UNIVERSITY of STRATHCLYDE
POWER NETWORKS DEMONSTRATION CENTRE

Innovation Mapping to Identify Distribution System Operation Gaps – Closedown Report

Document No.: 01

Classification: Public

18 December 2019

DOCUMENT INFORMATION	
Title:	Innovation Mapping to Identify Distribution System Operation Gaps – Closedown Report
Document No.:	01
Classification:	Public
Client(s):	ENA

DOCUMENT AUTHORING, REVIEW AND APPROVAL	
Version No.:	Issued to client
Prepared By:	Han Xu
Reviewed By:	Kyle Jennett
Authorised By:	Simon Hill
Date of Issue:	18 December 2019

PROJECT CONTRIBUTORS

The following people contributed to this project:

Han Xu, Kyle Jennett, Ryan Sims

DOCUMENT DISTRIBUTION

Lynne McDonald

DOCUMENT AMENDMENT RECORD			
Version	**Date of Issue**	**Changes from Previous Version**	**Purpose**
0.1	27/11/2019	Initial draft	Initial draft for PNDC internal review
0.2	29/11/2019	Revised initial draft based on PNDC internal review	1st draft issued to Lynne McDonald for comment
0.3	16/12/2020	Revised draft based on Open Networks stakeholders' comments	2nd draft issued to Lynne McDonald for review
1.0	18/12/2020	Revised based on additional Open Networks stakeholders' comments	Issued for steering group approval

EXCUTIVE SUMMARY

All of the UK electricity network operators are working collaboratively to incorporate the learnings from previous and underway innovation activities and understand future innovation needs. The objective of this project was to identify Distribution System Operation (DSO) innovation opportunities that need to be developed further to meet the requirements for the future energy sector's smart grid plans. The findings from this project will inform industry stakeholders on key areas that need to be targeted in future innovation activities. This project was commissioned by the Energy Networks Association (ENA) as part of the Open Networks project, Product 5 Workstream 3, and ran from June 2019 to November 2019.

The areas of 'innovation opportunity that require further development' were identified through a multi-step process framework developed during the first stage of this project. This process was based on the learnings from several previous 'gap analysis' projects combined with feedback from ENA Workstream 3 team. This process utilised the 'DSO Capabilities' and 'Key Enablers' previously defined by the Open Networks Project in [1]–[3] and involved consideration and categorisation of 1,333 innovation projects. After the innovation projects had been categorised a list of underdeveloped innovation areas was generated by assessing project metrics, including: the number of projects; the monetary spend; and technology readiness level in each 'DSO Capabilities' and 'Key Enablers' area. This short list was then presented to industry stakeholder groups through a variety of workshops and forums to obtain industry feedback.

Based on the previous and present innovation activities, the findings from both the objective assessment of project metrics and the subjective assessment from industry stakeholders were combined to create a ranked shortlist of nine innovation focus areas[1]. The ranked shortlist is the ultimate output from this project and is presented below (with 1 being the area of highest priority and 7 being the area of lowest priority):

1. **DSO capability – Investment Planning & Forecasting**

Investment Planning
Identification of capacity requirements on the distribution network and processes to secure the most efficient means of capacity provision to customers. Coordinate with the Electricity System Operator (ESO) and Transmission Operators (TOs) to identify whole system options for addressing wider network limitations. These would include commercial DER options as well as distribution network investment.
Forecasting
Development of consistent, repeatable and auditable methodologies in operational and investment timescales for forecasting demand, generation, network power flows and the requirements for flexibility.

2. **DSO Key Enabler - Open Access for All Providers**

Enhanced and innovative account and contract management in flexibility markets.

3. **Joint third place:**

3.1 DSO capability – Service/Market Facilitation & Outage Planning
Service/ Market Facilitation
Facilitate local and national markets to enable Distributed Energy Resource (DER) access/participation in wider services for whole system optimisation through auctions and other market arrangements for whole system efficiency. Ensure these arrangements are fair and transparent.

[1] There are already activities (within innovation projects) that address the 9 DSO focus areas, these focus areas were identified based on:

1. Present innovation level: the project scope targeted for electricity innovation activities from 2010 up to June 2019;
2. Stakeholder validation and votes.

Discussion of the focus areas and details of wider industry activities can be found in section 7.

Outage Planning

Planning and managing network outages that reduce the impact on customers accessing the network, whilst ensuring the network remains secure.

3.2 DSO capability – Charging

Development of techniques to determine Distribution Use of System prices for the local network, Points of Connection, connection charges and informs of transmission reinforcement charges (if applicable). Noting that this would follow Ofgem's leading work on the network charging code reviews: Significant Code Review (SCR) on network access and forward-looking charge arrangements, and Targeted Charging Review (TCR) on residuals.

3.3 DSO Key Enabler – Forecasting DER Output

Long-term forecasting of network utilisation and DER behaviours is critical in order to allow efficient procurement of DER flexibility.

4. **DSO Key Enabler – Scalability of DSO Services**

The processes and methods to deploy at scale, moving from DSO service trial to early adoption to mainstream.

5. **DSO Key Enabler – Communication Infrastructure**

Development and roll out of advanced communication solutions and infrastructure.

6. **DSO Key Enabler – Organisational Changes**

Flexible organisational structure will be needed in order to adapt to the transition to DSO and use of new digital solutions.[2]

7. **DSO Key Enabler – Mechanism to Quantify Service Delivery**

Well-defined mechanisms in DSO markets to quantify delivery of flexibility services from providers and DERs.

[2] The stakeholder subjective analysis noted that in this focus area (DSO Key Enabler – Organisational Changes) there is low innovation activity. They suggested that this area may be being addressed elsewhere in organisational BaU teams or by non-electricity network operators (both scope areas were outside the focus of this assessment). In addition, stakeholders also identified elements of organisation change that could be related to new ways of working (e.g. augmented reality), these projects may warrant specific targeted innovation to progress.

LIST OF ABBREVIATIONS

BaU	Business as Usual
BEIS	Department for Business, Energy and Industrial Strategy
DER	Distribution Energy Resource
DNO	Distribution Network Operator
DSO	Distribution System Operation
ENA	Energy Networks Association
ENIS	Electricity Networks Innovation Strategy
ESO	Electricity System Operator
ICT	Information and Communication Technology
IDNO	Independent Distribution Network Operator
IFI	Innovation Funding Incentive
LCNF	Low Carbon Network Fund
NIA	Network Innovation Allowance
NIC	Network Innovation Competition
Ofgem	Office of Gas and Electricity Markets
ONP	Open Networks Project
RIIO	Revenue = Incentives + Innovation + Outputs
SCR	Significant Code Review
TCR	Targeted Charging Review
TO	Transmission Operator
TRL	Technology Readiness Level
UKERC	UK Energy Research Centre

Contents

1 INTRODUCTION

The UK's energy network is experiencing rapid transformation in both energy production and consumption. This is reflected in the renewables' component of total generation, seen at a record high level of 33.3% in 2018, up from 29.3% in 2017 [4]. The electrical utility industry is moving towards a cleaner, more digitised and decentralised series of networks.

Network operators are facing new challenges with the transition to decarbonised and decentralised smart grids. These changes require a corresponding change in business models (i.e. roles and responsibilities) if the aspiration of implementing optimum whole system operation of the electricity network is to be achieved. As part of this change UK Distribution Network Operators (DNOs) are presently transitioning to a Distribution System Operator role. This role will enable them to more actively manage the distribution network by procuring distributed flexibility resources and facilitating flexibility market implementation at the distribution level. This transition will enable increased utilisation of DERs and renewable energy generation.

The Open Networks Project (ONP) [5] is developing business models for network operators to facilitate the transition to a more flexible whole energy system approach. This requires a transformative shift in the way the energy system as a whole, operates and coordinates. The electricity sector has come together and agreed a shared vision outlined in ENA's Future Worlds Impact Assessment report [6].This shows strong agreement to building closer coordination between network operators (distribution system operators and TOs) and ESO. It is vital that we take an evidence based approach to set a positive course for the energy sector in the UK and that can only be done through "learning by doing", i.e. innovation.

Innovation allows technologies and ideas to be developed, trialled and tested before Business as Usual (BaU) deployment. Britain's energy network regulator Ofgem (Office of Gas and Electricity Markets) supports innovation activities of network operation via network innovation funding mechanisms, including the Network Innovation Allowance (NIA) and Network Innovation Competition (NIC). In addition, wider funding opportunities are also available for innovation activities, such as Innovate UK etc. This project specifically looked at identifying gaps in present and planned innovation that need to be developed further to meet the requirements for the future energy sectors smart grid plans.

1.1 Project Objectives

The ONP has 6 Workstreams, Workstream 3 supports the DNO to Distribution System Operator transition. This project was Product 5 of Workstream 3. The objective of this project was to review current innovation levels within different innovation areas and identify DSO innovation gaps and opportunities, from a whole electricity system point of view. By identifying the gaps and future opportunities, the findings from this project informed innovation areas that require future development. Based on this primary objective the project achieved:

- Formalising a unified framework for identifying innovation commonalities and gaps, based on: network operator innovation strategies, DSO transition roadmaps, and previous gap analysis projects.
- Identifing the innovation activity information that needs to be captured and then recording that information in a register for analysis.
- Applying the unified framework to innovation activities using open access project data (primarily obtained from the Smarter Networks Portal [7] in this project).
- Engaging with industry stakeholders for validation and provision of industry expertise knowledge.
- Combining the data analysis and industry knowledge into a unified whole to identify innovation gaps and opportunities.

1.2 Scope of Work

This project reviewed and categorised UK electricity innovation projects. This review activity included all projects funded by NIA [8], NIC [9][9], and LCNF [10][10] (Low Carbon Network Fund) that were listed on the Smarter Networks Portal up to June 2019. Projects funded via wider funding mechanisms[3] were also considered and these were fed into the project through engagement with industry stakeholders (including all UK network operators) involved in the project. The unified framework applied in this project does not relate to any recommendations on the future market models (i.e. Future Worlds) of the ONP. The developed framework is therefore market neutral and as it utilises the ENA DSO Capabilities and Key Enablers it reflects the least regret investment of DSO transition that can be implemented in the future.

The three deliverables that represent the three stages of the project are summarised in Figure 1:

- The first stage was to develop a framework that can be applied to reviewing and mapping of innovation activities.
- The second stage was to complete an initial analysis that categorises DSO relevant projects and mapping the DSO relevant projects to the framework.
- The last stage was to identify the DSO gaps and opportunities by combining the mapping analysis results in the second stage and industry stakeholders' knowledge.

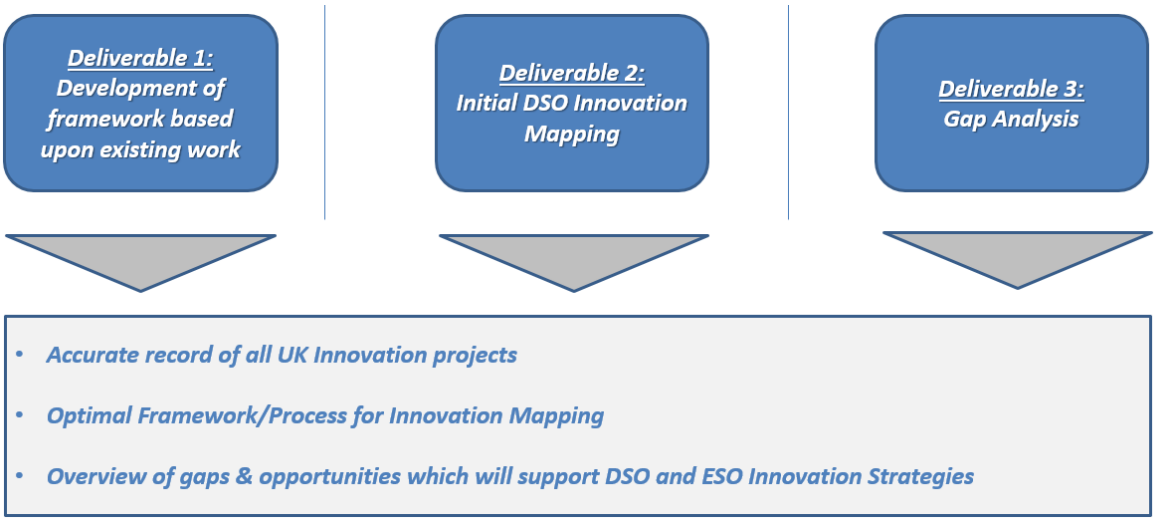


Figure 1 Project Scope

1.3 Method

A high level overview of the six-step method, used in the project, is described in this section. The six steps are:

1.3.1 Literature Review

The literature review was conducted to understand the whole energy system vision and individual network/system operators' DSO roadmaps. This helped to define the key messages along the pathway for DSO transition. The literature review was also used to inform the mapping framework of the project and identify opportunities to leverage previous gap analysis and reviewing work.

[3] Wider funding mechanisms include funding other than NIA, NIC, LCNF and IFI. For example, Innovate UK grant, BEIS (Department for Business, Energy and Industrial Strategy) competition funding, utilities' internal BaU (Business as Usual) funding and etc. were considered as wider funding mechanisms.

1.3.2 Framework Options

In this step, the relevant frameworks identified in Step 1 were reviewed, in order to identify effective framework techniques that could be adopted for the Innovation Gap Analysis.

1.3.3 Implemented Framework

Based on steps 1 & 2 and consultation with ENA stakeholders the two primary mapping framework techniques adopted for this project are:

- DSO capabilities (Functions and Competencies [1]): 8 DSO functions and 12 underlying competencies were chosen as being representative of the innovation needs for future DSOs.
- Key Enablers (defined within the Future Worlds [2], [3]) have been used as a guide for facilitating the least regret investment for DSO transition. 4 primary Key Enablers (as presented in Table 1) and 21 secondary Enablers have been identified.

Key Enablers
1. Changes to industry structure:
– Regulatory and policy changes
– Organisational changes
2. Developing a market-based approach:
– Market engagement
– Contract requirements
– Funding
3. Facilitating information and data exchange
– Communications infrastructure
– IT systems
– Network visibility and control
4. Wider Enablers

Table 1 High Level Overview of the Key Enablers

1.3.4 Objective Analysis

A combined assessment route was established to identify future innovation prospects. The assessment route has two parallel analysis paths: Objective and Subjective analysis.

In the objective analysis, innovation activities were shortlisted for DSO relevance, and then mapped against the framework established in Step 3. A total of 1,333 projects were considered and 416 were reviewed, including projects funded via Ofgem and from wider funding sources identified by stakeholders. To identify areas that presently have low innovation focus 6 heatmaps were generated and then later combined into a single unified heatmap incorporating:

- The number of projects in each area
- The monetary spend in each area
- Multiple metrics relating to TRL (Technology Readiness Level)

In the unified heatmap, present innovation levels of DSO capability and Key Enabler areas were categorised into three levels: low, medium and high. Low innovation level areas were labelled as "DSO Innovation Focus Areas" and at this stage included 3 DSO capabilities and 1 Key Enabler.

All of the objective analysis was based on open access data from the:

- ENA Smarter Networks Portal [7]
- Project proposals

- Project close down reports
- Miscellaneous associated project documentation (i.e. progress reports)

1.3.5 Subjective Analysis

Stakeholders were engaged throughout this project, and their feedback was incorporated into both the framework process and the final project outputs. Industry stakeholders in Workstream 3 of the ENA ONP provided an insight into the industry's view on future DSO innovation opportunities to supplement the objective analysis findings (i.e. identified focus areas). The stakeholders in Worksteam 3 provided a commentary on the low innovation areas identified from the objective analysis during a subject assessment workshop event and they also identified 5 additional Key Enabler focus areas to be added to the objective analysis list.

A similar assessment structure to the 2018 ENIS review [11] was used by the Workstream 3 stakeholders during the workshop to assess the focus areas. The assessment structure considered:

- *Urgency* to implement in order to enable industry progress towards DSO transition,
- Potential *Benefit/Value* from the implementation to customers, and
- *Timeline* of when a project should be scheduled to realise the appropriate DSO benefit.

At the conclusion of the subjective assessment workshop, 3 DSO capability and 6 Key Enabler focus areas were finalised. This shortlist was then used to engage with a wider group of industry stakeholders via: the LCNI 2019 conference and the November 2019 Advisory Group meeting of the ONP. In both instances, stakeholders were invited to vote on the area they believed to be the highest priority. At the LCNI 2019 event stakeholders were invited to vote during the two-day conference via an interactive board and/or an online voting questionnaire (available via SurveyMonkey). The brochure, interactive board and online survey used during and after the LCNI 2019 conference are available in Appendix C.

