LV NETWORK MONITORING
ENGINEERING JUSTIFICATION PAPER

RIIO-ED2

Scottish & Southern Electricity Networks

1. SUMMARY TABLE

Summary table for LV Network Monitoring			
Name of Scheme/Programme	LV network monitoring		
Primary Investment Driver	Load		
Scheme reference/ mechanism or category	421/SSEPD/OT/LV_MONITORING		
Output references/type			
Cost	£22.41m CAPEX £13.55m OPEX		
Delivery Year	RIIO ED2		
Reporting Table	CV11		
Outputs included in RIIO ED1 Business Plan	No		
Spend apportionment	ED1 700 monitors £931k CAPEX £398k OPEX	ED2 19,424 monitors £22.41m CAPEX £5.43m OPEX	ED3+ 0 monitors £0.00m CAPEX £8.12m OPEX

2. EXECUTIVE SUMMARY

At present we have almost no visibility of consumption, generation and power quality on our Low Voltage (LV) networks.

With the expected increase in decarbonised heating and transport connecting to our networks we will need to have improved visibility across many of these networks, and whilst there is the ability to utilise data from smart metering it will not be possible to gather it in near real-time due to a combination of Data Privacy and system issues. As a result, we are planning to deploy LV network monitoring devices which will be able provide ourselves and external stakeholders the visibility needed to better utilise energy, assets and services.

As the flexibility services market matures and more customers are able to offer their services to both us and other parties to help manage issues and seize opportunities across the entire energy system (from generation down to LV network management), it is essential that granular data is made available to inform the decisions made in signalling, procuring, requesting and dispatching them.

Anticipating the scale of LV network monitoring required has been carried out using granular projections of Low Carbon Technology (LCT) uptake under the Consumer Transformation scenario in our Distribution Future Energy Scenarios (DFES) in conjunction with existing LV network asset data, which allowed us to plot where and when we would start to see constraints. A range of deployment options were considered, before we decided to focus on providing ourselves, customers and third parties with as much visibility as possible on networks where we would anticipate issues arising in the near future. By using Smart Meter data and customer profiles, we can model the load on every LV transformer and LV feeder. This gives us low resolution monitoring of every part of our network and we can use this data to identify the sites which benefit from near real-time and higher resolution monitoring. This equates to us installing monitoring on every LV transformer which is projected to be using >80% capacity, and also every transformer where at least one LV feeder is projected to be using >80% capacity (even if the Tx is not heavily loaded). By focussing on these networks we will provide the bulk of visibility necessary for future network management of circuits at risk of overload - thereby facilitating flexibility and the neutral market required for those customers and ourselves.

As a result we expect over 21,000 LV network monitors to be required across RIIO-ED2 – a significant increase from the 700 procured to date in RIIO-ED1 (note 19,424 monitors are referenced for the ‘prioritised deployment’ option being selected in this paper due to 1,700 monitors being funded through the Green Recovery scheme and effectively bringing these forward into RIIO-ED1).

Having previously stimulated the market to produce low-cost monitoring devices, we have seen prices for devices reduce by over 80% in as little as five years, which supports the widespread deployment of monitoring across our networks.

Along with the benefits of facilitating more accurate and timely use of flexibility services, the LV network monitoring is expected to provide a number of further benefits such as reducing CI and CML, helping support requests for connections to our networks and improving asset management.

TABLE OF CONTENTS

3. INTRODUCTION

This Engineering Justification Paper sets out our plans to deploy LV monitoring during the RIIO-ED2 period (April 2023 to March 2028).

There is virtually no visibility of demand and power flows on LV networks. With the onset of the DSO transition, rapid uptake of EVs and HPs and other new technologies, plus the need to utilise flexibility, we need to start monitoring our networks at scale to have the required granular visibility.

The primary investment driver is load.

There are no secondary investment drivers.

The timing of investment has been proposed based on the anticipated impact of electric vehicle (EV) and heat pump (HP) uptake on LV networks, carried out using granular projections of uptake (under the Consumer Transformation scenario as part of our Distribution Future Energy Scenarios (DFES)) in conjunction with LV network asset data.

The expected outputs are 21,000 LV network monitors installed across RIIO ED2.

4. BACKGROUND

This proposal relates to LV network monitoring devices which connect to secondary transformers (either Ground Mounted or Pole Mounted).

