UK Energy Research Centre

Distribution Network Operators' Areas of Focus in the RIIO-ED2 Period

UKERC Working Paper

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Executive Summary

This report examines the priority areas and transition trends of Distribution Network Operators (DNOs) within their innovation plans for the RIIO-ED2 price control period of 2023-28. DNOs vary in their categorisation of innovation projects. In order to identify common focus areas, this study establishes a unified classification of innovation themes across all the RIIO-ED2 plans of all DNOs (except National Grid Electricity Distribution (NGED) for which published information was unavailable when plans were reviewed for this report) and conducts comparative analyses to highlight the significance of each subject and individual DNOs' focus.

This study traces the evolution of innovation area priorities since the conclusion of the Low-Carbon Networks Fund (LCNF) programme in 2015 to understand shifting trends. The proposed classification organises headlines into four innovation themes:

1. Network assets and practices;
2. Digitalisation;
3. Engagement with partners and network users; and
4. Distribution system operation (DSO) and flexibility.

Digitalisation emerges as the most frequently addressed theme in published RIIO-ED2 innovation plans.

In comparison with the LCNF programme, areas like the role of batteries in network management and direct control of residential low carbon technologies have seen reduced emphasis. Some DNOs continue prioritising innovations related to active voltage control and real-time dynamic asset rating. Routine practices for customer interruption reduction and asset management are treated as business as usual.

In comparison to the LCNF programme, RIIO-ED2 innovation plans introduce innovation areas related to the DSO role, facilitation of flexibility markets and emerging digitalisation aspects like data handling and transparency. These, plus areas carried on from before, represent opportunities for innovators to work with DNOs. DNOs face a number of common challenges and show overlap in innovation themes, emphasising the importance of knowledge sharing to avoid duplication in research, development and demonstration and accelerate progress towards adoption of successful innovations.

Improved information sharing would enable innovators both within DNOs and potential collaborators outside to see where further opportunities exist and give confidence to network customers and other stakeholders that innovations proven to be useful and cost-effective are being taken forward.

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1 Innovation Landscape

1.1 Introduction

The rapidly evolving energy landscape, characterised by the integration of renewable energy sources, the electrification of transportation and increasing demand for electricity for heating, cooling and digital technologies, has encouraged a new era of innovation in power networks. Sustainable energy system development involves a trilemma: it must be reliable, affordable, and green, a principle that applies to every perspective in the energy sector. Distribution Network Operators (DNOs) play a pivotal role in ensuring the reliable and efficient delivery of electricity to homes, businesses and industries.

DNOs operate as regulated monopolies in their designated service areas following licence conditions monitored by the Office of Gas and Electricity Markets (Ofgem). Under terms defined by Ofgem, DNOs have been permitted since 2004 to recover the majority of the costs of innovation projects via the charges levied on network users[1] . Drawing lessons from their past innovation plans, DNOs' innovation strategies aim to comply with their licence obligations while also addressing stakeholder goals and policies. They are under increasing pressure to facilitate reduction in greenhouse gas emissions and improvements in energy efficiency, as outlined in their business plans. These plans often highlight the integration of variable renewable resources, such as wind and solar, into the grid, advanced monitoring and control systems and grid automation. This report delves into the key areas of focus for DNOs' planned innovation activities as evident from their business plans for the "RIIO-ED2" price control period (2023-2028) published at the end of 2021. However, due to lack of published information on NGED's innovation plan at the time when reviews were undertaken for this report, NGED has been excluded from our evaluations.

1.2 Distribution Network Operators

In Great Britain, the DNOs play a central role in overseeing the local distribution of electricity. Figure 1.1 shows six DNOs in Britain, which are responsible for the maintenance, expansion, and operation of distribution networks within fourteen licence areas. DNOs in Britain include: (1) ENWL: Electricity North West Limited; (2) NPG: Northern Powergrid; (3) SPEN: Scottish Power Energy Networks; (4) SSEN: Scottish and Southern Electricity Networks; (5) UKPN: UK Power Networks; (6) WPD: Western Power Distribution which was acquired by National Grid in 2021 was renamed National Grid Electricity Distribution, NGED, in September 2022.

DNOs hold ownership and operational responsibilities for the distribution networks in their specified geographical regions. These networks comprise a system of power lines, transformers, substations and associated infrastructure operated at voltages of 132 kV and

[1] See, for example, https://smarter.energynetworks.org/funding-timeline/.

below[2], facilitating the last stage of delivery of electricity to the vast majority of end-users. Regulated by Ofgem, the DNOs are essential for ensuring the reliability and robustness of the distribution networks. Their networks are interconnected with the transmission network that is operated at voltages of up to 400 kV. They therefore interact with transmission network owners and Britain's Electricity System Operator.

Figure 1.1 Distribution network companies in Great Britain [1]

1.3 Electricity Distribution Funding Timeline

Up to the time of writing, different mechanisms for funding innovation by network companies have been approved by Ofgem (shown in Figure 1.2). The Innovation Funding Incentives (IFI) ran between 2004 to 2015, covering various programmes and initiatives that governments, organisations, or entities put in place to encourage and support innovation and research and development activities. The Low-Carbon Network Fund (LCNF) was established in 2010 to support the development and deployment of innovative technologies and approaches within the electricity distribution networks, with a focus on

[2] The 132 kV network in Scotland is classified as transmission and is owned and maintained by Transmission Owners.

reducing carbon emissions and improving the efficiency and reliability of the electricity grid [2].

"RIIO-ED" is the regulatory framework used to set price controls and regulatory policies for electricity distribution network companies. RIIO-ED stands for "Revenue = Incentives + Innovation + Outputs" applying to Electricity Distribution. The RIIO-ED1 framework was implemented to determine how much revenue distribution network operators could earn over the 8-year period of 2015-2023, intended to promote better performance, innovation, and the efficient delivery of electricity distribution services [3]. The second RIIO-ED price control period RIIO-ED2 started on 1 April 2023. As illustrated by Figure 1.2, the development of RIIO-ED2 was initiated in 2019 and DNOs design their business plans according to the Ofgem's RIIO-ED2 Business Plan Guidance published by 30 September 2021 [4].

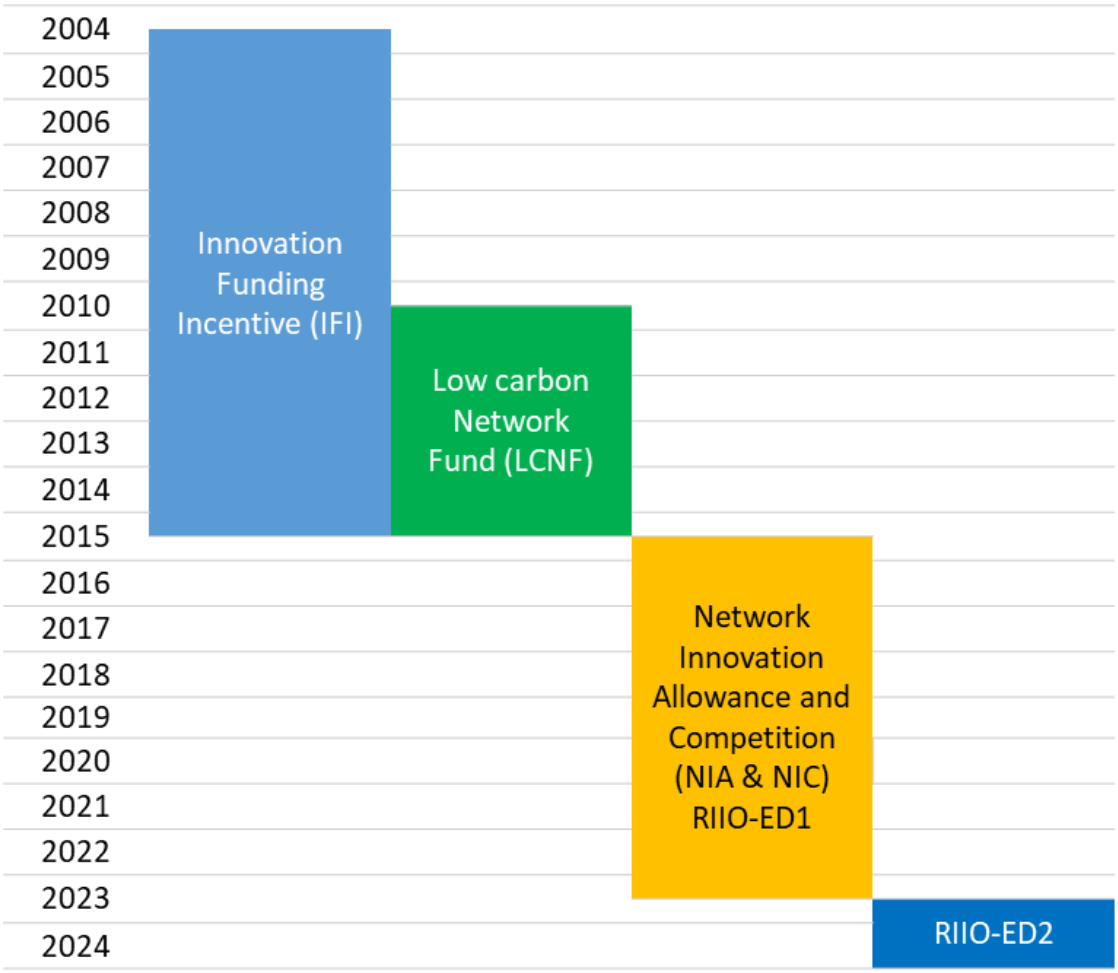

Figure 1.2 Electricity Distribution Funding Timeline [5]

1.4 Foundation of RIIO-ED2 Innovation Plans

As stated, the RIIO-ED2 period started in April 2023. Figure 1.3 shows the timeline of the evolution of the form of RIIO-ED2 from 2019. The RIIO-ED2 arrangements include an important annex related to innovation plans which every DNO develops in accordance with Ofgem guidance. Innovation plans encompass several themes that outline the focus areas for projects undertaken or led by DNOs to develop or demonstrate innovative technologies or practices. These will be further discussed in the subsequent chapters. It is important to note that the authors lacked access to the innovation plan of National Grid Electricity Distribution (NGED) since there was no specific innovation plan published on their website at the time when reviews were undertaken for this report. Consequently, NGED has been excluded from our evaluations.

