NETWORKS

Visibility Multiyear Plan

NATIONAL NETWORK,
LOCAL CONNECTIONS
PROGRAMME

DOC-280624-HYR

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TERM	DEFINITIONS
ADMS	Advanced Distribution Management System
AI	Artificial Intelligence
CRU	Commission for Regulation of Utilities
DER	Distributed Energy Resources
DPO	ESB Data Protection Officer
DSO	Distribution System Operator
EPRI	Electric Power Research Institute
GDPR	General Data Protection Regulation
GIS	Geographical Information Systems
IoT	Internet of Things
IP	Ingress Protection
LCT	Low Carbon Technologies
LTE	Long Term Evolution
LV	Low Voltage
LVND	Low Voltage Network Discovery
MPRN	Meter Point Reference Number
MV	Medium Voltage
NN, LCP	National Network, Local Connections Programme
NTC	ESB Networks' National Training Centre
OCA	Operational Control Architecture
OH	Overhead
OMS	Outage Management System
OVM	Operational Visibility Mapping
PLTE	Private Long-Term Evolution
PQQ	Pre-Qualification Questionnaire
PR5	Price Review 5
PSR	Power System Requirements
QA	Quality Assurance
RFT	Request for Tender
SMDH	Smart Metering Data Hub
THD	Total Harmonic Distortion
TSO	Transmission System Operator
UG	Underground

3. Background

3 Background

The core objective of the National Network, Local Connections Programme (NN, LCP) is to bring together changes in how we generate and use electricity, enabling all electricity customers and communities to play an active role in climate action, by using or storing renewable electricity when it is available to them locally. To deliver this, we will need "visibility" of the network, and of demand and generation on the network, down to the most local level.

This document sets out the "2023 Local Network Visibility Multiyear Plan" – the plan to secure and share this visibility of the network by mapping, modelling, and monitoring the electricity network down to the local, low voltage (LV) networks.

The decarbonisation of Irish society relies on fundamental changes to how energy is generated and consumed. To enable these changes at the right pace and the right price, we will rely on the electricity network, and we need to make the connection between how renewable energy is generated, and how we use or store it. Every Irish home, farm, community, and business is being called on to play a part. The National Network, Local Connections Programme has been established to work with and for, Irish electricity customers to make this possible. ESB Networks serves, and is funded by, all electricity customers.

NN, LCP is also in the process of enhancing the existing OT capabilities to improve the ability to forecast demand and optimise the network. For this, various functionalities such as power flow and state estimation will be developed in the interim and the enduring solution. The pilot initiatives will serve as lessons learnt that will help in developing these advanced capabilities. Therefore, it is important to have an accurate connectivity model (network schematics, phasing information, substations, etc.) of the LV and MV network that will help customers to participate in flexibility services.

To support Ireland's 2030 Climate Action Plan targets, ESB Networks has committed to:

1 Facilitate people in Ireland adopting up to 936,000 electric vehicles and 600,000 heat pumps;

2 Connect c. 10 GW of renewable generation at transmission and distribution level, so that we can charge our cars and heat our homes using 80% renewable electricity.

Much of the change needed to achieve these targets will happen at the most local or LV level on the electricity system. With heat pumps, electric vehicles, and microgeneration connecting at homes and businesses across the country, and the introduction of localised demand side flexibility as a core strategy to increasing the renewable energy consumed, there is a growing need for "visibility" of these local networks.

Increased visibility of the LV Network means that as we operate the low voltage electricity system, ESB Networks will have accurate and timely visibility of what is happening on the network. This includes:

1 Accurate and up to date data about the exact locations of customers on the network, and of larger demand like electric vehicle (EV) charging points, heat pumps, batteries, solar panels and other low carbon technologies;

2 Accurate and up to date data about how the network is connected, and the capacity and other attributes of its components (for example, how much capacity each wire and transformer has available for additional demand or generation);

3 Real time and forecast data about electricity flows on the low voltage network, as a result of customers' individual and aggregate demand on each local network.

ESB Networks' ability to use this information in network planning and operations is critical to enabling small customers to become active participants in the electricity system, in a secure and coordinated manner. To build up this picture, we need accurate maps, electrical models, and accurate monitoring of the system. Today we have the visibility of the high and medium networks, but we do not yet have an accurate view of demand and generation patterns on the LV system or how this varies by time of day, month, and season. Previously, ESB Networks estimated how heavily loaded MV/LV substations are, by aggregating traditional metering data.

However, the network model data and customer referencing used to do this is sparse and not always accurate, where a range of approximations and assumptions are needed. While this has met network development needs to date, it is not of the quality needed for operational purposes and to enable customers on the LV system to securely participate in flexibility services.

Increased visibility will allow ESB Networks, our customers, and emerging energy companies, to improve how we use and manage the LV system. It will allow ESB Networks to:

1. Introduce new solutions to help provide the capacity and reliability needed at this most local level, by incentivising customers to use or store renewable energy on the network when it is local and available;
2. To spread out localised peaks to support the integration of low carbon technologies such as electric vehicles and heat pumps;
3. To shift small customers' demand from periods of high carbon intensity to low carbon intensity on their local electricity network, without inadvertently causing harm or damage to the local network infrastructure;

To enable this, ESB Networks has been mandated to drive out programmes of work including LV mapping and monitoring. Using these increased levels of visibility, ESB Networks will need to manage and monitor the network more actively down to the most local level and empower domestic and small business customers to become "flexible" or "active customers".

We are working toward a target of 50% mapping/modelling visibility of the network by the end of 2025, in addition to monitoring installations on the LV side of 10,660 MV/LV distribution substations by the end of 2025.

In an update to our previous Visibility Multiyear Plans, the need to enhance the nature and quality of our MV network model is becoming increasingly apparent. Whilst our MV network models are of a high quality to meet the needs of planning the system, through our flexibility pilot activities over the period 2021 – 2023, we have learned that the specific information and tolerance levels needed for the MV network model to be used for automated decision making (e.g. scheduling and dispatching flexible demand) is more demanding. For example, we have evidence now that there is a need for more intensive collection and validation of the phasing data on the MV overhead network.

Having learned this, throughout H2 of 2023 we delivered a pilot to establish technical solutions for capturing the phase information of single phase OH spurs. This was completed in the Mullingar area, to align with in planning flexibility pilots. Following on from the findings of this pilot, a procedure will be developed for training delivery in Q2 2024 to support the rollout of a programme of work which will commence capturing and validating required phase data. Corrections will be made in the source databases, such as GIS and GMD, to ensure that the phasing information is accurate across all of the relevant data systems.

The purpose of this document is to update the multiyear plan by setting out our detailed plan for the period 2024 – 2026, and a high-level plan for 2027 – 2028. Where relevant to this forward-looking plan, we outline elements of the work delivered throughout 2021,2022 and 2023 to provide a roadmap for the approach to the programme management by ESB Networks in relation to reaching our targets mentioned above.

This document also provides detail in relation to the completion of procurement and planned installation of monitoring devices, resourcing requirements for the operational visibility and mapping work programme up until 2027, safety procedures, training, validation, installation, and commissioning. The success of the programme will require that certain milestones will continue to be met between now and the end of 2025 as detailed in Section 6 of this document.

4. What the Plan is Delivering

4 What the Plan is Delivering

4.1 INTRODUCTION

This multiyear plan relates to the delivery of two main pieces of work i.e., delivering increased levels of network mapping and increased levels of network monitoring. In this multiyear plan, subject to CRU approval of the proposed milestones, it is proposed that this plan will now also deliver MV phase validation and MV monitoring enhancements as we progress into 2024 and beyond. Further detail in relation to each of these two additional items can be found in sections 4.4 and 4.5.

Accurate network mapping will include accurate referencing of customers to substations and circuits, and the topology and electrical parameters of the LV circuits themselves. In cases where there are already records of the LV network, the information includes the LV network from the secondary substation down to the mini-pillar or pole outside a customer's premises. However, it does not include the overhead (OH) or underground (UG) service lines that connects the customer's premises to the LV network. The existing maps are not always complete and there are gaps in the network which may leave some customers disconnected from the LV electrical model. The LV mapping will improve the visibility of how customers are connected to the electrical network.

ESB Networks is continuing to target the installation of 10,660 monitors in MV/LV sub-stations to gather real time monitoring of the network by the end of PR5. Notwithstanding the progress that has been made in Ireland and elsewhere in recent years proving these monitoring technologies, over the period 2021 – 2023 the supply chain is highly immature. As a result, extensive efforts have been needed (and delivered) in 2021 – 2023 to establish the requisite supply chain. Having now achieved this, the monitoring devices will be installed over the period Q4 2023 – Q4 2025 and will comprise of both ground mounted and pole mounted devices.

Once installed, that will allow ESB Networks to measure certain electrical parameters including both voltage and current in up to 6 LV circuits in the MV/LV substation. Such measurements will then be used to calculate active and reactive power, power factor, power flow direction, and power quality total harmonic distortion (THD) at the monitored location. Once fed back to the control room this will result in ESB Networks having more visibility of the LV network (further detail in Appendix G).

4.2 LV NETWORK MAPPING (50% BY THE END OF PR5)

ESB Networks has begun to develop accurate maps/models of the low voltage system using and correcting existing Geographic Information System (GIS) data, smart metering data, data analytics along with field patrols.

The mapping solutions that have been developed and will continued to be developed throughout the remainder of the PR5 period, include:

1. GIS Geospatial Validation (further detail in Appendix A)
2. LV Network Discovery (further detail in Appendix B)
3. Artificial Intelligence (AI) Mapping (further detail in Appendix C)
4. Electric Power Research Institute (EPRI) Tool (further detail in Appendix D)
5. Other solutions – we will continue to seek and develop potential solutions

Each of these solutions have different requirements and different strengths in terms of the kinds of network to which they are best suited. By efficiently deploying these solutions in combination across the network, we can secure accurate visibility of the network as a whole.

To achieve the 50% visibility target, the GIS geospatial validation will continue to be deployed in additional planner groups throughout 2023, 2024 and 2025. This will target the correction and validation of the LV network associated with 50% of the customer base, by the end of PR5. The key focus areas will be strategically selected in line with work being carried out which may require or benefit from having LV works completed. Further detail in relation to the PR5 mapping strategy can be found in the Appendix F.

Accurate connectivity, which identifies which customers are connected at which network point, can provide an element of visibility. Such visibility can be achieved by validation of MPRN customer reference to the correct LV outlet & MV/LV substation. Accurate GIS schematics, impedances, and capacity, specifying the capacity available at each network point, provides visibility. LV network corrections and validations can be achieved using GIS to obtain the work necessary for visibility. As the GIS geospatial validation work is completed in each area and more smart metering data becomes available, the outputs from the EPRI tool and LV network discovery will be layered into the GIS model to give a full picture on customer referencing and phasing. LV network discovery and EPRI mapping tool will become key components to the mapping strategy in 2024 once the data access code is passed into legislation.

4.2.1 GIS GEOSPATIAL VALIDATION

GIS geospatial validation has been deployed since Q4 2022, which involves updating and correcting the connectivity of the LV network within the GIS model. The mapping strategy using GIS geospatial validation that was developed in 2023 will be adhered to until the end of 2025 to identify the resource requirements and the areas (and sub-stations) to meet our yearly mapping targets. As we progress through PR5 this strategy will be revised to account for changes in scope such as the newly introduced flexibility targets. Further details of our mapping strategy can be found in Appendix F.

The validation process involves GIS networks specialists visually examining the model and available data sets within each geographical area in the GIS to assess the network connectivity on a substation-by-substation basis with reference to the LV Network Validation Results (LVMVR) file (described in Appendix A).

Substations are identified where the connectivity is incorrect or in cases does not exist in the GIS. The GIS specialist will then endeavor to correct the connectivity in the GIS model where possible. If there is limited data within the model for the GIS specialist to fully correct the connectivity, other data sources, for example, historical paper map records, unposted designs, previous patrols and other ESB Networks personnel knowledge will be sought. Other processes like those described in this section (LVND, EPRI Tool, A.I Mapping) will greatly assist the GIS specialist in correcting and updating the network connectivity when available. When the GIS specialist has corrected the network connections, the network trace and the analysis query tools are then utilised to verify the connectivity.

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Various scripts have also been developed and ran within the GIS to streamline the validation process. The LV network validation script is used to create the LVNVR file as mentioned above. The MPRN validation script is used to connect and correctly reference the customer MPRNs to the LV network. Finally, when all the MPRNs are correctly referenced they are uploaded back to SAP using a MPRN SAP bulk upload script.

Once validation and corrections are complete in both the GIS and SAP systems, the output is a fully connected LV schematic from the MPRN to the sub-station. The process flow for the GIS geospatial validation is shown in the figure 1 below.