There is virtually no visibility of demand and power flows on LV networks. With the onset of the DSO transition, rapid uptake of EVs and HPs and other new technologies, plus the need to utilise flexibility, we need to start monitoring our networks to have the required granular visibility.

In the New Thames Valley Vision innovation project, the use of LV substation monitors was able to demonstrate the value of having granular visibility of networks, and the ability to improve forecasting and network operation as a result[1]. Due to the cost of the monitors the potential for widespread deployment of monitoring after the project was limited, so a further innovation project (Low Cost Substation Monitoring) was created to stimulate the market into producing a low cost monitor which would allow greater volumes to be procured and deployed but without losing key functionality as a result of the cost reduction. Thankfully the project was a success, trialling two types of monitor which met the requirements set by the New Thames Valley Vision project around measurement accuracy, dimensions, installation and communication. As a result of actively encouraging manufacturers to create disruptive technologies, e.g. borrowing from consumer grade products to drive unit costs down, and working with them to help them

[1] Learning Outcome Report - End Use and Network Monitoring Evaluation (**https://www.ssen.co.uk/WorkArea/DownloadAsset.aspx?id=13347**

understand the small changes in design that can result in big reductions in installation costs we were able to secure these new devices at a cost reduction of over 80%.

This is expected to save us over £90m across ED2, and all DNOs should benefit from the improved supply chain – we have facilitated conversations between several other DNOs and the suppliers of these reduced cost monitors in ED1 to support cost-efficient LV network monitoring deployment across GB.

Thanks to this reduction, and following a number of tenders, over 700 monitors have been procured, with the majority being planned for installation on networks we estimate to be at risk of overload and with electric vehicles (EVs) connected. To date over 300 monitors have been installed on networks across SHEPD and SEPD.

These devices are not yet in Business-As-Usual use across the business due to ongoing works needed to move them from being classified under Information Technology (IT) to Operational Technology (OT), which would enable the data to be used in operational timeframes. In addition, they are not deployed at the scale required to support us as a business, our customers, and third parties.

There are a number of benefits, drivers and uses of LV monitoring:

4.1 CI/CML BENEFITS

Through accurate/timely fault identification and pinpointing location, with associated dispatch of operational staff to investigate and restore the network, monitoring can support significant reduction in CI/CML penalties. There is also potential to use distance to fault and predictive fault analytics to further improve them.

By monitoring circuits at greater than 80% capacity, we will see load growth occurring, and be able to take action, before it causes faults due to over-heating.

4.2 FACILITATING TRANSITION TO DSO AND USE OF FLEXIBILITY

Monitoring data can provide ourselves and third parties with visibility of demand (via much-sought-after LV capacity maps), power flows, voltage and other aspects of network operation which will be needed to operate the distribution networks effectively as more complexity and intelligence is introduced/required with changing patterns and uses of energy. It is essential for the Neutral Market Facilitator role to be performed, allowing the procurement and use of flexibility as well as peer-to-peer trading with almost real-time go/no-go decisions. By installing monitoring on networks which are/anticipated to be heavily loaded it will provide the granular and timely visibility necessary for proactive management of our networks – enabling the strategic investment and associated benefits proposed in in both ***Load-Related Plan Build and Strategy (Annex 10.1)*** and *Appendix F,* ***DSO Strategy (Annex 11.1)*** of our RIIO-ED2 Business Plan, along with BPDT CV2.

4.3 COMPLEMENTING SMART METERING DATA

Suitable smart metering penetration levels will give us demand and voltage data but that is reliant upon high-levels of smart meter uptake on individual LV feeders and a network connectivity model being in place and accurate.

We have already utilised machine learning and advanced analytics to develop a load model using customer, asset and historic LV monitoring data, and expect to be able to further improve the forecasting of load on LV networks by incorporating data from smart meters (and LV monitoring in near real-time).

Work is already underway to enable us to poll smart meters for key information at scale, and create the pipelines for this data to feed into our Data and Analytics platform. Once complete, this will allow the incorporation of smart meter data into our load model and provide accurate and regularly updated views of load on every aspect of our network – in particular the local low voltage networks which we predict will be so susceptible to constraints as a result of LCT demand. The load model underpins the network constraint tool which we have developed, which allows us to estimate where and when we will likely see overloads on our networks as a result of LCT uptake, and so as result smart meter data will refine our ability to observe and predict network constraints. Smart meter data, coupled with data and analytics, is being used now to build our understanding of our network and create the Network Visibility that we need to operate as a DSO. This work is well advanced in ED1 and is proposed to be further developed in ED2.

