INVERARNAN 132kV SUPPLY AREA: STRATEGIC DEVELOPMENT PLAN

Our network serving communities across the Western Scottish Highland area

Draft for Consultation

September 2025

Scottish & Southern Electricity Networks

1. EXECUTIVE SUMMARY

Scottish and Southern Electricity Networks (SSEN) is taking a strategic approach to the development of its distribution networks. This will help to enable the net zero transition at a local level to the homes, businesses, and communities we serve.

Our Strategic Development Plans (SDPs) incorporate stakeholder feedback on future energy needs through to 2050 and translate these insights into strategic spatial plans for the future distribution network requirements. This enables us to transparently present our future conceptual plans and facilitate discussion with local authorities and other stakeholders. The overall methodology and how this fits into our wider strategic planning process is presented in the Strategic Development Plan Methodology (Strategic Development Plan Methodology - January 2025).

The focus area of this SDP is that supplied by Inverarnan 132kV supply area in the western Scotland area, as shown in Figure 1.

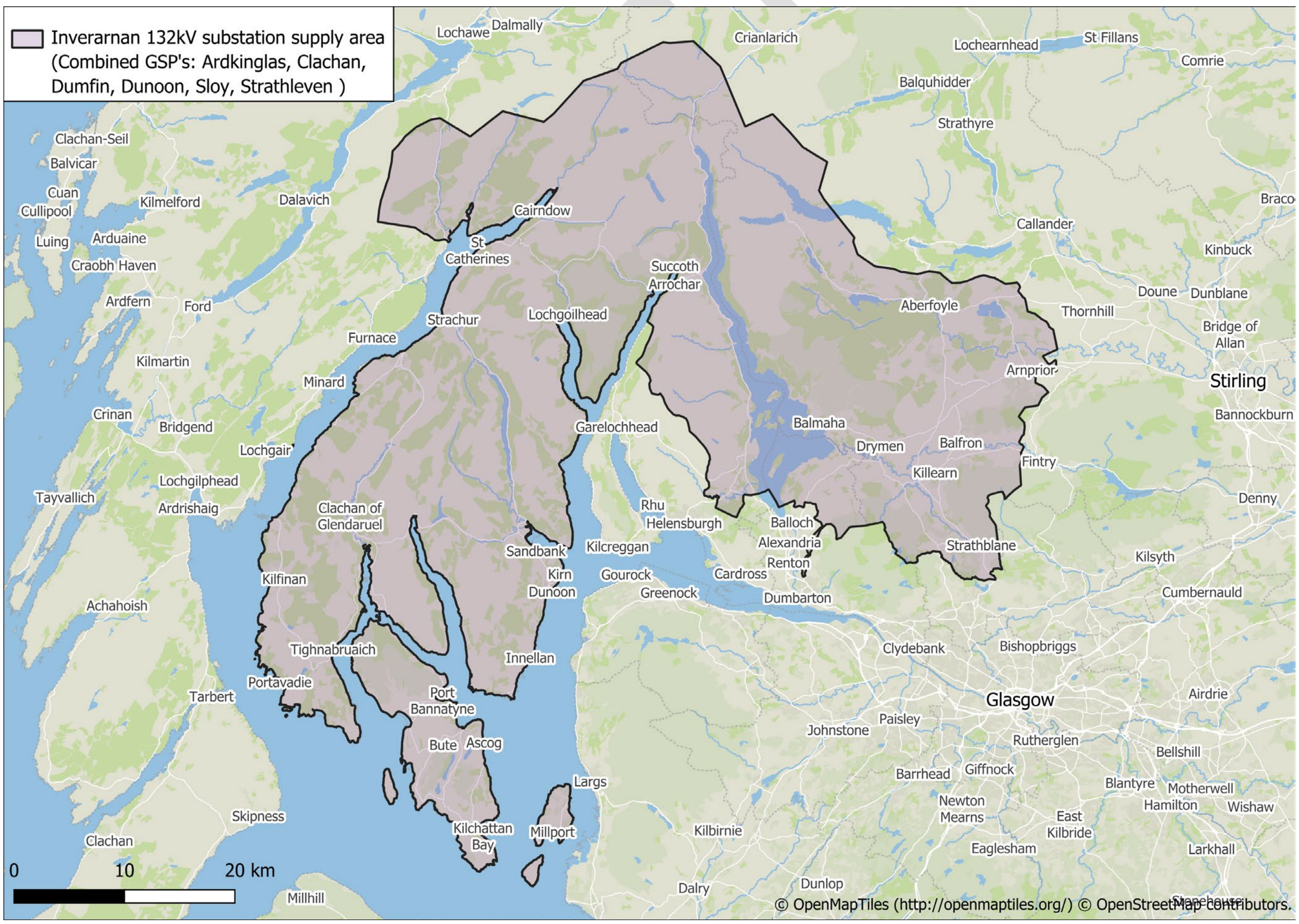

Figure 1: Area of focus for this SDP

This report documents the stakeholder led plans that are driving net zero and growth in the local area, the resulting electricity demands and the network needs arising from this. Plans across the western Scottish

Highlands have been considered in preparation of this plan. Some reinforcement work has been triggered in this area through the Distribution Network Options Assessment (DNOA) process.

This SDP utilises the Distribution Future Energy Scenarios (DFES) to understand the pathway to a 2050 network that can support net zero and growth in the local economy. Recommendations from this report outline the initial steps that we believe should be taken on that pathway to develop the network in an efficient and stakeholder-led way.

2. INTRODUCTION

The aim of this report is to demonstrate how local, regional and national targets link with other stakeholder views in the area to provide a robust evidence base for load growth out to 2050 across the Ardkinglas, Clachan, Dumfin, Dunoon, Sloy and Strathleven (GSPs) that make up the Inverarnan 132kV substation supply area. A GSP is an interface point with the national transmission system where SSEN then take power to local homes and businesses within a geographic area. In this SDP a number of such GSPs have been grouped by electrical connection to cover a larger area. Context for the area this represents is shown above in Figure 1. This report was produced in alignment with SSEN's Strategic Development Plan methodology[1]. The methodology report outlines the process that we follow in the development of our Strategic Development Plans and should be referred to alongside this report.

To identify the future requirements of the electricity network, SSEN commissions Regen to produce the annual Distribution Future Energy Scenarios (DFES). The DFES analysis is based on the National Energy System Operator (NESO) Future Energy Scenarios (FES), while incorporating more granular stakeholder insights from agencies such as local authorities and new demand and generation connection applications. The DFES provides a forward-looking view of how demand and generation may evolve under different scenarios as we move towards the national 2050 net zero target. These scenarios are summarized in Figure 2. SSEN uses Holistic Transition as the central case scenario, reviewing this position annually. Any more recent unforeseen demand changes, for example customer connection requests, is also considered in our forecasts to ensure that the projected load more accurately reflects what we expect to see in the future.

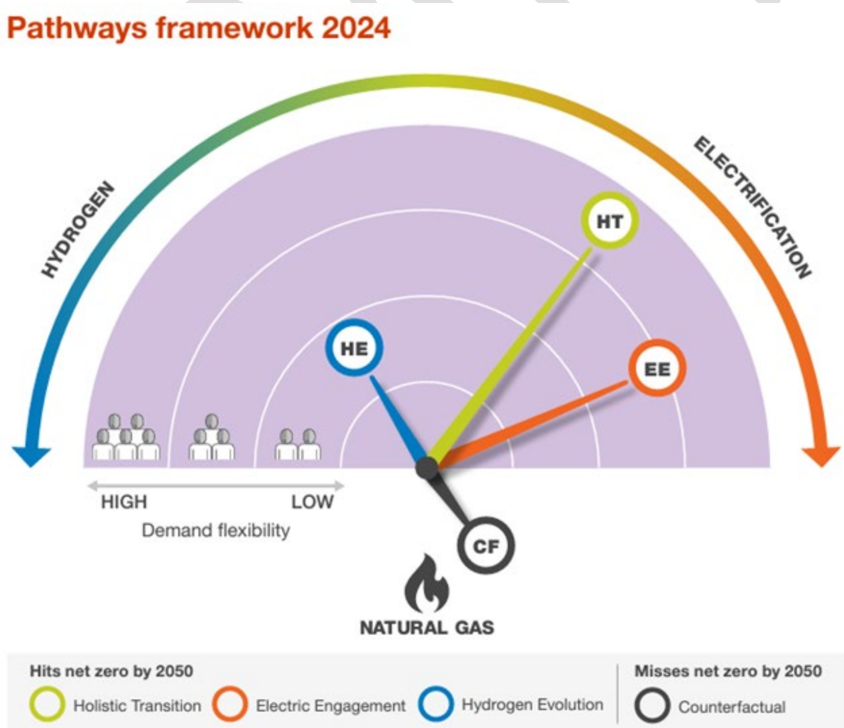

Figure 2: DFES 2024 Scenarios. Source ESO FES2023

1 Strategic Development Plan Methodology - January 2025

Using the DFES, power system analysis has been carried out to identify the future system needs of the electricity network. These needs are summarised by highlighting the year the need is identified under each of the scenarios, and the projected 2050 load. We model across the other scenarios alongside Holistic Transition to understand when these needs arise and what network capacity should be planned for in the event each scenario is realised.

The DNOA process provides more detailed optioneering for each of these system needs, improving stakeholder visibility of the strategic planning process. Opportunities for the procurement of flexibility are also highlighted in the DNOA to cultivate the flexibility markets.

Further information on the FES framework can be found in the DFES 2024 introductory report.

3. STAKEHOLDER ENGAGEMENT AND WHOLE SYSTEM CONSIDERATIONS

3.1. Local Authorities and Local Area Energy Planning

The electrical network covered by this SDP supplies areas within Argyll and Bute Council, Stirling Council, West Dunbartonshire and North Ayrshire, as shown in Figure 3. The plan covers the Cumbraes in North Ayrshire and the north-eastern part of West Dunbartonshire, as well as Bute in Argyll and Bute. It also includes Loch Lomond National Park. The development plans across these local authorities will significantly impact the potential future electricity load growth on SSEN's distribution network. Therefore, it is crucial for SSEN to engage with these plans when carrying out strategic network investments.

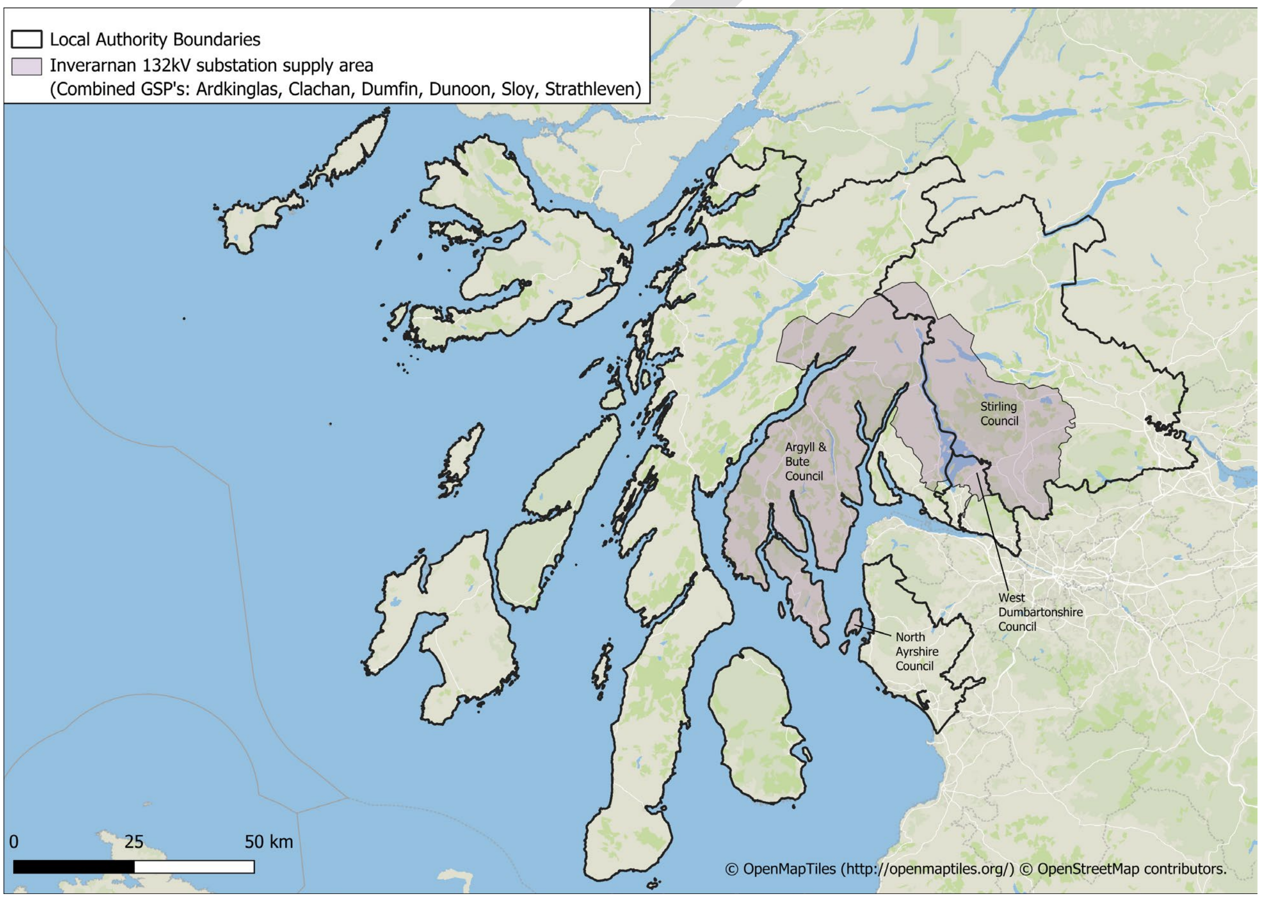

Figure 3: Local Authority Boundaries in the Inverarnan 132kV supply area

3.1.1. Argyll and Bute Council

Inverarnan 132kV supply area supplies parts of Argyll and Bute Council. This council has an estimated population of 87,920 (NRS' 2022 based Mid-Year Estimates)[2], making it the 27th highest population out of all 32 council areas in Scotland and covers the second-largest administrative area of any Scottish council, making up almost 9% of the country's land mass. The area has a diverse and vibrant economy, driven primarily by tourism, aquaculture, forestry, distilleries, and renewable energy.