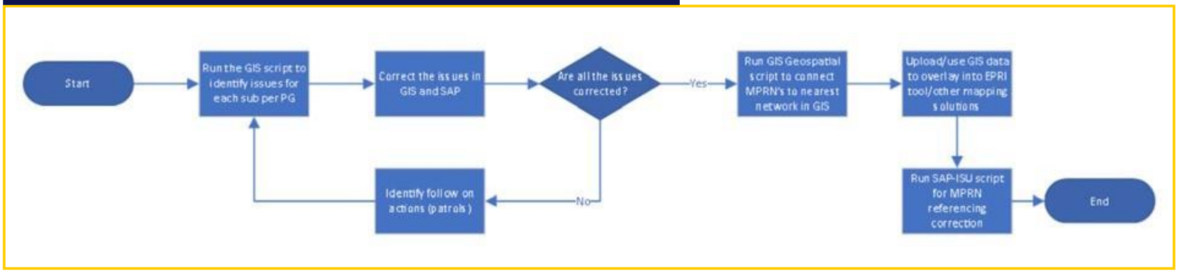
4.2.1.1 SUCCESS TO DATE

At present the current rate of network validation is 8.9% with live works are being carried out in the following geographical areas, Cavan, Drogheda, Dublin North, Dundalk and Mullingar.

The ESB Networks' GIS specialists are continually correcting, connecting and validating the LV network utilising the existing information within the ESB Networks GIS. In cases where there is an absence of information or incorrect information which obstructs the GIS specialist from completing the validation process then follow up queries will be compiled. The follow-up queries will request information from the ESB Networks area manager, ESB Networks Operational control specialists or network technicians. In the first instance the area manager or ESB Networks Operational control specialists for the area will be contacted to determine if they have any local knowledge or paper map records that might assist the GIS specialist. Failing this, then a site patrol will be requested so that a network technician can obtain the required information at each location. Information received back from the follow up queries will allow the GIS specialist to then complete the validation process.

Further details on the GIS geospatial validation tools and scripts can be seen in Appendix A.

FIGURE 1 – **PROCESS FLOW OF GIS GEOSPATIAL VALIDATION**

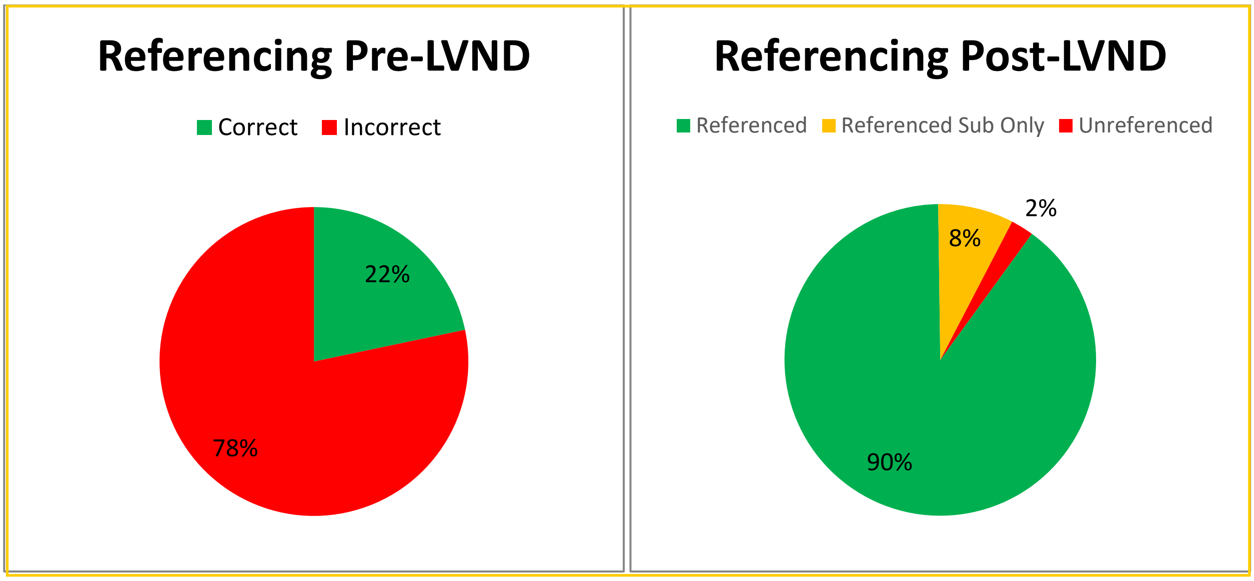


4.2.2 LV NETWORK DISCOVERY (LVND)

ESB Networks completed a pilot project in 2023 for mapping the LV network by utilising substation data recorded by the network technicians on an internal portal (MyForms) along with very brief “loss of supply” events data recorded on smart meters. ESB Networks will continue to explore the potential to roll this solution out across further locations in 2024. The process involved recording the loss of events supply to customers with smart meters in a methodical and repeatable way so that the events could be analysed and used to allow the customer to be correctly referenced to substation, outlet, and phase. During the potential solution, ESB Networks takes absolute measure to ensure minimum to no customer impact while safeguarding customer sensitive information.

The pilot was conducted across 13 locations in 2023 with very positive results. A total of 2,027 customers (MPRNs) were associated with the 13 locations in the pilot. Following the undertaking of the pilot of the LVND procedure, it was possible to immediately and directly correct 64% of referencing, and by close inference of adjacent customers correct a further 34%. In total 98% are now correctly referenced. A small number of MPRNs could only be referenced to the substation and not the outlet due to there being a low number of smart meters installed for that substation, however the substation reference for all MPRNs effected could still be inferred.

FIGURE 2 – LVND REFERENCING PROGRESS



This in turn allows for the schematics to be correctly updated to reflect the true connectivity of the LV network as shown below.

FIGURE 3 – **PRE LVND SCHEMATIC CORRECTION**

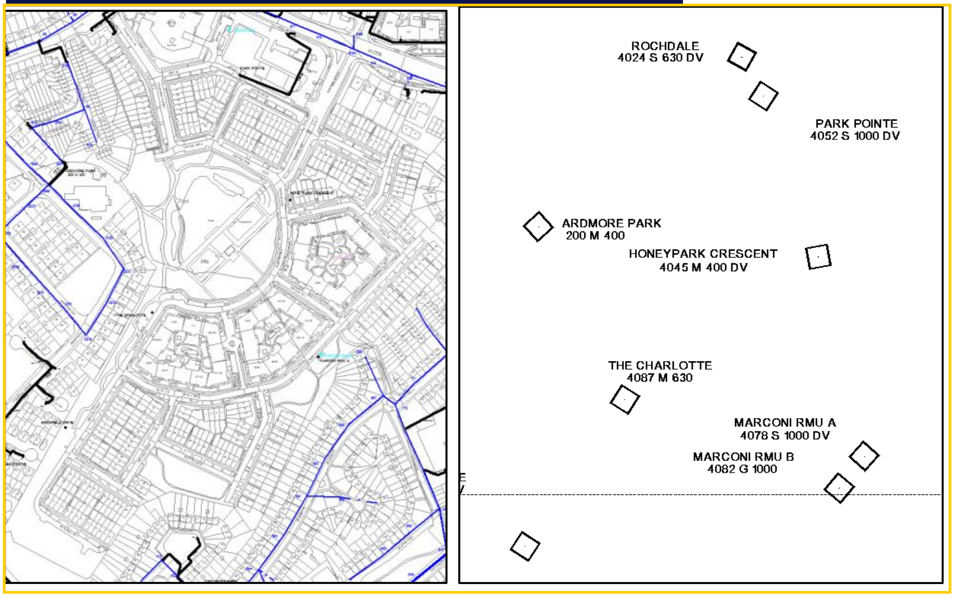
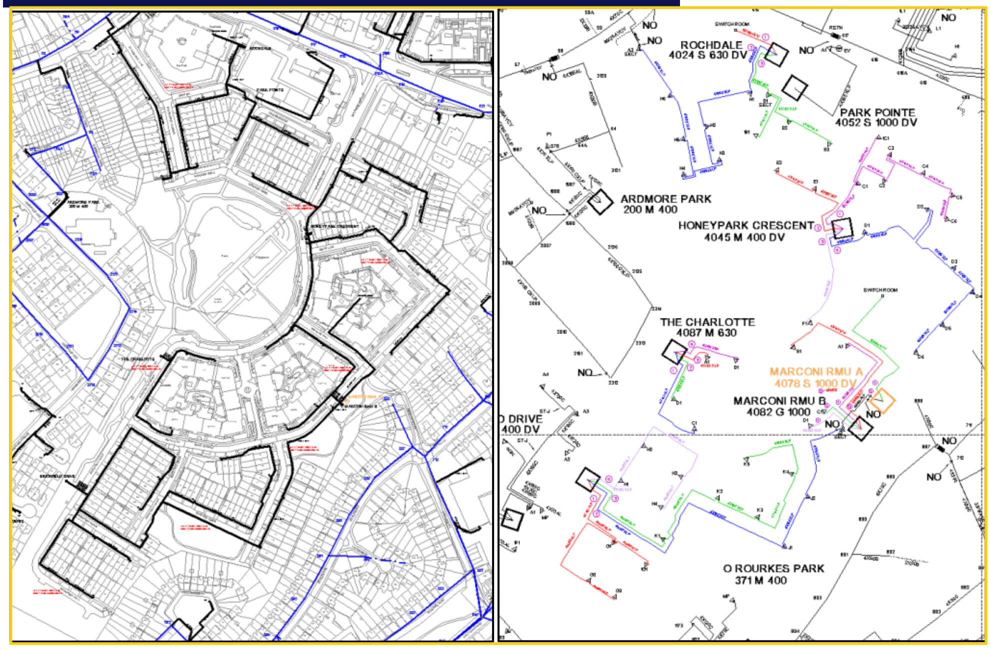


FIGURE 4 – **MAPS POST SCHEMATIC CORRECTION**



ESB Networks will now explore the potential to roll this solution out across further locations. For more details on the LV network discovery process, please refer to Appendix B.

4.2.3 AI MAPPING APPROACH

One of the largest gaps in ESB Networks' LV model data is the connection between the electricity utility pole to the customer premises. To address this, an initial proof of concept study was undertaken in Q2 2022. The success of this study allowed ESB Networks' move into the second phase where pilots were conducted in Q3 2022. This proof-of-concept study used artificial intelligence (AI) image recognition software to scan through street view images and identify OH assets.

ESB Networks is due to launch a more detailed proof of concept before the end of Q4 2023 in the Dun Laoghaire area of the Dublin south area in collaboration with a third-party vendor. This proof of concept has potential to be both cost effective and time efficient. The following functionalities were developed during the first two phases and will continue to be developed throughout the remainder of the proof of concept:

1. The tool inputs existing LV network georeferenced layers from the GIS and by using these it can automatically iterate through street view. When AI image recognition is deployed the tool find the images of electricity utility poles. It is possible to differentiate between electrical and non-electrical utility poles (i.e., telecoms).
2. The AI image recognition selecting a particular utility pole can determine whether there is conductor connecting from the pole to a customer's premises.
3. Where the conductor is identified, the tool delivers the start-point and endpoint coordinates for the conductor, which, in turn can then be imported back into the GIS and a service conductor layer can then be created.
4. Once this information is known, it can be used along with GIS geospatial validation to build out an LV connectivity model by connecting customer's MPRN locations to the new service conductor layer. The advantage of this method is that it will give us a more accurate picture of how and where our customers are connected to the network, as we will have more precise georeferenced locations on where the service conductor starts and ends in overhead LV networks. The initial results when testing this method were very positive as such, ESB Networks is exploring the potential to collaborate with a third party to roll out this solution across multiple areas.

Once the functionality of this tool is proven during the proof of concept, it may be expanded to look at more than just service conductor and pole locations:

1. Categorise wooden and steel poles
2. Determine OH conductor construction type (bundled for flat 4 construction)
3. Determine mini pillar locations

This solution will allow ESB Networks to fill in the gaps of missing O/H network data to help create a connected LV model. Further details on the AI mapping technique and different stages of the pilots can be seen in Appendix C.

4.2.4 EPRI TOOL

ESB Networks has to date being working closely with EPRI to test and build out a smart metering data tool. As this solution is dependent on smart metering data the initial deployment will focus on the areas where the smart metering programme has been rolled out. However due to ongoing data access restrictions associated with GDPR and the delayed rollout of the smart meter data code, ESB Networks have not been able to progress the rollout of this mapping solution.