1.3.6 Identifying DSO Future Innovation Opportunities

The objective and subjective analysis were combined together in the project findings. The objective analysis identified the current low innovation areas of DSO capability (Functions & Competencies) and DSO Key Enablers. From the subjective analysis, Open Networks Workstream 3 stakeholders validated the focus areas identified from the objective analysis and added 5 more Key Enabler focus areas. The output from this was a combined list of DSO focus areas that consider both objective assessment and stakeholder feedback. As the last step of the subjective analysis, the identified focus areas were then voted upon by a wider group of stakeholders. Based on the votes, a prioritised list of the focus areas was produced as the final outcome of this project.

1.4 Report Structure

The report structure follows the same structure specified in the method section (see section 1.3).

- Section 2 summaries the findings from the literature review at the start of this project.
- The findings from section 2 informed the options for the review framework and these options are listed in section 3.
- The framework that was implemented in this project is described in detail in section 4.
- To identify future DSO innovation opportunities, a combined assessment route was established and used, as illustrated in section 5. This included the objective data analysis and subjective stakeholder assessment.
- The objective data analysis procedure and the analysis results (DSO relevant project statistics and heatmaps) is reported in section 6.
- Section 7 highlights stakeholder touch points in this project and presents the subjective assessment outcomes.

- Combining the objective and subjective assessments, the final project outcome (a prioritised list of DSO focus areas) is also presented in section 8.
- A large component of the analysis from this project was based on the open access project data downloaded from the ENA Smarter Networks Portal. PNDC recommendations to improve the functionality of the Smarter Networks portal are given in section 9. In addition to these recommendations, lessons learned throughout the project are also discussed in section 9.
- Conclusions and future work are summarised in section 10.

2 LITERATURE REVIEW

The first stage of this project was to perform a literature review to: understand the overall industry trends within the energy networks; capture key messages along the DSO transition pathway; and identify previous review and gap analysis projects to find best practice methods for this project. The categories of the literature reviewed are listed below:

- Electricity and gas networks vision by Scottish government
- ENA ONP DSO vision and roadmap
- ENA Electricity Network Innovation Strategy
- Energy Data Taskforce report
- International DSO projects and strategy
- UK network/system operators' innovation strategy
- UK network/system operators' DSO transition roadmap
- Previous work implementing innovation gap analysis frameworks

A full list of documents considered can be found in Appendix A.

3 FRAMEWORK OPTIONS

Previous projects implementing innovation gap analysis frameworks were considered prior to finalising the framework implemented in this project (to ensure best practice). The following six frameworks were identified and a short summary of each is provided in the following list:

1. *'DSO Roadmap to 2030 framework'*[12] *published by ENA ONP:* The roadmap informs 3 high-level development areas for DSO transition, along the RIIO (Revenue = Incentives + Innovation + Outputs) timeline. The 33 innovation targets of the 3 high-level development areas have a lot of crossover with the DSO Functions and Competencies [1]published by ENA ONP. This means that the DSO Functions and Competencies can be collated with the 33 innovation targets along the timeline specified in the DSO roadmap.
2. *'Summary of LCNF Learning'*[13] *published by EA Technology:* The summary report mapped key learnings of LCNF projects to 6 RIIO output categories and 11 solution areas. The 6 RIIO outputs and 11 solutions relate to areas of DNO network operations. As a consequence, these are not specifically related to DSO transition and cannot therefore be readily incorporated into the scope of this project.
3. *'UKERC Review and Synthesis of LCNF Outcomes'*[14] *published by the University of Strathclyde:* LCNF projects were mapped against 4 policy drivers and 2 functional areas with 10 sub-topics that are related to DNO network operations. The 4 policy drivers have a significant crossover with the Key Enablers [2], [3] proposed by ENA ONP. However, as with the *'Summary of LCNF Learning'* report, the framework used in the UKERC (UK Energy Research Centre) review is not DSO specific and therefore cannot be readily incorporated into the scope of this project.
4. *'DSO Functional and System Requirement'*[1] *published by ENA ONP:* As part of the ONP Workstream 3 Product 2, 8 DSO functions and 12 underlying competencies were defined as functional requirements for DSO. In addition, the DSO functions and competencies are market model neutral. These functions and competencies were used as one part of the framework applied in this work, and they provided an appropriately balanced level of granularity for mapping and gap analysis.
5. *Key Enablers*[2] *published by ENA ONP with the Future Worlds:* The ONP published 4 high-level Key Enablers during the Future Worlds work. The Key Enablers indicate the least regret investment areas that enable the DSO transition and closer DSO – ESO interactions. The Key Enablers are market neutral as they are independent of the Future Worlds market models. The Key Enablers are used as one part of the assessment framework in this project to support least regret investments.
6. *'Electricity Networks Innovation Strategy (ENIS)'*[11] *published by ENA:* The ENIS reviewed the innovation projects and categorised them into 5 Key innovation themes and 31 challenge sub-categories. The framework used by ENIS has various levels of categorisation and it provided an appropriately balanced level of granularity on the innovation themes and challenges. However, the innovation themes and challenges are not DSO specific, therefore, they don't directly relate to those that are DSO transition specific.

Table 2 summarises the evaluation of the different frameworks listed above in the context of this project. The finalised framework combines aspects of each of the frameworks and utilises the DSO functions & competencies and Key Enablers for mapping and gap analysis. These were adopted as they are DSO specific and market model neutral.

Framework Option	Comments	Adopt
ENA – DSO Roadmap to 2030 framework • 3 high-level development areas • 33 innovation targets	• A lot of crossover with DSO Functional and System Requirements • Challenging to combine with other framework categories • Useful high-level DSO transition timelines outlined	✓
EA Technology – Summary of LCF Fund Learning • 11 solution areas • 6 RIIO outputs	• Not DSO specific • Lacks DSO specific detail to identify detailed gaps	✗
UKERC Review and Synthesis of LCNF Outcomes • 4 policy drivers • 2 functional areas with 10 sub-topics	• Not DSO specific • Lacks DSO specific detail to identify detailed gaps • Policy drivers have significant crossover with Key Enablers	✗
ENA – DSO Functional and System Requirements framework • 8 DSO functions • 12 underlying competencies	• DSO specific • Good level of granularity for mapping and future gap analysis • Leveraging existing framework allows for continuity	✓
ENA – Future Worlds Key Enablers • 4 high-level Key Enablers with 21 Enablers	• WS 3 P5 requested inclusion to support least regrets investments • Independent mapping required, separate to DSO functions	✓
ENA – Electricity Networks Innovation Strategy framework • 5 key innovation themes • 31 challenge categories	• Commonly used framework by all of Open Networks • Various levels of categorization can be used, e.g. 5 innovation themes • Not DSO specific • Challenging to combine with other framework categories without disrupting continuity of Open Networks DSO framework	✓

Table 2 Framework Options Considered in this Project

4 IMPLEMENTED FRAMEWORK

As presented in section 3, DSO capabilities (Functions & Competencies) and Key Enablers were used as the framework for this project. The relationship between the 8 DSO functions and 12 competencies identified from the 'frameworks options' section are shown in Figure 2. The 12 competencies are mapped to the 8 functions (given in blank cells in the figure) to reflect the capabilities required to deliver DSO functionality as specified in [1]. Greyed cells in Figure 2 indicate competency areas that are not required to deliver certain functions. Detailed descriptions of the functions and competencies are defined in the *'DSO Functional and System Requirements'* [1].

DSO Competencies / DSO Functions	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination												
Network Operation												
Investment Planning												
Connections and Connection Rights												
System Defence and Restoration												
Service /Market Facilitation												
Service Optimisation												
Charging												

Figure 2 DSO Functions and Competencies

4 primary Key Enablers and 21 secondary Enablers, as listed in Table 3, combined the Key Enablers proposed with the Future Worlds work [2] and the public consultation responses [3]. The Key Enablers incorporate: regulatory and industry structural changes, development of DSO markets, ICT (Information and Communication Technology) infrastructure changes, and evolving ways to engage with a wider customer base (e.g. home energy management system, smart devices, etc.). The reviewed innovation activities (projects) were mapped against the framework as shown in section 6.

High-level Enablers	Enablers	
Changes to industry structure	*E1 - Regulation and policy changes*	
	E2 - Organisational changes	
Developing a market-based approach	*E3 - Market engagement*	
	Contract requirements	*E4 - Specification of technical need*
		E5 - Engagement with potential service providers
		E6 - Scalability of DSO services
		E7 - Open access for all potential providers
		E8 - Defined payment mechanism
		E9 - Mechanism to quantify service delivery
		E10 - Settlement arrangement
	E11- Funding	
Facilitating information and data exchange	Communications infrastructure	*E12 - Communication infrastructure*
		E13- Interoperability and common data format
		E14 - Cyber security
	IT systems	*E15 - Determining the ability of DERs to provide system services*
		E16 - Forecasting DER outputs over various timescales on the distribution network
		E17 - Enabling active network management
		E18 - Increasing operational efficiency
		E19 - Providing congestion management services on the distribution network
	E20 - Network visibility and control	
E21 - Wider enablers		

Table 3 Key Enablers

5 COMBINED ASSESSMENT ROUTE FOR FUTURE INNOVATION OPPORTUNITIES

A combined assessment, which includes objective data analysis and subjective stakeholder input, was established in the project, in order to identify future innovation opportunities. The combined assessment route is illustrated in Figure 3.

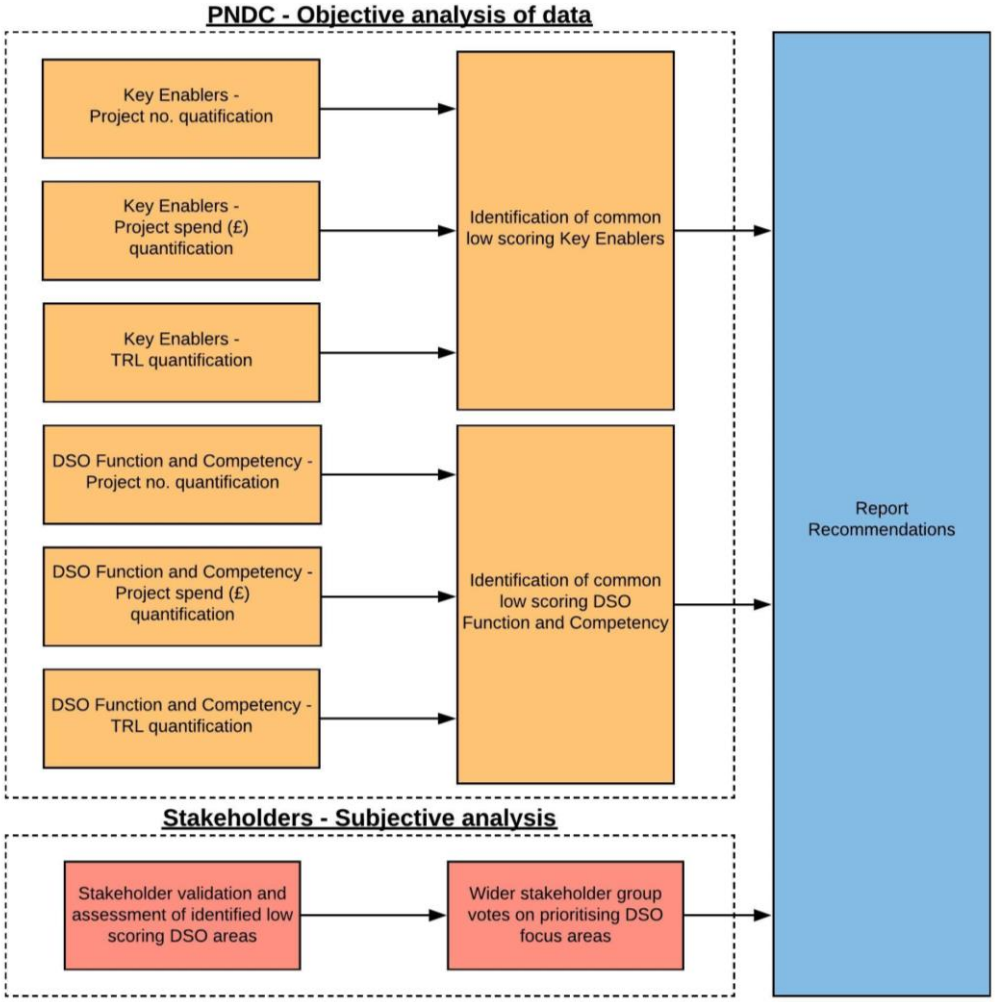


Figure 3 The Combined Assessment Route for Future Innovation Opportunities

In the objective data analysis, the innovation activities in the electricity sector were reviewed. DSO relevant projects were identified by mapping against the framework outlined in Section 4. 'Boundary' projects were also flagged in the data analysis to highlight activities innovating with wider sectors beyond electricity. The data analysis quantified the level of innovation activities, a summary of funding, and Technology Readiness Level (TRL) in each area of the framework (DSO capabilities and Key Enablers). The different quantification metrics were visualised using heatmaps. The heatmaps were then combined into a single unified heatmap to indicate the current innovation level.

In the subjective assessment the stakeholders' views on future DSO innovation opportunities were collected. At the subjective assessment workshop the ONP workstream 3 stakeholders validated and assessed the DSO areas that were identified in the objective analysis as having low innovation levels. The validation method used by stakeholders is similar to the lightbulb approach in the 2018 ENIS review [11], which considered the urgency, benefit/value and timeline of the DSO capability and Key Enablers areas. A detailed breakdown of lightbulb approach that was implemented can be found in Appendix B. After the subjective analysis workshop this shortlist was then used to engage with a wider group of industry stakeholders via: the LCNI 2019 conference and the November 2019 Advisory Group meeting of the ONP. In both instances stakeholders were invited to vote on the area they believed to be the highest priority.

6 RESULTS FROM OBJECTIVE ASSESSMENT

The follow innovation project data sources were used in the objective assessment:

- **ENA Smarter Networks Portal** [7]: The Smarter Networks Portal is an open and comprehensive database of both electricity and gas innovation projects funded via Ofgem. Detailed steps for accessing project data in the Portal can be found in Appendix D. Data from 1,308 electricity projects was downloaded from the Smarter Networks Portal for analysis. This included projects funded from NIA, NIC, LCNF (Tier 1 and Tier 2 funding) and IFI (Innovation Funding Incentive) [15]. The combined total value of the 1,308 projects is £1.38 billion. A breakdown of the number and value of projects per funding mechanisms is presented in Figure 4.
- **Wider funded project survey**: Survey questionnaires were sent to innovation leads from 10 network/system operators in the UK, including one representative of IDNOs, to gather wider funded projects data (i.e. not available on the ENA Smarter Networks Portal). The questionnaire follows the same format as the Smarter Networks Portal download format. Within the survey there was a filter request for an additional assessment by the innovation leads to identify if a wider funded project is DSO relevant, using the framework (DSO functions and Key Enablers). 25 wider funded projects were collected from the survey responses, with a total value of £62.77 million. The innovation activities and value of wider funded projects are also given in Figure 4 (in the final column).
- **DNOs and ESO's innovation webpage**: DNO and ESO innovation webpages have information and documentation of individual innovation projects. In addition to the project documentation that can be found on the ENA Smarter Networks Portal, dissemination documents, such as presentation slides, are also available from the DNO and ESO websites. The additional documentation provided information when reviewing innovation activities.
- **Electricity Network Innovation Strategy, Mar 2018** [11]: The 2018 ENIS reviewed over 250 innovation projects and categorised them into 5 Key innovation themes and 31 challenge sub-categories. In the 2018 ENIS work, 6 projects were categorised as enabling DNO to DSO transition. These 6 projects have therefore been included and reviewed in this project.