Argyll and Bute Council has an ambition to become a Net Zero organisation by 2045[3],in alignment with national targets. In their 2022-2025 Decarbonisation Plan[4], the Council states that they endeavour to install more solar PV on council buildings, identify further opportunities for renewable energy sourcing, and produce an Electric Vehicle Infrastructure Strategy. The Council is expanding the electric vehicle charge point network via funding secured from Scottish Government[5]. This may involve installing higher voltage connections for rapid charging in towns, villages, and ferry departure points, which are often rural locations. Through March 2026, residents in rural areas can take advantage of ECO Grants to install heat pumps and insulation in their homes[6]. The Council are also progressing the Oban Strategic Development Framework[7].

3.1.2. Stirling Council

Stirling Council recorded an estimated population of 92,530 in the 2022 Census, with Stirling being its largest city. Two Distribution Network Operators (DNOs) manage the area's distribution system: SSEN Distribution and Scottish Power Energy Networks (SPEN). Stirling itself falls within SPEN's licence area, while SSEN predominantly serves the region's more rural areas.

Stirling Council have developed a Regional Energy Masterplan, which was approved in December 2023. They aim to achieve net zero by 2045, in line with Scottish Government targets. The masterplan outlines strategies for enhancing energy efficiency, optimising heat management, increasing renewable energy generation, and sequestering residual emissions to reach net zero. Additionally, the plan fulfils the statutory requirements of the Local Heat and Energy Efficiency Strategies (LHEES).

3.1.3. North Ayrshire (Cumbrae)

The mid-year population estimate for North Ayrshire was 133,570 in 2023[8]. SSEN Distribution supplies the islands of Arran and Great and Little Cumbrae in North Ayrshire. The mainland is supplied by Scottish Power Electricity Networks. This plan includes the Cumbraes only, the isle of Arran has been included with the Port Ann

2 Argyll-bute.gov.uk, May 2024, Population: Where We Live.

3 De-carbonisation plan update Jan 24

4 Decarbonisation Plan 2022 - 2025

5 Electric vehicles | Argyll and Bute Council

6 ECO4 Grant Scheme Scotland: Insulation Solar Panels Heating

7 Oban Strategic Development Framework.pdf

8 Key facts and figures

and Carradale Strategic Development Plan, published by SSEN this year[9]. The main settlement within Great Cumbrae is Millport.

North Ayrshire currently has an ambition to achieve net zero by 2030, ahead of Scottish Government targets. The Council have developed various strategies including the Sustainable North Ayrshire Strategy for 2024 – 2027 which outlines nine priorities and five strategic workstreams, including a Carbon Footprint and Project Register. They have also developed the Council Plan which includes four interconnected priorities: wellbeing, communities and local democracy, climate change and a sustainable council for 2023 – 2028.

3.1.4. West Dunbartonshire

The mid-year population estimate for West Dunbartonshire was 88,750 in 2023[10]. The area is mostly served by Scottish Power Electricity Networks, including the communities of Balloch, Dumbarton, and Alexandria. SSEN supplies the northern area of West Dunbartonshire, including the village of Gartocharn and the southern part of Loch Lomond.

West Dunbartonshire Council has an ambition to achieve net zero by 2045, aligning with Scotland's national net zero targets. The Council has developed a Climate Change Strategy as a route map to achieving their net zero ambition. This overarching strategy is implemented through the Climate Change Action Plan, which outlines short, medium, and long-term measures to mitigate and adapt to climate change[11]. The Climate Action Hub has been setup to empower communities across West Dunbartonshire to take climate action. In addition, the Council has received support through the Towards Net Zero Grant, helping to accelerate local decarbonisation projects and community-led climate initiatives[12].

3.2. Whole System Considerations

We have worked closely with local stakeholders, customers, market participants, government bodies and SSEN Transmission to build upon our engagement prior to RIIO-ED2, in order to develop an enduring whole system solution to meet the future energy needs of the Inverarnan 132kV supply area and to enable the region to support the transition to net zero through its extensive natural resource potential.

Through our whole system approach, several options have been considered. The route to decarbonisation for coastal regions will rely on a mix of various energy vectors, for example renewable energy resources and supporting infrastructure. Offshore wind, subsea interconnectors and other clean generation technologies will provide low carbon electricity, while alternative energy vectors such as hydrogen and e-fuels can support shipping, heavy transport and port operators. As a result, whole system thinking is required to progress solutions that benefit the whole system rather than favouring a particular energy vector.

---

9 port-ann-and-carradale-grid-supply-points---strategic-development-plan---april-2025.pdf

10 West Dunbartonshire - National Records of Scotland (NRS)

11 west-dunbarton.gov.uk/media/4319776/climate-change-strategy.pdf

12 Towards Net Zero Grant | West Dunbartonshire Council

3.2.1. Transmission Interactions

Due to the significant potential for renewable energy resources across the western Scotland area and the Inverarnan 132kV substation supply area, there is a list of contracted generation connections due to connect to the transmission network. To facilitate this, SSEN Transmission have a long-term strategy which consists of two projects that are relevant to the Inverarnan 132kV supply area[13]:

- Inverarnan 132kV Quadrature Booster (QB);
- Creag Dhubh Network Management Scheme;

Inverarnan 132kV QB[14]

A QB is an electrical device to manage flows on a transmission network. This project would see the supply and installation of power flow control devices to provide required power flow stability within local area network.

Creag Dhubh Network Management Scheme

This project will see the Installation of an intertrip scheme between Creag Dhubh, Dalmally, Inverarnan and Windyhill 275kV substations, which will monitor the Dalmally – Creag Dhubh – Inverarnan – Windyhill 275kV double circuit tower line.

There remains an open dialogue between Scottish Power, SSEN Transmission and Distribution regarding the portfolio and as the future plans pass through strategic planning and development processes, this open dialogue will be a key component in a successful whole system solution for the central highlands area. SSEN Distribution will continue to engage with SSEN Transmission regarding the evolution of their plans for the network covered by this SDP.

3.2.2. Load Managed Areas (LMAs)

Historically we have managed electrical heating demand in this area using Load Managed Areas (LMAs). These have relied on the use of radio teleswitches to optimise residential heating demand. Moving forwards, we will continue to value this use of flexibility to manage demand, and we are in the process of transitioning to a market-based solution. In the spirit of a Smart and Fair transition, SSEN have committed to removing LMAs during ED2 and ED3.

The percentage of customers currently subject to LMA ruling are outlined in Table 1 below.

Substation Name	Site Type	% of RTS customers
Clachan GSP	Grid Supply Point	22.8
Dunoon GSP	Grid Supply Point	10.2
Sloy GSP	Grid Supply Point	n/a
Strathleven GSP	Grid Supply Point	13.6

13 Transmission Owner Reinforcement Instruction (TORI), Quarterly Update Report, February 2025

14 Transmission Owner Reinforcement Instruction (TORI), Quarterly Update Report, February 2025

Table 1: Number of LMA customers subject to RTS (2024)

3.2.3. Security of Supply

Engineering Recommendation P2/8 requires Distribution Network Operators to maintain security of supply to its connected customers in line with the standards laid out in that document, depending on the total demand of the substation. Scottish Hydro Electric Power Distribution (SHEPD) electricity distribution network includes a number of networks that were installed in the period 1950 - late 1980s to provide the first mains electricity supplies to rural communities. These networks were installed on a minimum cost basis and did not meet the standards laid out in Engineering Recommendation P2/8. It was previously considered uneconomic to improve them and these were therefore determined to be exempt from the Engineering Recommendation P2/8. In the context of decarbonisation and increased reliance on electricity, as demand rises in these areas, this position will be reviewed for larger demand groups and where justified the exemption will be removed.

3.3. Flexibility Considerations

SSEN procures Flexibility Services from owners, operators, or aggregators of Distributed Energy Resources (DERs) or Consumer Energy Resources (CERs), which can be generators, storage, or demand assets. These services are needed in areas of the network which have capacity constraints at particular times or under certain circumstances. SSEN purchases Flexibility Services from all types of providers (e.g. domestic or commercial). Information on the process of procurement and how to participate are published on the Flexibility Services website 15 and information on real time decision making on which providers are dispatched can be found in the Operational Decision-Making document[16,17].

SSEN regularly recruits new Flexibility Services providers and increases the procured Flexibility Services with the latest bidding round for long term requirements held in May 2025 and recruitment through the Mini-Competition process most recently opening in mid-July 2025[2].

15 Flexibility Services - SSEN

16 SSEN, Flexibility Services Procurement (Flexibility Services Procurement - SSEN)

17 SSEN, 02/2024, Operational Decision Making (ODM), (SSEN Operational Decision Making ODM)

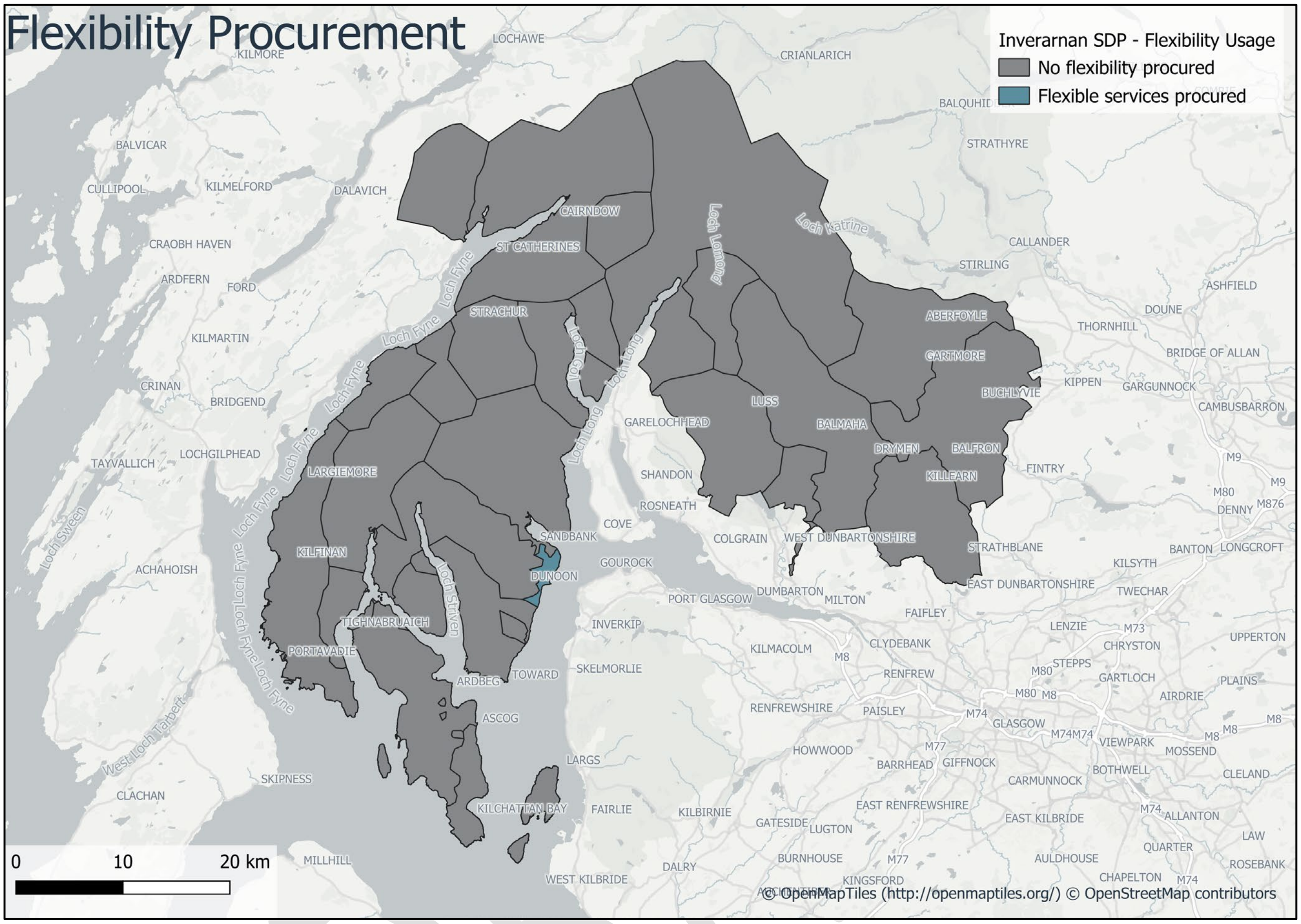

Figure 4: Flexibility procurement areas across Inverarnan 132kV supply area

To date, Dunoon is the only region within Inverarnan that flexibility has been procured. The area will continue to be monitored for future opportunities to deploy this service.

4. EXISTING NETWORK INFRASTRUCTURE

4.1. Inverarnan 132kV Supply Area Context

The Inverarnan 132kV supply area network is made up of 275kV, 132kV, 33kV, 11kV, and LV circuits. It is a mix of rural and urban network spanning across the Scottish highland region. While much of the land is used for agricultural purposes, there is a mix of residential, commercial, and industrial land, which is located throughout the supply area. In total, the Inverarnan 132kV supply area supplies approximately 22,900 customers with the breakdown for each Grid Supply Point shown in Table 2 below. A further breakdown by primary substation can be found in Appendix A.

Substation Name	Site Type	Number of Customers Served	2023/24 Substation Maximum MVA (Season)
Clachan GSP	Grid Supply Point	1,200	3.65 (Winter)
Dunoon GSP	Grid Supply Point	15,600	19.12 (Winter)
Sloy GSP	Grid Supply Point	615	2.63 (Winter)
Strathleven GSP	Grid Supply Point	5,200	10.23 (Winter)
TOTAL		22,900	25.39 (Winter)

Table 2: Customer number breakdown and substation demand readings (2024)

4.2. Current Network Topology

Figure 5 below highlights the existing 33kV network topology in the Inverarnan 132kV supply area. The SSEN Transmission network supplies the distribution network at various Grid Supply Point (GSP) sites. It is then distributed to the primary substations via the 33kV distribution network.