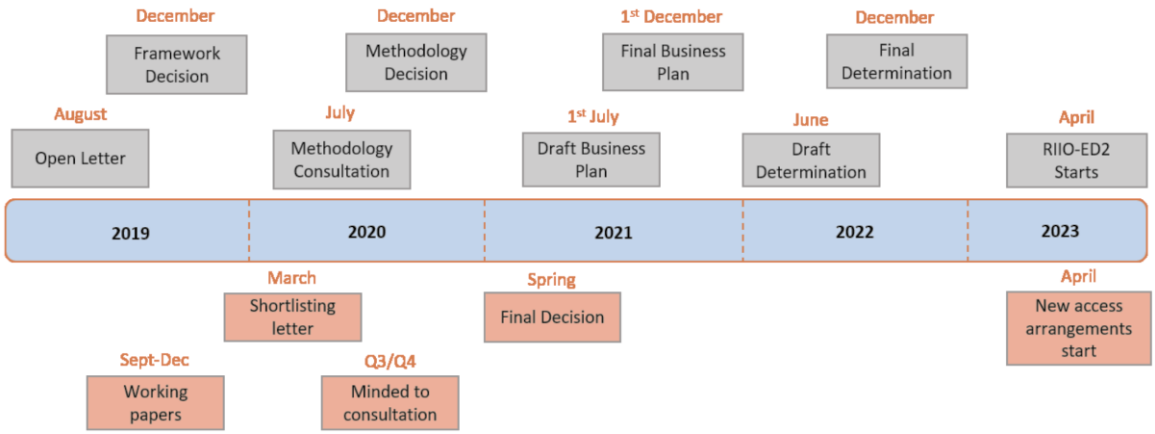

Figure 1.3 RIIO-ED2 timeline [6]

1.5 Innovation Funding Mechanisms

The framework for innovation in electricity distribution networks in GB includes several funding programmes set up by Ofgem to support the development, testing, and rollout of new solutions.

Ofgem introduced the Network Innovation Allowance (NIA) and Network Innovation Competition (NIC) in 2015 during the RIIO-ED1 period [7]. NIA has been a key funding programme, helping DNOs work on small to medium-sized innovation projects. However, there is no strict definition of size of NIA project in the governance documents. Past projects funded through NIA have ranged from relatively small initiatives to those costing up to £5 million. NIA focuses on exploring early-stage innovations (typically low to medium Technology Readiness Levels) to improve network efficiency, reliability, and customer services. In the RIIO-ED2 period, NIA continues to support innovation, but with greater focus on environmental benefits and consumer outcomes, in line with net zero goals [8, 9].

NIC, on the other hand, encourages long-term innovation and has been used to support larger projects, with costs of upwards of £2 million. It helps move successful pilot projects, like those from NIA, towards becoming part of BAU operations [7]. Its competitive nature is

aimed at ensuring funding goes to projects that are impactful and scalable, matching the goals of RIIO-ED1 and RIIO-ED2 [10].

In 2023, with the start of RIIO-ED2, the Strategic Innovation Fund (SIF) replaced NIC for distribution licensees [11]. SIF, run by Ofgem and InnovateUK, is a competitive programme focused on tackling major, system-wide challenges. SIF takes a challenge-based, multi-phase approach to innovation. It consists of a *Discovery* phase, where projects explore feasibility and define potential benefits, followed by an *Alpha* phase, which tests solutions in controlled environments before progressing to large-scale demonstration in the *Beta* phase. While NIC in RIIO-1 funded large-scale development and demonstration projects without structured phases, SIF introduces a step-by-step approach, ensuring feasibility is established before progressing to larger trials. SIF formalises early feasibility assessments that NIC-funded projects also had to undertake before full implementation. It supports solutions that deliver clear benefits across the energy sector and help the UK achieve its broader energy transition targets. It aims to support innovations that promise to deliver clear benefits across the energy sector and help the UK achieve its broader energy transition targets [12, 13].

1.6 What are the Focus Areas in This Study?

This study examines the innovation plans publicly shared by DNOs on their websites as part of the RIIO-ED2 process. It aims to provide a comprehensive understanding of their innovation strategies in RIIO-ED2 by analysing information explicitly included in their plans and supporting innovation annexes. These plans offer valuable insights into the evolving priorities of DNOs as they navigate the challenges of a dynamic energy sector.

The final link in the chain of developing innovative ideas is applying them in an ongoing business. Deployment and application depend on the technology readiness level and how much benefit an innovation can deliver. Also, it depends on how the industry and stakeholders are willing to invest in it based on their priorities and in comparison with established approaches. At the time when the review for this report was undertaken, RIIO-ED1 had concluded. This provides an opportunity to reflect on the DNOs' priorities from eight years ago and compare them with their updated focus as RIIO-ED2 began.

In [14], a 2016 study by the University of Strathclyde systematically reviewed innovation projects funded through the LCNF mechanism at the early stage of RIIO-ED1. The study measured the readiness of these innovative concepts for business-as-usual (BAU) integration by examining the tangible results, demonstrated benefits, and lessons learned from the completed pilot projects associated with each innovation. At the time of writing this report, at the early stages of RIIO-ED2, this study evaluates how DNOs designed their innovation plans based on the lessons they learned from RIIO-ED1 and how they integrate mature innovations into their BAU.

This report explores British DNOs' innovation strategies outlined for RIIO-ED2 and delves into their key areas of focus. Under RIIO-ED2, DNOs are required to set out their business plans, including investment proposals and innovation strategies, to secure funding for the next regulatory period. It should be clarified that our source for this review is Innovation Plans that DNOs publicly shared on their website at the time of writing this report and

considered information included in the report or cited in their innovation plans under RIIO-ED2.

This report also compares the focus areas of DNOs in RIIO-ED2 with the projects initiated under the LCNF. By evaluating the trends and alignment between these two initiatives, we can gain valuable insights into the progression of DNOs' innovation strategies and how they align with broader national energy goals.

1.7 Our Main Research Questions

The main research questions in this study are as follows:

1. What are the common areas of innovation shared among different DNOs?
2. Which particular innovation areas receive heightened emphasis from multiple DNOs?
3. How have the prioritised innovation areas shifted in RIIO-ED2 compared to LCNF?
4. What changes are observed in innovation themes regarding the categorisation of Business as Usual, ongoing innovation, or cessation of pursuit?
5. What are the implications of these innovation trends for the research and innovation community, policymakers, and industry stakeholders?

2 Ongoing Innovations – Classification

This chapter aims to delineate the innovation themes and areas of focus in RIIO-ED2. As mentioned, this review is based on the innovation plans publicly shared by DNOs on their websites at the time of writing, focusing on information included or cited under RIIO-ED2, and our categorisation aims to capture the main apparent areas of interest that emerged from the business plans. We will categorise innovation themes based on the innovation plans published by DNOs and what they have in common.

2.1 Importance of Common Classification for Innovation Themes

As indicated in section 1.4, each DNO tailors its innovation plans based on guidance from Ofgem. The specifics of these plans may differ across regions due to unique requirements in their distribution networks and varied experiences in managing networks and executing innovative projects. Despite disparities in their circumstances and priorities, the fundamental tasks and responsibilities are similar, as DNOs grapple with analogous challenges related to future energy scenarios and network needs. While operating as distinct entities with individual business focuses, pinpointing common innovation themes among them can help to identify the most crucial areas for the development of electricity network assets and practices.

2.2 Proposed Classification for Innovation Themes in RIIO-ED2

To identify common innovation themes, we analysed the focus areas and direction of innovation projects, reclassifying them into themes that best align across DNOs based on their documented innovation plans. The proposed classification for RIIO-ED2 innovation themes, common across various DNOs, are briefly outlined in Table 2.1. This list of common innovation themes encompasses four key areas of focus, namely: (i) Network Assets and Practices; (ii) Digitalisation; (iii) Engagement with Partners and Network Users; and (iv) DSO and Flexibility: Commercial and Regulatory Evolution.

The *Network Assets and Practices* innovation theme focuses on creating an efficient, reliable electricity distribution network by optimising performance, balancing supply and demand, and enhancing resilience. It addresses asset management, investment planning, and the energy transition to reduce costs and support net zero targets. Emphasising collaboration with energy system operators, this area of innovation includes projects that integrate renewable energy, consider the impacts of heat and transport electrification and foster workforce development. This theme also contains design procedures, optimisation approaches, and protocols critical for a sustainable, dependable power network.

The innovation theme of *Digitalisation* in RIIO-ED2 involves the integration of advanced digital technologies and data-driven solutions into the distribution network. These initiatives mainly aim to enhance backbones and enablers for other innovations for the enhanced

operation of power networks. The focus areas are on leveraging digital tools and analytics to improve data handling, enhance network visibility and increase data availability and transparency. According to the DNOs' innovation plans, this innovation theme can be categorised in four directions including: (i) Data Handling; (ii) Data Analysis and Forecasting; (iii) Monitoring and Control; and (iv) Data Transparency and Interfaces.

The innovation theme *Engagement with Partners and Network Users* involves innovative projects designed to enhance service delivery to network users by leveraging technical advancements and fostering collaboration with partners. This innovation theme is categorised into three main headlines: (i) LCT Connection Facilitation; (ii) Engagement with other System Operators and Local Communities; and (iii) Consumer Vulnerability.

Lastly, the innovation theme concerning *DSO and Flexibility: Commercial and Regulatory Evolution* emphasises the transformation of DNOs into a new role as Distribution System Operators (DSOs). The objective is to enhance flexibility and adaptability, utilising available local flexibility more efficiently. This innovation theme comprises two prioritised areas for innovation: (i) Active Network Management and Flexibility; and (ii) Commercial and Regulatory Evolution.

Table 2.1 DNOs' innovation themes

Network Assets and Practices	Digitalisation	Engagement with Partners and Network Users	DSO and Flexibility: Commercial and Regulatory Evolution
1. Assets and the Energy Transition 2. Improvement of the Reliability and Resilience of Networks 3. Innovative Methods to Train and Upskill the Workforce 4. Minimising the Impact of Assets on the Environment	1. Data Handling 2. Data Analysis and Forecasting 3. Monitoring and Control 4. Data Transparency and Interfaces	1. LCT Connection Facilitation 2. Engagement with other System Operators and Local Communities 3. Consumer Vulnerability	1. Active Network Management and Flexibility 2. Commercial and Regulatory Evolution

2.3 Detailed Innovation Themes

As mentioned earlier, DNOs have outlined their innovation priorities in the innovation annex of their RIIO-ED2 business plans [15-19]. However, due to varying categorisation preferences among DNOs, it is challenging to directly compare specific innovation themes. Therefore, we have organised and categorised innovation priorities across DNOs, considering the previously mentioned innovation themes in the preceding sections. This section will provide detailed information on our categorisation of DNOs' innovation themes, mentioning the associated company of every innovation headline.

2.3.1 Network Assets and Practices

This section delineates innovation areas classified under the overarching theme of *Network Assets and Practices* that propose to optimise the planning and investments to reduce costs and pollution and increase efficiency in the use of assets.