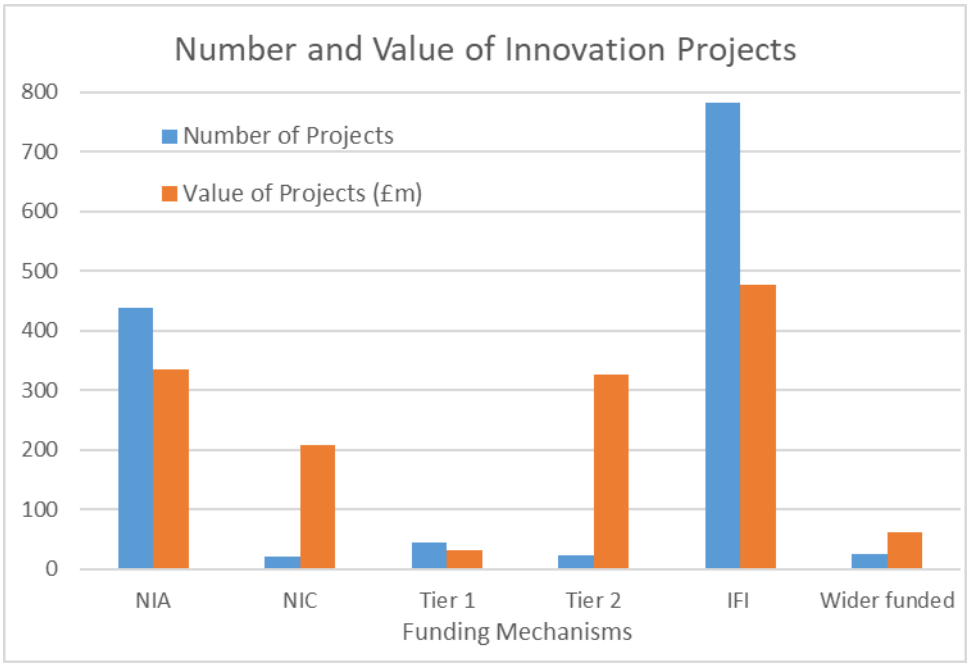


Figure 4 Key Stats from Project Data Collection

6.1 Number of Projects Reviewed

A total of 1,333 innovation projects have been considered. This takes into account 1,308 projects funded via Ofgem and 25 wider funded projects. Among the 1,308 projects funded via Ofgem, IFI projects were excluded from the review because IFI project details were limited (both in the Smarter Network portal and network operators' innovation webpages). In addition, over 250 projects funded via Ofgem were pre-reviewed in the 2018 ENIS review. Therefore, 416 projects were reviewed in detail in this project for DSO relevance, including 391 projects funded via Ofgem and 25 wider funded projects.

6.2 High Level Shortlisted Results

The 416 innovation projects were shortlisted for DSO relevance, by using DSO Functions and Key Enablers. 138 projects were identified as DSO relevant, with a total value of £329.83 million. As summarised in Table 4, this includes 114 projects funded via Ofgem and 24 wider funded projects.

The review also classified DSO relevant projects as 'boundary' projects if they are innovating in a wider sector (e.g. transportation, gas, etc) instead of being solely electricity focused. 28 out of 138 DSO projects were classified as 'boundary' projects, with a total value of £92.56 million.

	Number of identified DSO projects:	Innovation Funding (£m) of DSO projects
Projects funded via Ofgem	114	£ 267.17
Wider funded projects	24	£ 62.66
Total	**138**	**£ 329.83**
	Number of identified boundary projects	Innovation Funding (£m) of boundary projects
Projects funded via Ofgem	23	£ 82.01
Wider funded boundary projects	5	£ 10.55
Total	**28**	**£ 92.56**

Table 4 Summary of Innovation Activities and Value of DSO and Boundary Projects

The 138 DSO relevant projects were mapped against the 8 DSO functions and 21 secondary Key Enablers[4] separately, during the short listing stage. In addition to the mapping analysis, DSO projects were grouped by DSO function and by year to show innovation activities that were/are running concurrently.

6.2.1 High Level Mapping against DSO Functions

Quantified levels of innovation activities and innovation funding across the 8 DSO Functions were generated based on the mapping results. The number of projects related to DSO Functions is presented in Figure 5, and the monetary value (£) of projects within a DSO Function is given in Figure 6. It can be observed from both figures that 'System Defence and Restoration' and 'Charging' are the two Functions with the least innovation activity and funding when compared to the other 6 DSO Functions.

6.2.2 High Level Mapping against Key Enablers

In a similar process to the DSO Function mapping, the number of projects and value of projects for each secondary Key Enabler were summed, as seen in Figure 7 and Figure 8. It can be observed that the Key Enablers 'Organisational changes (E2)', 'Mechanisms to quantify service delivery (E9)', 'Settlement arrangements (E10)', and 'Forecasting DER outputs (E16)' have the least number of projects and monetary value (£) compared with the other key Enablers.

[4] A project was double counted if it attributes to more than one DSO function/competency/Key Enabler

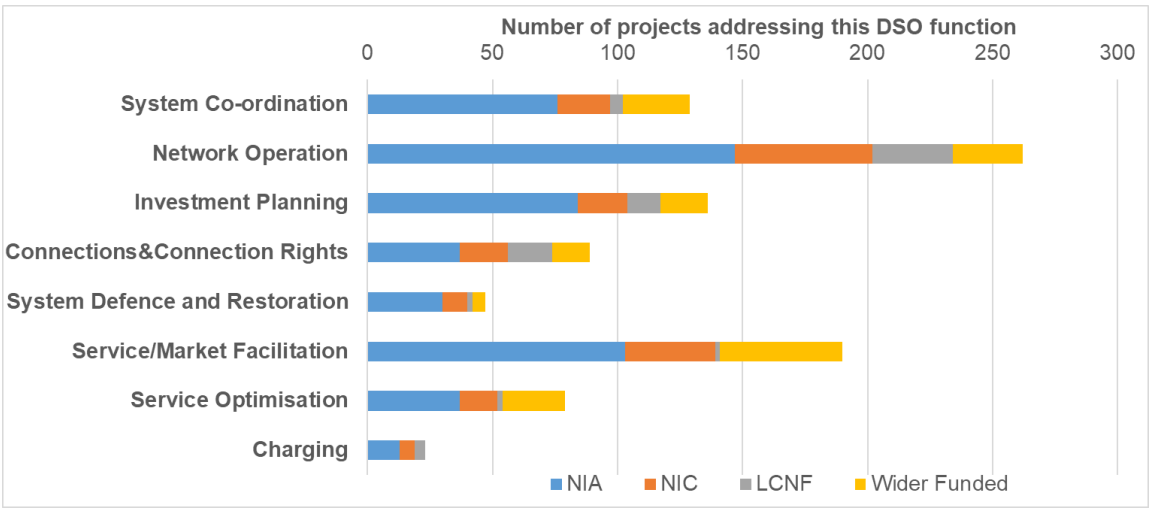


Figure 5 Quantified Level of Innovation Activities in DSO Functions

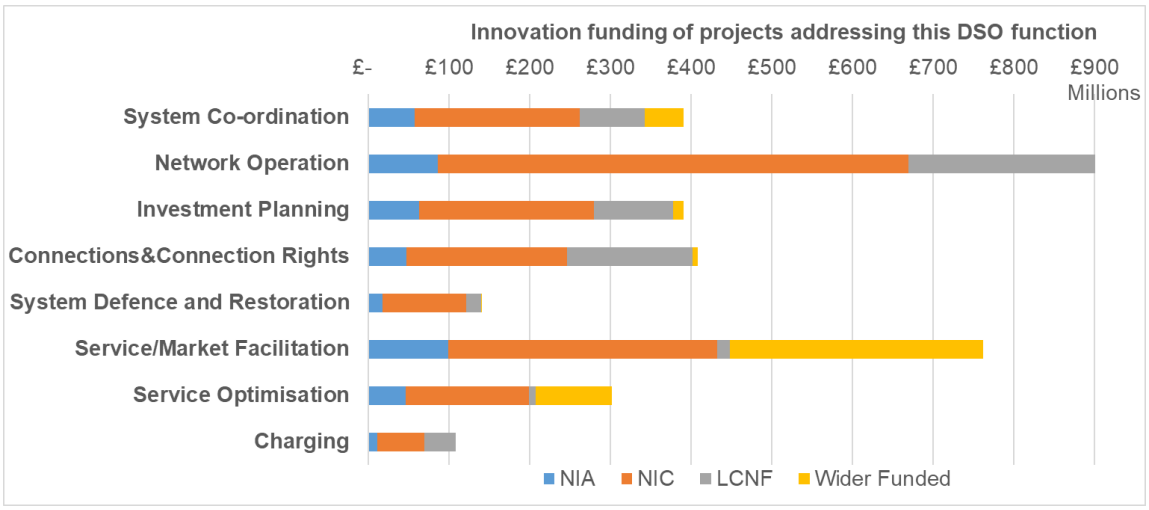


Figure 6 Value of Innovation Funding in DSO Functions

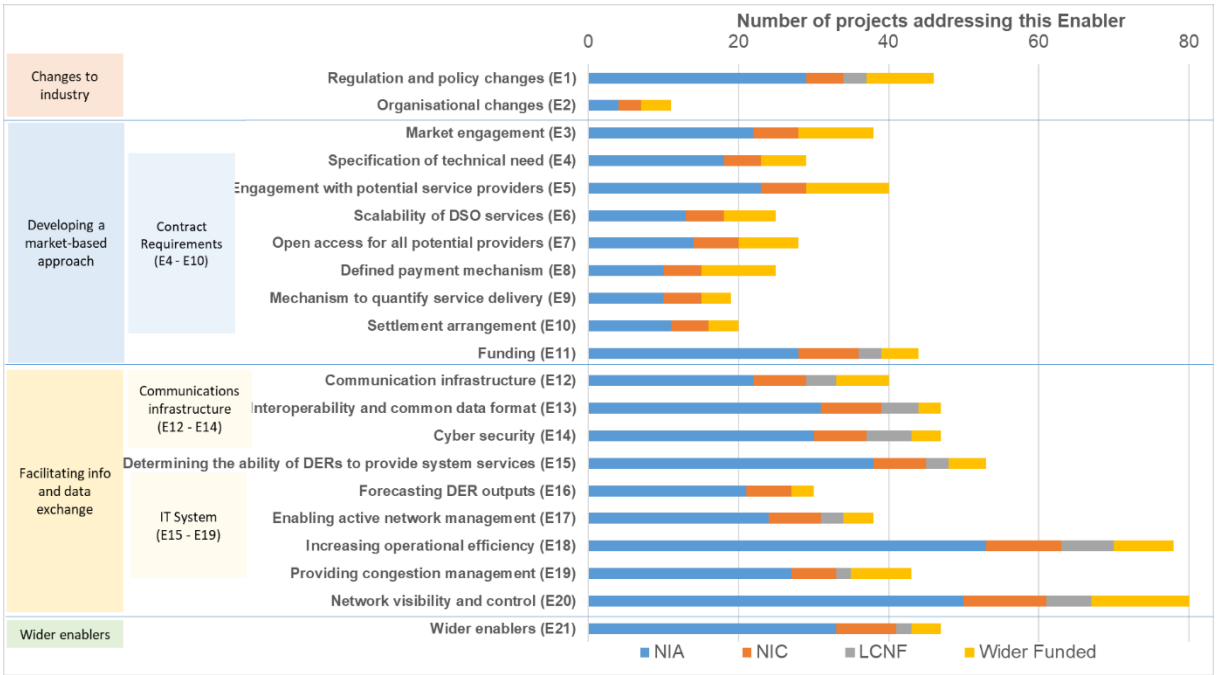


Figure 7 Quantified Level of Innovation Activities in Key Enablers

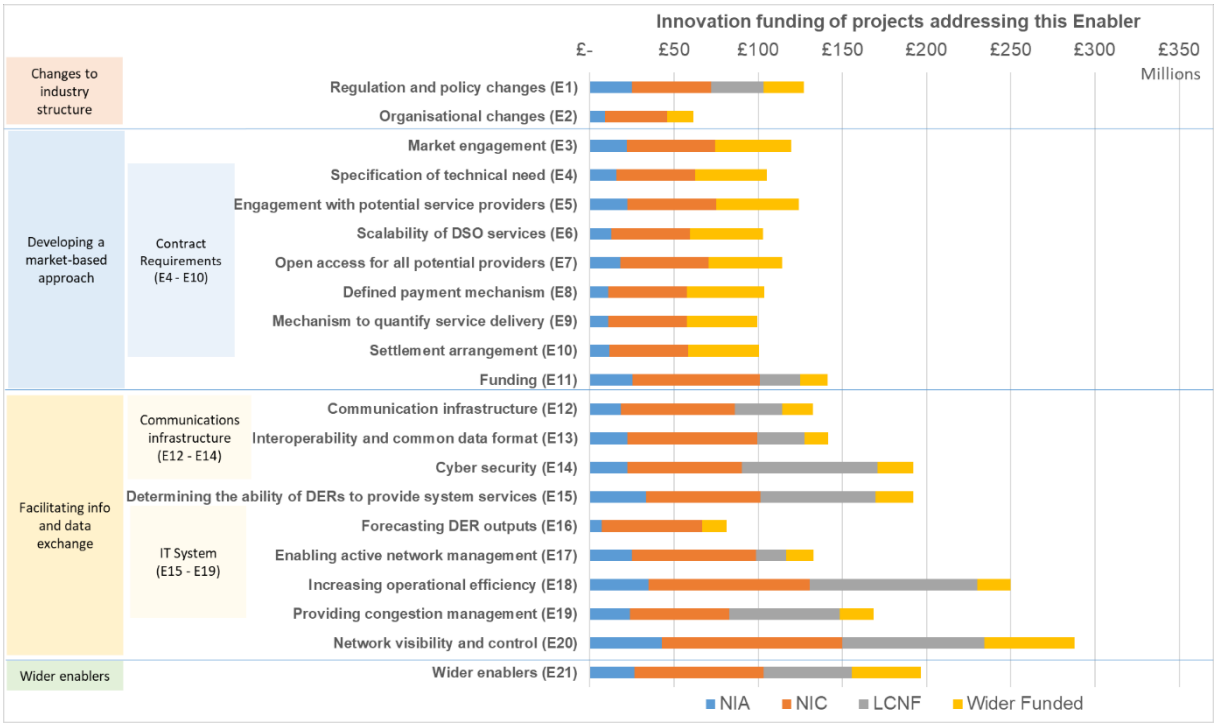


Figure 8 Value of Innovation Funding in Key Enablers

6.2.3 DSO Projects Timeline

Concurrent DSO innovation activities[5] and their value in each year are summarised in Figure 9 and Figure 10. These figures are based on the mapping of identified DSO projects against DSO functions in the objective analysis. The concurrent DSO activities and funding were categorised by DSO Function.

[5] The DSO relevant projects were spread across their duration when counting concurrent project numbers and funding.