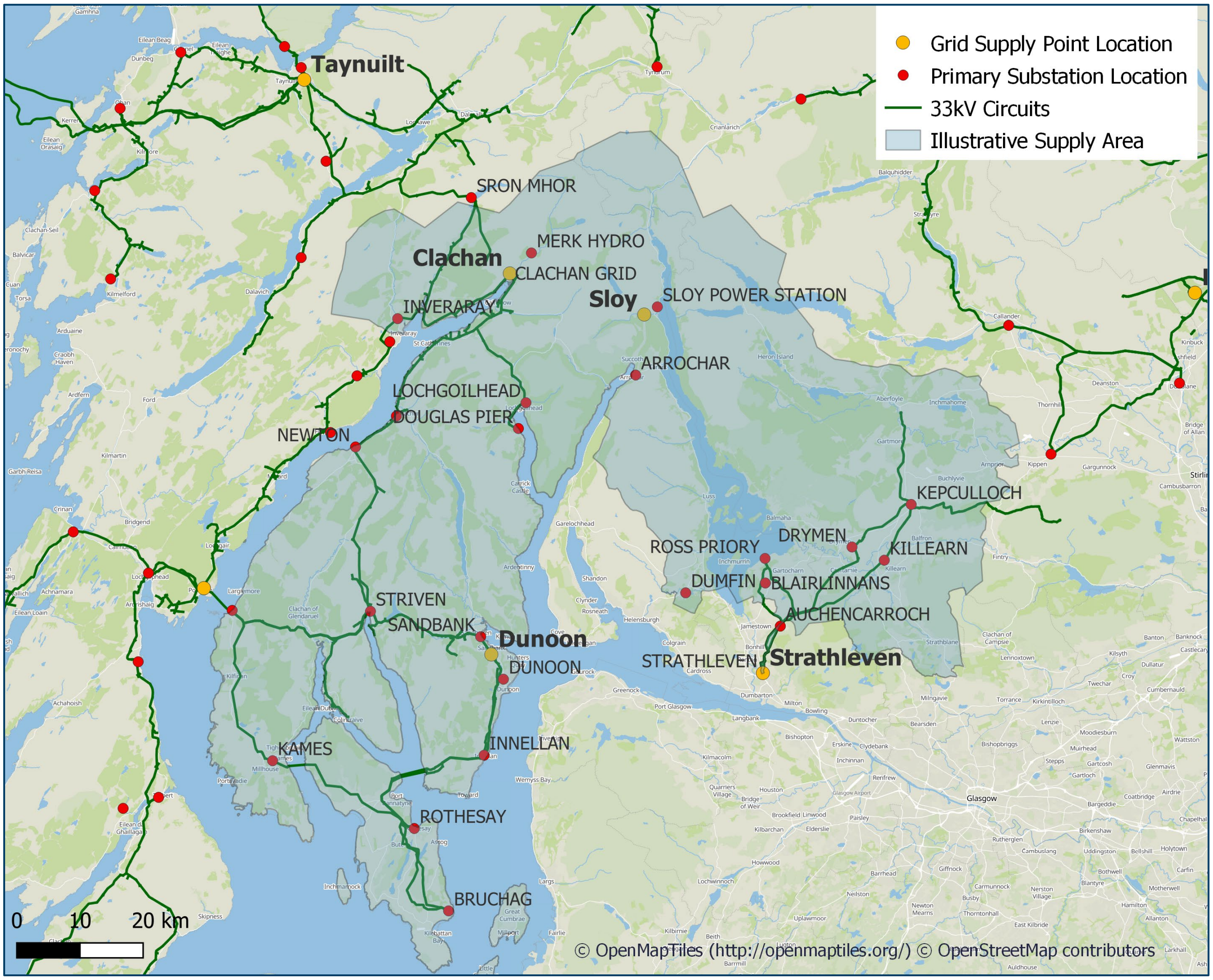

Figure 5: Current network topology of the Inverarnan 132kV supply area.

4.3. Network Schematic

The network schematics in Figures 6 - 8 (below) depict the existing 33kV distribution network at Clachan, Dunoon and Strathleven GSPs.

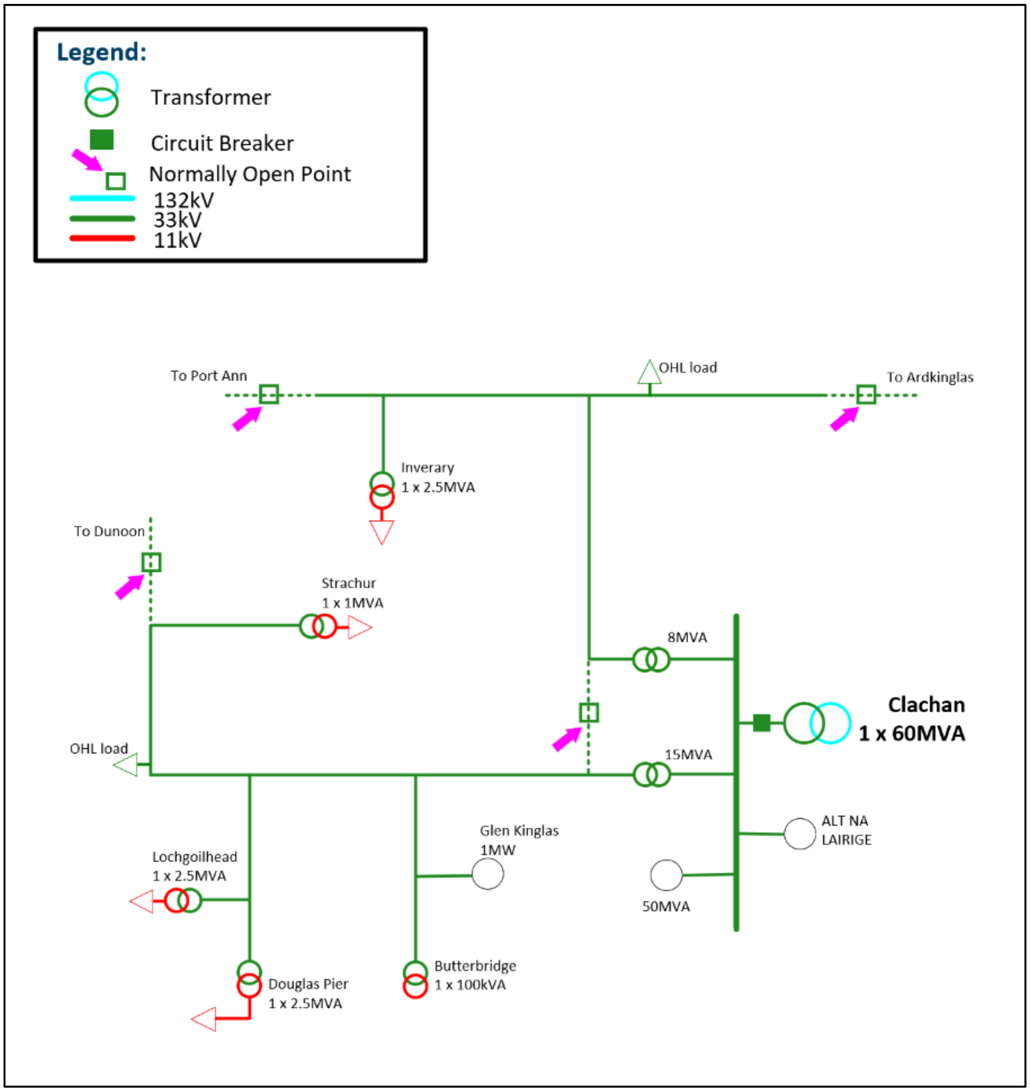

Figure 6: Existing Clachan 33kV Network Schematic

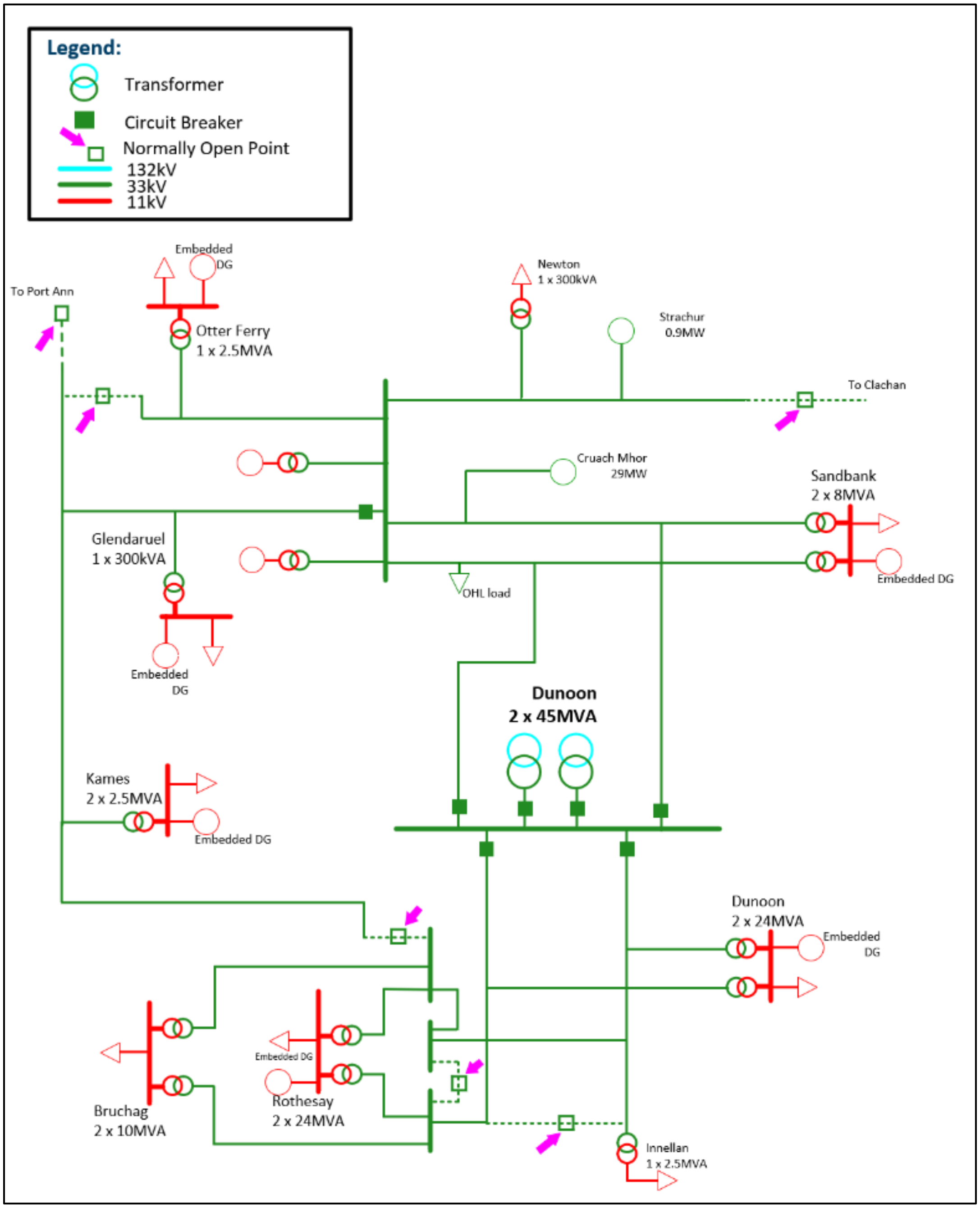

Figure 7: Existing Dunoon 33kV Network Schematic

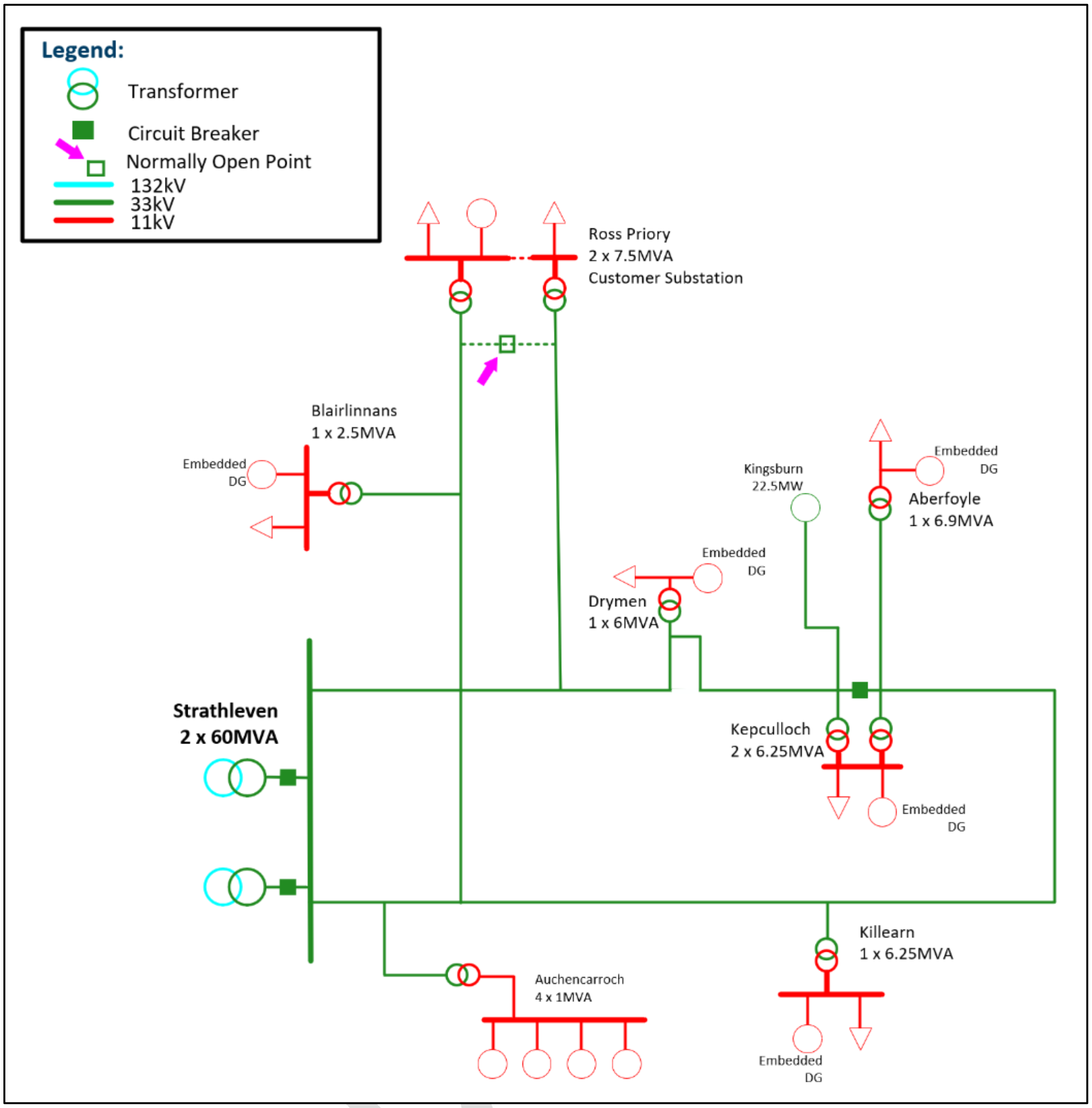

Figure 8: Existing Strathleven 33kV Network Schematic

5. FUTURE ELECTRICITY FORECASTS FOR THE INVERARNAN 132KV SUPPLY AREA

The following section details load growth across the technologies projected in the Distribution Future Energy Scenarios. There are important notes on the values presented here:

- This SDP and the analysis conducted has been completed ahead of any changes arising from Clean Power 2030.
- These projections relate to the GSP supply area highlighted in Figure 3 and are not directly aligned to a particular local authority.
- Where MW values are presented in this section, they represent total installed capacity. When conducting network studies these values are appropriately diversified to reflect the likely peak demand experienced on the network. Diversifying load values accounts for the fact that not all demand load connected to the network peaks at the same time and so provides a more realistic total expected peak power.
- For projections specific to individual primary substations or local authorities, please refer to our online dashboard.[18]

5.1. Generation and Electricity Storage

DFES Scenario	Generation capacity (MW)				Electricity storage capacity (MW)			
	Baseline	2030	2040	2050	Baseline	2030	2040	2050
Holistic Transition	58MW	192 MW	237 MW	280 MW	0MW	55 MW	68 MW	76 MW
Electric Engagement		193 MW	242 MW	282 MW		55 MW	63 MW	72 MW
Hydrogen Evolution		133 MW	167 MW	203 MW		54 MW	59 MW	65 MW
Counterfactual		130 MW	149 MW	172 MW		53 MW	55 MW	59 MW

Table 3: Projected cumulative generation and electricity storage Inverarnan 132kV Supply Area (MW).
Source: SSEN DFES 2024

18 SSEN DFES Technology Projections - Microsoft Power BI

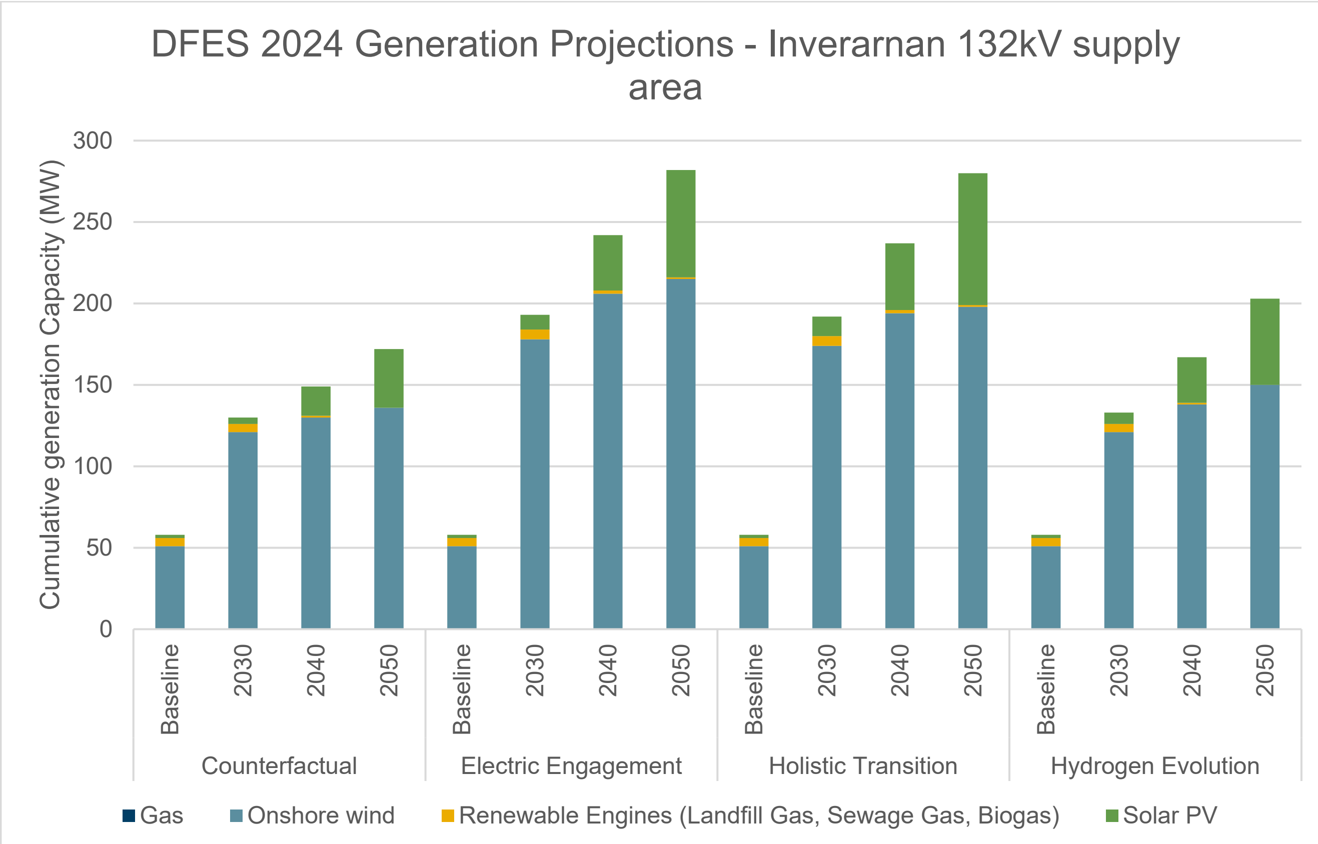

Figure 9: Projected cumulative distributed generation capacity across Inverarnan 132kV Supply Area.
Source SSEN DFES 2024

5.2. Electric Vehicle Charging

DFES Scenario	Domestic EV chargers – off-street (number of units)				Non-domestic EV chargers & domestic on-street EV chargers (MW)			
	Baseline	**2030**	**2040**	**2050**	**Baseline**	**2030**	**2040**	**2050**
Holistic Transition	132	2,989	11,887	12,225	0MW	0MW	9MW	10MW
Electric Engagement		5,070	11,965	12,227		2MW	9MW	10MW
Hydrogen Evolution		2,933	11,689	11,986		1MW	8MW	8MW
Counterfactual		2,345	9,248	11,903		0MW	5MW	9MW

Table 4: Projected cumulative Electric Vehicle Charge Point Capacity across Inverarnan 132kV Supply Area (MW).
Source: SSEN DFES 2024

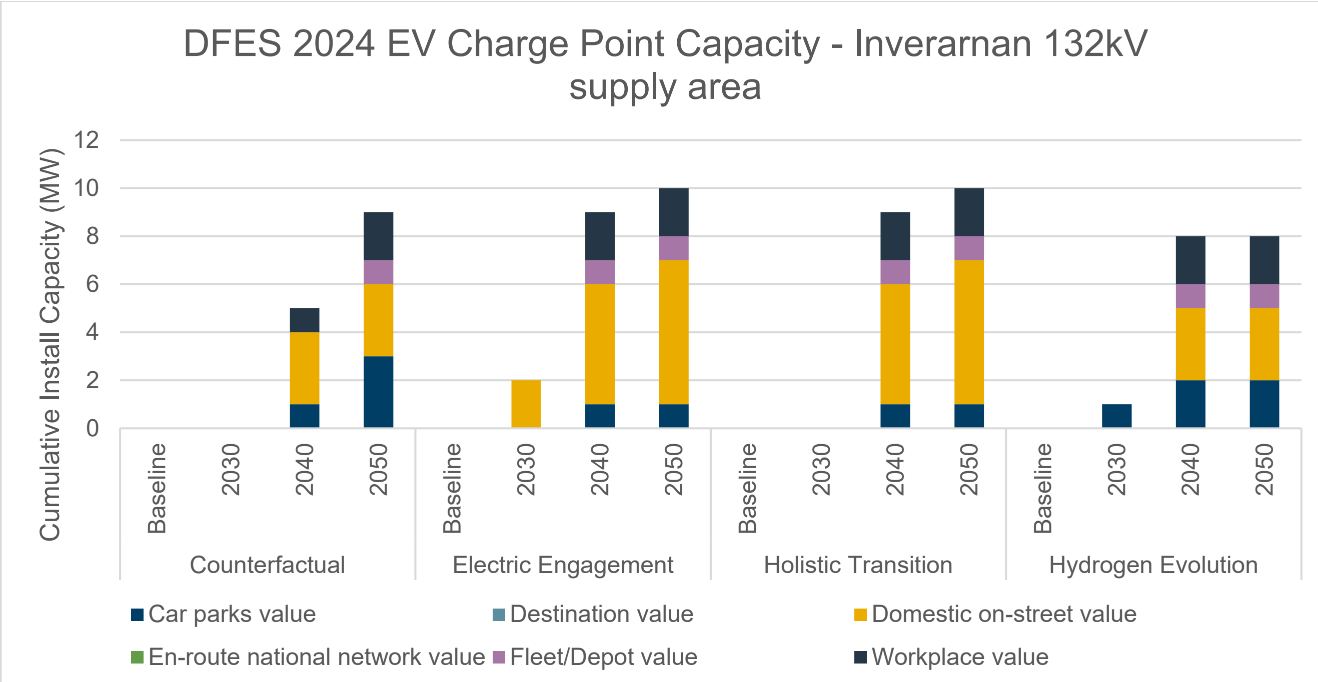

Figure 10: Projected cumulative EV Charge Point Capacity across Inverarnan 132kV Supply Area.
Source SSEN DFES 2024

5.3. Electrification of heat

DFES Scenario	Non-domestic heat pumps and resistive electric heating (m² of floorspace)				Domestic heat pumps (number of units)			
	Baseline	2030	2040	2050	Baseline	2030	2040	2050
Holistic Transition	0m²	0m²	41,420m²	41,420m²	7,278	10,380	19,836	22,685
Electric Engagement		0m²	36,954m²	36,954m²		10,354	20,303	24,629
Hydrogen Evolution		0m²	36,954m²	36,954m²		9,141	17,365	22,540
Counterfactual		0m²	24,598m²	31,201m²		8,480	12,101	20,842

Table 5: Projected cumulative Domestic Heating / Cooling Technologies across Inverarnan 132kV Supply Area.
Source SSEN DFES 2024

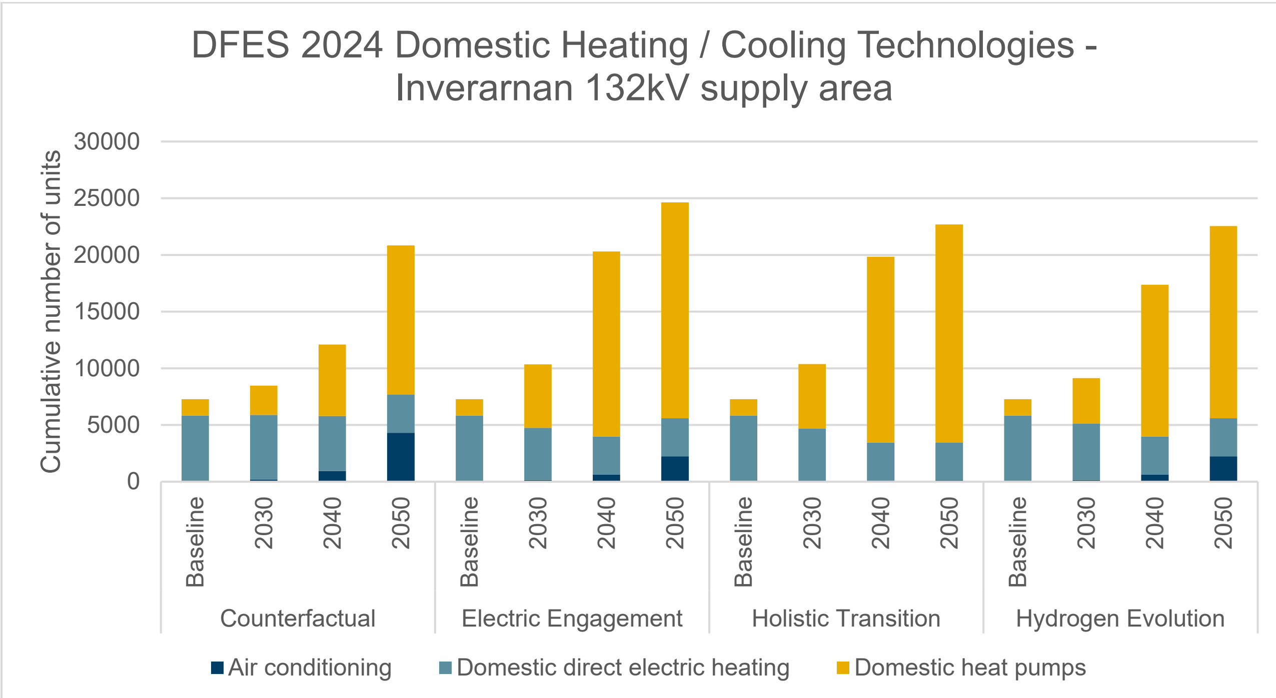

Figure 11: Projected cumulative Domestic Heating / Cooling Technologies across Inverarnan 132kV Supply Area.
Source SSEN DFES 2024

5.4. New Building Development

Through engagement with local authorities, we have developed an understanding of new development across our licence areas. This has allowed us to gauge an insight into future electricity demand for new developments ahead of a formal connection application. Below we investigate the developments across the study area for this SDP.