Once smart metering data becomes available, we will continue to test this approach with the vison to roll this out on a national level throughout 2024 and beyond, The EPRI tool will initially be deployed across 50% of the LV network, if successful it is envisaged that deployment will continue beyond PR5 into PR6. It is anticipated that once the tool goes live in 2024, 10% of generated mapping results will be validated by a "boots on the ground" patrol between now and the end of PR5. This innovative approach will be a data-based first where the requirement for onsite patrols is targeted to improve timelines and costs effectiveness.

The validation will be carried out by ESB Networks' field staff, and the results will be imported into the GIS system with continued consultation with EPRI. All procedural and safety protocols relating to this validation have been approved by the ESB Networks' Safety Programme Implementation Group (SPIG) committee. Training will continue to be provided in consultation with the ESB Networks' National Training Centre (NTC) to the required ESB Networks' field staffs. More details about this approach can be found in Appendix E.

4.2.5 COMPARISON

A comparison of different mapping options is shown in the table below, with the strengths and drawbacks, and the training requirements for each of the different mapping options.

METHOD	STRENGTHS	DRAWBACKS	TRAINING REQUIREMENTS
GIS Geospatial Validation	- Data based exercise, can be completed largely without deployment of field resources - Creates a fully LV connected schematic - Identifies specific sections of the LV network which require patrols in targeted fashion	- Dependent on availability pre existing network data - Does not give phase information	Full training for mapping resources to correct the network model in GIS
AI Mapping	- Can be used in areas with no GIS records - Can be used with geospatial tool to connect MPRNs into the network model	- Does not indicate normally open positions, phasing or asset details - Applicable to overhead assets only	Dependent on successes and viability of the proof of concept
EPRI Tool	- Geospatially maps customer connections onto the network model	- Requires high existing schematic model to be corrected prior to use - In development, accuracy unknown - Without smart metering data access, tool cannot be used (currently on hold)	Training required for mapping resources to run the tool, once testing and development is complete
LV Network Discovery	- Produces accurate outlet & phase referencing for customers - Can be used as data source to infer networks where no GIS records exist - Can be used to find normally open positions - Pilot results have been very positive	- Results in momentary customer interruptions - Requires smart meters to be installed in assessment areas	Briefing required for network technicians. Training required for GIS resource for inferring methods

Table 1- Various Mapping Options with their features

To achieve visibility of the LV network, two types of validation and correction work may be required.

Element of Visibility	Works Required
Accurate GIS schematics model will assist in identifying capacity	LV network corrections and validations within GIS
Accurate connectivity, identifying which customers are connected at what network location	Validation of MPRN customer referencing to correct LV outlet & MV/LV sub station

Table 2- Validation types for LV network Visibility

The attributes that are required to be updated as part of the referencing are listed below:

1. Phase information
2. Outlet information
3. Sub-station information

Each of the different mapping options are compared in the table below identifying each of the attributes that can be captured using a particular technique (mentioned in appendix).

MAPPING OPTIONS	**CONNECTIVITY/ REFERENCING ATTRIBUTES**		
	OUTLET INFO INFO	**PHASE INFO**	**SUB-STATION**
GIS Geospatial Analysis	✓		✓
LV Network Discovery	✓	✓	✓
Field Validation patrols	✓	✓	✓
EPRI Tool *proxy phasing		✓	

Table 3- Connectivity and Referencing information for various mapping projects

4.3 LV MONITORING (10,660 INSTALLATIONS BY END OF PR5)

For ESB Networks to have an active, real-time view of the LV network, the installation of LV monitors on both ground mounted, and pole mounted MV/LV substations is required. Therefore, ESB Networks will install 10,660 during the remainder of PR5. These devices will measure electrical parameters (voltage and current) of the sub-station and perform calculations on these measurements (active and reactive power, power flow direction, voltage total harmonic distortion). The data will be fed back to a cloud platform through ESB Networks' IT systems via 4G connection initially, and then through the private long-term evolution network once it becomes available. LV monitoring of the LV network is necessary for ESB Networks to offer flexibility services to its customer base, and to enable their participation in all markets for flexibility.

At the time of writing ESB Networks is in the final stages of device testing ahead of vendor selection. The immature nature of the supply chain for the monitoring devices and unavailability of standardized products, have resulted in significant delays to the overall procurement timelines. Product development have continued throughout the procurement process and detailed analysis and testing's have been completed throughout 2023.

The test devices from vendors were installed at the live sub-stations to check the performance of the device and its data transmission capabilities. Commencement of installations is scheduled for Q4 2023 dependent on contracts being signed with the selected vendors, the number of installs will then be ramped up significantly in 2024 and 2025 to achieve the target of 10,660 devices by the end of 2025.

ESB Network Telecoms have completed the procurement of a partner to work with them to design and build the private long term evolution network. The deployment of core and radio infrastructure was finalised in Q2 2023 and the service go-live is scheduled for Q3/Q4 2023 and will continue to be rolled from one area to the next across the network for the remainder of the PR5 period. Further details on the installation of LV monitors can be found in Appendix G.

4.4 MV NETWORK VISIBILITY ENHANCEMENTS

An important part of delivering the objectives of ESB Networks' wider activities to drive and enable flexible demand in Ireland is the augmentation of existing OT capabilities to include advanced functionality such as power flow and state estimation to support our ability to forecast demand and optimise management of the network. With power flow as a foundation, ESB Networks can assess network constraints against estimated/calculated network states to warn operators and systems managers in case of any capacity congestions, voltage violations, reverse flow from low carbon technologies and other issues that could be mitigated in proactive manner. In combination with weather forecast (wind speed, solar irradiance etc.) and historical profile information, distribution management system power flow and forecasting engine would be able to produce hourly load and generation predictions that would serve as input for requesting flexibility services from customers at MV and HV voltage level. The long-term plan is to deliver this functionality with an integrated ADMS, however we have commenced enabling this functionality on the existing OT platforms to;

- support the NN,LC pilots and
- facilitate delivery of the CAP 2023 objectives and
- learn the extent to which our existing network model was capable of supporting advanced capabilities.

Geospatial data provides the physical location and attributes of network assets such as switchgear, conductors, transformers and substations within the system. This data enables the network model to accurately represent the characteristics of the distribution network. Where the model does not accurately represent the network, this will lead to incorrect analysis, and decisions that could negatively impact network performance, reliability, and efficiency. The model analysis identified several key data attributes which will need on site validation. A pilot to identify the best method to capture this data was initiated for the Mullingar area and will inform the approach for the national rollout.

4.4.1 NETWORK MODELLING METHODOLOGY

Both the outage management system (OMS) and supervisory control and data acquisition (SCADA) functionality have been used at ESB Networks for nearly 20 years. Both require a logical connectivity model and there was no need to provide extensive network equipment data. For advanced distribution management system functions such as load flow and state estimation, the network model needs to be expanded to include engineering attributes like resistance, reactance, and configuration for power system objects along with the physical characteristics of equipment such as correct phasing data, transformer sizing, conductor rating, and length.

Accurately modelling the behaviour of network equipment such as transformers, substations, consumer loads and DERs is a critical aspect of achieving an accurate network model.

During the ESB Networks local flexibility pilot assessment it became apparent that phasing data on the MV network was not of the quality that would be needed to support automated operational decision making, which had a negative impact on power flow analysis. Where the distribution network is unbalanced (single phase spurs at 10 and 20kV supply customers and their single phase load, typically domestic), in case of missing or incorrect spur/lateral phasing information, the power flow and state estimation output would produce errors (i.e. false load imbalance across phases) thus preventing system managers, operators and engineers to use it for real time and study/forecasting purposes.

Given the importance of having accurate phasing information to ensure the correct operation of the system we determined that line patrol is necessary to assess the level of accuracy and correct any inaccuracies. Corrections will be made in the source databases, such as GIS and GMD, to ensure that the phasing information is accurate and up to date.

Network analysis results have also shown that the existing “simplified” network model which has a single load object at a MV/LV transformer site cause high discrepancy in the results of power flow solution as compared with real time data. A new load modelling approach is proposed where the network model design and the loading data is granular enough to accommodate the different load and microgeneration categories at a single MV/LV transformer site.

4.5 MV MONITORING ENHANCEMENTS

As with the MV network visibility enhancements detailed in section 4.2, additional MV monitoring enhancements will be required to allow the ADMS system and associated functionality delivery better quality power flow and state estimation results, greatly enhancing our ability to optimally operate the distribution system and ensure optimal dispatch of flexibility service providers.

To achieve further improvements in network analysis, we plan to perform state estimation in addition to powerflow. This approach will provide more accurate results, as state estimation uses MV real-time measurements to analyse the network and improve the quality and robustness of the output from ADMS. At present the existing MV telemetry has been sufficient for existing operational requirements, however additional enhancements in MV telemetry will be required to fully utilise state estimation techniques. Our SCADA load (current) measurements are in most cases available for single phase at the feeder head (10 or 20kV) and thus the other 2 phases remain non-telemetered. To facilitate state estimation and real time system monitoring, improved methods of monitoring the MV network are needed, and more telemetered devices will be required at MV level to provide 3 phase Voltage and Current measurements at suitable points (feederhead, downline and near end of line) on the MV Network.

To establish efficient, evidence-based proposals for the degree and nature of additional MV real time monitoring capability required, we have commenced technical studies. These are addressing issues like the nature of increases in the amount of telemetry required at station level, the feasibility of retrofitting ground mounted RMUs and overhead switchgear with monitoring solutions. We plan to conduct test installations of this equipment in 2024 with a view to informing the approach for nationwide rollout.

4.6 INTEGRATION TO INTERIM AND ENDURING ADMS SOLUTION

As the LV Network model is corrected this will be bought into the interim ADMS solution for assessing functionality testing. The MV phase data corrected in the GIS will be quickly utilized within the interim solution. This data will be crucial for testing and successful rollout of the flexibility services. Additionally, as the LV and MV data is improved through the network mapping process, this along with monitoring data will be key for improving network planning and studies developments going forward.

ENDURNG ADMS – MAPPING

As part of the overall National Network, Local Connections Programme, ESB Networks is implementing an advanced distribution management system (ADMS). Visibility of both the LV and MV networks will be integrated into the ADMS which will allow optimal operation of the distribution system and optimise usage of flexible service providers.

Pending the potential for programme adaptation based on conditions emerging over the coming years, this full integration may be possible from 2026.

ENDURING ADMS – MONITORING

Once installed on the network, data from the LV and MV monitors will be pointed to a gateway in an internet of things (IoT) hub environment. From here, ESB Networks will be able to import monitoring data from the IoT hub into the new ADMS once available. Real time information will then be fed to operations/control room staff to assist with network performance. Real time and historical data will also be made available to different functions (for example network asset managers and investment planners) for further analysis when required.

5. Programme Delivery Approach

5.1 IMPLEMENTATION OF THE OPERATIONAL VISIBILITY ROADMAP

The implementation of visibility refers to the piloting and rollout of a range of technical approaches and strategies to inform the advancement of LV mapping and monitoring activity. This will include the continued rollout of our mapping strategy for 2023-2025 and into PR6 (Appendix F). Programme-specific pilots will continue to be undertaken where necessary throughout 2024. ESB Networks to date have accumulated the result of various pilots and as such will seek to roll out techniques such as, low voltage network discovery and artificial intelligence mapping at a national level as we progress into the more mature stages of the project. The programme will also continue to implement the previous agreed resourcing plans by onboarding additional staff across the workstream in the areas for GIS mapping, device installation and back-office support.

“Securing visibility” refers to the continued development of operational quality, LV map and model information, by securing accurate referencing of customers to MV substations, and validation of information gathered on the LV network. Details on visibility and associated elements are mentioned in the section 4.2.5.

The implementation of the roadmap will see the continued ramping up of geospatial validation and the associated data analytical scripts, this process is the key enable for us achieving mapping target in 2025. As we advanced through the various geographical areas, we will continue to explore new technologies with automation in mind. In relation to LV monitoring installations our roadmap of installations and carefully selected locations will be continually reviewed to make sure that we are aligned to the overall NN, LC objectives in terms of both flexibility and an integrated ADMS system.

To date, visibility has involved the exploration of technical approaches and strategies for increasing the level of mapping of the LV electricity networks that are accurate and efficient. The future blueprint for increasing this level of mapping in PR5 will involve the continued rollout of GIS geospatial validation across further geographical areas, as referenced in the mapping strategy. This process will correct any existing data issues found while also identifying areas where network information is inaccurate. Once GIS geospatial validation is complete in a given geographical area, ESB Networks will then run the EPRI tool and potentially the LV network discovery option allowing them to layer on additional information into their GIS system. Pending the milestones CRU adopts on response of this submission, it will also see the introduction of MV phasing patrols and associated testing of MV monitoring device installations.

At the beginning of PR5, as much as 4.5% of ESB Networks’ customer base were not referenced to a connection point on the network and 12.3% of the customer base were referenced to an “unknown” LV feeder (i.e., a dummy feeder) on a secondary substation. These have been rectified.