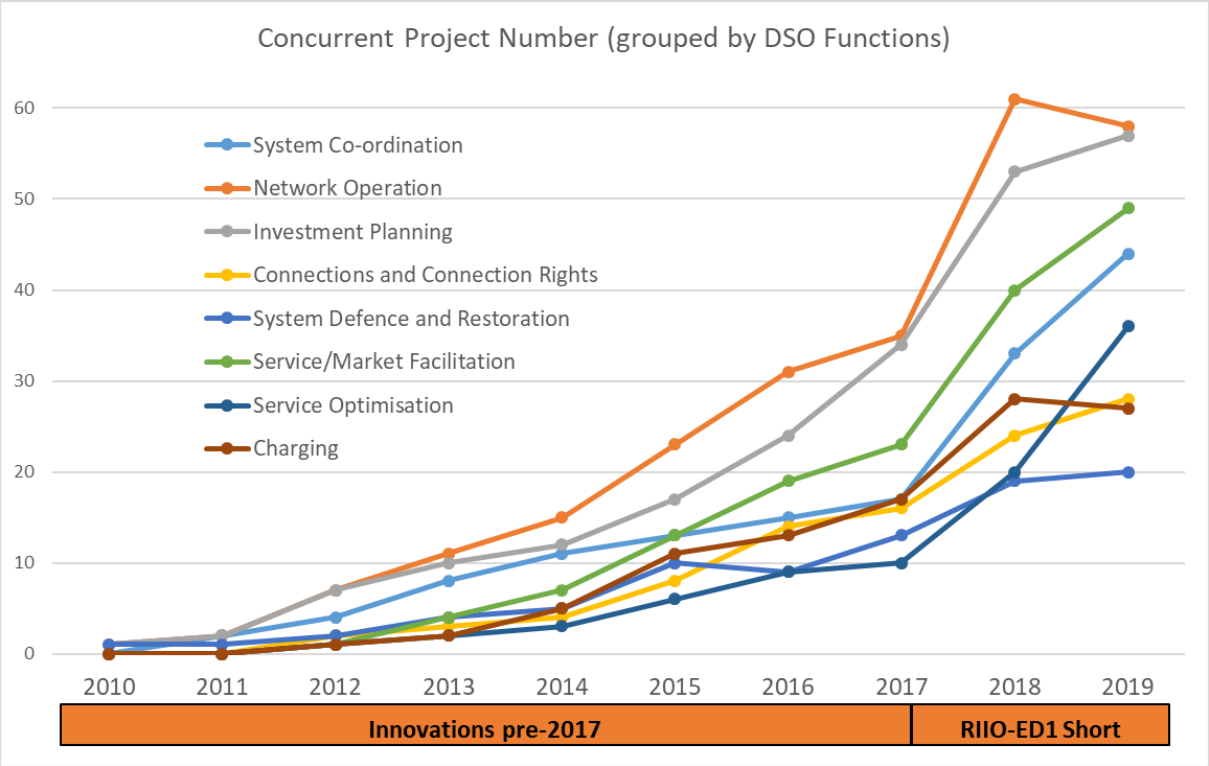


Figure 9 DSO Innovation Activities Running Concurrently up to 2019 by DSO Functions

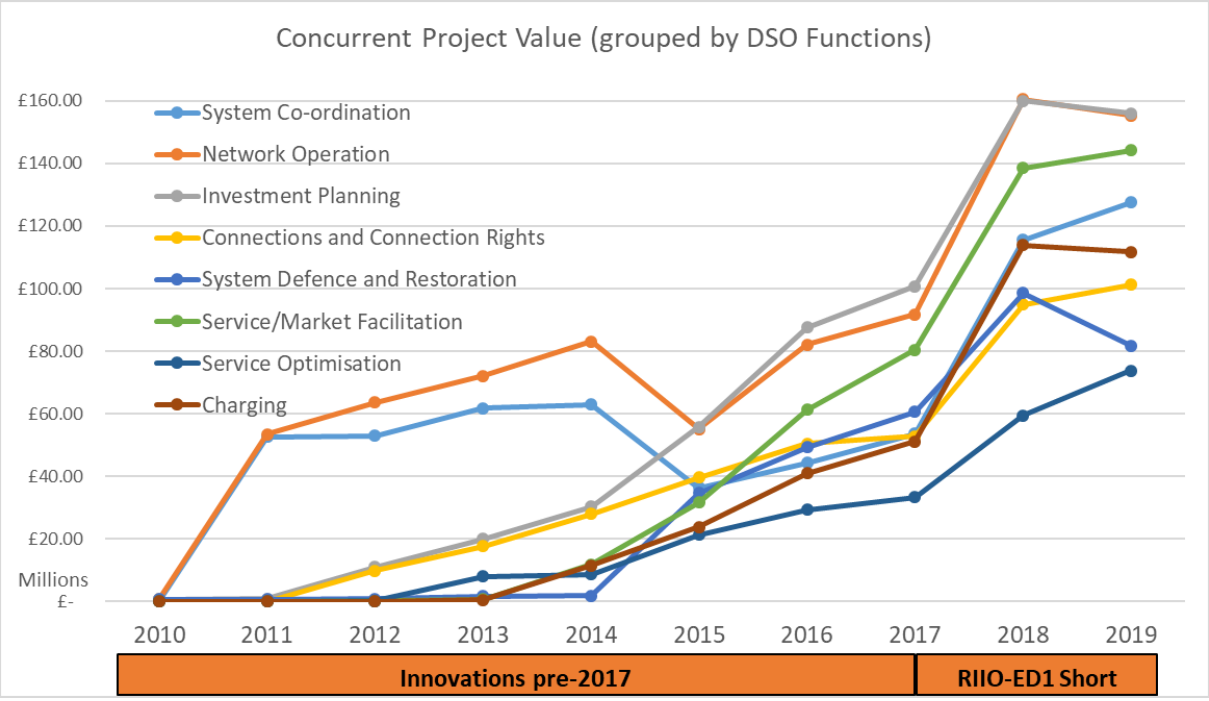


Figure 10 Value of DSO Innovation Activities Running Concurrently up to 2019 by DSO Functions

6.3 Deeper Level Mapping

After mapping the short listed DSO projects against DSO functions, a further mapping step was carried out in the project that mapped the DSO projects to DSO Competencies. At this stage, each DSO innovation project has been assigned to DSO capability (Functions & Competencies) and Key Enablers. Heatmaps for DSO capabilities and Key Enablers, were generated during the process of deeper level mapping. These heatmaps visualised the quantification of 6 different project parameters, including:

- Project number,
- Project value,
- Average TRL (Technology Readiness Level),
- Maximum TRL,
- Average TRL delta, and
- Maximum TRL delta,

Five heat levels ranging from dark red (low) to dark green (high) were applied to all the heatmaps generated from the deeper level mapping, in order to show concentration levels of the six quantified project parameters.

6.3.1 Deeper Level Mapping against DSO Functions & Competencies

Heatmap 1 – Quantified Level of DSO Innovation Activities

A heatmap visualising the number of projects mapped to each DSO area is shown in Figure 11. It shows the concentration of innovation activities. The threshold of each heat level can be found in Figure 11 as well. Greyed out cells are Competencies that were not required to deliver DSO Functions. The Function 'Connections & Connection Rights' & Competency 'Outage Planning' and the Function 'Charging' & Competency 'Forecasting' have the lowest number of projects, whilst the Function 'Network Operation' & Competency 'Power System Analysis' is the most concentrated innovation area since 2010.

DSO Competencies / DSO Functions	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination	35	73	43	72		63	38		67	43	70	64
Network Operation	73	138	56	74	179	89	46	16	119		130	143
Investment Planning	39	60	35	45	84				64		63	66
Connections and Connection Rights		58	24	29	60	49		4	43		68	51
System Defence and Restoration	11	23	19	21	30	17	8	10	17		16	19
Service /Market Facilitation	50	113	67	100		135		9	89	91	147	112
Service Optimisation	26	46	32	40	56	51	27	8	35	32	54	45
Charging	4	16	5	7		12			12	7	17	12

Number of Projects ≤ 10 | 10 < Number of Projects ≤ 40 | 40 < Number of Projects ≤ 70 | 70 < Number of Projects ≤ 100 | Number of Projects > 100

Figure 11 Heatmap 1 – Quantified Level of Innovation Activity in DSO Functions & Competencies

DSO Competencies / DSO Functions	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination	£ 244.43	£ 350.02	£ 186.07	£ 230.27		£ 254.39	£ 184.07		£ 258.71	£ 191.18	£ 295.31	£ 320.94
Network Operation	£ 479.98	£ 920.60	£ 291.59	£ 314.31	£ 789.54	£ 558.96	£ 274.15	£ 119.30	£ 596.13		£ 602.30	£ 874.27
Investment Planning	£ 183.45	£ 304.93	£ 124.23	£ 139.19	£ 279.54				£ 259.93		£ 194.96	£ 295.94
Connections and Connection Rights		£ 312.06	£ 128.18	£ 150.98	£ 324.57	£ 202.76		£ 52.36	£ 270.00		£ 273.22	£ 304.22
System Defence and Restoration	£ 82.13	£ 111.20	£ 85.42	£ 86.01	£ 114.05	£ 82.41	£ 64.46	£ 57.95	£ 102.56		£ 66.55	£ 115.37
Service /Market Facilitation	£ 404.30	£ 474.74	£ 390.42	£ 467.45		£ 646.24		£ 50.13	£ 471.37	£ 408.74	£ 502.71	£ 500.90
Service Optimisation	£ 228.59	£ 267.67	£ 231.75	£ 264.71	£ 270.74	£ 244.37	£ 206.55	£ 48.02	£ 253.52	£ 213.60	£ 257.37	£ 258.88
Charging	£ 36.40	£ 94.58	£ 15.79	£ 17.52		£ 35.04			£ 65.12	£ 17.60	£ 50.48	£ 76.00

Spend£ of Projects ≤ £50m | £50m < Spend£ of Projects ≤ £200m | £200m < Spend£ of Projects ≤ £350m | £350m < Spend£ of Projects ≤ £500m | Spend£ of Projects > £500m

Figure 12 Heatmap 2 – Value of Innovation Funding (£m) in DSO Functions & Competencies

Heatmap 2 – Summary of Innovation Funding

A heatmap visualising the value of projects mapped to each DSO function is given in Figure 12, including the threshold of heat levels. As can be seen from the legend at the bottom of the table, the monetary spend in Figure 12 is listed in GBP-millions.

The Function '*Charging*' & Competency *'Commercial Relationships & Whole System Pricing'* has the lowest innovation spending at £15.79 million, while the Function *'Network Operation'* & Competency *'Regulatory Codes & Framework'* has the highest spending at £920.6 million.

Heatmap 3 – Average TRL Quantification

A heatmap visualising average TRL data in each DSO area is presented in Figure 13. The average TRLs were calculated using the TRL at completion[6] data from the DSO relevant projects. 5 heat levels (from basic technology idea to system deployment and operation), as indicated in Figure 13, were employed in the average TRL heatmap. The lowest average TRL is 4.0, which is the Function *'Charging'* & Competency *'Commercial Relationships & Whole System Pricing'*. The Function *'Connection and Connection Rights'* & Competency *'Outage Planning'* has the highest average TRL at 8.0.

Heatmap 4 – Maximum TRL Quantification

A heatmap visualising maximum TRL data in each DSO area is given in Figure 14. 6 heat levels are used in the heatmap in order to add more granularity. Similar to the average TRL, the maximum TRL was calculated based on 'TRL at completion' data. The maximum TRL indicates if there is a technology that is ready for BaU (Business as Usual) deployment in one DSO Function & Competency area. From Figure 14, it can be observed that nearly all areas have a maximum TRL larger or equal to 8, which means technologies or solutions exist in these areas that have been tested and might be ready for network operation[7]. Only the Function *'Investment Planning'* & Competency *'Data Management'* has a maximum TRL of less, at 6.5.

Heatmap 5 – Average TRL Delta Quantification

A heatmap visualising average TRL delta in each DSO area is given in Figure 15. The average TRL deltas were calculated as the difference between the 'TRL at start' and the 'TRL at completion' data of each DSO relevant project. The TRL data was extracted from the innovation projects' proposals/registration documents. The difference between the TRLs of a project implies if a technology addressing a DSO area is evolving fast or slow. The majority of DSO areas have an average TRL delta below 3, 6 heat levels therefore are used in Figure 15. The Function *'Charging'* & Competency *'Commercial Relationships & Whole System Pricing'* and Function *'Charging'* & Competency *'Whole System Coordination'* both have the lowest average TRL delta at 1.5. The highest average TRL delta is in the Function *'Connections and Connection Rights'* & Competency *'Outage Planning'*, and it is 4.0.

[6] TRL at completion was estimated in the project proposal/registration document. This is due to network/system operators are not required to re-assess TRL at completion when a project closed down.

[7] Although a high 'maximum TRL' indicates there are technically suitable solutions they may not be commercially viable, or there might be other reasons for them not to be deployed at scale yet.

Heatmap 6 – Maximum TRL Delta Quantification

A heatmap visualising maximum TRL delta in each DSO area is given in Figure 16. Similar to the average TRL delta, the maximum TRL deltas were calculated based on the difference between the 'TRL at start' and the 'TRL at completion' data. The minimum value of TRL delta max, which is 2.0, occurs in the Function *'Connections and Connection Rights'* & Competency *'Commercial Relationships & Whole System Pricing'*, Function *'Charging'* & Competency *'Commercial Relationships & Whole System Pricing',* and Function *'Charging'* & Competency *'Whole System Coordination'*, which indicate these three areas are slow evolving when compared to others.

DSO Functions \ DSO Competencies	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination	6.8	6.6	6.4	6.1		6.7	7.0		6.3	7.4	6.5	6.4
Network Operation	7.0	7.2	6.9	6.6	6.6	6.9	7.5	6.4	6.8		7.1	6.9
Investment Planning	4.9	6.7	6.1	5.7	6.2				6.1		6.6	6.6
Connections and Connection Rights		7.7	7.1	7.6	7.5	7.8		8.0	7.7		7.5	7.5
System Defence and Restoration	7.2	5.8	5.5	5.4	6.1	6.8	7.7	7.0	6.7		6.0	6.5
Service /Market Facilitation	7.7	7.1	7.3	6.7		7.1		4.4	7.2	7.4	7.2	6.9
Service Optimisation	7.7	7.2	7.4	7.2	7.0	7.2	7.3	7.2	7.7	7.4	7.3	7.0
Charging	6.0	6.8	4.0	4.7		5.3			5.3	5.6	6.3	5.6

TRL 1-2 | TRL 3-4 | TRL 5-6 | TRL 7-8 | TRL 9

Figure 13 Heatmap 3 – Average TRL in DSO Functions & Competencies

DSO Functions \ DSO Competencies	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination	8.0	8.5	8.0	8.0		8.5	8.0		8.0	8.0	8.5	8.5
Network Operation	8.0	9.0	8.0	9.0	9.0	9.0	8.0	8.0	9.0		9.0	9.0
Investment Planning	8.0	9.0	8.0	9.0	9.0				6.5		9.0	9.0
Connections and Connection Rights		9.0	8.0	9.0	9.0	9.0		8.0	9.0		9.0	9.0
System Defence and Restoration	8.0	9.0	8.0	8.0	9.0	9.0	8.0	8.0	8.0		9.0	8.0
Service /Market Facilitation	8.0	9.0	8.0	9.0		9.0		8.0	8.0	8.0	9.0	9.0
Service Optimisation	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Charging	8.0	9.0	8.0	8.0		9.0			9.0	8.0	9.0	9.0

TRL 1-2 | TRL 3-4 | TRL 5-6 | TRL 7 | TRL 8 | TRL 9

Figure 14 Heatmap 4 – Maximum TRL in DSO Functions & Competencies

DSO Functions \ DSO Competencies	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination	2.0	2.2	2.2	2.2		2.0	1.9		2.2	2.2	2.2	1.9
Network Operation	2.3	2.4	2.2	2.0	2.6	2.2	2.1	3.1	2.3		2.6	2.3
Investment Planning	2.2	2.4	2.4	2.1	2.5				2.2		2.5	2.2
Connections and Connection Rights		2.6	2.0	2.1	2.8	2.5		4.0	2.4		2.5	2.3
System Defence and Restoration	2.7	2.4	2.5	2.5	2.6	2.9	2.9	3.1	2.6		2.8	2.4
Service /Market Facilitation	2.3	2.3	2.2	2.3		2.2		1.8	2.5	2.2	2.4	2.2
Service Optimisation	2.6	2.5	2.5	2.5	2.6	2.4	2.1	3.0	2.6	2.3	2.5	2.3
Charging	1.6	2.7	1.5	1.5		1.9			1.9	1.6	2.6	1.8

TRL 1 | TRL 2 | TRL 3-4 | TRL 5-6 | TRL 7-8 | TRL 9

Figure 15 Heatmap 5 – Average TRL Delta in DSO Functions & Competencies

DSO Functions \ DSO Competencies	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination	4.0	5.0	4.0	5.0		5.0	4.0		5.0	5.0	5.0	4.0
Network Operation	6.0	5.0	4.0	4.0	5.0	5.0	4.0	5.0	6.0		5.0	4.0
Investment Planning	4.0	4.0	4.0	4.0	5.0				6.0		5.0	4.0
Connections and Connection Rights		5.0	2.0	3.0	5.0	5.0		4.0	4.0		5.0	4.0
System Defence and Restoration	4.0	5.0	4.0	4.0	5.0	5.0	4.0	5.0	3.0		5.0	3.0
Service /Market Facilitation	5.0	5.0	4.0	5.0		5.0		5.0	5.0	5.0	5.0	4.0
Service Optimisation	5.0	5.0	3.0	5.0	5.0	5.0	3.0	5.0	5.0	5.0	5.0	4.0
Charging	3.0	5.0	2.0	2.0		5.0			4.0	3.0	5.0	4.0

TRL 1-2 | TRL 3-4 | TRL 5-6 | TRL 7-8 | TRL 9

Figure 16 Heatmap 6 –Maximum TRL Delta in DSO Functions & Competencies

6.3.2 Deeper Level Mapping against Key Enablers

In addition to mapping the DSO relevant innovation activities against DSO capabilities (Functions & Competencies), the innovation projects were also mapped against the 21 secondary Key Enablers. Quantifications of project parameters in Key Enablers are presented in **Error! Reference source not found.**. The number of projects and value of projects have also been illustrated in Figure 7 and Figure 8 in section 6.2.2, respectively. In addition to these two quantifications, TRL data including: TRL average, TRL max, TRL delta average and TRL delta max, were quantified against Key Enablers as well in **Error! Reference source not found.**.