DFES Scenario	New domestic development (number of homes)			New non-domestic development (m^2)		
	2030	2040	2050	2030	2040	2050
Holistic Transition	622	1784	2681	0m^2	47,106m^2	47,106m^2
Electric Engagement	523	1602	2361	0m^2	47,106m^2	47,106m^2
Hydrogen Evolution	558	1605	2364	0m^2	47,106m^2	47,106m^2
Counterfactual	400	1471	2147	0m^2	35,891m^2	47,106m^2

Table 6: Non-Domestic new developments across Inverarnan 132kV Supply Area.
Source SSEN DFES 2024

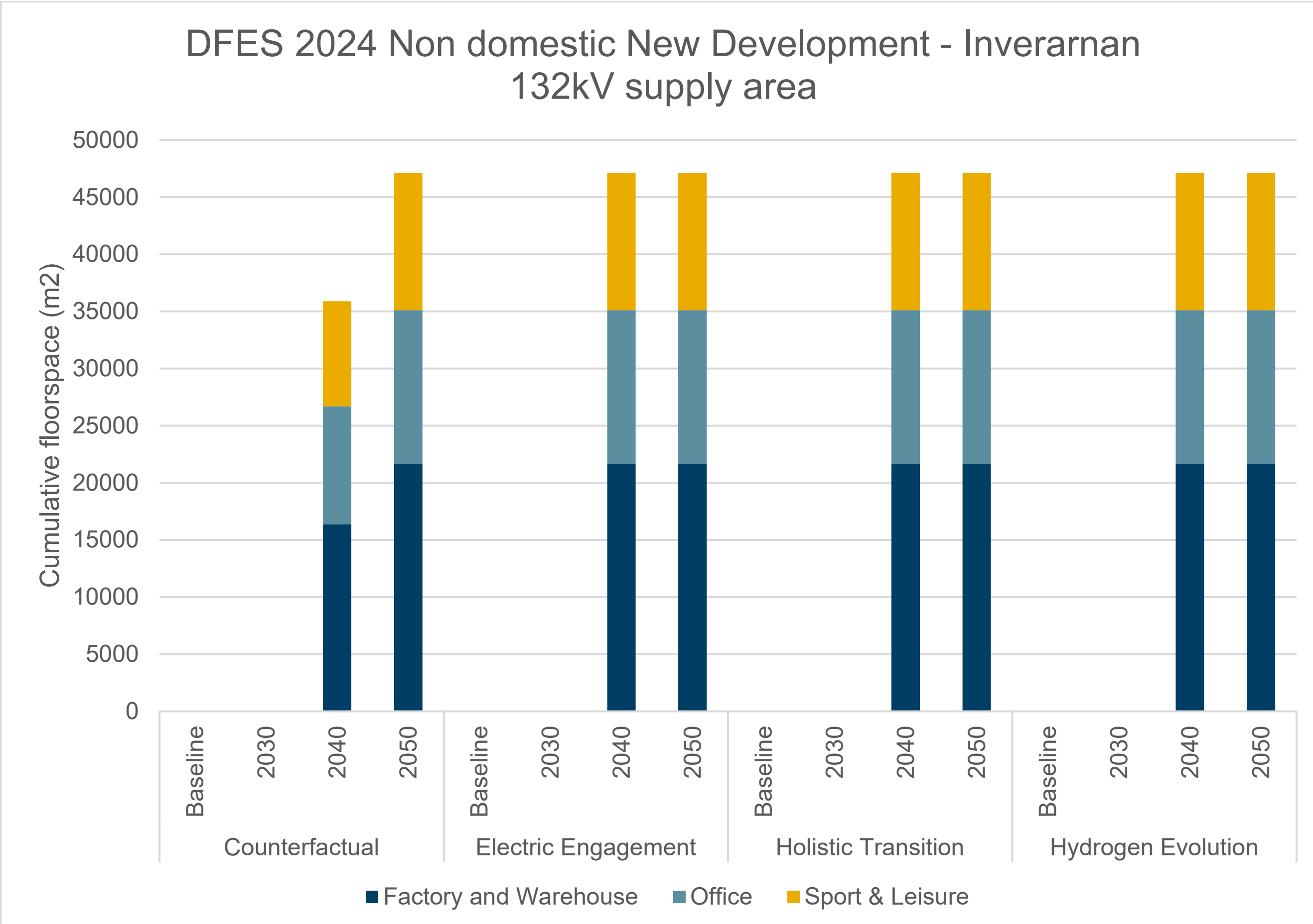

Figure 12: Non-Domestic new developments across Inverarnan 132kV Supply Area.
Source SSEN DFES 2024

5.5. Industrial and Commercial Electrification

The decarbonisation of industries specific to Northern Scotland and broader industries indicate there could be a range of potential electrification outcomes for the Inverarnan 132kV supply area. We have identified a number of industries below as areas of potential significant future industrial demand growth for the region.

Decarbonisation of the agricultural sector is an important consideration in this geographic area. SSEN leads the innovation project 'Future Agricultural Resilience Mapping' (FARM) which aims to understand the future energy requirements and means of decarbonising the domestic farming industry[19]. This sector is currently still largely dependent on fossil fuels, and the project will support its investigations into the impact of food production on the electricity distribution system, to work out where reinforcement is needed. A data-driven tool to inform network planning will be devised and through this work, FARM will address the gap between the energy demands for food production and future network planning.

19 FARM, SSEN Innovation Project, 09/2025, FARM | SSEN Innovation

SSEN leads an innovation project aimed at better understanding the potential electricity demands arising from the maritime industry, so assets and network in the area can be sized appropriately. SSEN's SeaChange innovation project has been funded through the Strategic Innovation Fund[20]. This project involves building a 'Navigating Energy Transitions' (NET) tool, which will help ports to plot their most viable pathways for decarbonisation.

20 SeaChange, SSEN Innovation Project, 10/2024, SSEN's nature and shipping innovation projects win £1m in new development funding - SSEN

6. WORKS IN PROGRESS

Network interventions can be caused by a variety of different drivers. Examples of common drivers are load-related growth, specific customer connections, and asset health. Across the Inverarnan 132kV supply area, these drivers have already triggered network interventions that have progressed to detailed design and delivery. For works to be delivered within the RIIO-ED2 timeframe, these works are assumed to be complete, with any resulting increase in capacity considered to be released.

This report highlights ongoing capital works to meet the demand and generation requirements within the Inverarnan 132kV supply area. A summary of existing works is shown in Table 4 below and further information on the schemes which have recently been through our DNOA process can be found in Appendix E. The network considered for long-term modelling is shown below in Table 7.

ID (Schematic Reference)	Substation	Description	Driver	Forecast completion	Fully resolves future strategic needs to 2050?
		Dunoon GSP			
1	Dunoon GSP	Reinforce existing circuits from Dunoon GSP to Dunoon and Rothesay PSS to address future load-related thermal and voltage issues on feeder 306 and 307 under N-1 operating conditions. Replace existing Craigagoul 33kV switching station with switchboard, comprising of 10 x 33kV breakers and two 8MVAr STATCOMs.	Security of Supply	2028/29	
		Strathleven GSP			
2	Strathleven GSP	Replace a section on the Strathleven 2L5 33kV circuit, replace 0.82km of 300mm2 Al XLPE with 800mm2 Al XLPE. 5.9km of 0.15in ACSR to be reinforced to operate at 65oC.	Customer Connection	2030/31	
3	Drymen PSS	Upgrade existing 6MVA TX to 7.5/15MVA.	Customer Connection	2027/28	

4	Kepculloch	Upgrade existing 2 x 5/6.25MVA to 7.5/15MVA.	Customer connection	2029/30	
5	Killearn PSS	Upgrade existing 6.25MVA TX to 7.5/15MVA	Customer Connection	2027/28	

Table 7: Works already triggered

Where the above works are marked as not providing sufficient capacity for 2050 peak demands, it is important to note that this relates to the individual primary substation's firm capacity. When considering the further works identified in this report, the holistic plans provide capacity across the whole Inverarnan 132kV substation supply area for 2050.

6.1. Network Schematic and GIS View (following completion of above works)

The network considered for long-term modelling is shown below in Figures 13 - 14.