A key element of DSO operations (namely requesting/ validating delivery of flexibility services) hinges upon near real-time visibility of demand on our networks. Whilst smart metering consumption data will be captured at half-hourly intervals and aggregated at LV feeder level to inform load levels, it will not be possible to gather it in near real-time due to a combination of Data Privacy and system issues – as a result, we will be gathering the data every 2-4 weeks. It is not possible to provide ourselves and external stakeholders the visibility needed to request/ dispatch/ operate flexibility services with historic data that is gathered weeks in arrears. Whilst smart meter data (in conjunction with the LCT uptake projections in our Distribution Future Energy Scenarios (DFES)) can inform us where networks are going to require appropriate investment, LV monitoring will then be required to provide us with the required aggregated load readings in near real-time, with the added advantages of power quality monitoring, predictive fault analytics and other benefits which are also not available from smart meter data.

LV monitoring can further complement smart meter data in the creation of connectivity maps. Whilst LV monitoring provides us with visibility of loadings on each individual phase of an LV feeder, due to challenges with historic connections records it is not possible on many networks to determine which customers are connected to what phase, which limits our ability to determine the most effective means of supporting those networks and customers as more heat and transport are decarbonised and as they seek to use/ generate/ distribute their energy in new ways (i.e. providing flexibility services). We have developed algorithms which allow us to use smart meter voltage data to build phase connectivity maps, which if automated could combine with LV monitoring to enhance network visibility and support connection of LCTs, balancing of networks and the smarter investment in networks to deal with constraints (i.e. adjusting number of customers connected to phases, identifying network losses and highly targeted flexibility procurement, etc).

4.4 THERMAL CONSTRAINT MANAGEMENT

Constant updates on load levels can indicate which assets are experiencing thermal constraints, along with any trends of loading which will allow appropriate management of those constraints thanks to this granular data. We need this granular level of detail to address changes in traditional cyclic loading patterns and avoid wide-scale load-related faults as electricity demand increases with the uptake of Low Carbon Technologies.

4.5 NETWORK AND POWER QUALITY MANAGEMENT

Monitoring data allows levels of imbalance to be known, which can be used to support phase balancing activities to maximise use of assets and avoid unnecessary load-related faults.

LV monitors also provide power quality alerts, identifing occurances of high harmonic content (noise) on the LV network. This gives us the ability to investigate power quality complaints effectively and proactively. The use of power electronics in many Low Carbon Technologies can increase the harmonic content on our network.

4.6 CONNECTIONS AND ASSET MANAGEMENT IMPROVEMENTS

The data from the monitors allows far greater accuracy and frequency of load readings to be recorded than Maximum Demand Indicators currently provide. This supports load and health indices analysis and asset management. The ability to immediately assess current and historic loadings supports investment plans and Connections and Commercial activities for new connections.

Having this data available will enable automated load checks, in turn supporting at least one quotation for connection per monitor per year, saving 30 minutes per quote which is a cashable benefit over ED2 of £0.32m. (36_SSEPD_IT_CONNS_CONNECTIONS+)

4.7 MANAGING LOAD MANAGED AREAS (LMAS)

For many years, we have had Load Managed Areas (LMAs) with storage heating loads being controlled by radio based signals. This radio service was provided by the BBC but is now end of life. With the Radio Tele Switching (RTS) service being switched off, it is essential we are able to continue to define our Load Managed Areas and provide improved visibility of loading so that we can work with suppliers to optimise the load across these networks. Monitoring data will allow us to achieve this.

4.8 STRATEGIC INVESTMENT

Data from monitoring can help manage the impact and use of strategic investment in networks, justifying decisions and providing more confidence in planning expenditure.

As part of our Distribution Future Energy Scenarios (DFES) we commissioned energy consultant Regen to produce high granularity projections for key Low Carbon Technologies (LCT), taking the four National Grid Future Energy Scenarios (FES) and projecting these down to the 400,000 street-level LV feeders and over 100,000 distribution substations that are located in our Electricity Distribution licence areas, with existing EV and HP connections seeding the uptake model. The aim was to provide greater understanding of the potential impact of LCTs such as Electric Vehicles and Heat Pumps on our networks from now to 2050.