2.3.1.1 Assets and the Energy Transition

Assets and the Energy Transition contains innovative asset management that considers the facilitation of energy transition goals and consists of four areas as follows:

Principles and initiatives in investment planning

This subject contains DNO's considerations, which the associated innovation headlines itemised below, concerning the use of new principles, assets, features or data that could make investment planning more efficient and facilitate pathways to net zero targets. These innovation headlines can be categorised into three groups.

Energy Efficiency and Maximising Capacity

This area of innovation focuses on enhancing the efficiency and utilisation of energy distribution networks, ensuring optimal performance while meeting the demands of a growing energy landscape. Key innovation headlines include:

- Optimised Distribution Operations (ENWL)
- Voltage Optimisation for Energy Efficiency (NPG)
- Alternative Options to Get the Most Out of Our Existing Asset Base (UKPN)

Asset Management and Health

This area emphasises advancements in managing, maintaining, and monitoring energy assets to extend their lifecycle, mitigate risks, and ensure reliable operation. Innovation headlines under this area are as follows:

- Improved asset management (ENWL)
- Safety measures for our operators and the general public: risk management (ENWL)
- Asset life extension (SSEN)
- Improved investment in asset management (SSEN)
- Asset life extension/understanding failure: maintain the networks' asset health risk broadly constant (UKPN)
- Inspection and maintenance: improve processes to target those assets likely to become the highest risk as their age profile increases (UKPN)
- Condition monitoring (SSEN)

Next-Generation Network Development

This area focuses on creating innovative capabilities to design and manage integrated energy networks that are dynamic, responsive, and capable of balancing diverse energy sources in real-time. Key innovation headlines under this area include:

- Create capabilities to deliver a next-generation local energy network that links up whole system energy sources and vectors, balancing in real-time (NPG)
- Inter-seasonal Energy Planning (NPG)

System Impact of Coordination with Other Energy Systems Operators

This innovation sub-area explores innovative approaches to asset management through whole system planning and collaboration with other energy system operators, considering impacts that extend beyond electricity to include heat, transport, and other energy vectors. Innovation headings under this subject are as follows:

- Multi-vector whole system planning: improve customer service and reduce bills (ENWL)
- Understanding seasonal transport and heating shifts (NPG)
- Coordinate system-wide cost-benefit analysis with partners, developing techniques that consider broader benefits, i.e. those in generation and population health (SPEN)
- Whole system planning: supporting local and national forward planning and investment optimisation across energy boundaries (UKPN)
- The interplay between decarbonisation of heat and transport and their network impacts (UKPN)

2.3.1.2 Improvement of the Reliability and Resilience of Networks

Electricity system reliability ensures uninterrupted power delivery under normal conditions, while resilience addresses the system's ability to withstand, recover, and adapt to disruptions, minimising their impact [20]. The innovations related to the enhancement of reliability and resilience indices of networks are categorised in this section within two sub-areas.

Improvements to Reliability

Enhancement of reliability indices using innovative approaches and performing new approaches to measure them was the subject of the following DNO's innovation headlines:

- Enhanced network reliability: reliability (ENWL)
- Local reliability and resilience from a single energy vector (after electrification of heat and transport) (NPG)
- Local year-round security of supply from renewable energy sources after electrification of heat and transport (NPG)
- Distribution wide visibility and contingency scenario analysis (SPEN)
- Reduce and mitigate unplanned supply interruptions (SPEN)
- Enhance reliability (SSEN)
- Optimise reliability and resilience for cost-efficient operations and minimised interruptions, i.e. leverage embedded generation for increased resilience (UKPN)

Improvements to Resilience

Maintaining network resilience and preparing requirements to enhance the resilience of the system was the goal of following DNO's innovation headlines:

- Enhance network resilience: resilience (ENWL)

- Solar flare resilience (SPEN)
- The role of thermal and electrical storage in transport and heat to maximise resilience (UKPN)

2.3.1.3 Innovative Methods to Train and Upskill the Workforce

Enhancing workforce safety, scaling up the workforce to meet industry demands, and exploring innovative training methods are considered as follows:

- Work practices and systems (SPEN)
- Ensure future skill requirements and workforce resilience (SPEN)

2.3.1.4 Minimising the Impact of Assets on Environment

Several innovative projects, outlined in the following headlines, focus on optimising assets in ways that minimise environmental pollution and reduce carbon footprint.

- Carbon emissions: carbon emission management (ENWL)
- Coordinated use of assets between system operators for environmental management (ENWL)
- Impact of SF6: risk management (ENWL)
- Carbon and energy reduction (SPEN)
- Collaborate with the supply chain to enhance environmental sustainability standards (SPEN)
- Land and biodiversity improvement (SPEN)
- Network losses (SPEN)
- Pollution prevention (SPEN)
- SF6 leakage (SPEN)
- Sustainable procurement in line with the guidance in ISO 20400 (SPEN)
- Sustainable resource use (SPEN)
- Business carbon footprint (SSEN)
- PCBs/creosote (SSEN)
- Reduce losses (SSEN)
- SF6 (SSEN)

2.3.2 Digitalisation

This section outlines innovation areas categorised under the overarching theme of digitalisation. Beyond enhancing efficiency and operations, digitalisation will play a crucial role in enabling and accelerating other innovation themes and projects. It involves providing equipment, methods, and platforms that enhance visibility, controllability, and transparency to maximise the utilisation of existing and forthcoming assets and equipment more efficiently.

2.3.2.1 Data Handling

Innovations in data handling build upon advanced practices for standardising information management processes. These innovations focus on efficiently gathering data and

establishing comprehensive databases to enable smarter and more effective management of energy systems. The associated headlines in innovation plans of DNOs related to data handling are as follows:

- Data stream integration (NPG)
- Externally focused smart asset records (NPG)
- Sophisticated data management and analytics (NPG)
- Consumer vulnerability dataset development (SPEN)
- Data and digitalisation (SPEN)
- Integrated models and datasets (SPEN)
- Data analytics (SSEN)
- New data sources (SSEN)

2.3.2.2 Data Analysis and Forecasting

Data analysis and forecasting assist DNOs in different areas such as asset management, load forecasting, cost optimisation, technology adoption, and performance measurement.

Forecasting Methods

The enhancement of forecasting methods and access to more accurate forecast data can assist DNOs in achieving a more realistic network management/optimisation that aligns with future networks. This is particularly crucial as there will be a significant increase in loads, LCTs, and integration with other vectors. The innovation headlines of DNOs aligned with the development of forecasting methods are as follows:

- Forecasting: accuracy in forecasting – improved investment plans (i.e. for loads/EVs) (ENWL)
- Energy system forecasting, planning and real-time decision-making (NPG)
- Forecast of electric heating and EV charging patterns (NPG)
- Demand forecasting (SPEN)
- Enhanced forecasting and modelling (SPEN)
- Study the impact of hydrogen on demand (SPEN)
- Develop forecasting methods (SSEN)
- LCT forecasting (SSEN)
- LCT headroom forecasting (SSEN)

Data Analysis

Data analysis aids in assessing the condition and performance of assets, optimising and standardising the use of data. Furthermore, through the analysis of data on equipment failures, maintenance records, and other pertinent information, DNOs can formulate predictive operation and maintenance models. These models have the potential to minimise downtime, reduce operational costs, support vulnerable consumers, and ensure reliability and resilience. The associated innovation headlines are as follows:

- Digital engineering (SPEN)
- Improved priority services register artificial intelligence data cleansing (SPEN)
- Priority services register probability gap analysis (SPEN)
- Using data and analytics to optimise network planning (SPEN)
- Artificial intelligence (SSEN)

- Machine learning (SSEN)
- Artificial intelligence (UKPN)
- Edge computing (UKPN)
- Machine learning (UKPN)

2.3.2.3 Monitoring and Control

DNOs actively pursue innovations in monitoring and control mechanisms, aiming to use the most up-to-date and precise information for seamless real-time analysis, control, and increased operational efficiency. The associated innovation subareas include *Visibility and Monitoring*, *Fault Monitoring* and *Digital Enablers for Real-time Analysis and Control*.

Visibility and Monitoring

The innovation sub-area of *Visibility and Monitoring*, as outlined below, predominantly focuses on innovative projects dedicated to deploying advanced technology equipment. These initiatives aim to collect, transfer, and configure information regarding the states and conditions of the network and assets on digitised platforms.

- Microgrid technology (NPG)
- Enable digitalisation for network and system optimisation (SPEN)
- Expanded network monitoring, telecommunications, and control (SPEN)
- Improved visibility and control on the LV network (SPEN)
- Improved visibility of customers and their behaviour (SPEN)
- Network monitoring (SSEN)
- Network visibility (SSEN)

Fault Monitoring

The innovation headlines related to fault monitoring encompass the following projects, which are designed to enhance existing techniques and develop new methods to support the protection of distribution networks.

- Fault anticipation (SSEN)
- HV faults (SSEN)
- LV faults (SSEN)

Digital Enablers for Real-time Analysis and Control

DNOs follow innovation projects, encompassing elements like automation, communication advancements, and advanced data capture, to facilitate real-time analysis and control of their networks, as detailed in the following innovation headlines:

- Automation (NPG)
- Speed of communications and data provision (NPG)
- Accurate data capture (SPEN)
- Developing the control room of the future (SPEN)
- Increasing real-time visibility and autonomous operation (SPEN)
- Automation (SSEN)
- Augmented reality and state estimation (UKPN)

2.3.2.4 Data Transparency and Interfaces

Several innovation projects by DNOs are dedicated to enhancing data transparency and interfaces, aiming to foster open communication, streamline information exchange, and improve interoperability, ultimately promoting collaborative and informed decision-making. The associated headlines are as follows:

- Data access: data provision - increased level of autonomy (ENWL)
- Interface arrangements: data sharing and improve customer services (ENWL)
- Dynamic data platforms (NPG)
- Ensure availability of information on benefits to relevant customer groups (NPG)
- Transparent digital capacity information: streamlining interactive requirements (NPG)
- Two-way open data platforms integrating energy, user, and planning data (NPG)
- Data availability to customers (SSEN)
- Improving customer interaction (SSEN)
- Development of digital twins (UKPN)
- Enhanced visualisation (UKPN)
- Gamification of the interface (UKPN)

2.3.3 Engagement with Partners and Network Users

This innovation theme focuses on innovative projects that adhere to technical arrangements and considerations related to engaging with parties intending to use or receive services from the network. The theme includes a wide range of projects aimed at enhancing services, such as facilitating LCT connections, collaborating with other system operators and local communities, and addressing consumer vulnerability.

2.3.3.1 LCT Connection Facilitation

DNOs consider innovative approaches to release network capacity and manage distribution network constraints in a way that facilitates the connection of more LCTs. This includes considerations related to the connection of loads, storage and distributed generation (DG).