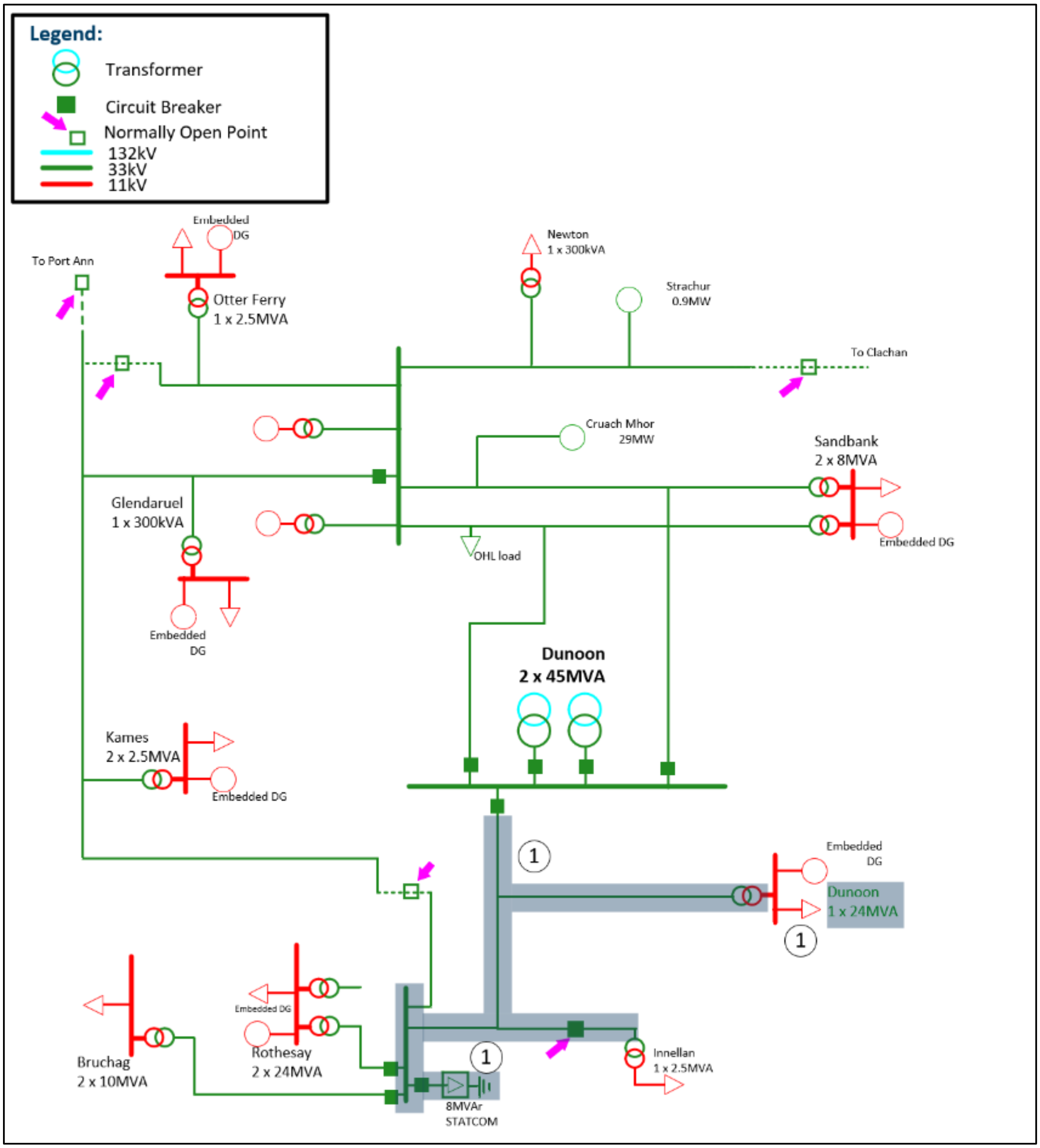

Figure 13: Future distribution network development Dunoon 33kV supply area

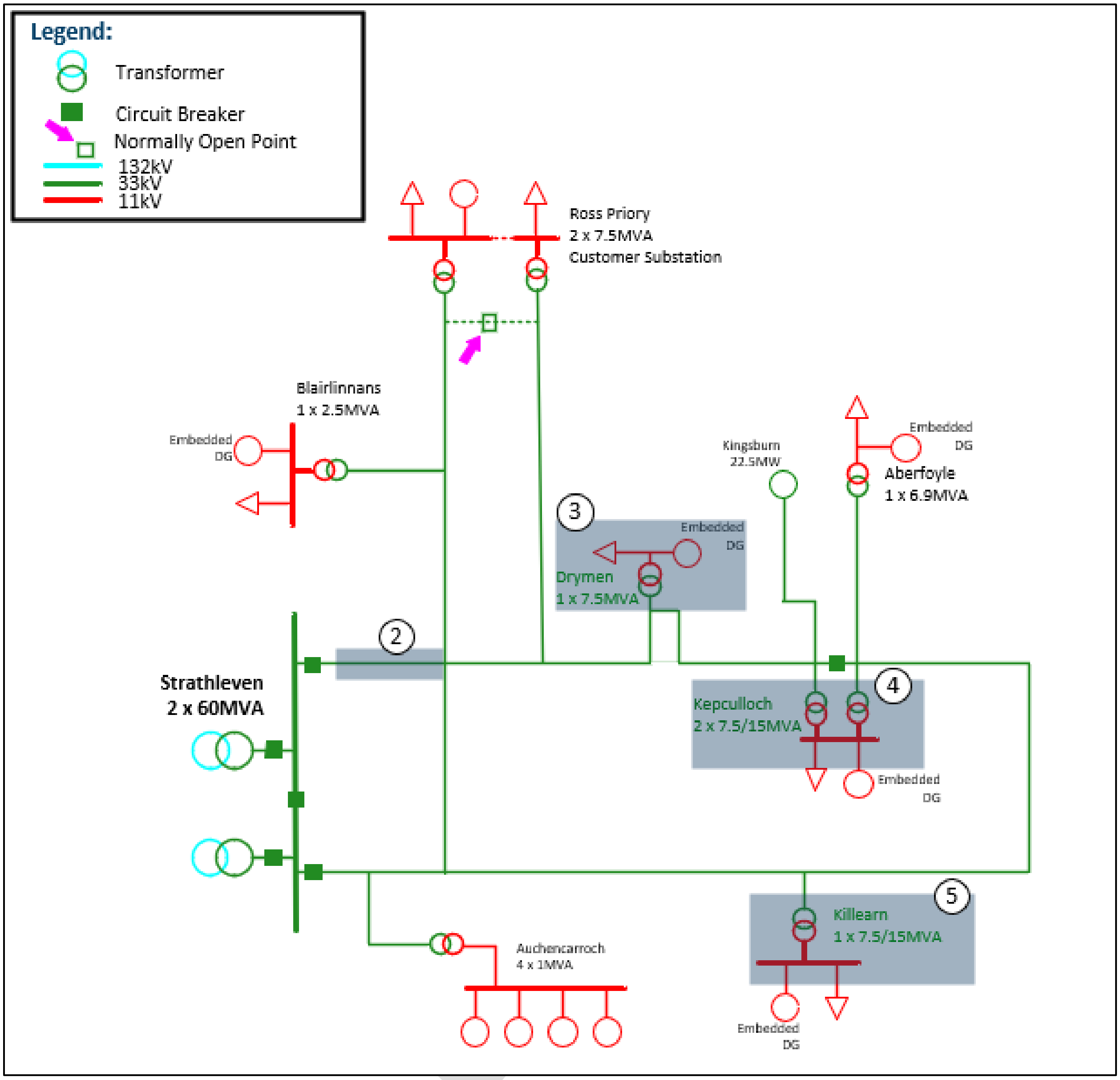

Figure 14: Future distribution network development Strathleven 33kV supply area

7. SPATIAL PLANS OF FUTURE NEEDS

7.1. Extra High Voltage/High Voltage Spatial Plans

The EHV/HV spatial plans shown below in Figure 15 shows the projected headroom or capacity shortfall due to demand increases at primary substations across the Inverarnan 132kV supply area. Darker purple shades indicate that there is a projected capacity shortfall whereas lighter shades indicate that there is headroom capacity based on current projections. EHV/HV spatial plans for the other DFES pathways are presented in Appendix B. The values are taken from the Network Scenario Headroom report (NSHR), part of the Network Development plan (NDP)[21]. It should be noted that the NSHR is produced annually and was last published in May 2025, where work has been triggered between this date and the time of publication of this report, future capacity may not be reflected.

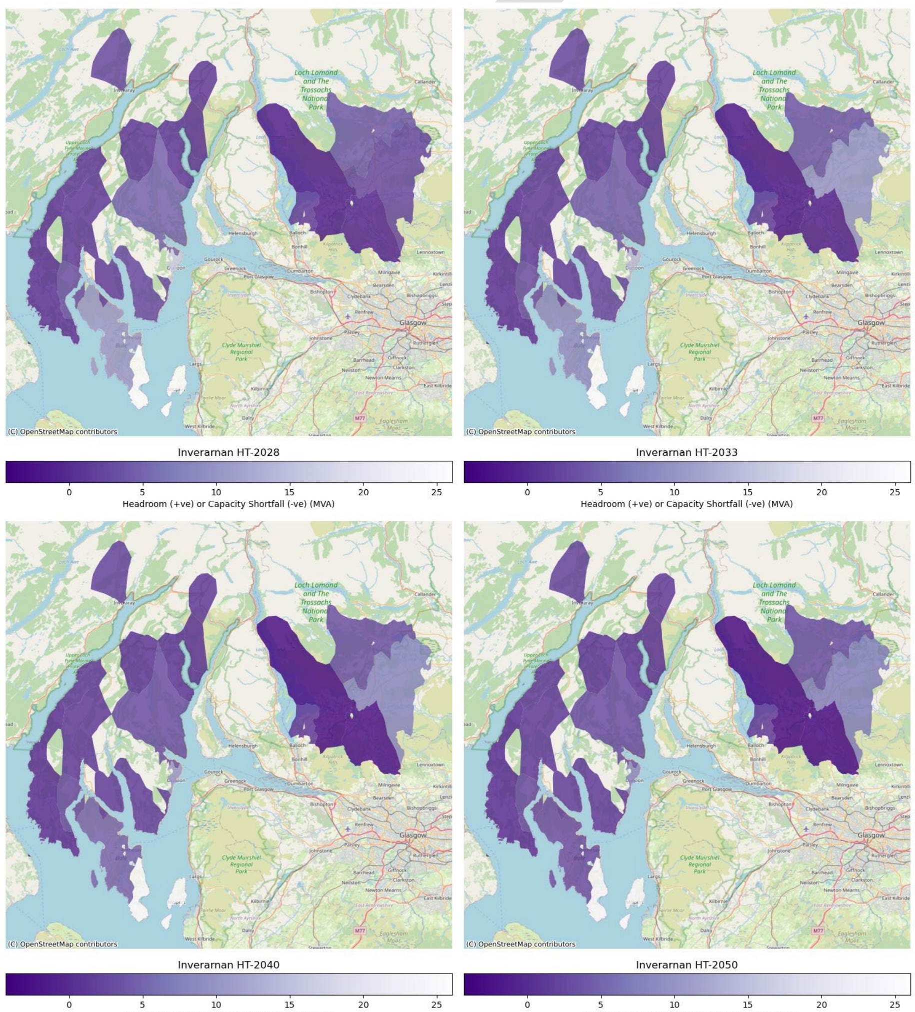

Figure 15: Inverarnan 132kV supply area EHV network spatial plans for HT 2028, 2033, 2040, and 2050

21 [SHEPD Network Development Report - Data Asset - SSEN Distribution Data Portal]

7.2. HV/LV spatial plans

The HV/LV spatial plans shown show the point locations of secondary transformers supplied by Inverarnan 132kV supply area. The secondary transformer projected percentage loadings for each of the four DFES scenarios are highlighted below in Figure 16 and Appendix D. As shown in the legend, the points are coloured based on their percentage loading with green being low percentage loading, and darker reds indicate higher percentage loading (see legend for details on loading bands and colouring).

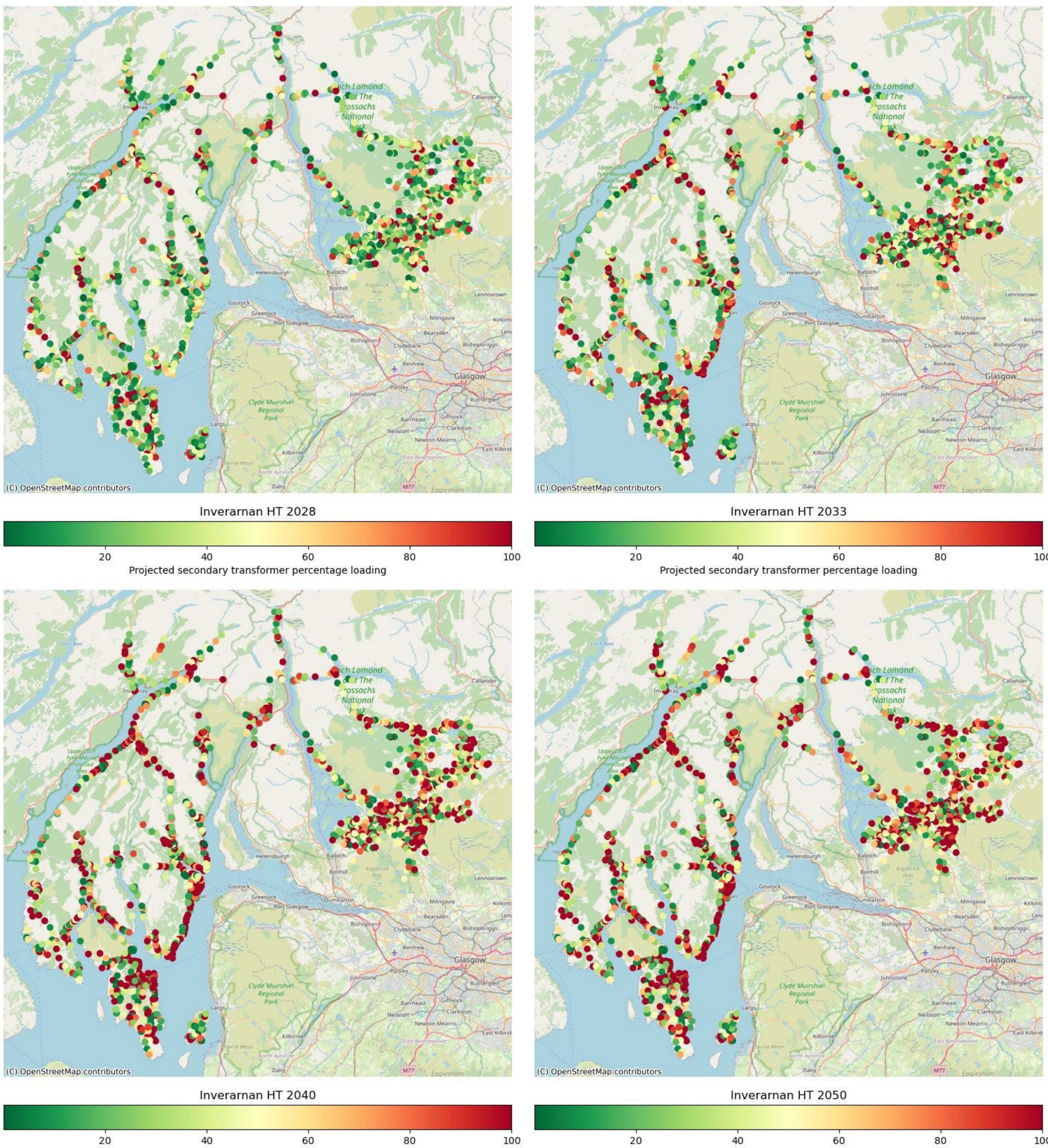

Figure 16: Inverarnan 132kV supply area HV/LV HT spatial plans for 2028, 2033, 2040, and 2050

8. OPTIONS TO RESOLVE SPECIFIC SYSTEM NEEDS

In this section we summarise the specific needs arising from our future spatial plans. The outputs of the power system analysis in this section show where we may observe the need for further intervention on the distribution network. This could be through asset solutions or flexibility services including access products which may be used to enable connection of projects ahead of reinforcement delivery. We also propose some initial options to resolve the needs forecasted. If required during the next ten years, these will be further developed through the DNOA process.

The section consists of two sets of results:

- Future EHV system needs to 2050 – this timeframe provides more opportunities to work with stakeholders to develop strategic plans and our outline solutions reflect this initial phase of the work as we look to engage with interested parties. Any needs within the next 10 years should be progressed through the DNOA process and more detailed development.
- Future HV/LV system needs to 2050 – the future needs of the HV and LV networks are locationally specific but can be considered as an aggregated volume. In this section we provide information on our future forecasts for local HV and LV network needs.

8.1. Overall dependencies, risks, and mitigations

There are several overarching risks to the delivery of our strategic plan. Below we list these alongside proposed mitigating actions. We will work with stakeholders to develop these mitigating actions further.

Highlighted below are the potential dependencies/risks and what we have done here or plan to do in order to mitigate these risks.

Dependency: Connections reform process is likely to change the number and composition of generation/storage projects currently in the connections queue.
Risks: The reinforcements currently planned, that have been triggered by generation connections, may not be necessary if the generation projects drop out of the connections queue.
Mitigation: Works triggered by generation projects that have a level of uncertainty have not been included in the works in the progress or the network modelling. This assumes these works will not release capacity so network can be planned for worst-case scenario in terms of these works going ahead. Network models will be rerun when there is more clarity.

Dependency: Growth of generation in the area may begin to cause reverse power flow on the network. It should be ensured that the assets currently on the network are able to handle the projected levels of reverse power flow and increased fault level.
Risks: Further reinforcement than identified here is required to enable connection of generation. Increasing fault levels leads to damaged distribution network assets.
Mitigation: We should further assess the near-term generation requirements to ensure that we are in a position to facilitate the Clean Power 2030 targets set by DESNZ. Consideration of future fault level to prevent the risk of damaged assets should be considered when designing future schemes.

Dependency: The future works described in this section are only indicative and further detailed study through the DNOA will be required when delivery of the work needs to be initiated.

Risks: Changes in forecasts and/or practical considerations may result in changing the scope of the high-level solutions detailed here.
Mitigation: The purpose of this section is to highlight the long-term requirements based on current forecasts, annual update of the SDP and more detailed assessment in the DNOA will ensure proposed work that is passed from DSO to the asset owner is appropriate.

Dependency: SSEN has committed to removing Load Managed Areas (LMAs) during the ED2 and ED3 price control period.
Risks: Firstly, some of the smart meters being used to replace the radio tele switching may not be able to connect to the smart network. Secondly, participation in flexibility markets from previous LMA customers is not as high as expected.
Mitigation: Technical support is given for the installation of smart meters. Detailed network studies are undertaken for areas most impacted by the removal of LMAs to determine whether flexibility solutions or reinforcements will be required

Dependency: Procurement of flexibility services is required to optimise load related needs.
Risks: Insufficient flexibility in the relevant area to resolve system reinforcement need.
Mitigation: Flexibility viability assessments are carried out as part of the DNOA process. Last build date identified to allow time for traditional reinforcement if procurement for flexibility services is not successful in procuring the required capacity.