It can be observed in **Error! Reference source not found.**, *'E2 – Organisational Changes'* has the lowest numbers in the 'Project no.', 'Project Spend', 'TRL delta average' and 'TRL delta max' columns, however, it has a higher average TRL. *'E20 – Network Visibility and Control'* has the highest numbers in the 'Project no.' and 'Project Spend' columns, but it has a lower average TRL.

With all the heatmaps and quantifications mapped against DSO capabilities and Key Enablers the next step was to identify the areas that score consistently low across all the metrics. The data analysis method that was implemented is introduced in the next section.

6.4 Data Analysis to Identify Low DSO Innovation Areas

The data analysis method employed in the project is summarised in the flowchart in Figure 17. A weighting system, with weights ranged from 1 to 5, was applied to the heatmaps. In this case, weight 5 was allocated to the (dark green) DSO areas (have lower requirements for innovation). Dark red cells were allocated with weight 1 (indicates areas have a high requirement for innovation). After assigning weights to corresponding heat levels in each heatmap, the weights for DSO capabilities (Functions & Competencies) and Key Enablers were summed across all heatmaps. The summed values represent the current DSO innovation level, and these values were then divided into three levels: Low, Medium and High. The low scoring (i.e. summed values) areas were regarded as DSO focus areas that require higher requirements for future innovation.

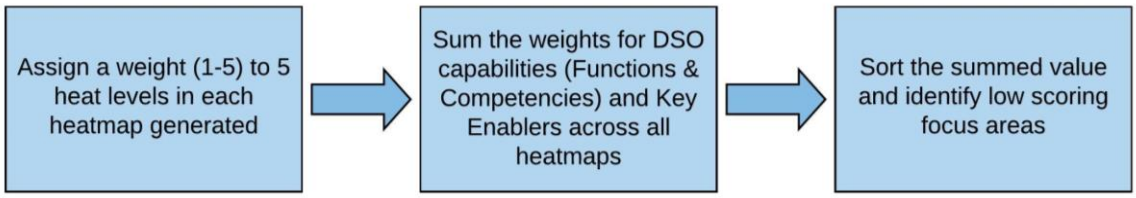


Figure 17 Data Analysis Method

High-level Enablers	Enablers		Project no.	Project Spend (£m)	TRL average	TRL max	TRL delta average	TRL delta max
Changes to industry structure	***E1 - Regulation and policy changes***		46	£ 127.30	6.6	9	2.4	5
	E2 - Organisational changes		11	£ 61.55	7.3	8	1.8	2
Developing a market-based approach	***E3 - Market engagement***		38	£ 119.39	7.0	9	2.6	5
	Contract requirements	***E4 - Specification of technical need***	29	£ 105.23	7.0	9	2.7	5
		E5 - Engagement with potential service providers	40	£ 124.22	6.8	9	2.5	5
		E6 - Scalability of DSO services	25	£ 102.80	6.7	8	2.4	5
		E7 - Open access for all potential providers	28	£ 114.36	6.8	8	2.5	5
		E8 - Defined payment mechanism	25	£ 103.40	6.9	8	2.2	5
		E9 - Mechanism to quantify service delivery	19	£ 99.54	6.8	8	2.3	5
		E10 - Settlement arrangement	20	£ 100.41	6.9	8	2.3	5
	E11- Funding		44	£ 141.11	6.3	9	2.4	6
Facilitating information and data exchange	Communications infrastructure	***E12 - Communication infrastructure***	40	£ 132.53	6.8	9	2.7	6
		E13- Interoperability and common data format	47	£ 141.70	6.5	9	2.6	6
		E14 - Cyber security	47	£ 192.26	6.6	9	2.5	6
	IT systems	***E15 - Determining the ability of DERs to provide system services***	53	£ 192.00	6.3	9	2.3	5
		E16 - Forecasting DER outputs over various timescales on the distribution network	30	£ 81.19	6.0	9	2.3	4
		E17 - Enabling active network management	38	£ 132.77	7.1	9	2.4	5
		E18 - Increasing operational efficiency	78	£ 249.81	6.3	9	2.4	5
		E19 - Providing congestion management services on the distribution network	43	£ 168.46	6.7	9	2.4	5
	E20 - Network visibility and control		83	£ 288.01	6.4	9	2.6	6
E21 - Wider enablers			47	£ 196.80	6.7	9	2.8	6

Project no ≤ 15	Project value ≤ £45m	TRL 1-2
15<Project no ≤30	£45m<Project value ≤£90m	TRL 3-4
30<Project no ≤45	£90m<Project value ≤£135m	TRL 5-6
45<Project no ≤60	£135m<Project value ≤£180m	TRL 7-8
Project no>60	Project value>£180m	TRL 9

Figure 18 Heatmap 7 – Quantification Mapping against Key Enablers

6.4.1 Focus Areas of DSO Functions & Competencies

The present innovation levels in DSO capabilities (Functions & Competencies) can be found in Figure 19. It shows the added values from the 6 heatmaps generated for DSO capability areas. The current innovation levels are divided into three levels: Low, Medium and High, with thresholds as defined in Figure 19. The areas identified as 'Low' in the figure indicate the DSO capability areas that require focus, while areas identified as 'High' indicate the DSO capabilities that are already receiving a high level of focus. 6 DSO capabilities that are presently at a Low innovation level, as identified in Figure 19, are highlighted in Table 5.

6.4.2 Focus Areas of DSO Key Enablers

After adding up the weights assigned to the 6 heatmaps produced for Key Enablers, the current innovation levels of Key Enablers are presented in Figure 20. The same thresholds of the present innovation levels as in Figure 19 are applied in Figure 20 as well. It can be observed that 'E2 – Organisational changes' is the only Enabler identified as presently having a 'Low' innovation level and therefore requiring focus in the future.

To summarise, from the objective data analysis, 3 DSO capabilities and 1 Key Enabler were identified as currently having a Low innovation level. Thus, these 4 areas have a higher requirement for innovation.

DSO Functions \ DSO Competencies	Forecasting	Regulatory Codes & Frameworks	Commercial Relationships & Whole System Pricing	Whole System Coordination	Power System Analysis	Contractual Arrangements & Service Compliance	Dispatch	Outage Planning	Data Management	Settlement	Customer Account Management	Change Management
System Co-ordination	Medium	Medium	Medium	Medium		Medium	Medium		Medium	Medium	Medium	Medium
Network Operation	Medium	High	Medium	Medium	High	High	Medium	Medium	High		High	High
Investment Planning	Low	Medium	Medium	Medium	Medium				Medium		Medium	Medium
Connections and Connection Rights		Medium	Medium	Medium	Medium	Medium		Medium	Medium		Medium	Medium
System Defence and Restoration	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium		Medium	Medium
Service /Market Facilitation	Medium	High	Medium	Medium		High		Low	Medium	Medium	High	High
Service Optimisation	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Charging	Low	Medium	Low	Low		Medium			Medium	Low	Medium	Medium

Low (< 14)	(14≤) Medium (<22)	High (≥ 22)

Figure 19 Current Innovation Level in DSO Functions & Competencies

DSO Function	DSO Competency
Charging	Commercial Relationships & Whole System Pricing
Charging	Whole System Coordination
Charging	Forecasting
Charging	Settlement
Service/Market Facilitation	Outage Planning
Investment Planning	Forecasting

Table 5 Low Present Innovation Level DSO Functions & Competencies

High-level Enablers	Enablers		Current Innovation Level
Changes to industry structure	***E1 - Regulation and policy changes***		Medium
	E2 - Organisational changes		Low
Developing a market-based approach	***E3 - Market engagement***		Medium
	Contract requirements	***E4 - Specification of technical need***	Medium
		E5 - Engagement with potential service providers	Medium
		E6 - Scalability of DSO services	Medium
		E7 - Open access for all potential providers	Medium
		E8 - Defined payment mechanism	Medium
		E9 - Mechanism to quantify service delivery	Medium
		E10 - Settlement arrangement	Medium
	E11- Funding		Medium
Facilitating information and data exchange	Communications infrastructure	***E12 - Communication infrastructure***	Medium
		E13- Interoperability and common data format	Medium
		E14 - Cyber security	Medium
	IT systems	***E15 - Determining the ability of DERs to provide system services***	Medium
		E16 - Forecasting DER outputs over various timescales on the distribution network	Medium
		E17 - Enabling active network management	Medium
		E18 - Increasing operational efficiency	High
		E19 - Providing congestion management services on the distribution network	Medium
	E20 - Network visibility and control		High
E21 - Wider enablers			Medium

Low (< 14)	(14≤) Medium (<22)	High (≥ 22)

Figure 20 Current Innovation Level in Key Enablers

7 SUBJECTIVE ASSESSMENT

In parallel with the objective data assessment, subjective assessments were undertaken by associated industry stakeholders. The subjective assessment aimed to collect stakeholders' view on future DSO innovation opportunities, in order to supplement the findings from the objective data analysis.

In this project, there five stakeholder touch points, as highlighted in Figure 21:

- Touch point 1: Stakeholder feedback on the framework applied in this project were considered in Deliverable 1,
- Touch point 2: Survey questionnaires were sent to innovation leads of 10 DNOs and ESOs in the UK, including the DNO and ESO in Ireland and also IDNO representatives, to gather information on wider funded innovation activities,
- Touch point 3: Stakeholder validation on the mapping analysis of DSO innovation activities, as part of the objective data assessment,
- Touch point 4: A subjective assessment workshop arranged with ONP Workstream 3 stakeholders to collect feedback on the DSO focus areas identified from the objective data analysis, and
- Touch point 5: After incorporating stakeholders' feedback on the DSO focus areas, the findings were presented via handouts [4] at the Low Carbon Network Innovation (LCNI) conference 2019, in order to get views from a wider group.

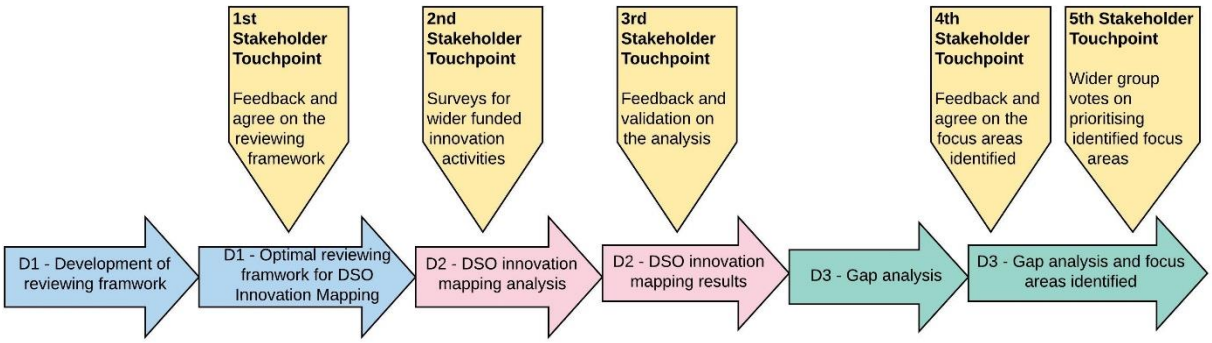


Figure 21 Stakeholder Touch Points Throughout The Project

Touch points 1 – 3 have been considered within the objective data analysis. A lightbulb approach, as presented in detail in Appendix B, is used in the subjective assessment workshop (Touch point 4) for ONP Workstream 3 stakeholders to validate and assess the focus areas identified from the objective assessment. From the subjective assessment workshop, stakeholders agreed on the 3 focus areas identified for the DSO capabilities from the objective data analysis. However, they suggested it should be noted that there are activities presently underway within other disciplines that may support some of these areas. The stakeholder team has identified these activities as being of particular relevance:

- Charging Futures Forum [16] and SCR (Significant Code Review) [17], Ofgem
- Regulatory sandbox [18] and the latest regulatory sandbox call [19], Ofgem
- Innovate UK [20] projects carried out by non-DNO groups
- Flexibility exchange demonstration projects: FleX competition [21], BEIS

Stakeholders also agreed on the focus area (*E2 - Organisational Changes*) identified for the Key Enablers. They also remarked that flexible organisational structure is being addressed by the BaU team in utilities. However, there might be areas of innovation that can be potentially targeted, for example, the use of advanced digital technologies and innovative ways of workflow to improve day to day work efficiency. In addition to the *'E2 - Organisational Changes'*, the stakeholder team proposed that of the areas presently identified as having a 'medium' innovation level in Figure 20, these are the 5 enablers that will require focus in the near future:

- Long term forecasting of E16,
- Scalability of DSO services – E6,
- Open Access for all potential providers – E7,
- Communication infrastructure – E12, and
- Mechanism to quantify service delivery – E9.

To summarise the findings from the subjective analysis, 3 DSO capability areas and 6 Key Enabler areas were identified as future DSO innovation opportunities. These are:

- DSO capability (Function & Competencies) focus areas:
    - Charging
    - Service/Market Facilitation & Outage Planning
    - Investment Planning & Forecasting
- DSO Key Enabler focus areas:
    - E2 – Organisational changes
    - E16 - Long term forecasting of DER outputs over various timescales on the distribution network,
    - E6 – Scalability of DSO services,
    - E7 – Open Access for all potential providers,
    - E12 – Communication infrastructure
    - E9 – Mechanism to quantify service delivery

8 DSO FUTURE INNOVATION OPPORTUNITIES

The identified 9 DSO focus areas were then presented and voted on at LCNI 2019, at ONP advisory board meeting, and via Survey Monkey, in order to get a wider group of stakeholders' insights into the focus areas they would like to prioritise. By counting and adding the votes, a prioritised list of the 9 focus areas was finalised as (with 1 being the areas of top priority):

1 DSO capability – Investment Planning & Forecasting

Investment Planning

Identification of capacity requirements on the distribution network and processes to secure the most efficient means of capacity provision to customers. Coordinate with the NETSO and TOs to identify whole system options for addressing wider network limitations. These would include commercial DER options as well as distribution network investment.

Forecasting

Development of consistent, repeatable and auditable methodologies in operational and investment timescales for forecasting demand, generation, network power flows and the requirements for flexibility.

2 DSO Key Enabler - Open Access for All Providers

Enhanced and innovative account and contract management in flexibility markets.

3 Joint 3rd:

3.1 DSO capability – Service/Market Facilitation & Outage Planning

Service/ Market Facilitation

Facilitate local and national markets to enable Distributed Energy Resource (DER) access/participation in wider services for whole system optimisation through auctions and other market arrangements for whole system efficiency. Ensure these arrangements are fair and transparent.

Outage Planning

Planning and managing network outages that reduce the impact on customers accessing the network, whilst ensuring the network remains secure.

3.2 DSO capability – Charging

Development of techniques to determine Distribution Use of System prices for the local network, Points of Connection, connection charges and informs of transmission reinforcement charges (if applicable). Noting that this would follow Ofgem's leading work on the network charging code reviews: Significant Code Review (SCR) on network access and forward-looking charge arrangements, and Targeted Charging Review (TCR) on residuals.

3.3 DSO Key Enabler – Forecasting DER Output

Long-term forecasting of network utilisation and DER behaviours is critical in order to allow efficient procurement of DER flexibility.

4 DSO Key Enabler – Scalability of DSO Services

The processes and methods to deploy at scale, moving from DSO service trial to early adoption to mainstream.

5 DSO Key Enabler – Communication Infrastructure

Development and roll out of advanced communication solutions and infrastructure.

6 DSO Key Enabler – Organisational Changes

Flexible organisational structure will be needed in order to adapt to the transition to DSO and use of new digital solutions.

7 DSO Key Enabler – Mechanism to Quantify Service Delivery

Well-defined mechanisms in DSO markets to quantify delivery of flexibility services from providers and DERs.

