receive your feedback on our tender. I continue to be interested in your project as your learning will be most important in assisting the development storage solutions. Cellstrom GmbH is very keen to promote the use of storage as a means of increasing the efficient utilisation of assets on the electricity network throughout Europe and worldwide….."
Dr Ing Ilja Pawel

Full Copies of Letters of Support can be provided on request.