8.2. Options to resolve future EHV System Needs to 2050.

The following tables details the distribution network system needs that have been identified through power system analysis. While asset solutions are described in the table below it is important to note that the use of flexibility will be evaluated for all schemes to ensure the best possible solution is progressed.

The interactions between possible options have been considered to identify potential synergies and efficiencies. As such, constraints have been grouped strategically to be considered alongside each other and any additional interactions between constraints referenced

Table 8 below summarises the specific system needs we have identified.

ID	Location of proposed intervention	HT Year	EE Year	HE Year	CF Year	Network State	Comments and potential options to resolve the system need
33kV Network							
1	Strachur PSS	2035	2032	2035	2038	Intact	Transformer experiences thermal constraints. Option to resolve this constraint: - Reinforce existing assets to provide capacity out to 2050
2	Glendaruel PSS	2041	2039	2042	2049	Intact	Transformer experiences thermal constraint. Option to resolve this constraint: - Reinforce existing assets to provide capacity out to 2050
3	Innellan PSS	2041	2041	2049	-	Intact	Transformer experiences thermal overload. Option to resolve this constraint: - Reinforce existing assets to provide capacity out to 2050
4	Strathleven GSP, Kepculloch PSS and Auchencarroch PSS.	2040	2040	2044	2050	N – 1 outage	Circuits experience thermal overload and low volts from Strathleven to the tee between Auchencarroch PSS and Kepculloch PSS. Option to resolve thermal constraint includes: - Reinforcement of existing circuits from Strathleven GSP.
5	Kepcullcoch PSS	2042	2044	-	-	N – 1 outage	Both circuits to Kepculloch PSS from Killearn and Drymen PSS experience low volts. Option to resolve constraint include: - Reinforcement both the existing circuits PSS to provide capacity out to 2050.

Table 8: Options to resolve system needs between through to 2050

8.3. Future requirements of the High Voltage and Low Voltage Networks

Our HV/LV spatial plans have shown that there is no clear pattern to future demands on these lower voltage networks. We are therefore planning on a forecast volume basis. This section provides further context on the work for the Inverarnan 132kV supply areas high voltage and low voltage network needs up to 2050.

8.3.1. High Voltage Networks

As well as the EHV system needs identified in the previous section, increased integration of low carbon technologies (LCTs) connecting to the distribution network will result in system needs on the High Voltage (HV) and Low Voltage (LV) networks. To provide a view on the impact of these technologies on the distribution network, we have used the load model produced by SSEN's Data and Analytics team[22].

The load model is a machine learning product which estimates a half-hourly annual demand profile for each household based on a series of demographic, geographic and heating type factors. This enables us to estimate capacity on the electricity network while protecting individual customers data privacy by using modelled data. These insights are then aggregated up the network hierarchy based on the combinations of customers associated with each asset. This view is supplemented with the DFES to highlight the projected impact of LCTs on the network.

For all primary substations supplied within the Inverarnan 132kV supply area, the percentage of secondary substations where projected peak loading exceeds the nameplate rating of the secondary transformer was taken from the load model data. Figure 17 demonstrates how this percentage changes under each DFES scenario from now to 2050.

To satisfy these requirements a variety of solutions will need to be investigated. It is likely that a combination of flexibility and asset replacement will be employed to resolve the projected HV system needs. It is important to note that for HV needs, flexibility is likely to be provided through Distributed Energy Resources (DER), Consumer Energy Resources (CER), and domestic/commercial Demand Side Response (DSR). One of the challenges associated with procuring flexibility to High Voltage and Low Voltage system needs is that only a small number of customers can provide a flexible service due to the requirement to be supplied by a specific secondary transformer. As the role of aggregators develops, we may see a shift in the potential for flexibility in an area. Where the magnitude of an overload is too large for flexibility to be feasible, addition of new assets or asset replacement will be necessary.

22 SSEN Open Data Portal, 2023, SSEN Secondary Transformer – Asset Capacity and Low Carbon Technology Growth.

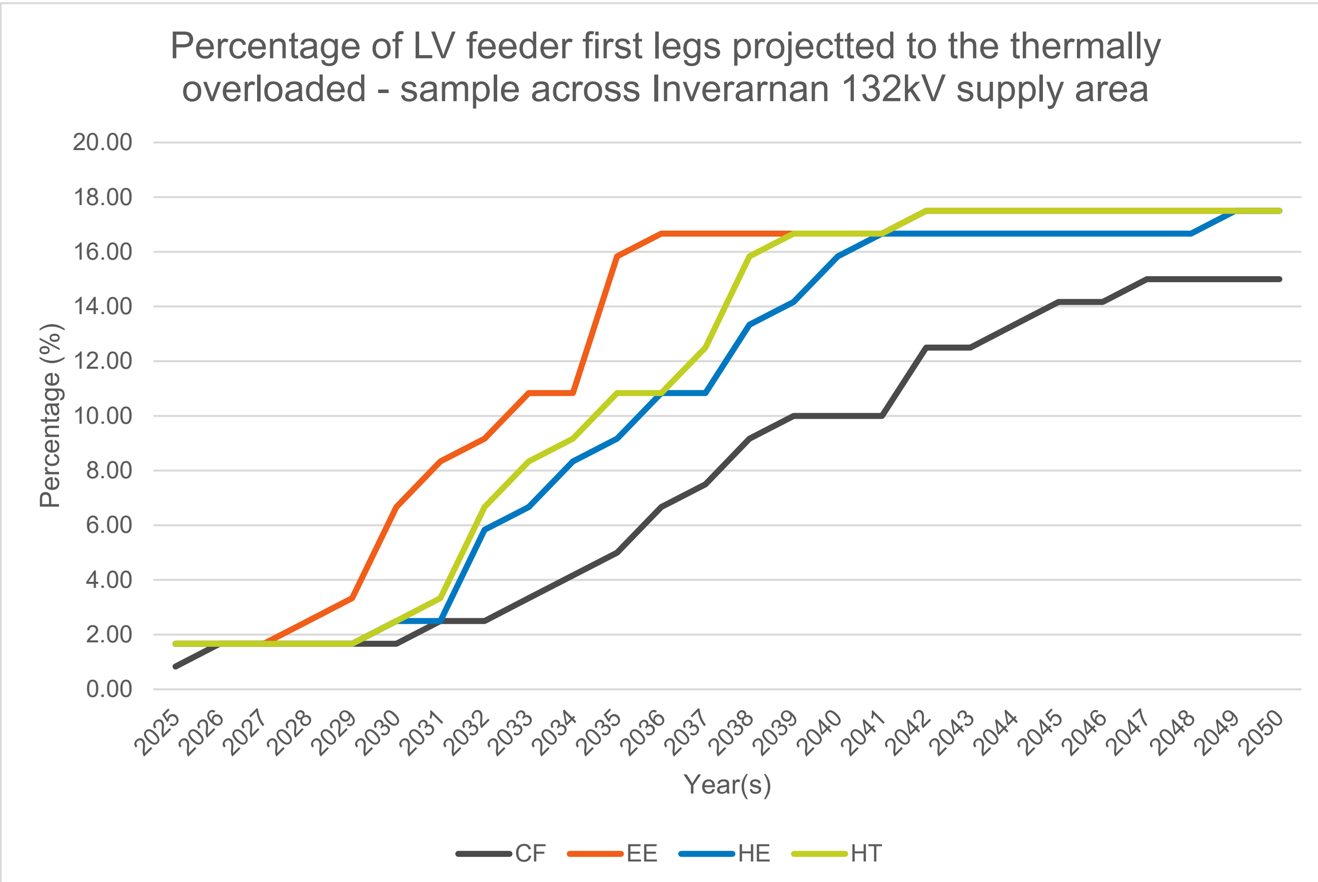

Figure 17: Inverarnan 132kV supply area Projected Secondary Transformer Loading.
Source: SSEN Load Model

Considering the Just Transition in HV Development

SSEN is building on the findings from the Vulnerability Future Energy Scenarios (VFES). This innovation project investigated how the use of new fore sighting techniques, along with data analytics and expert validation could be used to identify and forecast consumers in vulnerable situations as we move toward net zero. The insights from the VFES enable SSEN to develop the network in a way that genuinely accounts for the levels of vulnerability their customers face in different locations.

One of the outputs from this innovation project was the report produced by the Smith Institute.[23] This work groups Lower layer Super Output Areas (LSOAs)[24] that share similar drivers of vulnerability. The groupings were informed by mathematical analysis of demographic data and of SSEN's priority service register, using machine learning to model the complex relationships that exist between the two. The resulting group numbers and descriptions are shown in Table 9.

---

23 VFES Machine Learning Discovery of Vulnerability Signatures Report, Smith Institute, 08/11/2022, (NIA SSEN 0063: VFES – Vulnerability Future Energy Scenarios | SSEN Innovation)

24 Lower layer Super Output Areas (LSOAs) (Statistical geographies - Office for National Statistics)

Group Number & Level of Vulnerability	Description of Group
1 – Very high	Driven up by higher levels of poor health and disability/mental health benefit claimants, reduced by smaller household sizes.
2 – High	Driven up by larger household sizes, reduced by lower elderly population levels.
3 – High	Driven up by larger elderly population levels, reduced by lower levels of disability and mental health benefit claimants.
4 – Slightly higher than average	Driven up by larger elder population levels and moderately higher provision of care, reduced by smaller household sizes.
5 – Slightly lower than average	Driven down by lower elderly population levels and larger levels of ethnic diversity, increased by higher household sizes and greater provision of care.
6 – Low	Driven down by lower level of bad health and disability/mental health benefit claimants, increased by moderate elderly population levels and household sizes.
7 – Very low	Driven down by substantially lower elderly population levels, less provision of care and a higher level of households in private rented dwellings.

Table 9: VFES Grouping

To understand the vulnerability groupings across the Inverarnan 132kV supply area, we have visualised the LSOA categorisation for the study area. By overlaying secondary transformers that are projected to be overloaded by 2028 (under Holistic Transition), we begin to understand the crossover between network capacity needs and areas categorised as high vulnerability through the VFES work. This is shown below in Figure 18.

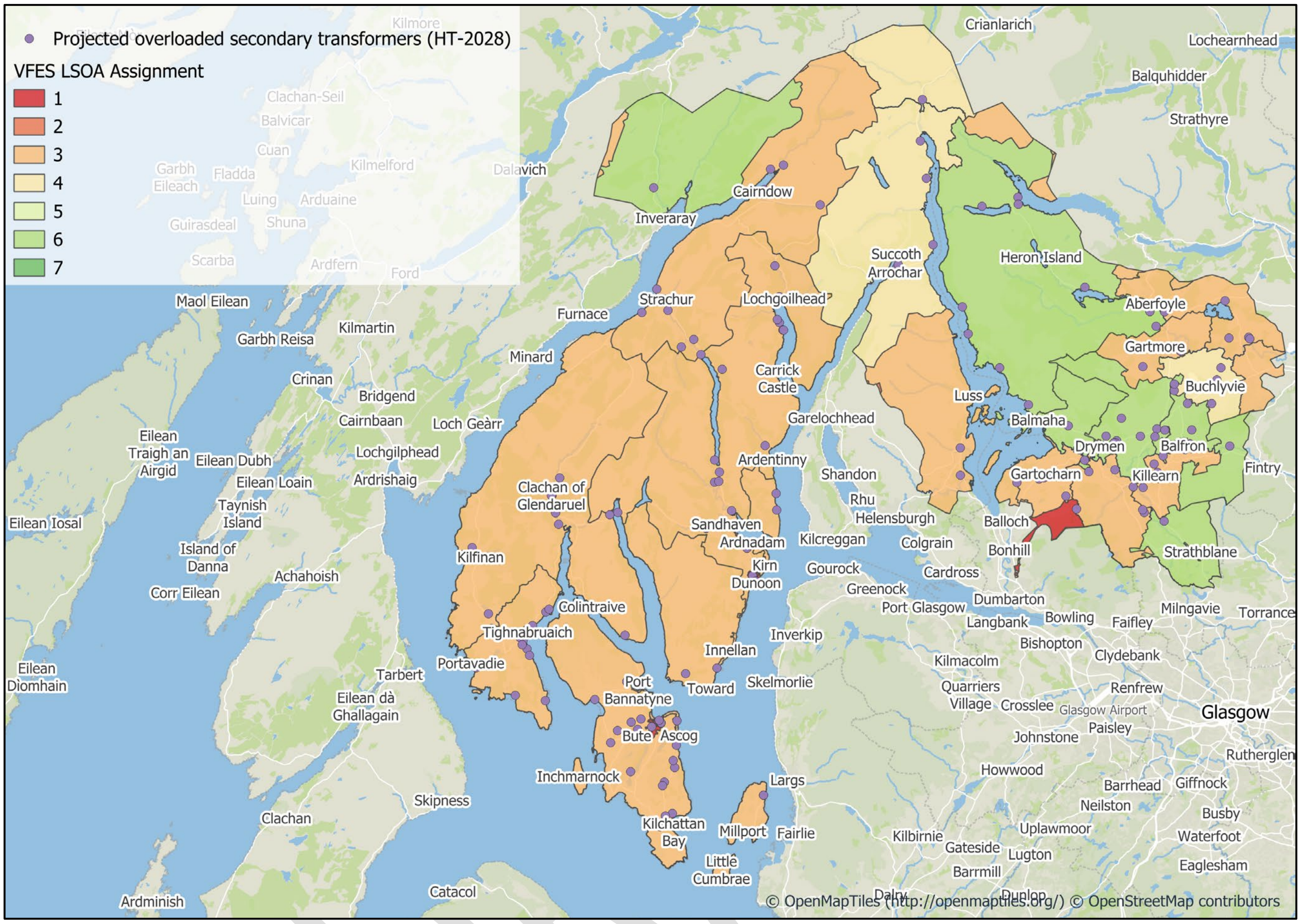

Figure 18: Inverarnan 132kV supply area VFES Output with secondary transformer overlay

We can see that the majority of the area falls within group 3, indicating relatively high levels of vulnerability. This level of vulnerability is driven up by a larger elderly population and reduced by lower levels of disability and mental health benefit claimants. In the Inverarnan 132kV supply area there are several LSOAs that fall into the higher categories of vulnerability (groups 1, 2, and 3). We also see two LSOA areas falling into the group 1 – very high vulnerability, around Ballock and Bute. This very high vulnerability classification is driven up by higher levels of poor health and disability/mental health benefit claimants but reduced by smaller household sizes.