Facilitation of Low Carbon Demand Connections

The innovation focus in this section revolves around optimising load and demand connections to maximise network headroom and effectively manage congestion and constraints. The pertinent headlines are outlined below:

- Connections: improve customer experience and services (ENWL)
- Use of domestic flexibility for affordable connections and energy bill savings (ENWL)
- Optimisation of domestic customers' future equipment (NPG)
- Optimisation of industrial and commercial customers' future equipment (NPG)
- Facilitate the electrification of heat and transport (SPEN)
- Changes in demand and customer behaviour (SSEN)

- Supporting local heat and energy efficiency strategies to decrease both energy costs and emissions (SSEN)
- Encouraging energy efficiency to reduce energy needs (UKPN)
- Whole heat solutions: pioneering comprehensive system innovations for district, industrial & commercial, on-gas grid, and energy efficiency (UKPN)
- Whole transport: innovating to overcome barriers to decarbonising road, rail, water and air transport, including essential services (UKPN)

Facilitation of Storage Connections

The innovation headlines related to optimised connection of storage devices are listed as follows:

- Whole energy system batteries (NPG)
- Facilitate connection of low carbon electricity storage (SPEN)
- Application of hydrogen as potential storage (SPEN)
- Impact of energy storage technologies (SSEN)
- Store electricity for hydrogen production (UKPN)

Facilitation of Connection of Distributed Generation

The innovation headlines aligned with the same goal orientation for distributed connected generations are as follows:

- Low carbon technology adoption: capacity release (ENWL)
- Mobile demand and generation (NPG)
- Facilitate connection of low carbon electricity generation (SPEN)
- Connecting renewables (SSEN)
- Island decarbonisation initiatives to reduce the environmental impact of diesel backup generation (SSEN)
- Minimise renewable generation curtailment (UKPN)

2.3.3.2 Engagement with Other System Operators and Local Communities

DNOs have established innovation priorities, outlined below, to improve coordination with other system operators and engage with local communities, ensuring the seamless integration of innovative solutions into the network infrastructure and maximising the utilisation of assets and network capabilities.

- Joined-up approaches to regional network planning and forecasting (SPEN)
- Local communities (SPEN)
- Cross vector working (SSEN)
- Engaging with local communities and authorities as well as organisations in the energy and transport, telecoms, and water sectors to increase management efficiency (SSEN)
- Local authority engagement (SSEN)
- Local energy area plans (SSEN)
- Local heat and energy efficiency strategies (SSEN)

- Island decarbonisation initiatives to reduce the environmental impact of diesel backup generation (SSEN)

2.3.3.3 Consumer Vulnerability

Within this innovation domain, DNOs have proposed employing inventive methods to tackle issues such as fuel poverty, the identification of vulnerable consumers, the priority services register, and safeguarding vulnerable and fuel-poor customers. The corresponding headlines are outlined as follows:

- Fuel poverty: optimised distribution system operation (ENWL)
- Break energy market barriers for all: emphasising inclusivity, especially for the vulnerable; ensure access to energy data (NPG)
- Identify potential market failures (NPG)
- Make new energy offerings attractive to all (NPG)
- Safeguard customers whose vulnerability is increased by the pace of change (NPG)
- Support passive customers (NPG)
- Additional resilience requirements (SSEN)
- Fuel poverty (SSEN)
- Future vulnerability needs as we move to net zero (SSEN)
- Priority services register (SSEN)
- Support for vulnerable consumers (SSEN)
- Data-driven understanding of vulnerability: harnessing analytics to inform, share, prioritise, and customise our customer vulnerability approach (UKPN)
- Digital inclusion solutions: proactively engaging trusted partners and communities to reach hard-to-access, digitally excluded customers (UKPN)
- Inclusive net zero initiatives: collaborating to ensure vulnerable and fuel-poor customers can fully participate in the evolving flexibility and DSO market (UKPN)

2.3.4 DSO and Flexibility: Commercial and Regulatory Evolution

The evolving potential for the involvement of distribution-connected energy providers in service provision anticipates changes in the operation and governance regime of distribution systems. Proactively managing networks is crucial for leveraging available flexibility services at the distribution level and DNOs are set to contribute to this transformation. According to Ofgem guidance, DNOs are expected to adopt a new role as DSOs, taking on responsibilities for the operation of distribution systems. Therefore, several projects outlined in RIIO-ED2 plans contribute to active network management and flexibility, along with the necessary commercial and regulatory adjustments required to support DNOs in their new roles and responsibilities.

2.3.4.1 Active network management and flexibility

The National Energy System Operator (NESO) defines energy system flexibility as the capacity to adjust supply and demand to maintain energy balance [21]. DNOs are expected to actively manage networks and facilitate the use of flexibility services. Active distribution network management consists of innovative operational methods to release

network capacity, manage constraints, and facilitate the provision of flexibility services. This includes coordination with other operators to avoid conflicts and enable flexible connections. The corresponding headlines for these innovation areas are listed as follows:

- Ability to model power flow effects of flexibility (NPG)
- Adapting network operations for real-time DSO support (NPG)
- Call-off procedures for flexible support in contingency (NPG)
- Facilitate higher volumes and different types of connection between areas (NPG)
- Understanding the locational load shift caused by temporal load shift (NPG)
- Active network management (SPEN)
- Distribution and transmission network coordination (SPEN)
- Facilitate the adoption of flexibility and smart systems (SPEN)
- Increased whole system coordination: network planning coordination across distribution, transmission, and other energy vectors. (SPEN)
- Influencing behaviour beyond the meter (SPEN)
    - Aggregator/service provider platforms
    - Smart domestic control systems
    - Integration of domestic thermal and electrical storage
    - Direct load control techniques
    - Variable time-of-use tariffs
- Optimising smart meters, data, and network charging reforms opportunities (SPEN)
- Deployment of innovation regarding flexibility and DSO (SSEN)
- DSO operation (SSEN)
- Flexible connection options (SSEN)
- Scaling ep flexibility (SSEN)
- Transmission and distribution coordination (SSEN)
- Designing flexibility for enhanced network efficiency, i.e. energy and heat (UKPN)
- Whole electricity: enhancing customer benefits in the electricity system – power potential project collaboration with national grid ESO (UKPN)

2.3.4.2 Commercial and Regulatory Evolution

The transformation into a DSO necessitates new commercial evaluations and regulatory arrangements. These have been proposed within a series of innovative projects categorised in this section.

Financial Assessment and Facilitation of Flexibility Markets

Ofgem envisions the creation of flexibility markets within distribution systems. Consequently, DNOs are assessing their financial evaluations to align with the necessary arrangements and incorporate them into their business plans. The listed innovation headlines of DNOs below illustrate their adoption of economic assessments to gauge benefits, explore opportunities, and examine options for facilitating trading services.

- Benefit quantification: Evaluating the impact of flexibility on consumers' bills and DNOs' costs (NPG)
- Development of commercial frameworks with third parties for flexibility markets (NPG)
- Interplay of flexible energy and network services markets (NPG)
- Enable domestic flexibility and local energy markets (SPEN)

- Holistic conflict management regime: interacting more closely with customers, other network parties and other markets to prevent any conflict of interests (SPEN)
- Maximise the opportunities from smart meters, data, and network charging reforms (SPEN)
- Market facilitation (SSEN)
- New flexibility products and services (SSEN)
- New markets (SSEN)
- Blockchain/P2P trading (UKPN)
- Advancing market platforms: developing and testing capabilities with third parties, e.g. optimise prime and energy exchange projects (UKPN)
- Innovative commercial models to offset environmental levy on tariffs (UKPN)
- Proactive policy engagement – influencing regulatory initiatives for fair network access, reduced electricity costs, and empowered local energy markets (UKPN)

Trials for Flexibility Markets and DSOs

The implementation of flexibility markets and the DSO role are new concepts at the distribution level, and DNOs seek the actual requirements and prerequisites through trial projects, as indicated by the corresponding headlines listed below.

- Deploy the use of flexibility and innovation to facilitate the transition to DSO (ENWL)
- Trial and implement arrangements to support network management and flexibility (SPEN)
- Testing and evaluating new flexible solutions for new and emerging network issues (SSEN)
- Testing real-time and net zero operations: investigating benefits and leading dispatch framework development (UKPN)

Required Governance Arrangements

The following innovation headlines are detailed in RIIO-ED2 innovation plans to identify requirements for reform in governance arrangements. These innovative projects are defined based on the new roles and responsibilities associated with the DSO role, as well as the requirements for facilitating flexibility markets.

- Develop flexible connection arrangements to facilitate customer choice (SPEN)
- Identify organisational changes to ensure ongoing safe, reliable, and cost-effective DSO services, instilling market confidence in our flexibility service procurement choices (SPEN)
- Identify regulatory barriers and make recommendations for reform: some existing regulations could potentially adversely affect the energy system transition (SPEN)

3 Ongoing Innovations – Comparative Analysis

This chapter will compare the ongoing innovation themes in RIIO-ED2 among different DNOs. The evaluation will showcase the specific focus areas of each DNO, indicating the extent to which they plan to innovate in each theme. Furthermore, the chapter will categorise innovation themes for each DNO, providing insight into how they manage these themes in line with the common innovative practices. While financial allowances awarded by Ofgem enable DNOs to deliver innovation activities and inevitably impact their ability to focus on priority themes, the RIIO-ED2 plans reviewed here provide limited transparency on budget allocations for specific innovation themes and innovation areas, constraining a deeper financial analysis. In our evaluation, we consider the number of innovation headlines defined under each subject and theme as a factor reflecting the focus and priority DNOs assign to these areas.

3.1 Levels of Interest in Innovation Themes: Theme by Theme

Identifying common and widely embraced innovation themes across DNOs is essential for understanding industry trends and collaborative opportunities. The DNOs' published innovation plans reflect different approaches used to describe the main innovation activities and group them under different thematic areas. In order to provide a consistent approach, this study explores the DNOs' plans via the headlines of sections of their reports that are associated with the four primary innovation themes introduced in the earlier chapter. This exploration not only highlights the diversity of approaches within the sector but also underscores the interconnected nature of innovations that transcend individual operators, fostering a more comprehensive understanding of the evolving landscape in energy distribution. In order to provide insights into the significance of each topic in their innovation plans and in the absence of data such as the planned level of expenditure for specific projects in each area, the study also quantifies the number of project headlines (number of headlines, NoH) relating to each innovation area for each DNO as a proxy for the level of interest. However, because of this approach's sensitivity to how each DNO has structured their business plan report, this should be taken only as a rough guide.

3.1.1 Network Assets and Practices

According to Table 3.1, the innovation area of *Assets and the energy transition,* along with the subarea of *Principles and initiatives in investment planning*, stands out, attracting the highest level of attention based on the number of DNOs and the corresponding headlines. The second most popular innovation theme among DNOs is innovative projects focused on enhancing reliability and resilience. Additionally, it is noteworthy that innovative projects addressing the minimisation of the impact of assets on the environment capture significant attention, particularly in terms of the number of headlines dedicated to this theme.