Using the Consumer Transformation scenario projections, we then utilised SSE Group's Data & Analytics team to build a network constraint tool which allowed us to build a connectivity model, as well as a load model with expected demands from LCT types and properties, and finally combine this with asset data such as transformer ratings, loading history (i.e. Maximum Demand Indicator (MDI) readings) to provide us with estimations for where and when we would likely see overloads on our networks as a result of LCT uptake, and where we would need to invest strategically to maximise customer benefits and minimise disruption.

This combination of historic, existing and future datasets resulted in the outputs which form the argument for investing in the volumes of LV network monitoring in RIIO ED2 (21,000 LV network monitors).

5. OPTIONEERING

We assessed the outputs of our analytics and considered varying levels of LV monitoring equipment deployment, with a view to finding the right balance between customer benefits and experience, deliverability and cost. As a result, we have 3 suggested options for the implementation of LV monitoring equpment:

- The minimum deployment – through the constraint mapping work carried out by the SSE Group Data and Analytics team, we have projections of how many assets will likely be overloaded each year under the Consumer Transformation scenario. This will tell us the minimum number (and locations) we should be procuring (and installing) each year to at least keep the network within limits and continue providing a secure and reliable supply of electricity. For the minimum deployment we are proposing monitoring every secondary transformer which is projected to be using >100% capacity, and also every transformer where at least one LV feeder is projected to be using >100% capacity (even if the respective transformer is not overloaded).
    - Benefits: low TotEx easier coordination of rollout, will allow us to support customers and investment on potentially worst circuits.
    - Risks: likely to under-deliver the necessary visibility for future network management and expectations for DSO enablement, leading to gaps in our operations and poor stakeholder engagement.
- The prioritised deployment – these assets have been selected based on a further refinement of the above process. This process takes 100% rollout as a starting point, and discounts any assets where there are 5 or less customers connected (we are proposing we rely on smart metering data instead) and where LCT uptake projections would not result in the asset using over 80% of its capacity by end of ED2. As a result, we are proposing monitoring every secondary transformer which is projected to be using >80% capacity, and also every transformer where at least one LV feeder is projected to be using >80% capacity (even if the Tx is not heavily loaded).
    - Benefits: will provide the bulk of visibility necessary for future network management of circuits at risk of high-loading as well as overload - thereby facilitating flexibility and the neutral market required for those customers and ourselves by giving sufficient lead times for both the signalling to markets of the need for investments such as via flexibility services, as well as their ability to prepare suitable bids in response. Triggering monitoring deployment when an asset reaches 80% capacity utilisation will support proactive investment and management of assets, with lead times that should allow us to stay ahead of expected load growth, as well as providing contingency should uptake rise rapidly as the assets near capacity. This should also result in the benefit of positive stakeholder feedback as a result of supporting a number of external initiatives.

  - Risks: likely high TOTEX, increased complexity for processing data volumes and coordinating and carrying out the deployment, and still a debate as to whether the volume is sufficient to enable our transition to a DSO with widespread visibility of network operation and facilitation of flexibility markets.

- The complete deployment – this would involve deploying monitoring to every network (either avoiding or seeking consent from customers on networks where fewer than 5 customers connected to align with smart meter data privacy aggregation limits).
  - Benefits: will deliver complete visibility necessary for network management, optimising networks and delivering complete services to DSO, with exceptional stakeholder feedback as a result of supporting a wide range of stakeholder and community initiatives.
  - Risks: extremely high TOTEX, significant complexity for processing data volumes and coordinating and carrying out the deployment.

6. ANALYSIS AND COST

5.1. COSTS

There are multiple elements needed for deployment and use of LV monitoring which must all be costed.

Capital costs include: monitoring devices and current sensors; time needed for installation; SIM cards; external aerials; extension cables for aerials; and spare voltage leads.

Annual operational costs include: communications data transfer (e.g. GPRS), the investigation and replacement of faulty devices and service support. Service support is a helpdesk service provided by the equipment providers which we can call upon if we need to troubleshoot anything relating to commissioning or post-install aspects, as well as helping with any firmware updates needed, etc.