Specific procedures and training for the installation and commissioning of LV monitoring devices will need to be finalised once the procurement process is complete in Q4 2023. These procedures will address:

1. On-site safety risk assessment
2. Installation of monitors using live working procedures
3. On-site commissioning for the device, including telecommunications commissioning
4. Repair and maintenance of the device

During the procurement process, ESB Networks has completed pilot installations of the vendor devices in ESB Networks’ sub stations. Installation procedures have been drafted for field staff to install LV monitors, referencing ESB Networks' safety rules, policies, and protocols. During Q4 2023 training procedures will be finalised and will be provided by ESB Networks to network technicians carrying out installations under agreed work programmes.

5.1.1 DELIVERY DOCUMENTATION

Prior to the EPRI field validation and procurement and installation of monitoring devices, documentation defining the necessary procedures and protocols for field staff to carry out this work has been drafted and approved using ESB Networks' OneSource procedure development policy, a standardised approach introduced in recent years as part of our organisational safety system.

Procedure documents and training material were also developed for the mapping processes mentioned i.e., the geospatial analysis, EPRI field validation, AI mapping and LV network discovery further detail included in the Appendix. Once each procedure document is approved, it is then published in ESB Networks' OneSource documentation system, after which any training will take place for the relevant staff who are carry out the procedures.

The suite of documentation developed or in development at the time of writing includes:

PROCEDURE DOCUMENT SET NAME	DOCUMENT DESCRIPTION	COMPLETION/FORECAST DATE
Installation of LV Monitors for National Network, Local Connection Programme	1. Installation and commissioning procedure document for field staff. 2. Safety Risk Assessment Document for installation task 3. Business Impact Assessment document (BIA)	Targeting to complete in Q4 2023
EPRI field Validation results for National Network, Local Connections Programme	1. Procedure document for validation of LV mapping output results from EPRI tool and the recording of updated data. 2. Safety risk assessment document for validation for field staff.	Developed in May 2022 Approved in July 2022
Low Voltage Network Discovery	1. Procedure document for LV Network Discovery 2. Safety risk assessment document LV Network Discovery	Pilot developed Q3 2022 Approved Q3 2022 Overall updated document target approval Q4 2023
GIS Geospatial analysis	Safety risk sessment for ospatial analysis	Developed in Q3 2022 Approved in Q4 2023
AI Mapping	1. Safety risk assessment for AI mapping using image recognition technique	Targeting to complete in Q4 2023

LV Network Discovery DPIA	1. Data Protection Impact Assessment for the use of substation data recorded on the MyForms portal along with "loss of supply" event data recorded on Smart Meters	Developed in Q2 2022 Approved in Q3 2022
EPRI Tool DPIA	1. Data Protection Impact Assessment for the use of smart metering power quality data and GIS data	Developed in Q1 2022 Redrafted in Q3 2023

Table 5 - Documentation and training Materials

The development and update of the requisite delivery documentation will continue as an on-going process into 2024 and beyond. This documentation will need to be added to or adapted to account for:

1. Process improvement opportunities identified year on year
2. To support any new emerging methods and technologies
3. To support the introduction of additional delivery models
4. To support any new or additional technology or devices introduced for field staff

5.1.2 USE OF DATA ANALYTICS FOR MAPPING

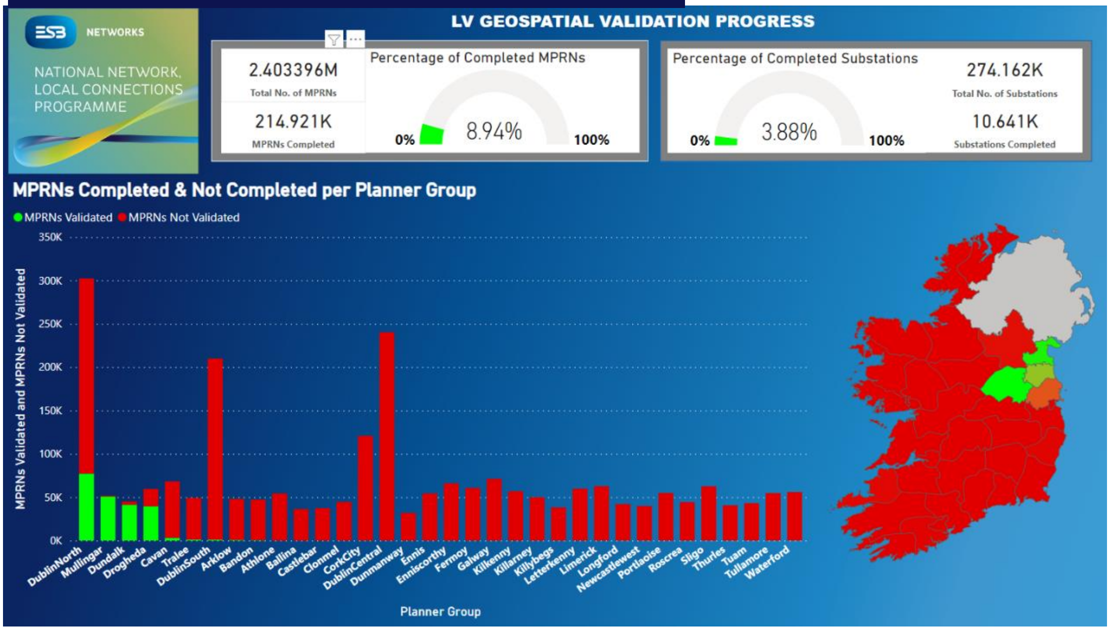
Data analytics has been used in different areas of the programme to date, including the identification of locations for the installation of monitoring devices. ESB Networks has also used a data analytical approach to create a dashboard showing geographical locations of 10,660 LV monitoring devices between now and the end of PR5.

The key areas where further data analytics developments will be delivered between now and the end of PR5 are as follows:

1. GIS geospatial validation script has been developed and will be deployed across each of the 34 planner groups as we complete our validation and corrections. This script extracts an LV Network Validation Results (LVMVR) file in microsoft excel format from the GIS Model. The LVMVR lists all Substations within each geographical area along with a variety of attributes associated with it.
2. A MPRN referencing validation script has been developed to validate and correctly reference MPRNs in the ESB Networks' GIS and SAP system. The script is used to connect the MPRNs to the nearest network. This script will be run on a regular basis to identify any errors as the mapping solutions are rolled out
3. A MPRN SAP bulk Upload script has been developed so that when the MPRN referencing is corrected and updated in the GIS the MPRN references can be uploaded back to SAP-ISU in bulk.
4. AI Mapping has the potential to determine LV overhead network that is currently not recorded in our GIS system therefore allowing us to build a more detailed schematic

LV network discovery data integration- ESB Networks will utilise data analytics techniques to streamline and simplify the process for extracting the outage event data from the Smart Metering data hub (SMDH), where the event data linked to the MPRN is stored. A Mapping dashboard has been developed using power BI and will continue to be updated as we progress across the various geographical areas,

FIGURE 5 – VALIDATED MPRN FOR EACH PLANNER GROUP



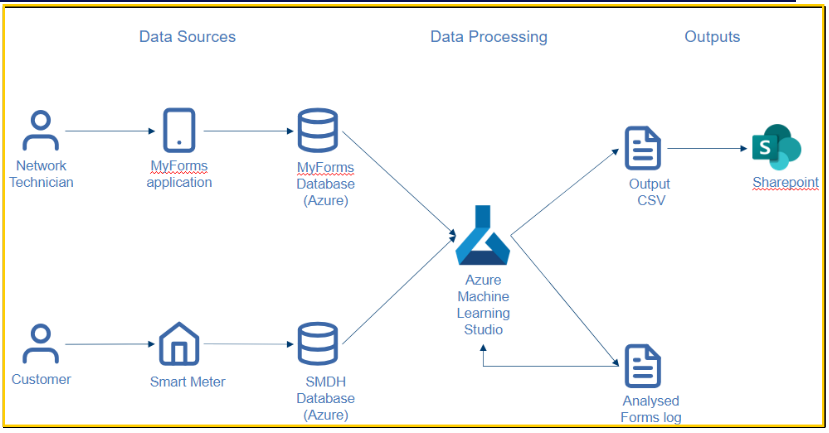
LV network discovery may be used as an alternative method to correct customer referencing in SAP IS-U and network data in GIS. The pilot was completed in Q2 2023 (see Figure 2 for the LV network discovery pilot process). Network technicians will record data in the MyForms app as they complete the work in the field. Outage Event data will be extracted from the smart metering smart meter dashboard and the time from the outage events and time from the MyForms portal will be analysed to correlate outages caused by the network technician with outages recorded in the smart meter. This correlation will give us the correct customer network reference. This information will be validated against referencing data available in the APEX application. Updated customer referencing will then be uploaded into SAP IS-U. This reference data will also be used to update missing sections of our LV maps in GIS. A more detailed process is described in Appendix B.

Automation of the data processing was set up in the Azure machine learning studio. It is set up to check every day if there is a new LVND form entered. If there is, it extracts the data for this time period from the SMDH. It processes and analyses the data to produce the lists from section 4.2. These lists are exported to SharePoint so they can be updated in SAP-ISU.

The EPRI field validation safety and procedure documents were approved by ESB Networks' Safety Programme Implementation Group (SPIG) in July 2022 and were published in ESB Networks' OneSource document management system. The training for the on-the-ground validation exercise was carried out with teams involved in the pilot locations and in collaboration with the National Training Centre (NTC). The field validation is due to commence in Q4 2023. Several insight sessions were held with EPRI for delivering training on the EPRI tool, allowing ESB Networks to familiarise with the tool and its functionalities.

The procedure documents for alternate mapping projects- i.e., LV network discovery and the AI image recognition are currently under development and will undergo a similar process for approval. GIS geospatial validation analysis documentation has been developed, reviewed and has received the adequate approval.

FIGURE 6 – **SOLUTION ARCHITECTURE OF LVND AUTOMATION**



5.1.3 DATA ANALYTICS FOR MONITORING LOCATIONS

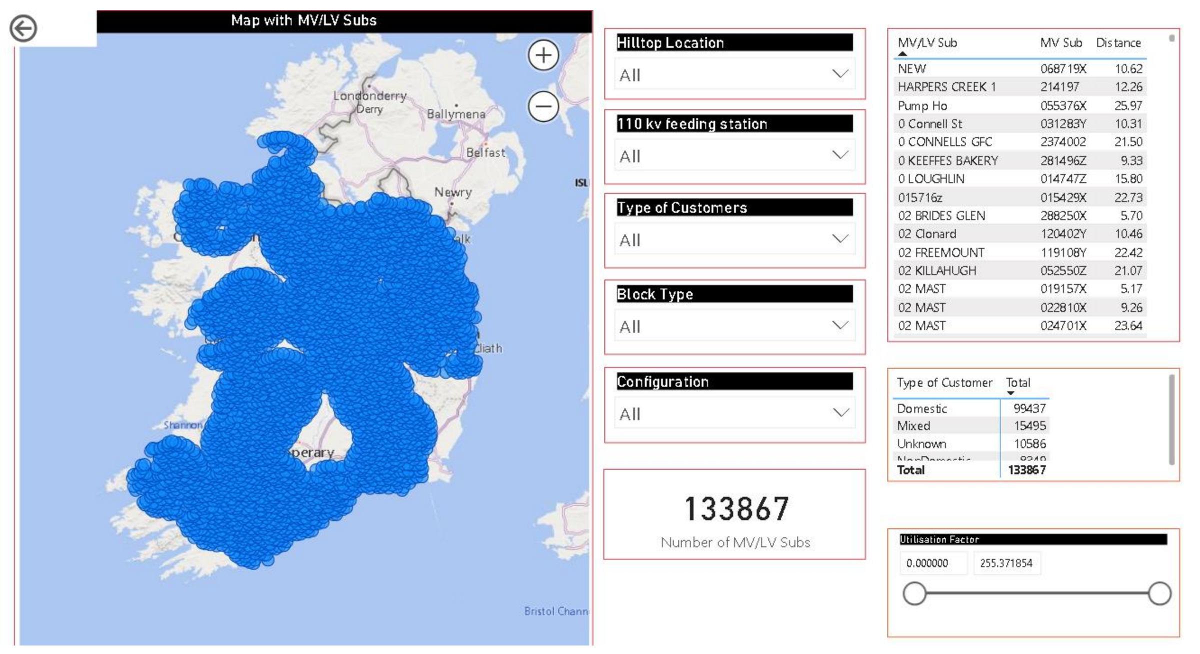
ESB Networks' target is to have 10,660 monitoring devices operational, gathering real time monitoring of the LV network by the end of 2025. These 10,660 monitoring devices will consist of pole mounted and ground mounted installations on MV/LV substations. The procurement for the purchase and supply of monitoring devices from a preferred vendor was substantively completed in Q4 2022. Training will be complete prior to commencement of installation in early 2023, monitor installations will continue throughout the years 2023-2025.