Table 3.1 Innovation priorities related to *Network Assets and Practices*

Innovation area of focus	Sub-area	DNOs	Number of headlines (NoH)
Assets and the energy transition	Principles and initiatives in investment planning	ENWL	3
		NPG	3
		SSEN	3
		UKPN	3
	System impact of coordination with other energy system operators	ENWL	1
		NPG	1
		SPEN	1
		UKPN	2
Improvement of the reliability and resilience of networks	Improvements to reliability	ENWL	1
		NPG	2
		SPEN	2
		SSEN	1
		UKPN	1
	Improvements to resilience	ENWL	1
		SPEN	1
		UKPN	1
Innovative methods to train and upskill the workforce		SPEN	2
Minimising the impact of assets on the environment		ENWL	3
		SPEN	8
		SSEN	4

3.1.2 Digitalisation

Table 3.2 provides an overview of the focus areas dedicated to the innovation theme of digitalisation. The topic of *Data Transparency and Interfaces* emerged as the most popular subject in DNOs' RIIO-ED2 innovation plans concerning digitalisation, with 11 headlines and four DNOs actively innovating in this area. The development of data analysis methods and forecasting ranked among the most frequently targeted innovation areas, given its crucial role in enabling accurate system management. Notably, monitoring and control emerged as a critical innovation theme for nearly all DNOs. Additionally, the topics of *Visibility and Monitoring* and *Digital Enablers for Real-time Analysis and Control* garnered similar attention in terms of the number of headlines, emphasising the importance of frameworks for increased visibility and control alongside the capability to analyse real-time data.

Table 3.2 Innovation priorities related to *Digitalisation*

Innovation area of focus	Innovation area of focus	DNOs	NoH
Data handling		NPG	3
		SPEN	3
		SSEN	2
Data analysis and forecasting	Forecasting methods	ENWL	1
		NPG	2
		SPEN	3
		SSEN	3
	Data analysis	SPEN	4
		SSEN	2
		UKPN	2
Monitoring and control	Visibility and monitoring	NPG	1
		SPEN	4
		SSEN	2
	Fault monitoring	SSEN	1
	Digital enablers for real-time analysis and control	NPG	2
		SPEN	3
		SSEN	1
		UKPN	1
Data transparency and interfaces		ENWL	2
		NPG	4
		SSEN	2
		UKPN	3

3.1.3 Engagement with Partners and Network Users

Table 3.3 surveys the innovation focus areas related to engagement with partners and network users. Facilitating LCT connections stands out as one of the most highlighted innovation topics among all subjects. The majority of innovation headlines in this area address technical considerations related to demands and the connection of distribution generators, and all DNOs include them in their innovation plans. Furthermore, DNOs recognise consumer vulnerability as a significant innovation subject, with 14 headlines defined on this topic by four DNOs.

Table 3.3 Innovation priorities in *Engagement with Partners and Network Users*

Innovation area of focus	Sub-area	DNOs	NoH
LCT connection facilitation	Facilitation of low carbon demand connections	ENWL	2
		NPG	2
		SPEN	1
		SSEN	2
		UKPN	3
	Facilitation of storage connections	NPG	1
		SPEN	2
		SSEN	1
		UKPN	1
	Facilitation of connection of distributed generation	ENWL	1
		NPG	1
		SPEN	1
		SSEN	2
		UKPN	1
Engagement with other System Operators and local communities		SPEN	2
		SSEN	6
Consumer vulnerability		ENWL	1
		NPG	5
		SSEN	5
		UKPN	3

3.1.4 DSO and Flexibility: Commercial and Regulatory Evolution

Table 3.4 depicts the frequency of headlines related to DSO and flexibility across various DNOs in RIIO-ED2 innovation plans. Accordingly, active network management and flexibility were repeated 18 times among project headlines, making it the most frequent innovation area in the context of DSO and Flexibility, as well as among all innovation subjects. Additionally, the innovation area of *Commercial and Regulatory Evolution* and the subarea of *Financial Assessment and Facilitation of Flexibility Markets* attract significant attention from DNOs, perceived as crucial enablers for performing the role of DSO and prerequisites for the development of local flexibility markets.

Table 3.4 Innovation priorities related to *DSO and Flexibility: Commercial and Regulatory Evolution*

Innovation area of focus	Sub-area	DNOs	NoH
Active network management and flexibility		NPG	5
		SPEN	6
		SSEN	5
		UKPN	2
Commercial and regulatory evolution	Financial assessment and facilitation of flexibility markets	NPG	3
		SPEN	3
		SSEN	3
		UKPN	4
	Trials for flexibility markets and DSOs	ENWL	1
		SPEN	1
		SSEN	1
		UKPN	1
	Required governance arrangements	SPEN	3

3.1.5 Evaluation of the Most Important Themes Across All DNOs

This section evaluates the most highlighted innovation themes across all DNOs, ranked by the total number of headlines defined for each theme:

1. **Active Network Management and Flexibility**
   - This theme is the most emphasised across DNOs, with a total of 18 headlines. It highlights the strategic importance of flexibility and active network management for addressing evolving energy demands and supporting decarbonisation goals.
   - SPEN leads in this area with 6 headlines, followed by SSEN and NPG, each with 5 headlines. This indicates their strong focus on flexibility innovations.
2. **Data Transparency and Interfaces**
   - A total of 11 headlines reflect this theme's foundational role in enabling innovation across all categories.
   - NPG leads with 4 headlines, followed by UKPN with 2, and ENWL and SSEN, each with 2. This showcases varying levels of commitment among DNOs.
3. **Principles and Initiatives in Investment Planning**
   - This innovation sub-area, within *Assets and the Energy Transition*, includes 12 headlines that highlight its critical role in supporting long-term infrastructure evolution.

- The equal contribution of four DNOs, each with 3 headlines, highlights consensus on the importance of robust investment planning.

4. **Consumer Vulnerability**
   - This theme, supported by 14 headlines, demonstrates the DNOs' recognition of equity and inclusivity in the energy transition.
   - NPG and SSEN lead with 5 headlines each, followed by UKPN with 3 and ENWL with 1.
5. **Enhancing Reliability and Resilience**
   - Improvements to network reliability and resilience have gained significant attention, with 10 headlines in total.
   - SPEN and NPG are the pioneers in this innovation area with 4 and 3 headlines, respectively, while other DNOs provide fewer inputs.

Active network management, data transparency, and consumer vulnerability are the most critical innovation themes across all DNOs. SPEN leads in active network management and digitalisation, while NPG excels in consumer-focused innovation. These trends reveal sector-wide priorities with distinct leadership roles.

3.2 Levels of Interest in Innovation Themes: DNO by DNO

This section presents the common list of innovation priorities associated with each DNO to provide a clear reflection of the distinctive areas of focus for each entity. Since DNOs publish their categorisation list of innovation topics, the differences in categorisation among DNOs make direct comparisons challenging. Consequently, this section presents individual innovation lists for each DNO, categorised according to the common classification proposed in Section 3.1. This approach aims to facilitate a straightforward and meaningful comparison between DNOs, providing insights into their respective priorities and strategies.

3.2.1 ENWL

Table 3.5 illustrates ENWL's innovation areas of focus based on the proposed categorisation list in this report. It is apparent that ENWL primarily emphasises the innovation theme of Network Assets and Practices. They employ innovative investment planning methods and seek to minimise the environmental impact of their assets. Additionally, ENWL gives similar attention to innovation themes related to digitalisation and engagement with network users and partners, as outlined in their published RIIO-ED2 innovation plan.

Table 3.5 Innovation priorities of ENWL

Innovation Theme	Innovation area of focus	Sub-area	NoH
Network assets and practices	Assets and the energy transition	Principles and initiatives in investment planning	3
		System impact of coordination with other energy system operators	1
	Improvement of the reliability and resilience of networks	Improvements to reliability	1
		Improvements to resilience	1
	Minimising the impact of assets on the environment		3
Digitalisation	Data analysis and forecasting	Forecasting methods	1
	Data transparency and interfaces		2
Engagement with partners and network users	LCT connection facilitation	Facilitation of low carbon demand connections	2
		Facilitation of connection of distributed generation	1
	Consumer vulnerability		1
DSO and flexibility: commercial and regulatory evolution	Commercial and regulatory evolution	Trials for flexibility markets and DSOs	1

3.2.2 NPG

The innovation theme of digitalisation, particularly the sub-area of *Data transparency and interfaces*, stands out as the primary focus for NPG, as depicted in Table 3.6. Consumer vulnerability is addressed through five innovation headlines in their innovation plan, ranking the innovation theme of Engagement with Partners and Network Users as the second most emphasised. Furthermore, NPG has outlined a significant number of innovation projects related to active network management within the theme of DSO and flexibility.

Table 3.6 Innovation priorities of NPG

Innovation Theme	Innovation area of focus	Sub-area	NoH
Network assets and practices	Assets and the energy transition	Principles and initiatives in investment planning	3
		System impact of coordination with other energy system operators	1
	Improvement of the reliability and resilience of networks	Improvements to reliability	2
Digitalisation	Data handling		3
	Data analysis and forecasting	Forecasting methods	2
	Monitoring and control	Visibility and monitoring	1
		Digital enablers for real-time analysis and control	2
	Data transparency and interfaces		4
Engagement with partners and network users	LCT connection facilitation	Facilitation of low carbon demand connections	2
		Facilitation of storage connections	1
		Facilitation of connection of distributed generation	1
	Consumer vulnerability		5
DSO and flexibility: commercial and regulatory evolution	Active network management and flexibility		5
	Commercial and regulatory evolution	Financial assessment and facilitation of flexibility markets	3

3.2.3 SPEN

Table 3.7 outlines the innovation themes featured in the RIIO-ED2 innovation plan of SPEN. Notably, digitalisation emerges as the most substantial focus, with 18 headlines, marking it as the most prominent area among all DNOs. Furthermore, as illustrated in Table 3.7 SPEN places significant emphasis on active network management and flexibility, with 6 innovation headlines, making it a top priority in their innovation plan. Additionally, SPEN defines numerous innovation headlines related to the sub-areas of Commercial and Regulatory Evolution, establishing it as a pivotal focus in their innovation plan. The third-ranked priority for SPEN is Engagement with Partners and Network Users, with LCT

connection facilitation being particularly noteworthy, garnering several innovation headlines.