These costs have been informed by a recent tender we carried out as part of our plans to create a procurement framework for LV monitoring devices that will allow us to source them at scale in ED2. Further detail on this can be found in the appendices.

Also, whilst currently all monitoring to date has been installed on Ground Mounted Transformers, it is expected that monitoring will be installed on Pole Mounted Transformers to maximise coverage, and these devices are about to be trialled with costs expected to be similar.

There are four scenarios under the Distribution Future Energy Scenarios (DFES) which align with National Grid's Future Energy Scenarios. These have differing rates and scales of EV and HP uptake. As a business the Consumer Transformation scenario has been chosen as the one we will base our decision on. The following costs are based upon analytics carried out using the projections under that scenario across our licence areas.

Note that CAPEX includes hardware and installation costs as a single unit cost per monitor, with OPEX covering all other operational costs. Replacement monitors at an anticipated 2% defect rate are also included in CAPEX.

The NPV has been calculated for each option. The NPV is reported over 10 years, with OPEX costs and benefits calculated for a 10 year period only. The NPV is heavily affected by the fact that LV monitoring is an enabler to a large range of other services and investments facilitating flexibility products, asset management, new connections and system control and operation. The benefits of those enabled investments are captured elsewhere in our RIIO-ED2 Business Plan (such as ***Load-Related Plan Build and Strategy (Annex 10.1)*** and *Appendix F,* ***DSO Strategy (Annex 11.1)***). To avoid any double counting of benefits, they are not included here.

The 'minimum deployment' option offers the best NPV but it leaves us at considerable risk of network impacts from changes to government policy which could accelerate the transition to net zero. As a result the ‘prioritised deployment’ option, which offers the next best NPV, would mitigate this risk and help us stay ahead of demand increases from technology/ commercial/ policy updates.

5.2. COSTS – MINIMUM DEPLOYMENT

Within all scenarios it should be noted that CAPEX costs for 1,700 monitors have been removed due to the Green Recovery scheme funding these, however the OPEX will still be included for them as Green Recovery would only fund the initial year of OPEX (to end of ED1).

With a projected requirement for a baseline of 10,890 monitors, costs for this option are forecast at £16.68m over the course of the RIIO-ED2 price control, as shown in Table 3. The 10 year NPV for this option is -£7.89m.

Monitoring group	Expenditure type	Cost (£m)
Minimum	CAPEX (hardware and installation)	11.91
Minimum	CAPEX (fault replacements)	0.67
Minimum	OPEX (service support)	2.31
Minimum	OPEX (data transmission)	1.80
Total Cost		**16.68**

Table 1 - Forecast costs for minimum deployment option

5.3. COSTS – PRIORITISED DEPLOYMENT

With a projected requirement for a baseline of 19,424 monitors, costs for this option are forecast at £27.85m over the course of the RIIO-ED2 price control, as shown in Table 4. The 10 year NPV for this option is -£12.45m.

Monitoring group	Expenditure type	Cost (£m)
Prioritised	CAPEX (hardware and installation)	21.25
Prioritised	CAPEX (fault replacements)	1.16
Prioritised	OPEX (service support)	2.31

Prioritised	OPEX (data transmission)	3.13
Total Cost		**27.85**

Table 2 - Forecast costs for prioritised deployment option

5.4. COSTS – COMPLETE DEPLOYMENT

With a baseline of 110,300 monitors to cover every LV network, costs for this option are forecast at £146.69m over the course of the RIIO-ED2 price control, as shown in Table 5. The 10 year NPV for this option is -£61.00m.

Monitoring group	Expenditure type	Cost (£m)
Complete	CAPEX (hardware and installation)	120.67
Complete	CAPEX (fault replacements)	6.43
Complete	OPEX (service support)	2.31
Complete	OPEX (data transmission)	17.29
Total Cost		**146.69**

Table 5 - Forecast costs for complete deployment option

7. DELIVERABILITY AND RISK

The “minimum deployment” option is proposing a baseline of 10,890 monitors, which is expected to result in approximately 2,178 monitors per year being delivered.

The “prioritised deployment” option is proposing a baseline of 19,424 monitors, which is expected to result in approximately 3,885 monitors per year being delivered.

The “complete deployment” option is proposing a baseline of 110,300 monitors, which would require approximately 22,060 monitors per year being delivered.