A two-phase approach is being adopted to select the locations for installing monitors. In both phases, data science approaches are being adopted. The first 2,000 monitor installation locations were selected based on the following criteria:

1. MV/LV substations fed from 110kV stations which have been identified as within the top 10 candidate areas for piloting, based on technical assessment as per the 2030 Power System Requirements analysis
2. From the above, individual substations whose utilisation factor is greater than 75% of MV/LV capacity
3. Finally, MV/LV substations with highest numbers of customers connected

The second phase of monitoring location selection began in 2022 during which a dashboard was developed in 2022, which was updated in 2023 with new set of criteria to aid the selection process (See figure below). The dashboard has enabled the selection of additional substation locations by choosing different profile groups used for the LV stratification. The second phase involved expert cross-functional collaboration within the NN, LC programme to enhance the analysis of candidate locations for piloting. Based on this, an additional 1554 locations have been selected and have been included alongside the initial 2,000 locations in the 2023 work programme. Furthermore, additional 6000+ locations were also shared with ESB Networks programme management plan for including in the 2024 work programme.

FIGURE 7 – **DASHBOARD FOR LV MONITOR LOCATION SELECTION**



In PR4, ESB Networks secured the spectrum needed to deliver a "smart grid" telecommunications network based on private long term evolution technology. This network is being developed during PR5. This connectivity offers a secure and efficient solution for the continuous gathering of real time LV monitoring data. As such, ESB Networks' target with respect to telecoms delivery readiness in 2022 was the design and development of the private long term evolution network.

The private long term evolution rollout is currently at the latter phase of the procurement process. It is envisaged that the deployment of core and radio infrastructure will be finalised in Q3 2023 and the service go-live is scheduled for Q4 2023 and will continue to be rolled out across the network for the remainder of the PR5 period.

5.2 SOURCING AND RESOURCING

To achieve our PR5 milestones ESB Networks will need to address all labour and technological needs as required. A key aspect of this is the onboarding of additional staff where required in relation to the various mapping and monitoring solutions under development.

ESB Networks has identified the need to deploy a team of network technicians for:

1. The installation of the 10,660 LV monitoring devices between now and the end of PR5
2. For the validation of LV maps/models derived using an analytics-based tool developed in collaboration with the Electric Power Research Institute (EPRI) – hereby referred to as the "EPRI tool"
3. For the successful implementation of the LV Network Discovery (LVND)–another alternative mapping / modelling solution – pending approval.

There is also a need to build out the current mapping team as the following options that will be continued to be developed throughout PR5 and into PR6:

1 GIS Geospatial Validation (further detail in the Appendix A)

2 LV Network Discovery (further detail in the Appendix B)

3 AI Mapping (further detail in the Appendix C)

4 EPRI Tool (further detail in the Appendix D)

ESB Networks activities for 2024-2028 will see the advancement of our both our LV mapping and monitoring strategies. This will include the ramping up of our GIS geospatial validation, the commencement of the use of the EPRI tool for LV network modelling and its associated validation works. In Q4 2023 the installation of LV monitoring devices will commence.

Throughout 2024 and 2025 GIS geospatial validation will remain as our high priority mapping solution. The EPRI modelling tool and LV Network Discovery solutions are interlinked with the geospatial validation. Each of these solutions once implemented will be layered over this corrected and connected GIS network. Technological needs will include the continued development of various dashboards and applications that will assist with progress on both mapping and monitoring of the network. As the LVND pilot is now complete ESB Networks will undertake a process of considering whether we should proceed beyond the pilot locations, on based on technical, economic, safety assessment alongside customer impact, if extended this process will require less resourcing then alternative mapping approaches.

5.2.1 GIS MAPPING EXPERTISE & TRAINING

In order to successfully onboard additional staff comprehensive training materials are currently being revised with a view to completion in Q4 2024. GIS Geospatial Validation will continue to be deployed in additional geographical areas throughout 2024 and 2025 with 50% of the LV network due to be complete by the end of PR5. There is a significant labor-intensive element to this solution due to the nature of the work as ESB Networks is validating and amending the existing network model in GIS. As such ESB Networks has identified the need for additional geospatial information system (GIS) mapping experts to be deployed within the ESB Networks mapping experts from Q3 2023 until the end of PR5.

5.2.2 LV NETWORK MAPPING QUALITY ASSURANCE

Quality Assurance is a particularly important aspect of the LV geospatial Validation that is being carried out within the mapping team. Standards of work have been developed that ensure the work being carried out consistent. There are tools within the GIS that allow QA to be carried out following the validation process. The network trace and analysis query tools (as described in Appendix A) are used to check and confirm the connectivity of the LV network.

The network trace tool is primarily used after the GIS specialist has validated the network from a substation. The tool will confirm if all connections have been correctly assigned. The analysis query tool, like the Network Trace, highlights the network where there are the connections issues in a given area.

Peer checking on the validation work carried out within the team has been put in place to strengthen the quality assurance processes. A quality assurance manager has been appointed who has extensive knowledge of the LV network and the processes involved in validating it. They will conduct checks on the validation work being done by other team members and will provide feedback on the quality of the work and suggest any improvements they deem necessary. They utilize the analysis query and trace tools to verify the work being done. A register is continually updated, which documents everything that is found when carrying out the quality assurance process. All the items are addressed during regular team meetings and workshops as well as one to one discussion with each member of the team.

5.2.3 MV PATROL/PHASE COLLECTION RESOURCING

Following on from the MV phase collection pilot completed in Mullingar planner group, there is a need scale up for delivery of targeted MV single phase spur patrols. This will include the initial delivery of a procedure document to set out the most efficient and safest method for capturing MV single phase spur data on site. It is planned to have a complete procedure approved by the ESB Networks' Safety Programme Implementation Group (SPIG) committee in place in Q1 2024, with training briefings commencing for nominated approved Network Technicians in Q2 2024. To support this rollout, the programme requirements have been added into the overall network programme delivery plan for 2024 and 2025. Throughout 2024 options for most efficient delivery will be assessed prior to commencement in H2 2024.

5.2.4 MONITORING DEVICE INSTALLATION

Throughout 2023 it became evident that due to the immature nature of supply chain for the monitoring devices and unavailability of standardized products, this has resulted in significant delays to the overall procurement process from the original timelines estimated for completion. However, sample monitoring devices have been received and tested in a live substation from each vendor included in RFT stage of the procurement process. Given the immaturity of available supply chains, product development been completed throughout the process. Each device has also been tested in a 3rd party laboratory to confirm their both their suitability and durability. As such at the time of writing we are able to determine the relevant supplier and issues award letters. Once contracts have been signed with the relevant suppliers ESB Networks will submit our initial orders with an expected delivery date of Q4 2023.

In preparation for the procurement process, technical and functional specifications for LV monitoring devices were previously developed. The specifications developed were informed by each of the following:

1. Market research and meetings with vendors/manufacturers to assess the technical capabilities of products on the market has informed this specification
2. Review of the lessons learned regarding LV Monitoring devices from the Dingle Project
3. Engagement with ESB Networks' procurement specialists
4. Engagement with ESB Networks' legal and finance specialists in relation to the procurement documentation
5. Engagement with both ESB Networks' overhead and underground assets specialists

Key aspects of the technical specification developed included:

1. Measurement of voltage and current on MV/LV substation LV outlets
2. Calculation of power and power flows of LV outlets on MV/LV substations
3. Inclusion of the telecommunications devices within the monitoring device housing
4. Data transfer to IT systems through 4G / private long-term evolution telecommunications

Before the end of 2023 we will complete the overall procurement of devices, place initial orders with the selected vendors, confirm locations for delivery of monitoring devices and commence installations. For further details on the monitor installation, please refer to Appendix G.

A resourcing approach has been agreed upon for the installation of these devices with an expected star date of Q4 2023. The resources secured (i.e., the field staff) will be required to undertake three different types of installation methods to suit our variety of MV/LV substationsoutdoor ground mounted, indoor ground mounted, and pole mounted devices. The ESB Networks mapping experts will also resource as appropriate for MV phasing work in 2024 and beyond. ESB Networks has drafted safety and procedural documentation in relation to LV monitoring installations. Field staff carrying out the commissioning of monitors will adhere to current procedural documentation for 'Commissioning of the LV network'. They will confirm telecommunications commissioning and connectivity of the device via their mobile device by logging-on to the relevant web browser while on-site. The procedure document for telecommunications commissioning and connectivity will be developed in conjunction with the successful monitoring device vendors in Q4 2023.

To support efficient delivery of the monitoring device installations, this work is being integrated with other work programmes so that where possible this work can be done as part of normal maintenance work undertaken at the relevant assets. There is ongoing review of the range of resourcing and delivery models which may be utilised to complete this work. (Note: The potential for integrating this work into other work programmes touching the same asset may be relatively limited. For example, the units which require monitoring may not otherwise be on the work programme in a given year, or the skills required to complete this work may not be aligned with the skills needed to complete other work on the asset).

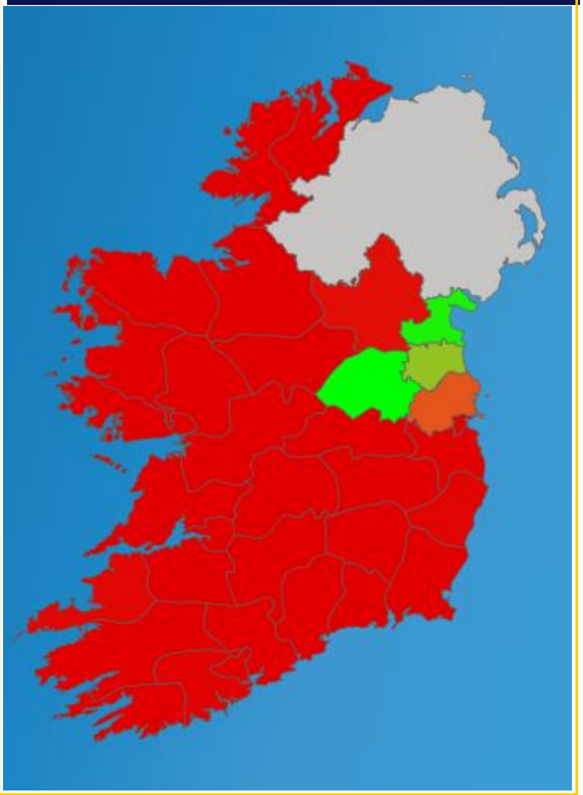
5.3 MAPPING PROGRESS TO DATE

To date ESB Networks has validated 8.9% of the LV Network in the country. This accounts for approximately 200,000 MPRNs. Over 10,000 Substations have their network validated also. The following Planner Groups have been, and are currently being worked on: Cavan, Drogheda, Dublin North, Dundalk and Mullingar. The progress is illustrated in Fig 8 below. The ESB Networks' GIS specialists are continually correcting, connecting and validating the LV network utilising the existing information within the ESB Networks' GIS. In cases where there is an absence of information or incorrect information which obstructs the GIS Specialist from completing the validation process then follow up queries will be compiled. The follow-up queries will request information from the ESB Networks Area Manager, POCESB Networks operational control specialists or network technicians. In the first instance the area manager or ESB Networks operational control specialists for the planner group will be contacted to determine if they have any local knowledge or paper map records that might assist the GIS Specialist. Failing this, then a site patrol will be requested so that a Network Technician can obtain the required information at each location. Information received back from the follow-up queries will allow the GIS Specialist to then complete the validation process.

Follow-up queries have been requested with the ESB Networks Operational Control specialists for a number of Planner Groups and NTs are currently undertaking site patrols in the Cavan planner group.

The MPRN Validation script developed allows for an automated process of connecting each MPRN to the LV Network, meaning each MPRN is referenced back to its substation. Some manual verification and correcting of the MPRNs is still required following this process. This has been completed for the Mullingar Planner Group, while the Dundalk and Drogheda Planner Groups are in the verification stage. A Bulk upload of the corrected MPRN referencing back into the SAP system has been completed for the Mullingar Planner Group.

FIGURE 8– **LV NETWORK VALIDATION PROGRESS**



5.3.1 AVAILABILITY OF SMART METERING DATA

The availability of smart metering data is critical to the success of the programme. The effectiveness of the GIS geospatial validation, EPRI tool and LV Network Discovery mapping methods are highly dependent on the availability of the smart metering data. The process for developing data access code is currently in progress and ESB Networks is working on the proposal with the various use cases for using smart metering data.