Table 3.7 Innovation priorities of SPEN

Innovation Theme	Innovation area of focus	Sub-area	NoH[3]
Network assets and practices	Assets and the energy transition	System impact of coordination with other energy system operators	1
Digitalisation	Data handling		3
	Data analysis and forecasting	Forecasting methods	3
		Data analysis	4
	Monitoring and control	Visibility and monitoring	4
		Digital enablers for real-time analysis and control	3
Engagement with partners and network users	LCT connection facilitation	Facilitation of low carbon demand connections	1
		Facilitation of storage connections	2
		Facilitation connection of distributed generation	1
	Engagement with other system operators and local communities		2
DSO and flexibility: commercial and regulatory evolution	Active network management and flexibility		6
	Commercial and regulatory evolution	Financial assessment and facilitation of flexibility markets	3
		Trials for flexibility markets and DSOs	1
		Required governance arrangements	3

3.2.4 SSEN

According to Table 3.8, *engagement with partners and network users* and *engagement with other system operators and* local communities emerge as the most prevalent innovation theme and area in SSEN's RIIO-ED2 innovation plan. Additionally, five headlines are dedicated to Consumer Vulnerability, indicating its popularity as a practice in their innovation plan. Digitalisation follows as the next frequent innovation theme in SSEN's plan during the second price control period, with innovation headlines spanning across almost all its innovation sub-areas. Furthermore, SSEN delves into several innovative projects under the themes of *network assets and practices* and *DSO and flexibility*. In summary, it can be inferred that SSEN has maintained a balance between innovation themes and areas in their RIIO-ED2 business plan.

Table 3.8 Innovation priorities of SSEN

Innovation Theme	Innovation area of focus	Sub-area	NoH
Network assets and practices	Assets and the energy transition	Principles and initiatives in investment planning	3
	Improvement of the reliability and resilience of networks	Improvements to reliability	1
	Minimising the impact of assets on the environment		4
Digitalisation	Data handling		2
	Data analysis and forecasting	Forecasting methods	3
		Data analysis	2
	Monitoring and control	Visibility and monitoring	2
		Fault monitoring	1
		Digital enablers for real-time analysis and control	1
	Data transparency and interfaces		2
Engagement with partners and network users	LCT connection facilitation	Facilitation of low carbon demand connections	2
		Facilitation of storage connections	1
		Facilitation connection of distributed generation	2
	Engagement with other system operators and local communities		6
	Consumer vulnerability		5
DSO and flexibility: commercial and regulatory evolution	Active network management and flexibility		5
	Commercial and regulatory evolution	Financial assessment and facilitation of flexibility markets	3
		Trials for flexibility markets and DSOs	1

3.2.5 UKPN

Table 3.9 provides a summary of the RIIO-ED2 innovation plan of UKPN. The innovation themes demonstrate a balanced distribution in terms of the number of innovation headlines assigned to each theme. According to the proposed classification, *commercial and regulatory evolution* emerges as the highlighted area of priority, while *financial assessment and facilitation of flexibility markets* stands out as a prioritised sub-area in their innovation plan. The next areas with the most frequent headlines, as per the published document for the RIIO-ED2 innovation plan by UKPN, are *assets and the energy transition* and *LCT connection facilitation*.

Table 3.9 Innovation priorities of UKPN

Innovation Theme	Innovation area of focus	Sub-area	NoH
Network assets and practices	Assets and the energy transition	Principles and initiatives in investment planning	3
		System impact of coordination with other energy system operators	2
	Improvement of the reliability and resilience of Networks	Improvements to reliability	1
		Improvements to resilience	1
Digitalisation	Data analysis and forecasting	Data analysis	2
	Monitoring and control	digital enablers for real-time analysis and control	1
	Data transparency and interfaces		3
Engagement with partners and network users	LCT connection facilitation	Facilitation connection of low carbon demand	3
		Facilitation connection of storage	1
		Facilitation of connection of distributed generation	1
	Consumer vulnerability		3
DSO and flexibility: commercial and regulatory evolution	Active network management and flexibility		2
	Commercial and regulatory evolution	Financial assessment and facilitation of flexibility markets	4
		Trials for flexibility markets and DSOs	1

3.3 Comparative Analysis of DNOs' Innovation Priorities

Figure 3.1 shows a comparison based on the number of headlines defined by Distribution Network Operators (DNOs) in the innovation themes of the proposed classification. As can be seen, SPEN has the most innovation headlines within the digitalisation theme, and SSEN leads in *engagement with partners and network users*. NPG and UKP have a more balanced distribution of innovation headlines within the four defined innovation themes. Based on this evaluation, digitalisation emerges as the most frequent innovation theme with 51 headlines, followed by *engagement with partners and network users*", *DSO and flexibility* and *network assets and practices* in subsequent ranks.

1. **ENWL:**
    - **Primary Focus:** network assets and practices.

        - There is a strong emphasis on minimising the environmental impact of assets.
    - **Leadership:** ENWL stands out interest in p*rinciples and initiatives in investment planning*," sharing equal leadership with other DNOs.
2. **NPG:**
    - **Primary Focus:** Digitalisation.
        - Most initiatives are related to *data transparency and interfaces* (4 headlines) and *active network management and flexibility* (5 headlines).
    - **Leadership:** NPG leads in interest in consumer-focused innovation, especially in *consumer vulnerability* with 5 headlines.
3. **SPEN:**
    - **Primary Focus:** Digitalisation.
        - Leads all DNOs with 20 headlines in digitalisation and significant focus on *active Network Management and Flexibility* (6 headlines).
    - **Leadership:** SPEN is a clear leader in interest in "Digitalisation" and flexibility-related innovations.
4. **SSEN:**
    - **Primary Focus:** Engagement with Partners and Network Users.
        - Particularly strong in *engagement with local communities and system operators* (6 headlines) and *consumer vulnerability* (5 headlines).
    - **Leadership:** SSEN demonstrates a kind of balanced innovation portfolio across themes.
5. **UKPN:**
    - **Primary Focus:** Balanced across all themes.
        - Leads in *commercial and regulatory evolution* with 4 headlines in financial assessments for flexibility markets.
    - **Leadership:** Shares leadership with SPEN in interest in commercial evolution and flexibility market facilitation.

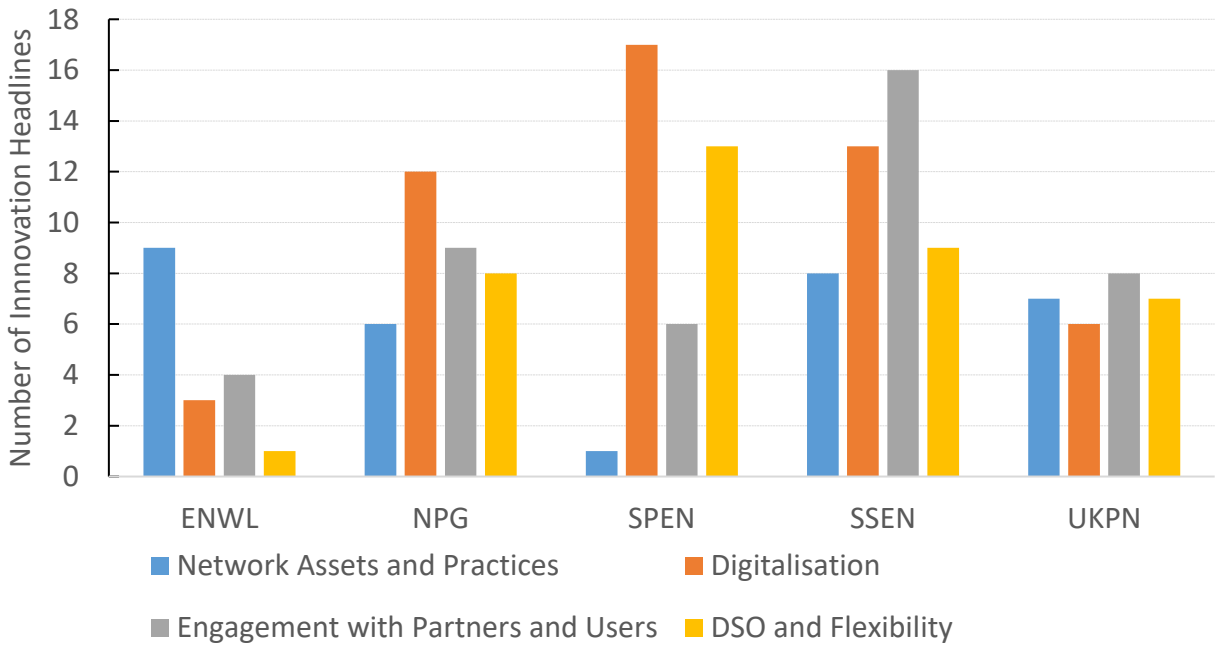

Figure 3.1 DNOs' headlines within the proposed innovation themes

4 Trend of Innovation Priorities

Following the categorisation of innovation themes among DNOs, it can be useful to evaluate their ongoing innovation priorities at the commencement of RIIO-ED2. This evaluation involves comparing their former innovation themes and examining the achievements following the implementation of the LCNF during the early stage of RIIO-ED1. Consequently, this chapter will evaluate the proposed innovation themes in RIIO-ED2 and draw comparisons with the innovation themes based on the evaluation conducted at the final stage of the LCNF programme.

4.1 Main Innovation Themes in LCNF

The innovation themes within the LCNF programme have been categorised into two groups, as indicated in the earlier study by the University of Strathclyde published in [14]. Table 4.1 provides a concise overview of the associated innovation themes. The first group contributes to those linked with network operation, covering innovation areas related to the efficient operation of power networks. The second category encompasses subjects associated with the planning and design of networks. We will delve into the specifics of innovation plans for each subject to identify emerging trends and explore how DNOs are aligning with these topics.

Table 4.1 Summary of DNOs' innovation themes (LCNF programme)

Network Operation	Visibility and Design
1. Storage devices	1. Real-time thermal rating
2. Flexible demand	2. Monitoring
3. Generator control	3. Visualisation
4. Network configuration	4. Understanding of existing demand
5. Active regulation of voltage	5. Understanding of low carbon technology

4.2 Innovation Dynamics in LCNF and RIIO-ED2

As evident from Table 4.1, the innovation priority topics in LCNF differ from those observed in current review of the RIIO-ED2 innovation plan. This discrepancy highlights the dynamic nature of innovation priorities over time, influenced by evolving needs. It becomes apparent that certain innovation areas may not deliver the anticipated value as initially perceived, leading to a reluctance to pursue them. Conversely, areas demonstrating clear benefits may transition into standard practices, commonly referred to as BAU practices. Following the former study in [14], areas of innovation are classified into three groups:

1. Those with evidence supporting their effectiveness recommended adoption as BAU.

2. Those with evidence suggesting ineffectiveness, advised against adoption as BAU.
3. Those with either weak evidence of costs or benefits, or requiring further innovation.

In this evaluation, the focus of this report is on determining whether innovations in the first category are indeed being adopted. We also aim to understand whether DNOs continue projects in the second category, despite earlier evidence indicating their lack of merit. Additionally, we explore if there are ongoing efforts related to the third category and if any new areas of work promised in the ED2 plans were absent in the LCNF projects.