To date, we have procured over 700 LV network monitors and installed over 300 of these. Installations require two employees and take approximately 1 hour per site, with further travel time required.

We have assumed that data will flow into our OT environment, coordinated with LV PowerOn, and be stored in our Data Lake to allow the data to be used across the business. Whilst it would provide considerable opportunities, there are challenges over deliverability of the volume of monitors proposed under the “complete deployment” option. From a resource capability, it would require significant time and resource to install them at the volumes needed, and market production capability. Recent orders have shown that monitors were able to be produced at the rate of approximately 50 per week. Although this should increase, it still presents a significant delivery risk.

A stakeholder engagement session was held with the LV monitoring supply chain in October 2020, and key feedback from this session included consensus that a target of procuring 1,800 monitors a year and total target of 9,000 in ED2 were achievable.

As a result, we believe the “complete deployment” option is not viable.

8. CONCLUSION

Taking account of the factors of cost, deliverability and stakeholder feedback, we have determined that the “prioritised deployment” option is preferred as it which will deliver:

- Monitoring of all assets projected to be overloaded within ED2.
- Monitoring of all assets projected to be using over 80% of their capacity within ED2 – giving sufficient lead times for both the signalling to markets of the need for investments such as via flexibility services, and their ability to prepare suitable bids in response.
- Resulting proactive management of assets.
- Ability to stay ahead of expected load growth (as opposed to using option with best NPV but which would leave us exposed to even modest changes in LCT uptake).
- Ability to utilise flexibility on LV networks as a result of the data flows and visibility.
- Ability to provide the granular and timely visibility necessary for proactive management of our networks enabling the strategic investment and associated benefits proposed in both ***Load-Related Plan Build and Strategy (Annex 10.1)*** and *Appendix F,* ***DSO Strategy (Annex 11.1)*** of our RIIO-ED2 Business Plan, along with BPDT CV2.
- Ability to dispatch fault restoration teams more effectively and potentially proactively thanks to the use of near real-time visibility of faults, predictive analytics and alarm signals.
- Monitoring of 19% of our LV networks.
- A deliverable volume of monitors (compared to the “complete deployment” option).

Monitoring scenario	Expenditure type	Cost (£m)	Benefits over 10 years (£m)	NPV (10 years) (£m)	NPV (45 years) (£m)
Prioritised	CAPEX	22.41	5.71	-12.45	-25.54
Prioritised	OPEX	5.43			
Total Cost		**27.85**			

9. APPENDIX A

Breakdown of unit costs for each monitor:

Capital costs for LV monitors	
Item	**Unit cost**
LV substation monitoring device with 5 sets of tri-head Rogowski coils with 4G SIM card and voltage lead	£ [redacted]
External aerial with cable	£ [redacted]
5m extension cable for external aerial	£ [redacted]
Total unit cost	**£ [redacted]**

Annual OPEX costs for LV monitors	
Item	**Unit cost**
GPRS - Roaming 4G SIM card data fees (based on 10 mins reporting)	£ [redacted]
Service Support (10% of hardware costs)	£ [redacted]
Total annual costs per unit	**£ [redacted]**

Installation costs for LV monitors	
Item	**Unit cost**
Installation (requiring 2 operatives)	£177.00
Total install costs per unit	**£ 177.00**

10. APPENDIX B

The top 4 suppliers responding to the tender we have recently carried out (to create a procurement framework for LV monitoring devices) provided the following cost evidence for our cost assumptions in the budgeting process:

Supplier	Item	Unit of measure	Unit Price (£)	Service Costs per annum (£)	Note

1	LV Substation 4G monitoring device	Each	[redacted]	[redacted]	
2	LV Substation 4G monitoring device	Each	[redacted]	[redacted]	
3	LV Substation 4G monitoring device	Each	[redacted]	[redacted]	Per unit, per annum
4	LV Substation 4G monitoring device	Each	[redacted]	[redacted]	

Generally we have seen a change in support and service costs from previous procurement exercises – mos suppliers have changed to a fixed support cost rather than a per unit support cost. By assuming an average of 5,000 units per supplier over ED2 we have calculated a cost for the one supplier looking for a per unit rate, and used an average figure for the supplier who has not provided a cost, to gives us a figure of £461,128 for overall supplier support costs per annum.