As part of the increased visibility, customers without a reference point on the LV network will have correct referencing assigned, based on the use of the smart metering validation data. Smart metering data is also required to produce the EPRI model using voltage, current, active power, and reactive power.

The implementation of 'Push-All' functionality from the smart meter is also required to develop the EPRI tool for modelling the network by assigning MPRNs to proxy phase groups and connection points using linear regression modelling. The smart metering outage event data is also critical for the success of LV network discovery pilot to co-relate event data with the sub-station data when a network technician operates on the sub-station.

The table below shows the different mapping options and their associated requirement for smart metering data:

METHOD	DEPENDENCY ON THE DATA	FUNCTIONALITY/ DESCRIPTION	STATUS
GIS Geospatial Validation	✓	This method is used in combination with EPRI and LV Network Discovery for a complete connectivity model of the LV Network	In progress.
EPRI Tool	✓	mart meter data required to import into the tool to perform linear regression modelling and assign MPRNs to proxy phase groups and connection points	Currently at the test phase. Go-live Q4 2023
LV Network Discovery	✓	Outage event data for co-relation	Currently in Pilot phase. Expected to be complete in Q1 2023
AI Mapping		NA	NA

Table 6 - Mapping options for smart metering

6. Visibility Milestone Plan

6. VISIBILITY MILESTONE PLAN

The objective of the visibility multiyear plan is to outline the roadmap for increasing visibility of the network between now and the end of year 2025. In 2020, it was agreed that visibility will be tracked and incentivised year on year by the CRU, working toward a target of 50% visibility of the network by the year 2025.

As well as introducing increased levels of visibility through the development of accurate network models and customer referencing, ESB Networks will need to begin to monitor the LV network. Such monitoring will be achieved by deploying measurement devices on the LV side of the MV/LV distribution substations.

Each year of the visibility multiyear plan, we will build upon learnings from the previous year. Delivery phases will follow typical project delivery life cycle phases of High-Level Design (HLD), Detailed Design (DD), build, test and deploy. The target for monitoring is to have 10,660 monitors installed by the end of 2025. This will follow a waterfall methodology, with substantial overlap between each year as part of a continuous, efficiently delivered programme of work.2023 will see the completion of detailed procurement exercises, data analytics with the engagement of EPRI, and data integration. 2024 will follow a similar path however procurement of both digital and private long-term evolution monitors will be complete in 2023.

During 2023, 2024 and 2025, ESB Networks must also gather and validate reference information required to support the visibility of the network. The target for 2023 is to capture 25% off the LV network, 37.5% by the end of 2024, and 50% by the end of 2025. During 2023, 2024 and 2025, a central element of accurate LV maps / connectivity models will be the gathering and validation of reference information (i.e., mapping individual customers to the MV/LV substation which is feeding them). ESB Networks will also aim to install 10,660 LV monitoring devices on the network between 2023 and 2025.

The table below reflects the milestones from 2024 onwards.

6.1 SCORECARD PROPOSAL

Throughout PR5, the CRU is measuring the delivery of visibility using an annual balanced scorecard based on ESB Networks' development and execution of a plan to secure increased visibility, and monitoring) prior to the end of 2025. The scorecard focuses on the following three pillars, sourcing, and resourcing, securing visibility, and sharing visibility.

The scorecard is designed to reflect the need for better information and visibility of the LV network, allowing the DSO to manage the networks more efficiently and deliver better outcomes for customers and market participants.

The balance scorecard we propose for 2024 as outlined below is based on progress against milestones for increasing the visibility of the LV and MV network, enabling a future outcome of ESB Networks actively managing the network to accommodate greater number of LCTs and manage capex reinforcements more efficiently.

The principles we used in the proposed scorecard are centered around customer value and the required effort needed to deliver on this. Based on outcomes from our local flexibility pilots, the need for enabling MV customers to participate in early flexibility markets is deemed to give the highest value for our customers at this point in time.

To facilitate the capture of our LV network model and MV phasing data in a timely manner, increased specialist resources are required to be onboarded to the project to deliver the model corrections in GIS and to support the patrolling rollout requirements. Increasing visibility and data accuracy on the LV and MV network enables participation earlier.

ESB Networks propose the following milestones and weightages for 2024 visibility incentives:

1 Cumulative Installation of 3,500 monitoring devices in the LV network – 20%

2 Achieve 37.5% visibility of the LV network - 50%

3 Use of data analytics to achieve the mapping and monitoring targets – 10%

4 Sourcing and resourcing activities to address technical, technological, and practical dependencies – 20%

VISIBILITY INCENTIVE	TASK	EVIDENCE PROPOSED	WEIGHTAGE
LV monitoring	Cumulative Installation of 3,500 monitoring devices in the LV Network	Report on the progress made in relation to the total number of monitors installed in the MV/LV sub-station	20%
LV Mapping & Visibility	Achieve 37.5% visibility of the LV Network	Report on the LV model capture and the customer referencing progress	50%
Use of Data Analytics	Application of data analytics for meeting the LV mapping and monitoring targets	Report on the use of data analytics across different work programme to achieve the mapping and monitoring targets.	10%
Sourcing and Resourcin g	Sourcing and resourcing activities to address the technical, technological, and practical dependencies	Report on the activities undertaken to address the various requirements (people, processes, and technology) to meet the yearly targets	20%

Table 7 – Proposed Scorecard for 2024

7. Dependencies

ESB NETWORKS

7. DEPENDENCIES

FOR	DESCRIPTION	ASSUMPTION	RISK
SMART METERING DATA	There is a dependency on the smart metering data access code being approved, this will allow the use of smart metering geospatial and voltage date in the development of the LV mapping model in order to achieve the 12.5% annual target of LV mapping from 2023 until 2025 inclusive.	ESB Networks is working on the core assumption that the smart metering data access code will allow the use of various associated functionalities to carry out mapping projects including the EPRI tool, LV Network Discovery and GIS geospatial validation as set out in detail in the document in section 4.2	There is a risk that Smart Metering “push all” functionality may be delayed beyond Q4 2023. This would result in the programme being unable to add data to the EPRI LV Mapping Solution. The impact being that the LV Mapping Solution would be unusable, and the programme would be unable to conduct LV Mapping.
CONTRACTOR RESOURCES	Contractor resources – There may be a requirement to onboard additional contractors for the rollout of each of the following: -Monitoring Device Installations - LV Model Validation -LV Network Discovery	It is expected that contractor resources will support with the delivery of work programme within the PR5 period	There is a risk in sourcing competent contractor resources to support the delivery of the various field activities such as EPRI field validation patrols, LV network discovery and LV monitor installations which will impact the milestones and visibility incentive targets

Table 8 - Programme dependencies with associated assumptions and Risks

8. Call for input

8. 2023 CALL FOR INPUT

As part of the call for input on the visibility PR5 incentives multi-year Plans 2025-2028 published in August 2023, ESB Networks invited stakeholders to comment on the inputs being developed in relation to the strategies relating to both the mapping and monitoring rollout. ESB Networks did not receive feedback via the call for inputs in relation to the visibility incentive.

9. Appendix

9 APPENDIX

A. GIS GEOSPATIAL VALIDATION TOOLS AND SCRIPTS

There are a number of tools and scripts that are used utilised during the GIS geospatial validation (described in Section 4.2.1). The following is an overview of the tools and scripts that are used to streamline the process.

Network Trace Tool

The Network Trace Tool is ran within the GIS and to verify Network connectivity. When it is ran it will carry out a trace along the conductor to assess if there any breaks in the connectivity and any such breaks or unconnected conductors will be identified.

Analysis Query Tool

The Analysis Query tool is similar in principle to the Network Trace tool. The analysis query tool identifies any network where there are connectivity issues on a planner group scale. The tool is primarily ran to identify connectivity issues in rural areas and also any connectivity issues which may be outstanding in an Urban area after the GIS specialist has completed their validation. The tool runs a logical model trace from a customer's Meter Point Reference Number (MPRN) back to the MV/LV substation, assessing if there are any breaks or problems with the LV network connectivity. This tool can be executed specifically for conductors or mini pillars to highlight any unassigned conductor or unassigned mini-pillars respectively.

LV Network Validation Script

The first step in the GIS geospatial validation is the analysis of the GIS tool by running a script to identify the issues across each sub in each planner group. Following this initial step any identified issues can be corrected in the existing GIS model and within SAP. This process is repeated until all identified issues are rectified in each planner group.

This script extracts an LV Network Validation Results (LVNVR) file in microsoft excel format from the GIS model. The LVNVR lists all substations within each planner group along with a variety of attributes associated with it. This is used by the GIS Specialists as the master file when validating and updating the Network Connectivity within the model as the LVNVR file will highlight any substations that have network issues needing to be addressed.

MPRN Validation

This is a script that has been developed in ESB Networks' GIS system. GIS geospatial MPRN referencing validation script is deployed to connect the MPRNs to the nearest network in the GIS The MPRN Referencing Validation script which when executed identifies any proposed corrections that may need to be made to the customer MPRN referencing. The basis of the script is that it connects an MPRN using its geographical coordinates, to the LV network based on its proximity (i.e., shortest distance) to the LV network. The script will output an excel file listing any proposed corrections and a CAD file to visually show them in the GIS model. The GIS specialist will validate, where possible, the identified corrections and update the model accordingly. Currently not all MPRN coordinates are recorded in GIS, however this information is being gathered as part of the smart metering programme. This will work slightly differently for urban and rural customers:

If a rural customer is referenced to a substation that is 500m away from their geospatial coordinate and the tool determines that there is a substation that is only 40m away, then it is more likely that the customer is connected to the closer substation and their reference can be updated.

For an urban customer, the underlying LV network first must be validated and any breaks in the network schematic must be corrected. Once completed, the customer's geospatial coordinates can be connected to the coordinates of the nearest connection point on the validated LV network (a pole or mini pillar). The tool can then determine the connection path back to the substation through the validated LV network, and the customer can be assigned a reference based on this substation path.

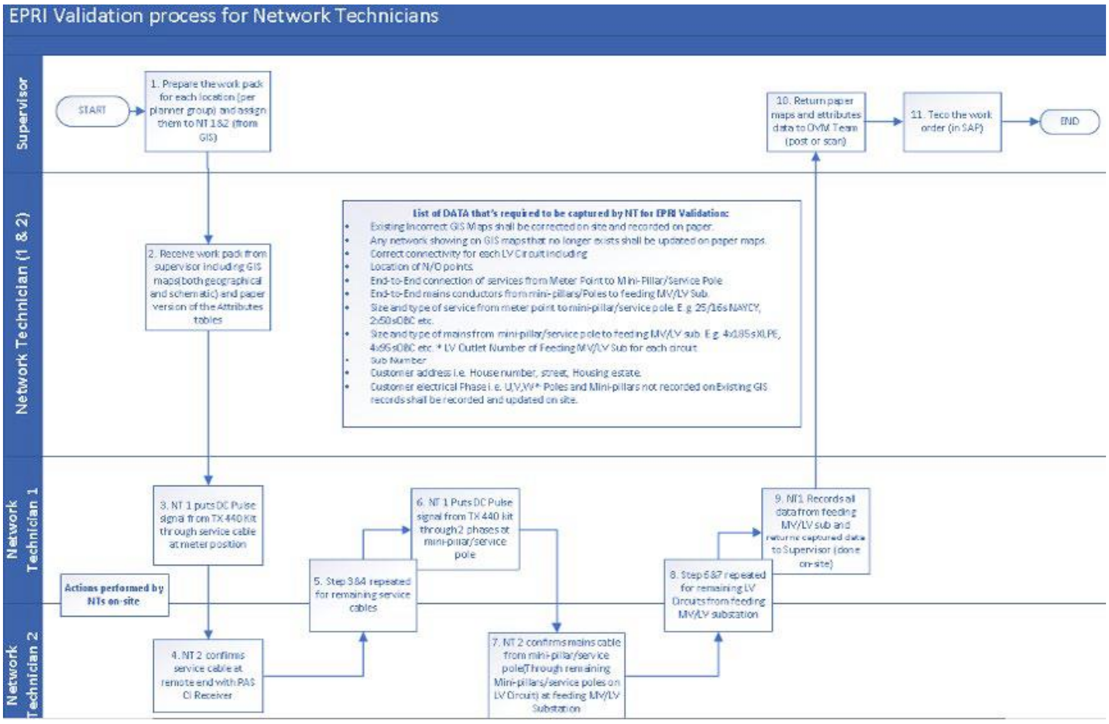
MPRN SAP Bulk Upload

When the MRPNs have been corrected, validated, and verified within the GIS then they need to be reflected in SAP. This process is undertaken for each individual substation across all 34 planner groups. The MPRN referencing is corrected and updated in SAP-ISU using a script that can validate and update the MPRNs in bulk.