4.3 Innovation Assessment Framework: Maturity and Implementation

To gain the benefits of innovative projects, it's crucial to understand how we integrate the lessons learned from the project into ongoing practices. The previous review of the LCNF projects has identified their readiness level for integration into BAU. In this context, our objective is to align this evaluation by comparing the BAU scoring assessment framework outlined in [14] with the ongoing status in RIIO-ED2.

4.3.1 Assessment of BAU Scoring in LCNF Review

Here, we will employ the identical BAU assessment framework as [14], which was proposed based on the outcomes of various projects conducted during the LCNF programme. Table 4.2 illustrates the corresponding BAU scoring chart, featuring a spectrum of colours from blue to red, representing grades ranging from *Strong Evidence Against* to *Strong Evidence For*, indicating the readiness level for integration into BAU. Additionally, the pink colour highlights a DNO that initiates innovation in a specific area in RIIO-ED2 that was not addressed in the LCNF programme.

Table 4.2 BAU Scoring Chart for LCNF

Strong Evidence Against		Indication Against		Inconclusive	Indications For		Strong Evidence For		New
-4	-3	-2	-1	0	+1	+2	+3	+4	New

4.3.2 Assessment of Innovation Status in RIIO-ED2

The innovation themes and headlines in RIIO-ED2 differ in several directions from those in the LCNF programme. Nevertheless, we examine the innovation plans of DNOs to assess the ongoing status of the previous innovation priorities set in the LCNF programme within the context of RIIO-ED2. To depict the status of innovation topics in RIIO-ED2, we utilise the colour-based framework outlined in Table 4.3.

Table 4.3 Innovation Status in RIIO-ED2

Not Mentioned	Still Innovating	Put as BAU
✗		✓

4.4 Comparative Analysis of LCNF and RIIO-ED2 Innovations

In this section, we will undertake a comparative analysis of innovations within the LCNF and RIIO-ED2 programmes. The primary emphasis is on conducting a thorough review of DNOs' innovation plans to discern the present status of innovation priorities initially established in the LCNF programme within the ongoing landscape of RIIO-ED2. The use of a colour-based framework, outlined in Table 4.2 and Table 4.3, enhances the clarity of the presentation by illustrating the status of innovation subjects in the context of RIIO-ED2. This comparative analysis provides insights into the evolution and alignment of innovation strategies, contributing to a deeper understanding of the accomplished advancements.

4.4.1 Network Operation

The first category of innovation themes within the LCNF programme comprises innovation projects linked to network operation. In this section, we assess the subjects linked to these projects.

4.4.1.1 Storage Devices

In the framework of LCNF, as indicated in

Table ***4.4***, the objective of projects concerning energy storage devices was to leverage the flexibility and services offered by them primarily for power flow management and voltage control, both at the local and coordinated levels within power networks. Interestingly, the utilisation of storage devices is not prominently featured in the innovation plans of DNOs in the RIIO-ED2 context. The innovation headlines related to the application of large-scale batteries for power flow management continue to be led by NPG and SPEN companies, as illustrated.

Table 4.4 Evaluation of innovations related to *storage devices*

Innovation			DNOs	LCNF-BAU	RIIO-ED2 Status
Large-scale batteries	Power flow management	Local	NPG	+1	
			SSEN	-2	✗
			UKPN	-2	✓
		Coordinated	SPEN	New	
	Voltage control	Local	UKPN	-2	✓
		Coordinated	NPG	0	✗
Distributed small batteries	Power flow management	Local	NPG	0	✗
			SPEN	New	
			SSEN	-2	✓
			UKPN	New	✓
		Coordinated	NPG	0	✗
	Voltage control	Local	NPG	0	✗
			UKPN	-2	✓

4.4.1.2 Flexible Demand

LCNF projects used a variety of terminology when referring to demand flexibility. Demand Side Management (DSM), Demand Side Response (DSR), Demand Response (DR), and Active Demand (AD) are all present in the LCNF reporting literature. Within the framework of the LCNF, a central focus was directed towards integrating and optimising network management – mainly controlling power flows – considering the use of flexible demand technologies.

Table ***4.5*** illustrates the specific innovation areas within the realm of flexible demand. Ongoing innovation programmes encompass various aspects such as flexible connections, call-off contracts, Residential Time-of-Use (ToU), and Residential Appliance/LCT control, all of which continue to be pursued in the RIIO-ED2 context for different classes of network user: residential, commercial and industrial. Additionally, several DNOs have identified specific innovations like voltage reduction, call-off contracts, Residential ToU, and Community engagement as BAU practices in RIIO-ED2. DNOs such as UKPN, ENWL, and SSEN explicitly incorporate the arrangements related to the connection of flexible demands in their innovation plans or designate it as part of their BAU practices based on their innovation strategy in RIIO-ED2.

Table 4.5 Evaluation of innovations related to *flexible demand*

Innovation		DNOs	LCNF-BAU	RIIO-ED2 Status
Flexible demand for network management	Voltage reduction	ENWL	+3	✓
	Industrial & commercial flexible connection	ENWL	+3	
		UKPN	New	✓
	Industrial & commercial call-off Contract	ENWL	New	
		NPG	+3	
		UKPN	+2	✗
	Residential ToU	ENWL	New	
		NPG	-1	✓
		UKPN	-1	✓
	Residential appliance control	NPG	-4	
		UKPN	-1	✗
	Residential LCT control	NPG	0	
		SSEN	+1	✗
		UKPN	-1	✗
	Community engagement	SSEN	New	✓

4.4.1.3 Generator Control

Within the framework of the LCNF, generator control entails the proactive management and optimisation of power flow and voltage control using DGs within a power network, with the overarching goal of improving overall efficiency and mitigating carbon emissions. Table 4.6 that UKPN and SPEN have incorporated active DG connection management into their BAU practices in spite of indications from LCNF reports against their use.

Table 4.6 Evaluation of innovations related to *generator control*

Innovation		DNOs	LCNF-BAU	RIIO-ED2 Status
Generator control for: power flow management & Voltage control	Actively managed DG connection	SPEN	+2	✓
		UKPN	+3	✓

4.4.1.4 Network Configuration

Network configuration entails strategically arranging and organising elements within a power network to facilitate the seamless integration of LCTs. This involves optimising network layouts and determining ideal equipment placement, specifically for power flow management and protection. As indicated in Table 4.7, network configuration for the 11 kV interconnection (by SPEN) and low voltage (LV) smart fuse (by ENWL) have become part of BAU practices, while ENWL continues to innovate in the realms of LV interconnection. It is worth noting that UKPN does not specify any innovation plans or BAU practices related to interconnections.

Table 4.7 Evaluation of innovations related to *network configuration*

Innovation		DNOs	LCNF-BAU	RIIO-ED2 Status
Network configuration for: power flow management and Protection	11 kV interconnection	SPEN	+3	✓
		UKPN	-3	✗
	LV interconnection	ENWL	+1	
		UKPN	0	✗
	LV smart fuse	ENWL	+3	✓

4.4.1.5 Active Regulation of Voltage

Active regulation of voltage involves dynamically controlling and optimising voltage levels within a power network to ensure stability and efficiency, particularly in the integration of renewable energy sources and emerging technologies. This regulation is critical for managing voltage fluctuations arising from the intermittent nature of renewable generation. As depicted in Table 4.8, ongoing innovation priorities include voltage reduction, primary substation enhanced Automatic Voltage Control (AVC), secondary substation On-Load Tap Changers (OLTC), and High Voltage/Low Voltage (HV/LV) regulators. Notably, UKPN and ENWL have incorporated primary substation enhanced AVC and HV/LV regulators into their BAU practices. In contrast, ENWL and SSEN are actively pursuing innovation and BAU practices as 'fast-follower' schemes within the RIIO-ED2 framework. It can be seen that NPG stopped innovating in various areas, even though these subjects were previously mentioned in their LCNF programme.

Table 4.8 Evaluation of innovations related to *active regulation of voltage*

Innovation		DNOs	LCNF-BAU	RIIO-ED2 Status
Active regulation of voltage	Voltage reduction	ENWL	+3	
		SPEN	+3	
	Primary substation enhanced AVC	ENWL	New	
		NPG	+1	✗
		UKPN	+1	✓
	Secondary substation OLTC	ENWL	+2	
		NPG	+2	✗
		SSEN	New	✓
	HV/LV regulators	ENWL	+1	✓
		NPG	0	✗
		SPEN	+2	
	Switched capacitors	NPG	0	✗

4.4.2 Network Visibility and Design

The second category of innovation themes in the LCNF programme includes projects related to network visibility and design. Network visibility involves monitoring and analysing

data to provide operators with insights into performance, security, and potential bottlenecks. The network visibility is essential for making informed decisions and optimising the network by anticipating scalability requirements, accommodating variable workloads, and adhering to industry standards. DNOs prioritised network visibility and design in the LCNF programme to enhance operational flexibility, reduce downtime, and enable the rapid connection of LCTs, contributing to a more responsive and resilient network infrastructure. This section assesses topics related to these subjects.

4.4.2.1 Real-time Thermal Rating

The term Real-time Thermal Rating (RTTR) involves the continuous observation and assessment of the actual, real-time thermal capacity of network components, considering variables such as ambient weather conditions such as temperature and wind speed and direction, and load fluctuations. This dynamic approach contrasts with conventional static ratings, enabling a more precise and flexible management of network assets.

As presented in Table 4.9, several DNOs still consider RTTR as an active innovation focus for Overhead Lines (OHLs) and transformers in RIIO-ED2, with NPG and SSEN appearing as pioneering innovators in this field. Additionally, there are no specified innovation priorities for underground cable RTTR in RIIO-ED2 innovation plans. Notably, some related innovation areas appear to be abandoned according to the innovation plans published by SPEN and NPG.

Table 4.9 Evaluation of innovations related to *real-time thermal rating*

Innovation			DNOs	LCNF-BAU	RIIO-ED2 Status
Network visibility and design	Real-Time Thermal Ratings	132 kV OHL RTTR	NPG	New	
			SPEN	+3	
		33 kV OHL RTTR	NPG	+2	
			SPEN	+3	
			UKPN	+2	✓
		11 kV OHL RTTR	NPG	+1	
		Underground cable RTTR	NPG	-4	✗
		Transformer RTTR	NPG	-1	✗
			SPEN	+1	✗
			SSEN	New	

4.4.2.2 Enhanced Network Monitoring

Enhanced network monitoring entails the deployment of advanced tools and technologies to capture real-time data on network performance, load flow patterns, and potential vulnerabilities specific to the low-carbon context. This approach enables operators to swiftly identify and address issues, minimising downtime, enhancing overall reliability, and optimising resource utilisation in the pursuit of a sustainable and resilient energy network.