11. APPENDIX C

Annual breakdown of total numbers of secondary transformers with more than 5 customers connected which are expected to be close to overload (using 80-100% of capacity) or overloaded (exceeding 100% of capacity) in ED2, as well as transformers where at least one LV feeder is projected to be using >80% capacity (even if the Tx is not heavily loaded), split by licence area. Note cut-off of 2027 due to analysis and projections being for a full calendar year.

Region	2023	2024	2025	2026	2027

SHEPD					
Transformers utilising 80-100% capacity	998	1128	1334	1500	1569
Transformers utilising >100% capacity	1286	1566	1951	2279	2653
Transformers utilising <80% capacity BUT have at least one LV feeder utilising 80-100% capacity	456	459	466	471	471
Transformers utilising <80% capacity BUT have at least one LV feeder utilising >100% capacity	826	863	938	966	988
Cumulative SHEPD total	**3566**	**4016**	**4689**	**5216**	**5681**
SEPD					
Transformers utilising 80-100% capacity	3778	4061	4409	4786	4946
Transformers utilising >100% capacity	4268	4910	5784	6719	7692
Transformers utilising <80% capacity BUT have at least one LV feeder utilising 80-100% capacity	1428	1468	1535	1554	1548
Transformers utilising <80% capacity BUT have at least one LV feeder utilising >100% capacity	1113	1149	1191	1225	1257
Cumulative SEPD total	**10587**	**11588**	**12919**	**14284**	**15443**
Cumulative SSEN Total of LV monitors needed	**14153**	**15604**	**17608**	**19500**	**21124**

12. APPENDIX D

Annual breakdown of total numbers of secondary transformers with more than 5 customers connected which are expected to be close to overload (using 80-100% of capacity) or overloaded (exceeding 100% of capacity) in ED3+, further split by licence area.

Region	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
SHEPD																							
Transformers utilising 80-100% capacity	1595	1677	1642	1696	1718	1732	1724	1731	1719	1742	1737	1744	1748	1735	1739	1739	1735	1725	1727	1727	1727	1725	1725
Transformers utilising >100% capacity	3093	3483	3885	4255	4655	4999	5231	5401	5505	5576	5632	5679	5717	5750	5768	5791	5810	5832	5830	5830	5829	5828	5827
Transformers utilising <80% capacity BUT have at least one LV feeder utilising 80-100% capacity	480	476	491	482	470	418	388	354	336	309	306	291	279	276	274	271	273	267	267	267	268	268	268
Transformers utilising <80% capacity BUT have at least one LV feeder utilising >100% capacity	987	999	990	995	1030	1050	1036	1044	1030	1015	992	977	972	966	961	957	951	953	953	953	953	956	957
Cumulative SHEPD total	6155	6635	7008	7428	7873	8199	8379	8530	8590	8642	8667	8691	8716	8727	8742	8758	8769	8777	8777	8777	8777	8777	8777
SEPD																							
Transformers utilising 80-100% capacity	5139	5231	5309	5273	5294	5181	5146	5091	5043	4975	4897	4838	4747	4705	4629	4576	4523	4488	4427	4370	4261	4190	4127
Transformers utilising >100% capacity	8610	9565	10508	11784	12826	13661	14325	14894	15312	15682	16037	16365	16676	16914	17147	17355	17561	17753	17934	18109	18310	18499	18653
Transformers utilising <80% capacity BUT have at least one LV feeder utilising 80-100% capacity	1538	1525	1503	1470	1407	1355	1314	1243	1212	1160	1128	1082	1057	1029	1019	1007	991	965	949	930	926	919	891
Transformers utilising <80% capacity BUT have at least one LV feeder utilising >100% capacity	1276	1295	1281	1263	1229	1229	1201	1167	1140	1127	1110	1083	1063	1047	1033	1024	1014	999	991	991	987	975	972
Cumulative SEPD total	16563	17616	18601	19790	20756	21426	21986	22395	22707	22944	23172	23368	23543	23695	23828	23962	24089	24205	24301	24400	24484	24583	24643
Cumulative Total	**22718**	**24251**	**25609**	**27218**	**28629**	**29625**	**30365**	**30925**	**31297**	**31586**	**31839**	**32059**	**32259**	**32422**	**32570**	**32720**	**32858**	**32982**	**33078**	**33177**	**33261**	**33360**	**33420**