As part of the survey, participants were given the option to add innovation areas that they believe should be considered, and are not captured within the voting system (9 focus area choice). These were the areas that were added by participants (taken directly from the survey responses):

- Real time monitoring of the 'health' of flexibility services and markets,
- Commercials
- Flexibility
- Interaction with customers in metering, "smart" technologies and provision of DSO services
- LV Monitoring to support DER integration

9 LESSONS LEARNED & RECOMMENDATIONS

The objective data analysis is mainly based on the project data available on the ENA Smarter Networks Portal [7], the following observations were made during the independent evaluation:

- Existing mapping frameworks used by the ENA across multiple completed pieces of work differ significantly based on the project context and outputs.
- Aligning Smarter Networks Portal data fields with an updated list of project data might help facilitate continuity across future work.
- There is often a delay in NIC project background information and project updates being added to the Smarter Networks Portal. This was observed during this project when attempting to download the latest 2019 NIC project data and finding it was not available on the Portal. However, the latest 2019 NIC projects were available on Ofgem's website with limited information. Based on stakeholder feedback, project updates are now running on an annual basis as per the NIC governance v3 [22]. This can negatively impact projects that are being scoped or are already underway if innovators are searching for the latest NIC project data on the Smarter Networks Portal. In both instances understanding the base scope and early insights of related projects could help avoid duplication of effort.
- Re-assessing TRL at completion when closing down a project will help to more accurately analyse innovation gaps.
- Recording learning continuity (i.e. parent and child relationships) properly in project proposals/registration documents will also help to identify innovation gaps. NIC project proposals provide relevant examples of assessing and recording learning continuity. In addition, the learning continuity information can be made available on the Smarter Networks Portal to inform future scoping of innovation projects.

When developing the framework, implementing the objective analysis, and engaging with industry in the subjective analysis there were several opportunities for learning. The key learning points are summarised below:

1. Open Access data of innovation activities is important for DSO transition and allow others to review, provide recommendations, and inform direction when scoping their own innovation activities. The ENA Smarter Networks Portal [7] provides this resource. In addition, project stakeholders have advised that the ENA Smarter Networks Portal is **'a globally unique platform'** that provides open and free data access of electricity and gas innovation activities.
2. The analysis of DSO innovation gaps and opportunities focuses on the past and currently underway electricity innovation activities. It is worthwhile to acknowledge that there are activities within other teams (e.g. Business as Usual (BaU)) in the utilities that are addressing the gaps as well.
3. Key stakeholders were engaged through every stage of this project, which proved to be a vital part of this work. Feedback from stakeholders was incorporated and combined with the data analysis carried out by Power Networks Demonstration Centre (PNDC), to identify future DSO innovation opportunities.
4. The lightbulb approach (as illustrated in Appendix II) was developed in this project for ONP WS3 stakeholders to validate the focus areas identified from the data analysis. The approach is similar to the method used in the Electricity Networks Innovation Strategy (ENIS) report [11] commissioned by ENA in 2018. This similar approach was adopted as a pre-validated technique that would allow this work to then feed into the next ENIS report (to be published in 2020). However, after development and prior to implementation it was realised that the lightbulb approach could not be utilised to its full potential due to the assessment time needed for stakeholders. Estimates suggest a full 2-days workshop would be required and this is beyond the scope of this project. Instead, the lightbulb

approach was applied as an assessment criteria tool for WS3 stakeholders when they validated the focus areas. The findings from this validation were then fed to a wider group of stakeholders (LCNI 2019 and ENA Advisory Group) to obtain their input.

10 CONCLUSIONS AND FUTURE WORK

There are two key deliverables from this project:

1. Development of a robust and market-neutral framework process for evaluating DSO innovation gaps. This frame was developed based on previous gap analysis projects and feedback from industry stakeholders. The DSO capabilities (Functions & Competencies) and Key Enablers were employed as the reviewing framework. As the development of DSO capabilities and Key Enablers (by ONP) considered least regret investments for DSO transition, they represent the commonality lies between market models (proposed in ONP) that can be realised in the near future.

2. 1,333 electricity innovation activities funded via Ofgem and wider funding mechanism were considered, and 416 innovation projects were reviewed to identify future DSO innovation opportunities. 9 DSO focus areas were identified from applying the framework to existing innovation activities (completed and present up to June 2019) and engaging with key stakeholders. These innovation focus areas fed into the 2019 ENA NIC call guidance. The 9 DSO focus areas are (prioritised by stakeholders' votes):
    - Top 1: DSO capability – Investment Planning & Forecasting
      Investment Planning
      Identification of capacity requirements on the distribution network and processes to secure the most efficient means of capacity provision to customers. Coordinate with the NETSO and TOs to identify whole system options for addressing wider network limitations. These would include commercial DER options as well as distribution network investment.
      Forecasting
      Development of consistent, repeatable and auditable methodologies in operational and investment timescales for forecasting demand, generation, network power flows and the requirements for flexibility
    - 2nd: DSO Key Enabler - Open Access for All Providers
      Enhanced and innovative account and contract management in flexibility markets.
    - Joint 3rd:
        - DSO capability – Service/Market Facilitation & Outage Planning
          Service/ Market Facilitation
          Facilitate local and national markets to enable Distributed Energy Resource (DER) access/participation in wider services for whole system optimisation through auctions and other market arrangements for whole system efficiency. Ensure these arrangements are fair and transparent.
          Outage Planning
          Planning and managing network outages that reduce the impact on customers accessing the network, whilst ensuring the network remains secure.
        - DSO capability – Charging
          Development of techniques to determine Distribution Use of System prices for the local network, Points of Connection, connection charges and informs of transmission reinforcement charges (if applicable). Noting that this would follow Ofgem's leading work on the network charging code reviews: Significant Code Review (SCR) on network access and forward-looking charge arrangements, and Targeted Charging Review (TCR) on residuals.

    - DSO Key Enabler – Forecasting DER Output
      Long-term forecasting of network utilisation and DER behaviours is critical in order to allow efficient procurement of DER flexibility.
- 4th: DSO Key Enabler – Scalability of DSO Services
  The processes and methods to deploy at scale, moving from DSO service trial to early adoption to mainstream.
- 5th: DSO Key Enabler – Communication Infrastructure
  Development and roll out of advanced communication solutions and infrastructure.
- 6th: DSO Key Enabler – Organisational Changes
  Flexible organisational structure will be needed in order to adapt to the transition to DSO and use of new digital solutions.
- 7th: DSO Key Enabler – Mechanism to Quantify Service Delivery
  Well-defined mechanisms in DSO markets to quantify delivery of flexibility services from providers and DERs.

Areas of future work:

1. Following the completion of this work, dissemination of the findings to stakeholders will continue.
2. Research activities at the PNDC will target DSO innovation in the focus areas identified.
3. Suggestion from the ONP team to DNOs and wider industry to focus DSO innovation on the key areas identified in this report. The ONP team have also stated that further innovation is still required to support and inform the DSO transition.
4. The reviewing framework completed in this project should be repeated and updated on a regular basis as new innovation activities start and priorities progress and change in the future. This will ensure the findings remain relevant and will continue to provide useful direction in the future for identifying future DSO innovation opportunities

REFERENCES

[1] Energy Networks Association, "Open Networks Workstream 3: Product 2 Functional and System Requirements," 2018. [Online]. Available: http://www.energynetworks.org/assets/files/ON-WS3-P2 DSO Functional Requirements.pdf.

[2] Energy Networks Association UK, "Open Networks Future Worlds," 2018. [Online]. Available: http://www.energynetworks.org/electricity/futures/open-networks-project/future-worlds/future-worlds-consultation.html.

[3] A. Wainwright, "Energy Networks Association Future Worlds consultation responses," 2018. [Online]. Available: http://www.energynetworks.org/assets/files/Future Worlds responses summary v1.3.pdf.

[4] PNDC & ENA, "DSO Innovation," 2019. [Online]. Available: http://www.energynetworks.org/assets/files/ONP-WS3-P5 LCNI Handout-FINAL.pdf.

[5] ENA, "Open Networks Project," 2017. [Online]. Available: http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/CURRENT Open Networks Factsheet June 2017.pdf.

[6] Baringa, "Future World Impact Assessment," 2019. [Online]. Available: http://www.energynetworks.org/assets/files/Future World Impact Assessment report v1.0_pdf.pdf.

[7] ENA, "Smarter Networks Portal," 2019. [Online]. Available: http://www.smarternetworks.org/site.aspx.

[8] OFGEM, "Electricity Network Innovation Allowance," 2019. [Online]. Available: https://www.ofgem.gov.uk/network-regulation-riio-model/network-innovation/electricity-network-innovation-allowance.

[9] OFGEM, "Electricity Network Innovation Competition," 2019. [Online]. Available: https://www.ofgem.gov.uk/network-regulation-riio-model/current-network-price-controls-riio-1/network-innovation/electricity-network-innovation-competition.

[10] OFGEM, "Low Carbon Networks Fund," 2019. .

[11] ENA, "Electricity Network Innovation Strategy," 2018.

[12] Energy Networks Association UK, "Open Networks Project – DSO Transition: Roadmap to 2030," *Presentation*, 2016. [Online]. Available: http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/DSO Roadmap v6.0.pdf%0Ahttp://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/DSO%0ARoadmap%0Av6.0.pdf.

[13] EA Technology, "Summary of the Low Carbon Networks Fund learning," 2016.

[14] D. Frame, K. Bell, and S. McArthur, "A Review and Synthesis of the Outcomes from Low Carbon Networks Fund Projects," 2016.

[15] OFGEM, "Innovation Funding Incentive," 2019. [Online]. Available: https://www.ofgem.gov.uk/electricity/distribution-networks/network-innovation/innovation-funding-incentive.

[16] OFGEM, "Charging Futures Forum." [Online]. Available: https://www.ofgem.gov.uk/publications-and-updates/charging-futures-forum.

[17] Ofgem, "Targeted Charging Review - Significant Code Review." [Online]. Available: https://www.ofgem.gov.uk/publications-and-updates/smart-flexible-energy-system-.

[18] OFGEM, "What is a regulatory sandbox?," *Factsheets*, 2018. [Online]. Available: https://www.ofgem.gov.uk/publications-and-updates/what-regulatory-sandbox.

[19] Ofgem, "Regulatory sandbox: Calling for expressions of interest," *Open letters and correspondence*, 2017. [Online]. Available: https://www.ofgem.gov.uk/publications-and-updates/regulatory-sandbox-2-calling-expressions-interest.

[20] UKRI, "Innovate UK," 2019. [Online]. Available: https://www.gov.uk/government/organisations/innovate-uk.

[21] "Flexibility exchange demonstration projects: FleX competition," 2019. [Online]. Available: https://www.gov.uk/government/publications/flexibility-exchange-demonstration-projects-flex-competition.

[22] Ofgem, "Version 3.0 of the Network Innovation Competition governance documents," 2017. [Online]. Available: https://www.ofgem.gov.uk/publications-and-updates/version-30-network-innovation-competition-governance-documents.

APPENDIX A

LITERARURE REVIEW: LIST OF ROADMAP DOCUMENTS

Document	Author	Focus
1 - High level electricity networks vision		
A vision for Scotland's electricity and gas networks	Scottish Government	Scotland's electricity and gas network vision
2 - Review of innovation projects and innovation strategies		
A Review and Synthesis of the Outcomes from Low Carbon Networks Fund Projects	Damien Frame et al, University of Stra	LCNF projects
Innovation in regulated electricity distribution networks: A review of the effectiveness of Great Britain's Low Carbon Networks Fund	Damien Frame et al, University of Stra	LCNF projects
An Independent Evaluation of the LCNF	Poyry	LCNF projects
Summary of the Low Carbon Networks Fund learning	EA Technology	LCNF projects
Electricity Network Innovation Strategy	ENA	Innovation Strategy
A strategy for a Modern Digitalised Energy System-Energy Data Taskforce report	Energy System Catapult	A Strategy for a Modern Digitalised Energy System
3 - International DSO strategy and projects		
TSO – DSO Report: An Integrated Approach to Active System Management	CEDEC, EDSO, ENSTO-E, EURELECTRIC, GEODE	TSO and DSO Active System Management
Flexibility in The Energy Transition: A Toolbox for Electricity DSOs	CEDEC, EDSO, EURELECTRIC, GEODE	DSO Active System Management
D6.2 Evaluation on project results related to a number of models and roadmaps	H2020 SmartNet	SmartNet project
Mapping of DSO Projects: A report for the Customer-Led Distribution System Project	Furong Li et al, University of Bath	DSO Projects (UK, EU, USA)
Grid Modernization: Distribution System Concept of Operations	Southern California Edison	Distribution network competencies
4 - ENA Open Networks DSO vision		
Modelling the DSO transition using the Smart Grid Architecture Model	EA Technology	DSO future worlds & functionalities
Future Worlds: Developing change options to facilitate energy decarbonisation, digitisation, and decentralisation	ENA Open Networks	DSO future worlds
Future World Impact Assessment	Baringa	DSO future worlds
DSO Definition and R&R (Roles and Responsibilities)	ENA Open Networks	DSO definition
DSO Functional and System Requirements	ENA Open Networks	DSO functionalities
Open Networks Project – DSO Transition: Roadmap to 2030	ENA Open Networks	DSO roadmaps
Least Regret Analysis - common functions across 'Future Worlds'	ENA Open Networks	Common DSO functionalities
5 - UK DNO & SO's DSO transition roadmaps		
Supporting a Smarter Electricity System: Our Transition to DSO	SSEN	DSO vision/roadmap
Distribution System Operator: Next steps and emerging thinking	NPG	DSO vision/roadmap
Powering the North West's future: Transitioning to a Distribution System Operator – a collaborative approach	ENWL	DSO vision/roadmap
Distribution System Operator (DSO) Update	Steve Shaw, ENWL	DSO vision/roadmap
SPEN DSO Vision	SPEN	DSO vision/roadmap
Future Roadmap: A smart grid for all: Our transition to Distribution System Operator	UKPN	DSO vision/roadmap
DSO forward plan	WPD	DSO vision/roadmap
DSO transition December 2017 update	WPD	DSO vision/roadmap
DNO to DSO Evolution (Website)	NIE	DSO vision/roadmap
Greater Access to the Distribution Network in Northern Ireland-Consultation Document	NIE	DSO vision/roadmap - consultation
Facilitating Whole Electricity System Outcomes: How the ESO is working with stakeholders to transform the energy landscape	NG ESO	ESO vision/roadmap
Whole Electricity System thinking: How the ESO can support a transition that delivers consumer value	NG ESO	ESO vision/roadmap
Network Development Roadmap	NG ESO	ESO vision/roadmap
Future of balancing services	NG ESO	ESO vision/roadmap

Document	Author	Focus
6 - UK DNO & SO's innovation strategy		
System Operator Innovation Strategy: A refresh for 2019/20 and how we performed over the last year	NG ESO	ESO innovation strategy
Our Innovation Strategy - ENWL	ENWL	ENWL innovation strategy
Innovation strategy - NPG	NPG	NPG innovation strategy
Innovation strategy - NIE	NIE	NIE innovation strategy
Innovation strategy 2018 - SPEN	SPEN	SPEN innovation strategy
Making innovation happen -SSEN	SSEN	SSEN innovation strategy
Innovation strategy update 2016 - SSEN	SSEN	SSEN innovation strategy -update
Our approach to Innovation: Strategy and delivery 2014- UKPN	UKPN	UKPN innovation strategy
Innovation strategy 2018 - WPD	WPD	WPD innovation strategy

APPENDIX B

LIGHTBULB ASSESSMENT STRUCTURE

The lightbulb approach considered three aspects related to identifying future innovation opportunities, which are:

- ***Urgency*** to implement in order to enable industry progress towards DSO transition:
  - Low: Not urgent to be implemented
  - Medium: Can be implemented later, in 1-2 years time
  - High: Urgent to be implemented immediately

- Potential ***Benefit/Value*** from the implementation to customers:
  The potential benefit/value could refer to the benefit to customers – reducing costs, improving network security and reliability, environmental friendly etc. We put the threshold of the Benefit/Value level based on if the learning outcomes would benefit (customers of) the whole system or just (customers of) specific stakeholders.
  - Low: Moderate potential benefit/value from the implementation, that will benefit 1-2 specific stakeholder(s) and need to be tested further for BaU deployment
  - Medium: High potential benefit/value from the implementation, that will benefit a few stakeholders and may require a follow-on project
  - High: Major potential benefit/value from the implementation, that will benefit the whole system and have an immediate impact

- ***Timeline*** of when a project should be scheduled to realise the appropriate DSO areas: short-term (now until 2020), medium-term (2020-2023), long-term (2023 onwards)
  A project could be scheduled depending on the motivation, resources, complexity etc.