B .LV NETWORK DISCOVERY

To achieve the mapping/modelling objectives for LV Network, ESB Networks is also considering an approach called LV network discovery that would help to develop a complete connectivity model of all customers and fill in the missing information in relation to LV mapping. This process will be piloted in Q1 2023 across 12 locations the outcome of the pilot will determine if we roll this out to further locations on a programme wide basis. The end-to-end process is explained in figure 8 below.

FIGURE 9– **EPRI VALIDATION PROCESS FOR NETWORK TECHNICIANS**



Process Explained:

1 Each LV outlet has a single fuse protecting each phase. A fuse will be 'pulled' and 'closed' one at a time by the network technician on each outlet, where the time, outlet and the phase information will be recorded on the My Forms portal. Network technicians will follow the process as presented below (fig. 7)

2 The time of this interruption will create a "loss of supply" event (also called 'Power Off') and will be recorded in the customer's smart meter, and sent to the Meter Data Management System (MDMS)

3 Info loaded into the MyForms portal can then be accessed by the ESB Networks

4 The ESB Networks will extract outage event data from the Smart Metering Data Hub (SMDH) (data in the form of a Power BI dashboard). This file will contain event data linked to MPRNs. The file will be saved in the dedicated SharePoint site

5 The ESB Networks will analyse the time from the outage events and time from the MyForms portal to corelate outages caused by the network technicians with outages recorded in the smart meter. The time the fuse was 'Pulled' would correspond with the 'Loss of Supply' event on the smart meter, therefore the MPRN can be aligned with the LV outlet and LV phase

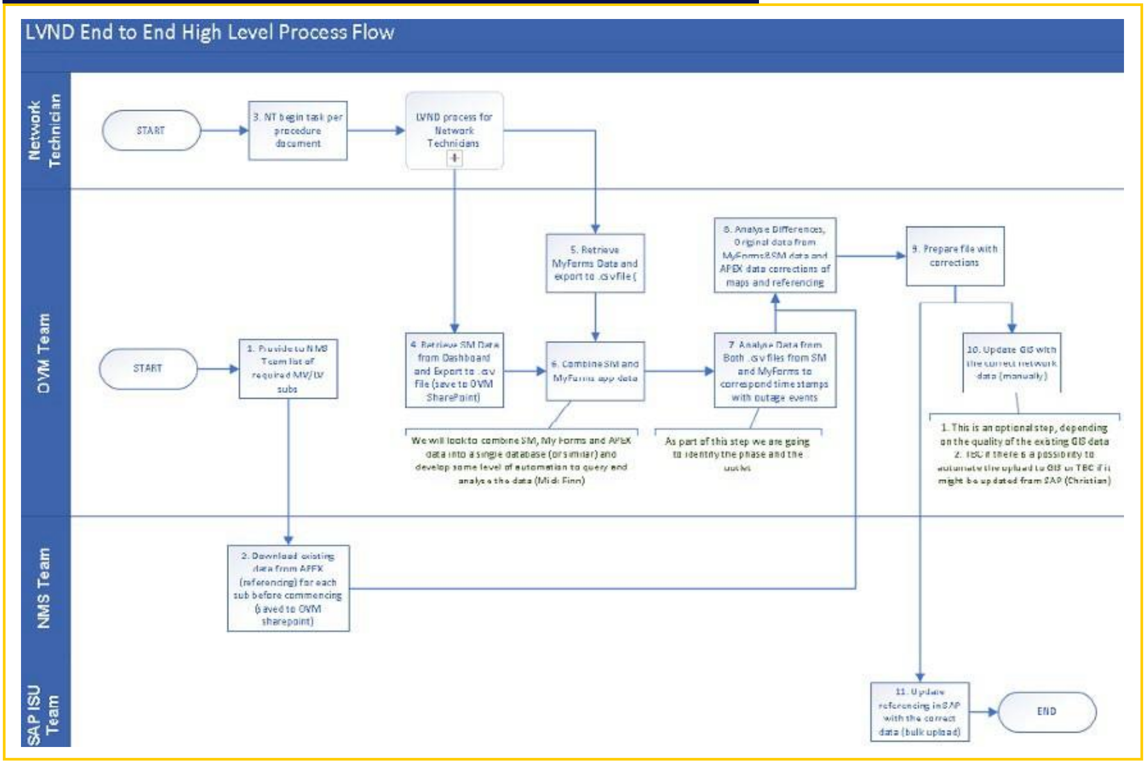
6 This correlation will provide the correct customer network reference and identify which part of the network the customer is electrically connected to giving ESB Networks a complete customer reference to substation outlet and phase. Updated customer referencing will be temporarily stored on the ESB Networks' SharePoint site

7 The ESB Networks will then update the new customer reference on SAP IS-U in conjunction with the SAP IS-U team

8 The ESB Networks will also use the reference data to update missing sections of our LV maps in GIS

The end-to-end process flow for LV network discovery is shown in the figure 7 below.

FIGURE 10 – **LV NETWORK DISCOVERY END TO END PROCESS FLOW**



C. AI MAPPING

This is a proof-of-concept project that aims to use AI image recognition software to process images to identify where ESB Networks' overhead network assets are located, and to translate this data into GIS. Once data is available in GIS, it can then be used in ESB Networks' electrical models. This proof of concept is being delivered in three phases as outlined below:

1 Pilot covering small area – complete in Q2 2022

This was conducted using a small data set of approximately 200 utility poles. The aim of the pilot was to assess if the AI image recognition software could be used for the purposes of identifying network. The initial result from the pilot was deemed a success and the pilot then progressed into phase 2.

This pilot was run using a twostep approach.

Step 1 was to train the AI model to recognise ESB Networks' poles.

The model was trained by manually tagging ESB Networks' poles in images. Once trained the model was able to identify ESB Networks' poles independently and differentiate between ESB Networks' poles and telecom poles.

The image on the left below shows the AI model being trained to recognise the conductor by tagging the ESB Networks and telecom poles.

The image on the right below shows the output of the model. The white box indicates what was manually tagged in order to train the model. Red is what the model recognised independently.

FIGURE 11 – **AI MAPPING**

The output accuracy from the initial assessment was high, which meant that the tool could be progressed to a pilot with larger area.

FIGURE 12 – **OUTPUT ACCURACY STATISTICS FOR THE INITIAL PILOT**

Performance Per Tag

Tag	Precision	Recall	A.P.	Image count
Utility Pole	88.9%	86.5%	94.0%	186
Telecom Pole	80.0%	80.0%	90.6%	72

Precision: If a pole is predicted, how likely is it to be right

Recall: Out of the poles that should be found, what percentage did the model find

mAP: Overall performance score (mean average precision)

Step 2 of the initial assessment involved training the AI model to recognise where there was conductor connecting a pole to a customer premises. The image below shows the AI model being trained to recognise the conductor.

FIGURE 13 – **AI MAPPING**

The image below shows the output of the model in red.

Again, the accuracy was high.

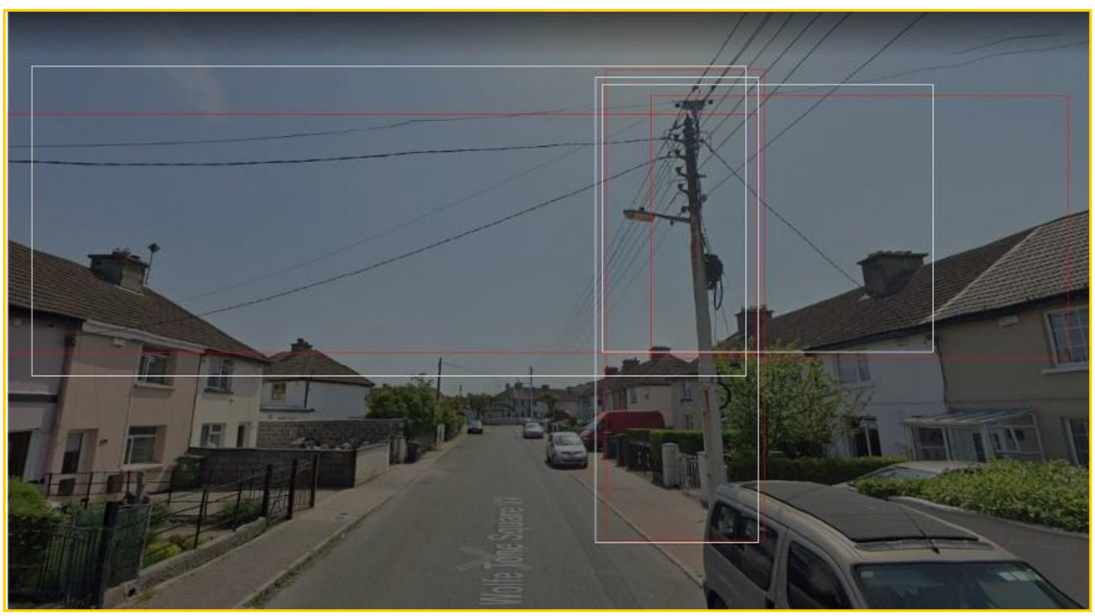


FIGURE 14 – **COMPLETED TARGETS IN 2022**

Predictions

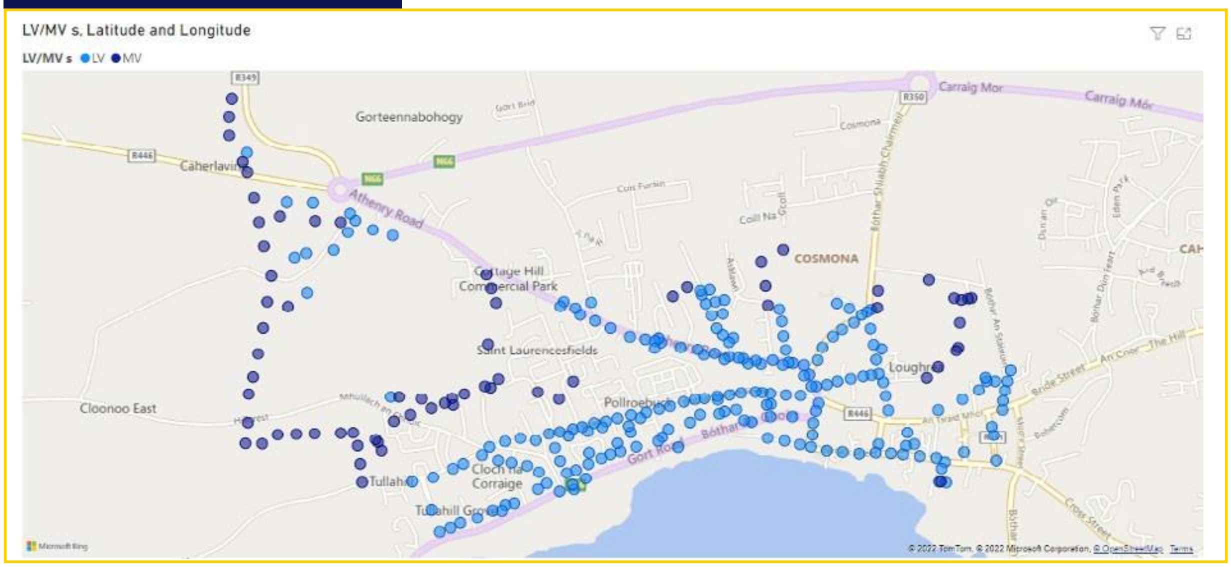
Predictions are shown in red

Tag	Probability
Utility Pole	99.9%
LV	96.3%
LV	94.1%

PILOT IN LARGER AREA- COMPLETED IN Q4 2022

The large pilot involved training the AI model on a known set of data from ESB Networks' patrols. This data is highly detailed and provides a good opportunity to check the accuracy of the AI model against known accurate data.