Table 4.10 illustrates that many innovation topics are categorised as business as usual in this area, and instances not mentioned by UKPN might be attributed to ongoing BAU practices without explicit mention in their innovation plans. Additionally, ongoing innovation projects by SPEN and SSEN are evident within the context of network monitoring.

Table 4.10 Evaluation of innovations related to *enhanced network monitoring*

Innovation			DNOs	LCNF-BAU	RIIO-ED2 Status
Network visibility and design	Enhanced network monitoring	11 kV feeder monitoring	NPG	+3	✓
			SPEN	+3	
			UKPN	+3	✓
		Secondary substation monitoring	ENWL	+3	✓
			NPG	+3	✓
			SPEN	+3	✓
			SSEN	+3	
			UKPN	+3	✗
		LV Feeder monitoring	ENWL	+3	✓
			NPG	+3	✓
			SSEN	+3	
			UKPN	+3	✗
		Utilising smart meter data	NPG	+3	✓
			UKPN	+2	✓

4.4.2.3 Enhanced Network Visualisation

The initiatives linked to enhanced network visualisation encompass the utilisation of cutting-edge visualisation tools and technologies to depict intricate network data in an accessible and informative format. Through the adoption of sophisticated graphical interfaces and data visualisation techniques within the LCNF framework, DNOs can attain a comprehensive understanding of the dynamic interactions within their networks. This includes insights into load distribution, the integration of renewable energy, and the identification of potential congestion points.

As Table 4.11 highlights NPG and ENWL are integrating innovation projects related to network modelling tools into their BAU practices. Additionally, the development of tools for data analysis and state estimation is not mentioned in the new series of innovation plans of SPEN and NPG, respectively. DNOs are still pursuing other innovation priorities as indicated by ongoing developments.

Table 4.11 Evaluation of innovations related to *enhanced network visualisation*

Innovation			DNOs	LCNF-BAU	RIIO-ED2 Status
Network visibility and design	Enhanced network visualisation	11 kV and LV network modelling tools	ENWL	+1	✓
			NPG	+2	✓
			SSEN	+1	
			UKPN	-1	
		Data analysis tool	SPEN	+1	✗
			UKPN	+3	
		Distribution system state estimation	NPG	+1	✗
			UKPN	+1	✓

4.4.2.4 Enhanced Understanding of Existing Demand and LCTs

This initiative aims to enhance operators' understanding of the existing demand on the network and the impact of LCTs, such as renewable energy sources and energy storage systems. By leveraging sophisticated data analysis, DNOs within the LCNF can optimise grid planning, anticipate shifts in energy demand, and proactively address potential challenges associated with the integration of low-carbon technologies. This strategic focus aligns with the overarching goals of the LCNF, fostering a more informed and adaptive approach to energy infrastructure management in the context of a low-carbon future.

Table 4.12 provides a comparison of innovation priority statuses in LCNF and RIIO-ED2, specifically focusing on the understanding of existing demand. It is apparent that NPG has incorporated innovation subjects related to new planning assumptions for secondary substation load and residential load into their BAU practices. Conversely, the UKPN company does not mention these associated topics in the RIIO-ED2 innovation plan. Furthermore, SPEN and ENWL continue to innovate in the related subjects.

Table 4.12 Evaluation of innovations related to *understanding of existing demand*

Innovation			DNOs	LCNF-BAU	RIIO-ED2 Status
Network visibility and design	Enhanced understanding of existing demand	New planning assumptions for secondary substation load	ENWL	+3	
			SPEN	+2	
			UKPN	+4	✗
		New planning assumptions for residential load	NPG	+4	✓
			UKPN	+4	✗

Table 4.13 compares initiatives related to understanding LCTs. ENWL treats new planning assumptions for LCT load as part of their BAU practices. Conversely, UKPN does not include new planning assumptions for PV in its RIIO-ED innovation plans. In a different approach, SPEN introduces an innovation priority focused on assumptions for LCT loads, indicating a unique strategy for addressing related innovation subjects.

Table 4.13 Evaluation of innovations related to *the understanding of LCTs*

Innovation			DNOs	LCNF-BAU	RIIO-ED2 Status
Network visibility and design	Enhanced understanding of LCT	New planning assumptions for LCT load	SSEN	+2	
			NPG	+2	
			ENWL	+1	✓
			SPEN	New	
		New planning assumptions for PV	UKPN	+3	✗
			SPEN	+3	

4.5 Findings on Innovation Priority Trends

Table 4.14 provides an overview of the ongoing status of innovation areas, categorising them into sections based on whether they are no longer pursued, areas of continuous innovation, put into BAU, or emerging as a new series of innovation areas.

Areas that were previously the subject of innovation projects but seem now to be generally treated as BAU include the accommodation of batteries, active management of generation, measures to reduce customer interruptions and various asset management actions. The utilisation of flexible demand, active voltage control, RTTR and different LV network configurations have been the subject of innovation projects over many years, but are the subject of proposed further activity.

Cybersecurity is one subject that did not seem to come out as a specific, standalone innovation theme. Rather, it emerges from this review as something that should be addressed as part of each and every project relating to communication, control or software, whether that's an *innovation* project or *business as usual* project.

Table 4.14 Summary of Innovation Trends

Areas that Are No Longer Pursued	Areas of Continuous Innovation	Innovation Areas Put into BAU	New Innovation Areas
1. Innovations related to batteries are mainly no longer pursued plus some innovations now treated as BAU; 2. Control of residential LCTs/appliances is not the subject of new attention; 3. Planning assumptions for residential demands and LCTs not the subject of new attention; former findings used for new studies.	1. LV network configuration and connection strategies still need innovation; 2. Innovations in the area of active voltage control and RTTR embedded in active network management (ANM); 3. Flexible demands are still an innovation area of focus.	1. Innovations related to generation control, mainly for DGs, are placed as BAU; 2. Innovations related to customer interruptions, operations and asset management are placed as BAU.	1. Active distribution networks and use of local flexibility services; 2. Network visibility and monitoring are still key innovation areas to facilitate DSO roles; 3. Network visualisation is embedded in a new theme as digitalisation.

5 Findings and Conclusion

5.1 Key Findings

This research illuminates the evolving landscape of innovation priorities among Distribution Network Operators (DNOs) and the transition from the Low-carbon Network Fund (LCNF) programme to the initiation of RIIO-ED2. Initially, a classification based on common innovation areas was formed to identify the focus areas and innovation themes among DNOs. The obtained classification of innovation projects and headlines revealed four distinct innovation themes among DNOs, namely: (i) Network assets and practices; (ii) Digitalisation; (iii) Engagement with partners and network users; and (iv) Distribution System Operators (DSO) and flexibility: commercial and regulatory evolution.

Through a comparative study of the distribution of DNOs' innovation headlines in published RIIO-ED2 reports, it was revealed that digitalisation stands out as the most frequent innovation theme, with SPEN emerging as the leader in emphasising this theme. The second most highlighted theme was engagement with partners and network users, in which SSEN shows the most interest. Although DSO and flexibility come in third, it remains a commonly highlighted innovation theme based on DNOs' plans.

The comparative analysis on innovation trends reveals significant changes in focus since the LCNF programme, showcasing specific innovation areas that have either become standard practices (BAU) or are undergoing re-evaluation based on empirical evidence. Changes in how different innovations are regarded are summarised as follows.

1. Areas that are *no longer pursued*: This study indicates a decline in emphasis on innovation focused on batteries and the control of residential low carbon technologies (LCTs)/appliances. This does not necessarily reflect that these areas have transitioned to BAU; rather, in the case of batteries, this may also be influenced by regulatory restrictions on DNO ownership and operation of storage assets. Planning assumptions for residential demands and LCTs are also less of an innovation priority, but without strong evidence that these have transitioned fully into BAU operations.
2. Areas of *continuous innovation*: The research emphasises that low-voltage (LV) network configuration and connection strategies still require innovation. Additionally, innovations related to active voltage control and real-time thermal rating (RTTR) embedded in advanced network management (ANM) and those connected to flexible demands remain areas of ongoing focus.
3. Innovation areas now regarded as BAU: This study highlights that innovations related to generation control, particularly for distributed generation (DG), are now considered as BAU. Innovations and learnings related to areas such as customer interruptions, operations and asset management are also generally integrated into BAU practices.
4. New series of innovation areas: The analysis identifies new priorities, such as active distribution networks making use of and providing opportunities for local flexibility providers. Network visibility and monitoring continue to be key innovation areas, facilitating the roles of DSOs. Moreover, network visualisation has evolved into a new RIIO-ED2 theme defined as *Digitalisation*.

5.2 Implications of Innovation Trends

The innovation trends identified in this research highlight important implications for stakeholders within the energy sector. For the research and innovation community, the findings emphasise the need to continue developing solutions in areas such as digitalisation and active network management, which have shown consistent focus across DNOs. The persistence of innovation in areas like flexible demand, active voltage control, LV network configurations and RTTR indicates opportunities for researchers to refine and advance these technologies to address ongoing challenges.

Policymakers are advised to ensure regulatory frameworks remain aligned with innovation trends, such as the transition to DSOs and the emphasis on flexibility markets. The findings underline the importance of integrating matured innovations, such as generation control and customer interruption management, into BAU practices while fostering innovation in emerging areas like network visibility and active distribution networks.

Industry stakeholders are encouraged to adapt by prioritising the implementation of proven innovations, particularly those already transitioning to BAU, such as distributed generation control and enhanced monitoring systems. Simultaneously, there is a need to invest in and adopt solutions in digitalisation and flexibility to remain competitive and aligned with regulatory and market expectations.

These implications emphasise the importance of a collaborative approach among researchers, policymakers and industry stakeholders to advance the energy sector's innovation agenda and to maximise the impact of ongoing and future initiatives within the dynamic landscape of RIIO-ED2. DNOs face a number of common challenges and show overlap in innovation themes. Effective knowledge sharing and dissemination of learnings are therefore vital to avoid duplication in research, development and demonstration, accelerate progress, and ensure successful innovations transition into widespread application and integrated into BAU practices.

Differences in emphasis and descriptions of innovation activities outlined in the RIIO-ED2 business plans may reflect regional differences in needs. However, they may be due to different states of knowledge within the various DNOs or levels of commitment to innovation in different subject areas.

While some cross-industry coordination exists, improving the standardisation of data sharing across DNOs is essential, supported by enhanced use of platforms such as the open data portals of individual DNOs and the Energy Networks Association (ENA) portal to provide better information on project learning and any planned actions towards adoption of innovations. This would enable innovators both within DNOs and potential collaborators outside to see where further opportunities exist and give confidence to network customers and other stakeholders that innovations proven to be useful and cost-effective are being taken forward.

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