Based on the Urgency and Benefit/Value levels assessed, by multiplying the Urgency and Benefit/Value, lightbulbs will be assigned to each DSO Functions & Competencies and Key Enablers, as illustrated in Figure 22 below.

1 lightbulb means low innovation opportunities expected, and 3 lightbulbs means high innovation opportunities expected.

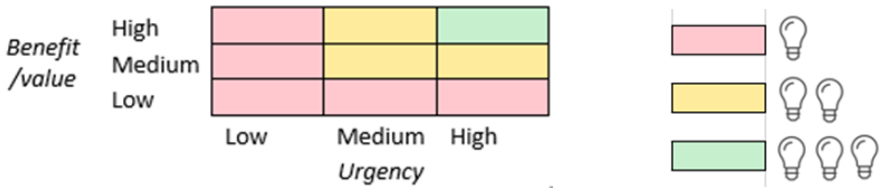


Figure 22 Process of information and assignment of lightbulbs

The objective analysis and subjective assessment were brought together in the example given in Table 6. Low 'current innovation level', high 'future innovation opportunities' (3 lightbulbs), and short-term 'Timeline' DSO areas were regarded as future DSO focus areas. WS 3 stakeholders use the lightbulb approach to validate and assess the focus areas.

DSO Competencies / DSO Functions	Competency '1 of 12'		
	Current Innovation Level *	Future Innovation Opportunities **	Timeline ***
Function '1 of 8'	Low		Medium

Table 6 Innovation Potential Example Table

*The current innovation level was identified by the objective data analysis results.

**The future innovation opportunities were processed from the stakeholders' input of the subjective assessment.

***The timeline was extracted from stakeholders' input directly.

APPENDIX C

LCNI 2019

LCNI Brochure:

Executive Summary

The energy industry is going through a time of unprecedented change. We are moving towards cleaner, more digitised and decentralised networks. Energy networks have responded quickly to the rapid growth of the low carbon transformation. Renewables' share of total generation was at a record high level of 33.3% in 2018, up from 29.3% in 2017.

Over 30GW generation has been connected to the distribution network. 25% of all electricity generation is now connected to lower voltage electricity networks, including large numbers of solar and wind generators. Innovation and collaboration is at the heart of facilitating an efficient, smarter, cleaner energy system fit for Britain's homes and businesses.

Role of innovation in a changing world

The transition to a smart grid has the potential to bring many benefits for homes, businesses, and communities. This requires a transformative shift in the way the energy system as a whole, operates and coordinates. As record and ever-increasing amounts of renewable energy are being fed into Britain's energy system the sector has come together and agreed a shared vision outlined in ENA's Future Worlds Impact Assessment report. This shows strong agreement to building closer coordination between Distribution System Operators (DSO) and the Electricity System Operator (ESO). It is vital that we take an evidence based approach to set a positive course for the energy sector in the UK and that can only be done through "learning by doing".

Our journey has already begun – *"learning by doing"*

Since 2010 network operators have been investing in innovation to support the transition. It will see network operators mature and build Distribution System Operation (DSO) capabilities to take a more active role in managing their networks with new low-carbon solutions, and ensure the energy system as a whole is properly equipped to deliver renewable energy we all rely upon into the future.

Networks have been relentless in their focus on innovation, and private investment has helped make Britain a superpower of renewable energy. Reaching our Net Zero target will require significant, long term investment, and the Open Networks Project is already delivering the step-change needed to reach Britain's decarbonisation goals.

Collaborating with innovators, creators and stakeholders

Network operators cannot deliver innovation alone. We want to work with innovators, creators and all stakeholders to help us harness the potential of the smart grid.

In assessing our innovation activities and mapping these to the Distribution System Operation capabilities and key enablers, we have identified DSO innovation opportunity areas where we believe further innovation could support and inform our transition.

This leaflet describes how we identified these areas and how you can help us to shape the smart grid system of the future. **If you want to find out more come and visit us at stand M07.**

We encourage you to cast your vote on the DSO innovation opportunity areas we have identified, provide us with feedback of others that we should be considering and give us your ideas to help us in our transition.

Introduction

ENA's Open Networks Project is a major industry initiative that will transform the way our energy networks operate, underpinning the delivery of the smart grid. The project seeks to enable the uptake of new smart energy technologies by more and more homes, businesses, and communities in the UK. As a key initiative in the transition to Distribution System Operation (DSO), Workstream 3 Product 5 has been working in partnership with the Power Networks Demonstration Centre to identify Distribution System Operation (DSO) innovation opportunities that need to be developed further and where innovators, creators and stakeholders could support to charge forward with the energy sectors smart grid plans.

The key initiative identified nine DSO innovation opportunity areas where further innovation could support, mature and build DSO capabilities and key enablers to facilitate homes, businesses, and communities to benefit from the smart grid system.

The assessment and identification was possible with the open access data of innovation projects available from the ENA Smarter Networks Portal. In total 1,333 electricity innovation projects were reviewed and the scope focused on those where electricity networks were involved.

ena energynetworks association

The **Open Networks Project** is a major industry initiative that will transform the way our energy networks operate, underpinning the delivery of the smart grid. http://www.energynetworks.org/electricity/futures/open-networks-project/

UNIVERSITY of STRATHCLYDE
POWER NETWORKS
DEMONSTRATION CENTRE

The **Power Networks Demonstration Centre** is a venture founded by government, industrial and academic partners with the aim of accelerating the adoption of innovative research and technologies from early stage research into business as usual adoption by the electricity industry. https://pndc.co.uk/

Summary of outcomes

What did we find out?

Pace of Distribution System Operation innovation has increased 23-fold in the last 2 years

- We have gone from six projects (published Electrical Network Innovation Strategy published in 2018) to 138 projects identified in this assessment.
- A total of 28 'boundary projects' have been flagged as innovation projects innovating in wider sectors beyond solely electricity. A boundary project is where an innovation trial is focused beyond the electricity sector.

Diverse innovation projects driving UKs low carbon transition

- An exciting mix of projects make up our innovation activities, ranging from electric vehicle integration to gas networks' coordination.

ENA Open Networks work shaping the direction of innovation

- This initiative has identified nine opportunity areas, of which two have been fed in and put out to innovators and creators in the ENA Joint Network Innovation Competition Call to help the energy sector charge forward with their smart grid plans.

1,333
Electricity Innovation projects reviewed

138
DSO Relevant Innovation projects identified

28
DSO Relevant Boundary projects

23
Fold Increase in Pace of Distribution System Operation innovation in the last 2 years

11
Funding Mechanisms identified

2010
The first DSO relevant projects started in 2010

How did we identify the DSO Innovation Opportunity Areas?

1. Literature Review

The objective of this review was to understand how the whole energy system vision and individual network/system operators' DSO roadmaps help to define the key steps along the pathway to DSO transition. The literature review was also used to identify previous Innovation Gap Analysis project frameworks that could be implemented within this initiative.

2. Innovation Analysis Framework

In this step the Innovation Gap Analysis project frameworks identified in step 1 were reviewed to identify effective techniques that could be adopted within the scope of this present Innovation Opportunity Analysis.

3. Implemented Framework

The two primary mapping framework techniques adopted for this project were:

DSO Capabilities as defined in Open Networks that are split into DSO Functions and Competencies. 8 DSO functions and 12 underlying competencies as per the ENA Open Networks definition and roadmap of a DSO.

DSO Key Enablers as defined in the ENA Open Networks Future Worlds as a guide for facilitating the least regret investment for DSO transition.

Then a combined assessment route was established to identify future innovation that included objective and subjective analysis.

4. Objective Analysis

In the objective analysis, to identify areas that presently have low innovation focus heatmaps were generated covering:

The number of projects in each area.

The monetary spend in each area.

Multiple metrics relating to Technology Readiness Level (TRL).

5. Identifying the DSO Innovation Opportunity Areas

To identify areas that presently have low innovation focus, the heatmaps generated were combined into a single unified heatmap.

6. Subjective Analysis

We are currently running the subjective analysis where we are seeking your feedback, as well as feedback from the whole industry.

06 DSO Innovation

The Nine DSO Innovation Opportunity Areas

3 DSO Capability Focus Areas

DSO Capability 1:

Charging

Development of techniques to determine Distribution Use of System prices for the local network, Points of Connection, connection charges and informs of transmission reinforcement charges (if applicable). Noting that this would follow Ofgem's leading work on the network charging code reviews: Significant Code Review (SCR) on network access and forward-looking charge arrangements, and Targeted Charging Review (TCR) on residuals.

DSO Capability 2:

Service/Market Facilitation & Outage Planning

Service/ Market Facilitation
Facilitate local and national markets to enable Distributed Energy Resource (DER) access/ participation in wider services for whole system optimisation through auctions and other market arrangements for whole system efficiency. Ensure these arrangements are fair and transparent.

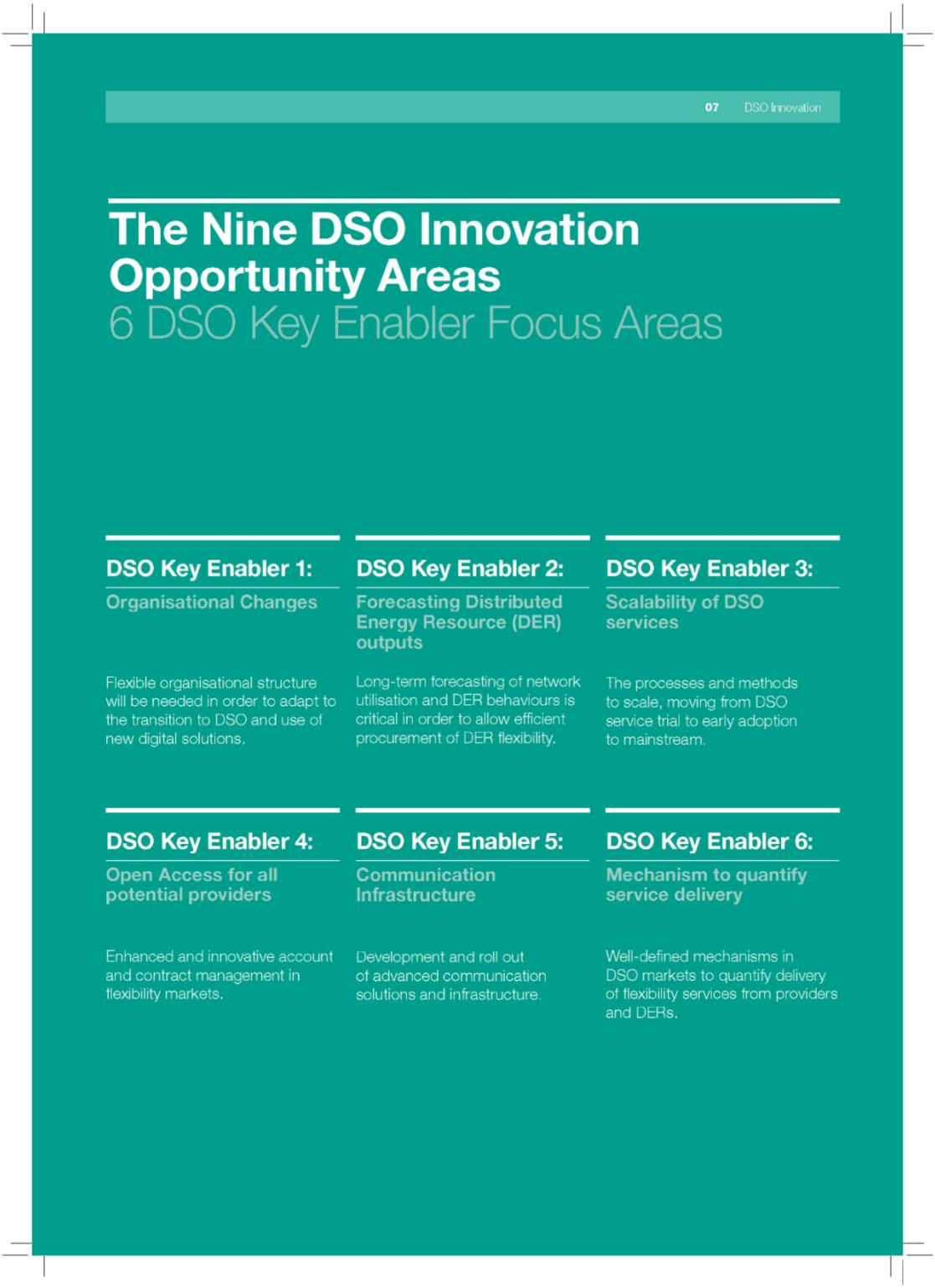
Outage Planning
Planning and managing network outages that reduce the impact on customers accessing the network, whilst ensuring the network remains secure.

DSO Capability 3:

Investment Planning & Forecasting

Forecasting
Development of consistent, repeatable and auditable methodologies in operational and investment timescales for forecasting demand, generation, network power flows and the requirements for flexibility.

Investment Planning
Identification of capacity requirements on the distribution network and processed to secure the most efficient means of capacity provision to customers.



07 DSO Innovation

The Nine DSO Innovation Opportunity Areas

6 DSO Key Enabler Focus Areas

DSO Key Enabler 1:
Organisational Changes

Flexible organisational structure will be needed in order to adapt to the transition to DSO and use of new digital solutions.

DSO Key Enabler 2:
Forecasting Distributed Energy Resource (DER) outputs

Long-term forecasting of network utilisation and DER behaviours is critical in order to allow efficient procurement of DER flexibility.

DSO Key Enabler 3:
Scalability of DSO services

The processes and methods to scale, moving from DSO service trial to early adoption to mainstream.

DSO Key Enabler 4:
Open Access for all potential providers

Enhanced and innovative account and contract management in flexibility markets.

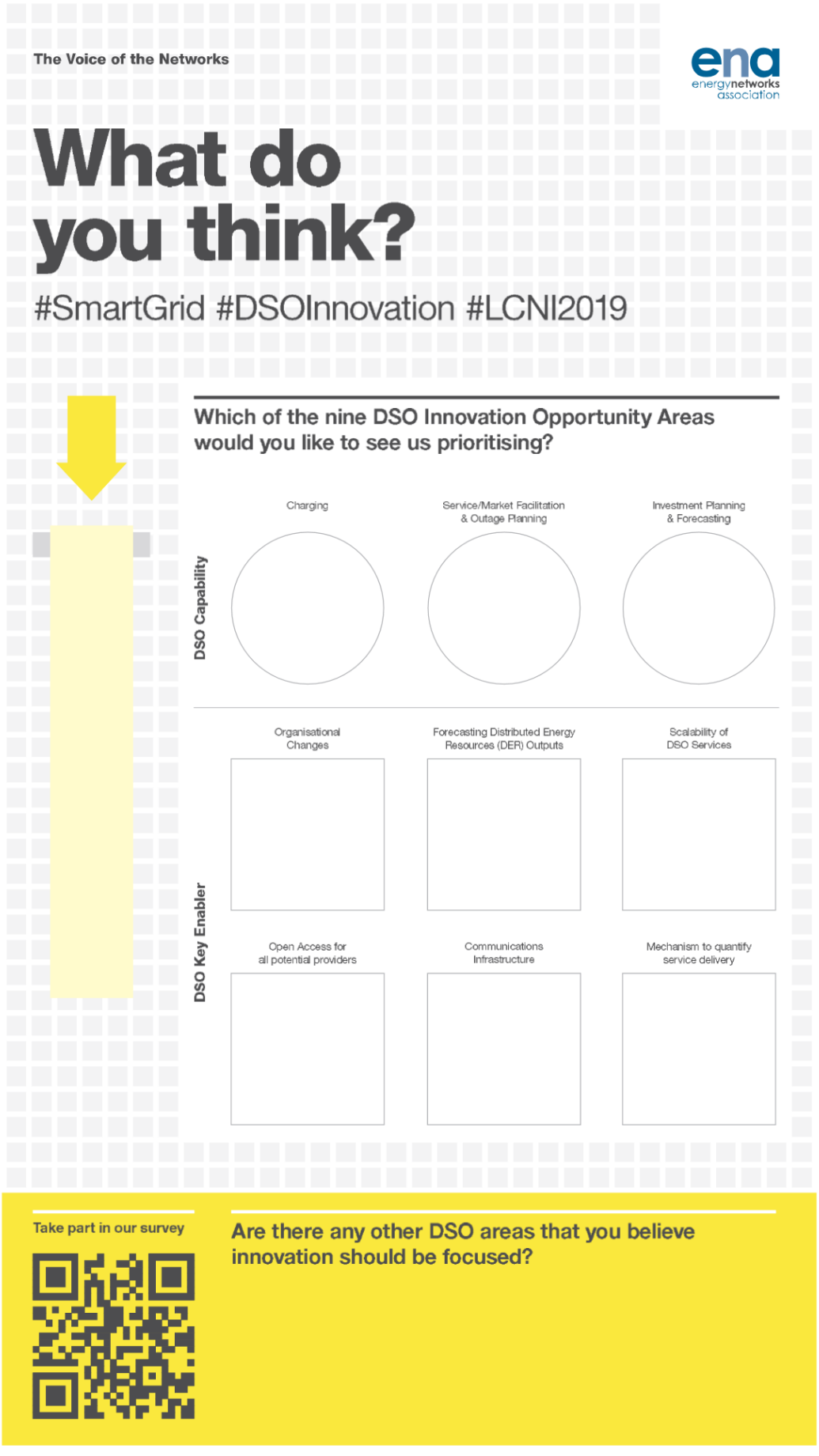
DSO Key Enabler 5:
Communication Infrastructure

Development and roll out of advanced communication solutions and infrastructure.