FIGURE 15 – **LV AND MV MAPS**

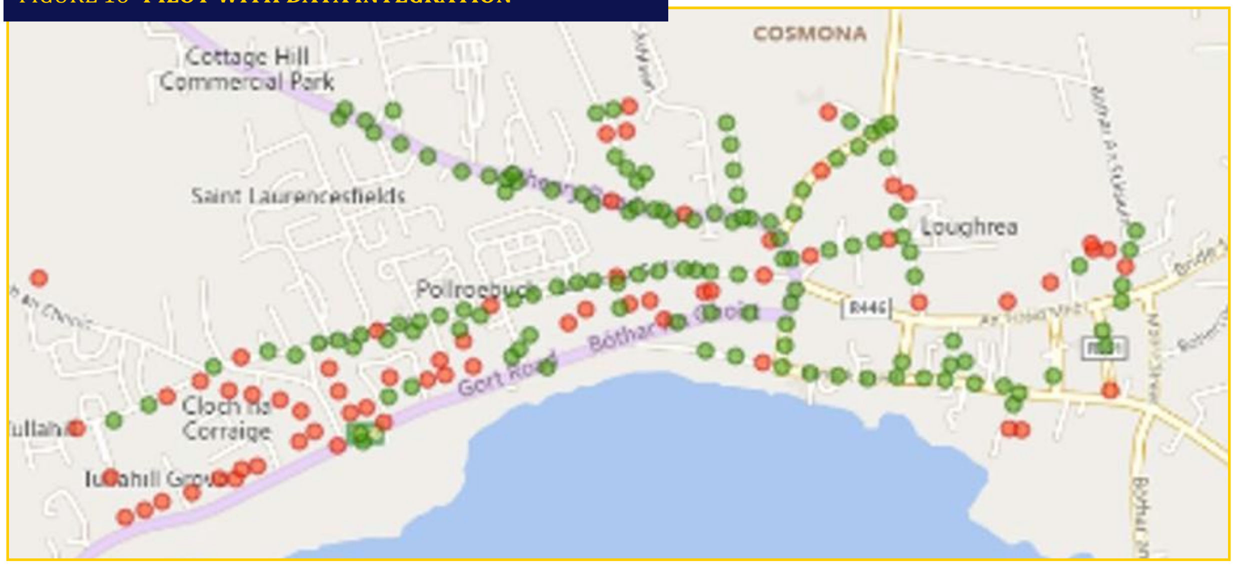


Below is a map of the pole data used for this pilot. Any MV pole and any LV poles that were not visible from the road were discounted from this pilot as it wasn't possible to get high enough resolution images of these poles.

The results from this trail were favourable:

1. 66% of all LV poles were found
2. 84% of LV poles visible from the road were found
3. 77% accuracy finding LV cable from pole to house

FIGURE 16- **PILOT WITH DATA INTEGRATION**



The pilot involves developing a script that can direct the AI model through an image set allowing data to be gathered automatically. There is also a software translation layer that will convert the data gathered by the AI model into a format that can be aligned to ESB Networks' GIS system so that the electrical models can be improved.

Once these developments are complete, it is proposed that the tool will gather data from a geographic area automatically and prepare it for import into GIS alongside validation and user intervention.

Initial functionality has been developed, but it is slow and requires a high level of compute power. ESB Networks are in discussion with a third-party vendor to assess if it is possible to access higher quality imagery data, and to see if there are any alternative technological solutions available to process the data once captured. Depending on the outcome of the conversations with third party vendors, this solution may be used in conjunction with aforementioned mapping options above.

D. EPRI TOOL

ESB Networks, in collaboration with EPRI developed a beta version of the LV network model tool in 2022. Once the tool is deployed into the ESB Networks' ecosystem it will use linear regression modelling of smart metering voltage data. Smart metering data will be used to produce a model using voltage, current, active, and reactive power. This will allow for the development of LV mapping, and customer referencing to the LV outlet in the substation and the customer phasing (the phase that the customer is on in a three- phase system).

The QA process will commence in Q1 2023 using a "boots on the ground" validation approach undertaken by suitably qualified and approved network technicians.

A high-level process flow has been defined for the capturing and updating of mapping & referencing for EPRI validation, see Figure 5.

The steps in this process are:

1. Network technicians will complete the validation process in accordance with the procedure document

2 ESB Networks Mapping resources will receive paper maps and data attributes from the network technicians as per the procedure document (which will be scanned and saved on SharePoint)

3 ESB Networks GIS specialists will extract existing GIS Data from GIS and will upload to the EPRI Tool

4 ESB Networks GIS specialists will extract smart metering data from smart meter data hub and will upload to the EPRI tool

5 The output from the EPRI tool will be generated and a comparative analysis will be carried out against the paper maps submitted by the network technicians

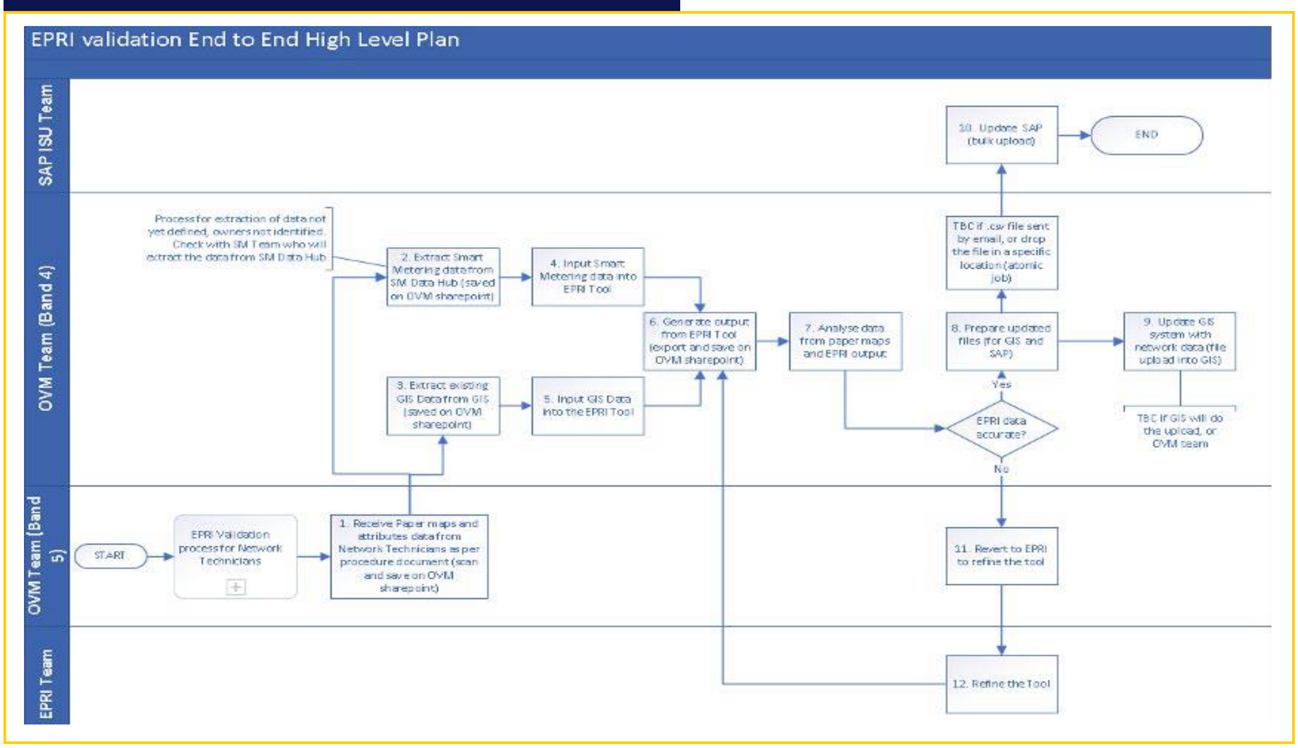
6 If the data taken from the EPRI tool is accurate, files will be prepared for both GIS and SAP and then uploaded with the correct/accurate network data

7 The SAP IS-U team will then update SAP with the correct network data GIS will also be

8 updated with the correct network data

9 If the data taken from the EPRI tool is inaccurate, the ESB Networks' team will revert to EPRI to refine the tool

FIGURE 17– **EPRI VALIDATION END TO END PROCESS**



E. NETWORK TECHNICIANS BREIFING FOR VALIDATION OF EPRI LV MAPPING RESULTS

Training material has been developed to support the EPRI field validation results process. The validation exercise will take place on-site and will be performed by network technicians.

The area briefings aim to provide a broader context of the LV Visibility work to be carried out by the network technicians. Each briefing provides instruction on how to undertake LV circuit confirmation from the meter point to the feeding MV/LV substation using the SEBA/MEGGAR TX440 CI kit on LIVE LV single phase and three phase circuits. It provides the networks technicians with the necessary skill set to record outcomes of on-site checks. Only network technicians with appropriate approvals and who have been briefed may carry out this task.

This briefing consists of below lessons:

1. Lesson 1: Use of the Seba/Meggar LCI TX 440 for LV Circuit Confirmation - Principle of operation of Seba/Meggar LCI TX 440 for LV Circuit confirmation
2. Lesson 2: LV Single Phase Circuit Confirmation - Confirm single phase O/H and UG LV circuit using Seba/Meggar LCI TX 440; Use of G-Clamp Connector for LV Circuit Confirmation
3. Lesson 3: LV Three Phase Circuit Confirmation - Confirm 3 - Phase O/H and UG LV Circuit using Seba/Meggar LCI TX 440
4. Lesson 4: Recording/Amending of GIS mapping- Recording/amending data on GIS paper maps

F. MAPPING STRATEGY

FIGURE 18– **PR5 TARGETS & PLANNER GROUPS**

Mapping Targets for PR5 & Planner Groups Identified

NETWORKS

LV MAPPING TARGETS

ESB Network's yearly targets for mapping and modelling the LV Network during the PR5 period as agreed with CRU are as follows:

Year	Mapping Target	Total MPRNs/customers to be mapped (approx.)
2023	Capture 25% of the overall LV network	600,000
2024	Capture 37.5% of the overall LV network	900,000
2025	Capture 50% of the overall LV network	1,200,000

PLANNER GROUPS IDENTIFIED FOR MEETING TARGETS

Year	Planner Group	Total Sub-stations	Total MPRNs
End 2023	Dublin North	9,196	302,286
	Dublin South	6,862	209,921
	Dundalk	5,232	44,942
	Mullingar	8,167	51,700
	Cumulative Total (by end of 2023)	**29,454**	**608,849 (25%)**
End 2024	Cavan	16,229	68,212
	Drogheda	4,986	59,615
	Dublin Central	2,370	240,217
	Cumulative Total (by end of 2024)	**53,039**	**976,893 (40%)**
End 2025	Cork City	3,565	120,828
	Galway	7,529	71,144
	Limerick	2,874	62,575
	Cumulative Total (by end of 2025)	**67,007**	**1,231,440 (51%)**

The mapping strategy is based on GIS geospatial validation which is the preferred method of choice for achieving the yearly mapping target (12.5%) from 2022 and beyond. This was decided after analysing and comparing all the mapping solutions by considering cost, time, risks, resources, and training requirements associated with them.

Criteria for selection of locations:

GIS geospatial validation will prioritise sub-stations with maximum number of customers (MPRNs) in each planner group. Therefore, the urban areas with sub-stations having the greatest number of MPRNs are selected to meet the yearly targets for the PR5 period. In addition, it is assumed that the GIS records in these areas are expected to be average to good (with at least some GIS records existing in GIS system) to build out the complete connectivity model.

Once the maps are corrected in the GIS system using GIS geospatial validation, they will be overlayed into other mapping options (as shown in image below) to get the complete customer referencing information and identify the correct customer outlet, phase, and sub-station. Also, as smart meters are predominantly rolled-out in the urban areas, this will be favorable to develop the complete connectivity model of all customers (using other options) and map the LV network.

In addition, the ESB Networks' team is also considering locations that are prioritized for flexibility services for mapping those areas, as they'll be important to develop network models and make informed decisions from the lessons learnt form the various pilot initiatives. The LV mapping strategy will be reviewed periodically in line with revised requirements for facilitating flexibility services.

G. INSTALLATION OF LV MONITORS IN MV/LV SUB-STATIONS

ESB Networks is planning to install 10,660 monitors in both ground mounted and pole mounted MV/LV sub-stations during the PR5 period to have an active, real-time view of the LV network. LV monitoring is necessary for ESB Networks to offer flexibility services to its customer base, and to enable their participation in all markets for flexibility.

Each device procured as per the specification that ESB Networks has put to market will measure voltage and current in up to 6 LV circuits in the MV/LV substation. The selected device will use these measurements to calculate active and reactive power, power factor, power flow direction, and power quality total harmonic distortion (THD) at the monitored location. Initially each measurement and calculation will be communicated back to ESB Networks' IT systems via 4G connection initially, however communication will be via ESB Networks' private long term evolution 4G) network once it becomes available. The data will be fed back to this cloud platform through ESB Networks' private long term evolution network. This cloud platform will have a web interface that can be used by ESB Networks' staff, and an API or FTP link so that the data can be accessed.

The device shall be actively powered from mains single phase or three phase electricity. The device shall be connected to the voltage leads through a removable plug, which shall have the ability to be locked onto the device.

Each device will have on-board memory which will be capable of storing measurements if the data signal is lost. These stored measurements will again be communicated back to ESB Networks once the data connection has been restored. Devices will be powered off the LV network and will have a capacitor backup so that they can perform a last gasp communication in the event of power failure. The devices will be sufficiently rated to protect against weather conditions and requirements will specify IP55 for ground mounted substations, and IP66 for pole mounted devices.