DSO Key Enabler 6:
Mechanism to quantify service delivery

Well-defined mechanisms in DSO markets to quantify delivery of flexibility services from providers and DERs.

Interactive voting board at LCNI:



Survey questionnaire issued to stakeholders via Survey Monkey for them to cast votes:

DSO Innovation

ENA Open Networks Project

1. Which of the nine DSO Opportunity Areas would you like to see us prioritising?

- ◯ Charging
- ◯ Service/Market Facilitation and Outage Planning
- ◯ Investment Planning & Forecasting
- ◯ Organisational changes
- ◯ Forecasting DER Outputs
- ◯ Scalability of DSO Services
- ◯ Open Access for all potential providers
- ◯ Communications infrastructure
- ◯ Mechanism to quantify service delivery

2. Are there any other DSO areas that you believe Innovation should be focused?

DONE

Powered by SurveyMonkey

APPENDIX D

ENA SMARTER NETWORKS PORTAL

Open access data of innovation projects in the UK are available in the ENA Smarter Networks Portal, https://www.smarternetworks.org/. A screen shot of the portal is available in Figure 23. The portal includes projects carried out by utilities within Electricity transmission, electricity distribution, gas transmission and gas distribution. Funding mechanisms covered in the portal are listed in Figure 24. The portal allows searching specific projects using the project name, network operators (as given in Figure 25), or specific technology (as shown in Figure 26).

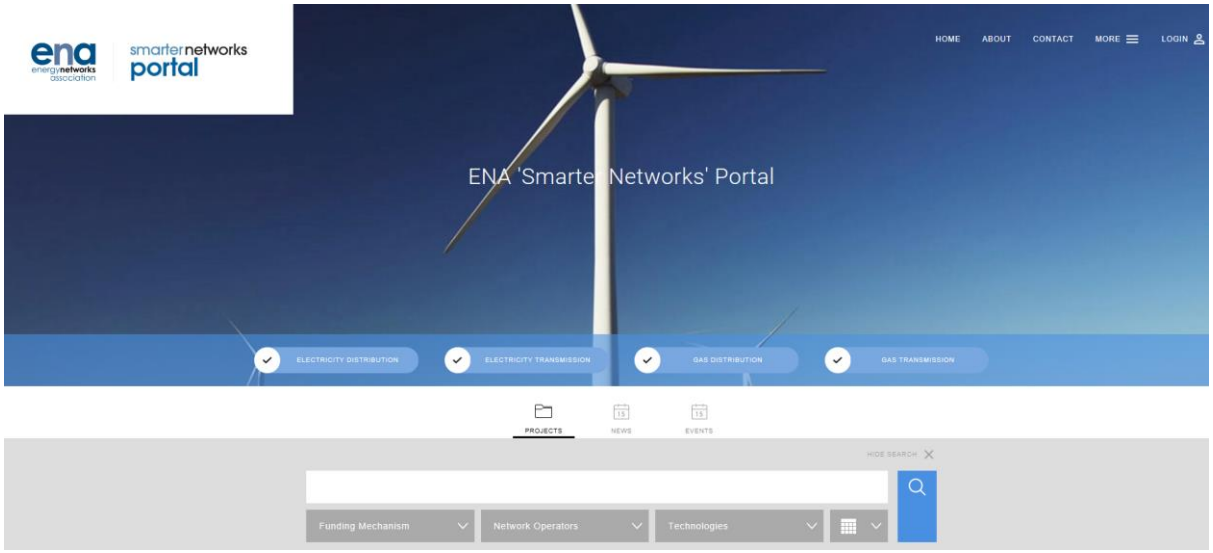


Figure 23 ENA Smarter Networks Portal

Figure 24 Funding Mechanisms Covered in ENA Smarter Networks Portal

Figure 25 Network Operators Covered in ENA Smarter Networks Portal

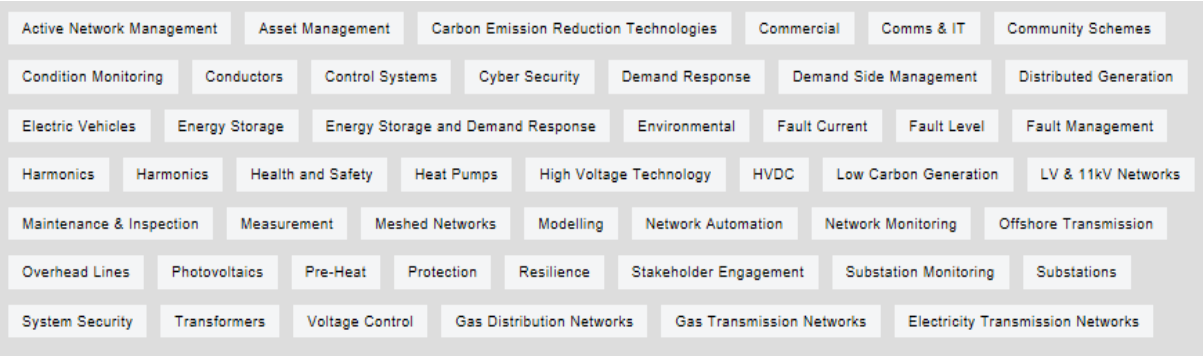


Figure 26 Technologies Covered in ENA Smarter Networks Portal

By searching for projects, a list of relevant projects can be downloaded into an Excel workbook (in .csv format). Project data to be included in the Excel download file can be selected in the Portal download fields, which are presented in Figure 27. An example of the structured project data export can be found in Figure 28.

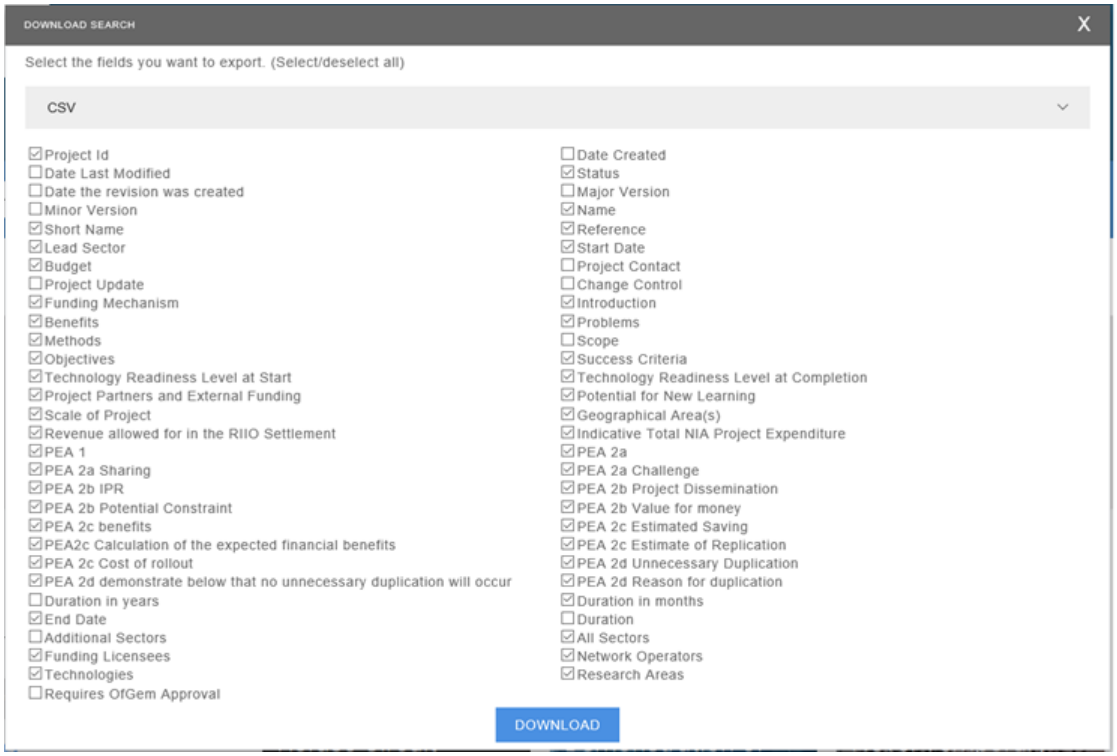


Figure 27 ENA Smarter Networks Portal Download Fields

smarternetworks portal

Project	Status	Name	Short Name	Reference	Lead Sector	Start Dat	Budget	Fu	Introdu	Metho	Objecti	Tech	Tech
fca11054-(	Live	Refase Cir	NIA_SHET_0026 Refase Circuit Prot	NIA_SHET_0026	ElectricityTransmission	01/06/2019	388361	NIA	The scope	This is a te	The objec	TRL 6	TRL 9
92522298-	Live	Demonstr	Demonstration of Virtual Synchron	NIA_NGSO0026	ElectricityTransmission	01/06/2019	275000	NIA	The Natio	This proje	By testing	TRL 4	TRL 6
d1cf6a65-	Live	Novel Ter	Novel Temporary Earthing & Bondi	NIA_SPEN_0042	ElectricityDistribution	01/06/2019	40000	NIA	This proje	A requirer	Stage 1 Ot	TRL 7	TRL 9
ddabcfd9-	Live	Proof of c	Tarmac Reinstatement Tester	NIA_SPEN_0041	ElectricityTransmission	01/06/2019	55000	NIA	The objec	The Proje	The objec	TRL 2	TRL 3
1ce6e419-	Live	Improving	Improving Storm Resilience	NIA_SPEN_0040	ElectricityDistribution	01/06/2019	150000	NIA	In this pro	In this pro	The main	TRL 5	TRL 7
7f3b0417-	Live	Firefly	Firefly	NIA_UKPN0051	ElectricityDistribution	01/06/2019	99000	NIA	Energy Eff	Firefly ain	The objec	TRL 5	TRL 7
941f9a6f-(	Live	Boston Sp	BEET	NIA_NPG_032	ElectricityDistribution	01/06/2019	500000	NIA	Alternativ	The proje	To test pr	TRL 3	TRL 8
708facb5-(	Live	THOR Han	THOR Hammer	NIA_SPEN_0039	ElectricityDistribution	01/06/2019	1317502	NIA	This proje	Over the l	Convert th	TRL 7	TRL 9
75fdfc53-(	Live	Low Volta	Low Voltage – Underground Fault L	NIA_SSEN_0037	ElectricityDistribution	01/06/2019	346000	NIA	This proje	Using nov	By the en	TRL 5	TRL 7
0dca9602-	Live	Urban Ene	Urban Energy Club	NIA_UKPN0050	ElectricityDistribution	01/05/2019	195238	NIA	As part of	Other pro	The main	TRL 5	TRL 8
922daaff-(	Live	Phase Swi	Phase Switch System	NIA_UKPN0049	ElectricityDistribution	01/06/2019	959000	NIA	National G	During the	The proje	TRL 3	TRL 6
70b4b890-	Live	Residenti	Residential Response	NIA_NGSO0025	ElectricityTransmission	01/04/2019	587000	NIA	The proje	The proje	At the enc	TRL 3	TRL 6
add75c3e-	Live	Unified Pr	Unified Protection	NIA_UKPN0048	ElectricityDistribution	01/04/2019	480693	NIA	The netwo	This proje	Analyse re	TRL 4	TRL 7
09638829-	Live	Intelligen	Mesh Switch	ENWL 023	ElectricityDistribution	01/04/2019	1870000	NIA	Existing DI	This proje	A staged a	TRL 6	TRL 9
024953d1-	Live	Multi Ass	MADE	NIA_WPD_040	ElectricityDistribution	01/03/2019	1655046	NIA	The proje	The resea	The Proje	TRL 3	TRL 6
9ffbb8ab-	Live	Social Cor	NIA_SSEN_0036 Social Constrained	NIA_SSEN_0036	ElectricityDistribution	01/03/2019	186000	NIA	SSEN have	The proje	The objec	TRL 5	TRL 8
f26abee5-	Live	Health Inc	EES HI	NIA_NPG_031	ElectricityDistribution	01/03/2019	35000	NIA	A small sc	To addres	The objec	TRL 2	TRL 5
51f52bc3-	Live	System He	System Health Map Phase 1	NIA_SPEN_0038	ElectricityTransmission	01/07/2019	354000	NIA	SPT propo	The aim o	Developm	TRL 5	TRL 7
3f9a7867-	Live	Electric Ve	EV-Up	NIA_SPEN_0037	ElectricityDistribution	01/02/2019	175000	NIA	EV-Up will	Working v	EV-Up wil	TRL 5	TRL 7
a8638516-	Live	Novel O-R	Novel O-Ring Designs (NORD)	NIA_NGTO032	ElectricityTransmission	01/03/2019	325000	NIA	Moisture i	This proje	The objec	TRL 3	TRL 4
cd0cdd1c-	Live	RecorDER	RecorDER	NIA_NGSO0018	ElectricityTransmission	01/02/2019	753000	NIA	‘Re	The proje	At the enc	TRL 3	TRL 6
d7524000-	Live	Short-terr	Short-term System Inertia Forecast	NIA_NGSO0020	ElectricityTransmission	01/03/2019	300000	NIA	This innov	This innov	This proje	TRL 3	TRL 6
ef1e4c8f-5	Live	HV Feede	HV Feeder monitoring to pre-empt	NIA_UKPN0047	ElectricityDistribution	01/02/2019	2256371	NIA	Distributic	This proje	The objec	TRL 6	TRL 8
e4a0e081-	Live	Reflect Ur	Reflect	ENWL 022	ElectricityDistribution	01/03/2019	192500	NIA	The expec	A three-st	The Refle	TRL 2	TRL 6
add3e7f0-	Live	Undergro	UG Fault Prediction	NIA_UKPN0046	ElectricityDistribution	01/02/2019	692887	NIA	UK Power	This proje	The objec	TRL 3	TRL 8
9dc174ca-	Live	Informed	Informed Lightning Protection	NIA_SSEN_0035	ElectricityDistribution	01/03/2019	521000	NIA	Lightning :	Lightning	1) &	TRL 1	TRL 8
ab8fb1e3-	Live	Enhancing	Water DSR	NIA_NGSO0024	ElectricityTransmission	01/03/2019	225000	NIA	With incre	The proje	The objec	TRL 3	TRL 4
994e3dd7-	Live	Network I	Network Islanding Investigation	NIA_WPD_039	ElectricityDistribution	01/01/2019	224408	NIA	It is anticij	This proje	The objec	TRL 3	TRL 5
483bc57b-	Live	Black Star	Black Start Capabilities from Non-t	NIA_NGSO0022	ElectricityTransmission	01/01/2019	200000	NIA	This innov	This innov	This proje	TRL 2	TRL 4
071b7350-	Live	OHL (Over	OHL Power Pointer	NIA_WPD_038	ElectricityDistribution	01/12/2018	1302413	NIA	As the util	As the util	1. Create	TRL 5	TRL 8
1a1fda91-	Live	Shift	Shift	NIA_UKPN0045	ElectricityDistribution	01/01/2019	1295500	NIA	Electric ve	Smart cha	This proje	TRL 4	TRL 7

Figure 28 Structured Project Data Export from ENA Smarter Networks Portal