By overlaying the point locations of secondary transformers projected to be overloaded (in 2028 under Holistic Transition), we identify areas that are categorised as more vulnerable and also may have capacity shortfalls at the secondary network level.

More vulnerable groups may have lower level of adoption of LCTs and therefore provide less ability to manage overloads through flexibility services. Further, they may point towards areas of social housing where there could be a more sudden rollout of LCTs such as heat pumps in the future.

We will use these insights to prioritise heavily loaded areas of our network, ensuring the network remains secure, stable, and resilient in the areas where vulnerable customers would be most impacted by outages.

8.3.2. Low Voltage Networks

Interventions in low voltage networks may be driven by either capacity related or be driven by voltage requirements. We are progressing options to resolve both of these drivers. From a network perspective the solution typically involves upgrading the number of LV feeders to split/ balance the load and improve voltage, or by installing another substation at the remote end of the LV network. In both instances, flexibility at a local level, especially voltage management products linked to battery export and embedded generation such as solar, is likely to be required alongside traditional reinforcement.

We are leveraging innovation work through Project LEO (Local Energy Oxfordshire)[25] and My Electric Avenue[26] to inform this strategy. Enhanced network visibility through Smart meter data analytics and low-cost substation feeder monitoring is also necessary to enable appropriate dispatch of services and network reconfiguration.

Initial analysis indicates that across the study area, *22.89%* of low voltage feeders may need intervention by 2035 and *33.94%* by 2050 under the Holistic Transition scenario as shown in Figure 19. The need is unlikely to be triggered until 2028 onwards. However, due to the timeline to grow the workforce (with jointing skills taking typically four years to be fully competent), it is necessary to start recruitment and initiate programmes ahead of need to be able to deliver the required volumes from 2028 onwards.

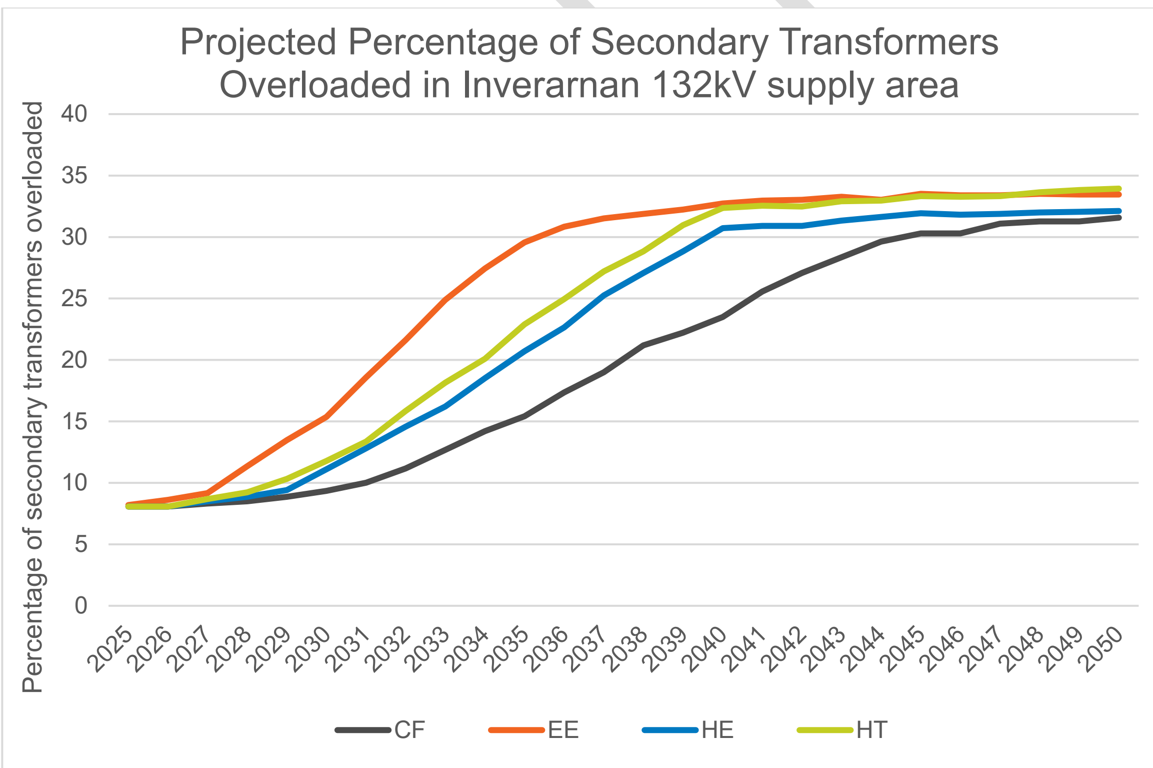

Figure 19: Percentage of LV feeders projected to be overloaded in Inverarnan 132kV substation supply area

25 Project LEO | SSEN Innovation

26 My Electric Avenue |

9. RECOMMENDATIONS

The stakeholder engagement insights and the SSEN 2024 DFES analysis provides a robust evidence base for load growth across the Inverarnan 132kV supply area in both the near and longer term. Load growth across the western Highlands region is driven by multiple sectors and technologies, impacting not only our EHV network but also driving system needs across all voltage levels.

Across the Inverarnan 132kV substation supply area, a variety of works have already been triggered, the latest of which has progressed through the DNOA process and published in a DNOA Outcomes Report. These are driven by customer connections and system needs that will arise this decade but are being developed to meet 2050 needs.

The findings from this report have provided evidence for eight key recommendations:

1. New system needs have been identified at earlier timescales (ahead of 2035):
    a. Strachur PSS 33kV transformer

2. System needs that have been identified post 2035 should continue to be monitored. This related to the assets in section 8.2. For this SDP, this includes:
    a. Glendaruel PSS 33kV transformer
    b. Innellan PSS 33kV transformer
    c. Strathleven GSP 33kV circuits (between Kepculloch PSS and Auchencarroch PSS)
    d. Kepculloch PSS 33kV circuits (from Strathleven GSP)

3. SSEN should ensure an open channel of communication is present between SSEN Distribution, SSEN Transmission and NESO regarding the following:
    - The creation of a long-term plan for the area so that alongside the delivery of any future SSEN Transmission works highlighted in section 3.2.2., we can plan the distribution network in parallel. This will enable efficient capacity release at both Transmission and Distribution level and should incorporate the outputs of CP2030 and connections reform.
    - The development of policy to unlock the ability of local and community-based generation to connect.
    - Co-ordination between prospective ANM schemes and the impact of T-D limits at GSPs.

4. Voltage constraints have been identified through the power system analysis network modelling results. Awareness and consideration of all future constraints will be critical in any further network studies and the successful optioneering of proposed interventions within the Inverarnan 132kV supply area. Some circuits will have both thermal and voltage constraints. Detailed studies should be carried out to determine where reinforcements could resolve both constraints, creating the most cost-effective solution and ensuring network does not have to be ‘touched twice’.

5. Understanding how rural decarbonisation could impact load on the network. Specifically, the electrification of distilleries and ports along the west coast of the Inverarnan 132kV supply area and how to capture those plans in load forecasts. This should be done through further engagement in the SeaChange project. It will also be important to understand how substations covered by security of supply derogations will be affected by increased demand.

6. As the move away from LMAs develops, continued work should take place to understand the impact of households not participating in flexibility markets and the network reinforcements triggered by this. The move away from radio tele switching (RTS) to smart meters should also be supported if technical difficulties arise.

7. The connection of low carbon technologies across the HV and LV networks will result in significant demand growth. Where it has been identified that there are overloads projected, mitigations will need to be put in place long term. There is no clear pattern to low voltage load growth in the Inverarnan 132kV supply area, so this should be taken on a volume driver approach. This needs to be based on strategic modelling of LV networks to understand the volume of work needed.

Actioning these recommendations will allow SSEN to develop an electricity network that supports local net zero ambitions and enables growth in the local economy.

Appendix A PRIMARY SUBSTATION CUSTOMER NUMBERS BREAKDOWN

Grid Supply Point	Primary Substation	Number of Customers Served (approximate)	2025 Substation Maximum demand in MW (Winter)
Clachan GSP	Butterbridge	3	0.01
Clachan GSP	Douglas Pier	331	0.99
Clachan GSP	Inveraray	259	0.97
Clachan GSP	Lochgoilhead	191	1.01
Clachan GSP	Strachur	343	0.76
Dunoon GSP	Bruchag	1922	2.56
Dunoon GSP	Colintraive	95	0.13
Dunoon GSP	Dunoon	5060	5.72
Dunoon GSP	Glendaruel	130	0.15
Dunoon GSP	Innellan	950	1.10
Dunoon GSP	Kames	664	1.03
Dunoon GSP	Newton	104	0.14
Dunoon GSP	Otter Ferry	325	1.25
Dunoon GSP	Rothesay	4645	4.55
Dunoon GSP	Sandbank	1735	3.35
Sloy GSP	Sloy Power Station	615	2.46
Strathleven GSP	Aberfoyle	936	2.19
Strathleven GSP	Blairlinnans	116	0.53
Strathleven GSP	Drymen	1224	2.57
Strathleven GSP	Kepculloch	1826	3.02
Strathleven GSP	Killearn	1122	1.92

Table 10: Primary substation numbers breakdown

Appendix B EHV/HV spatial plans for other DFES scenarios

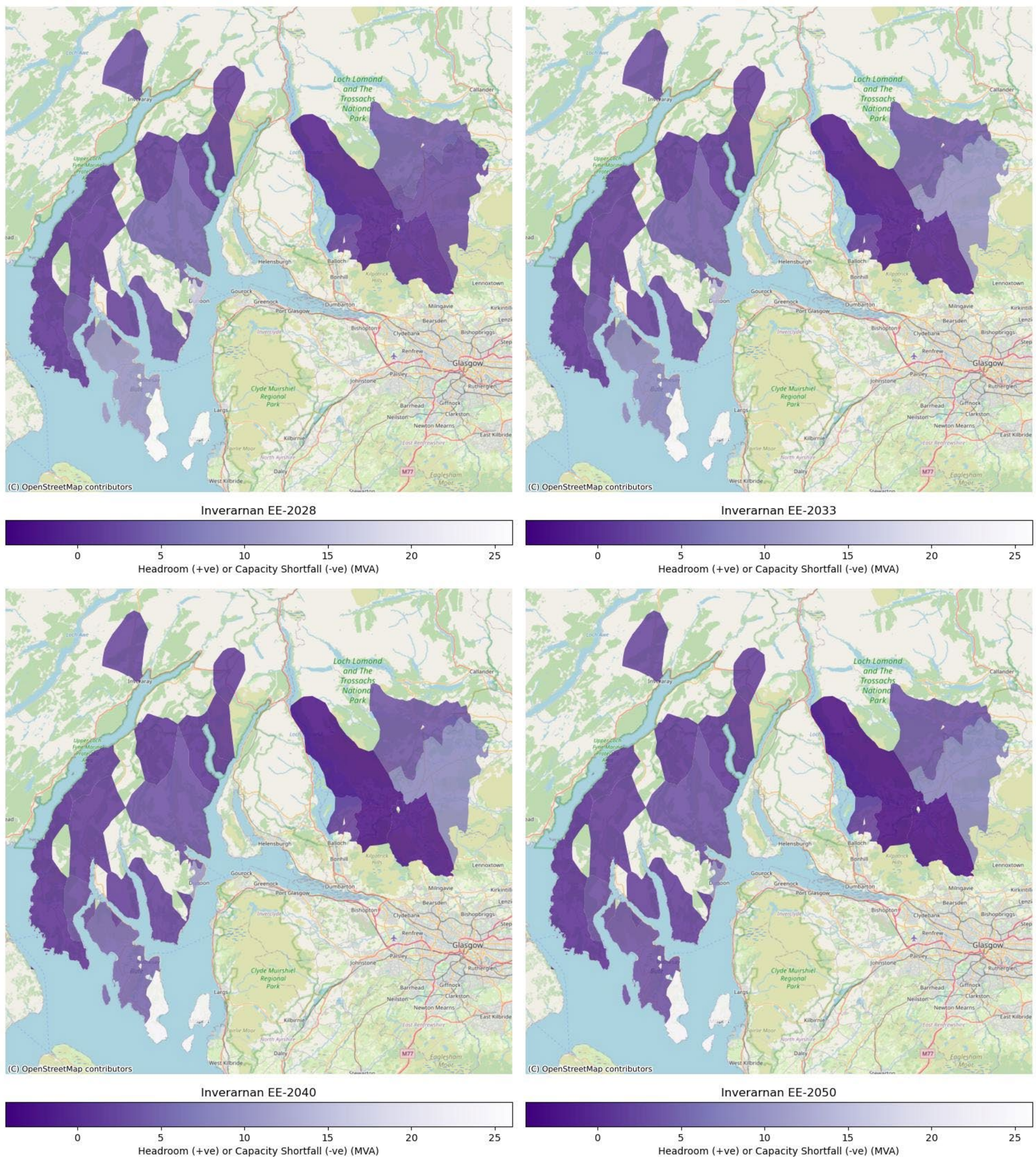

Figure 20: Inverarnan 132kV substation EHV network spatial plans for EE 2028, 2033, 2040, and 2050

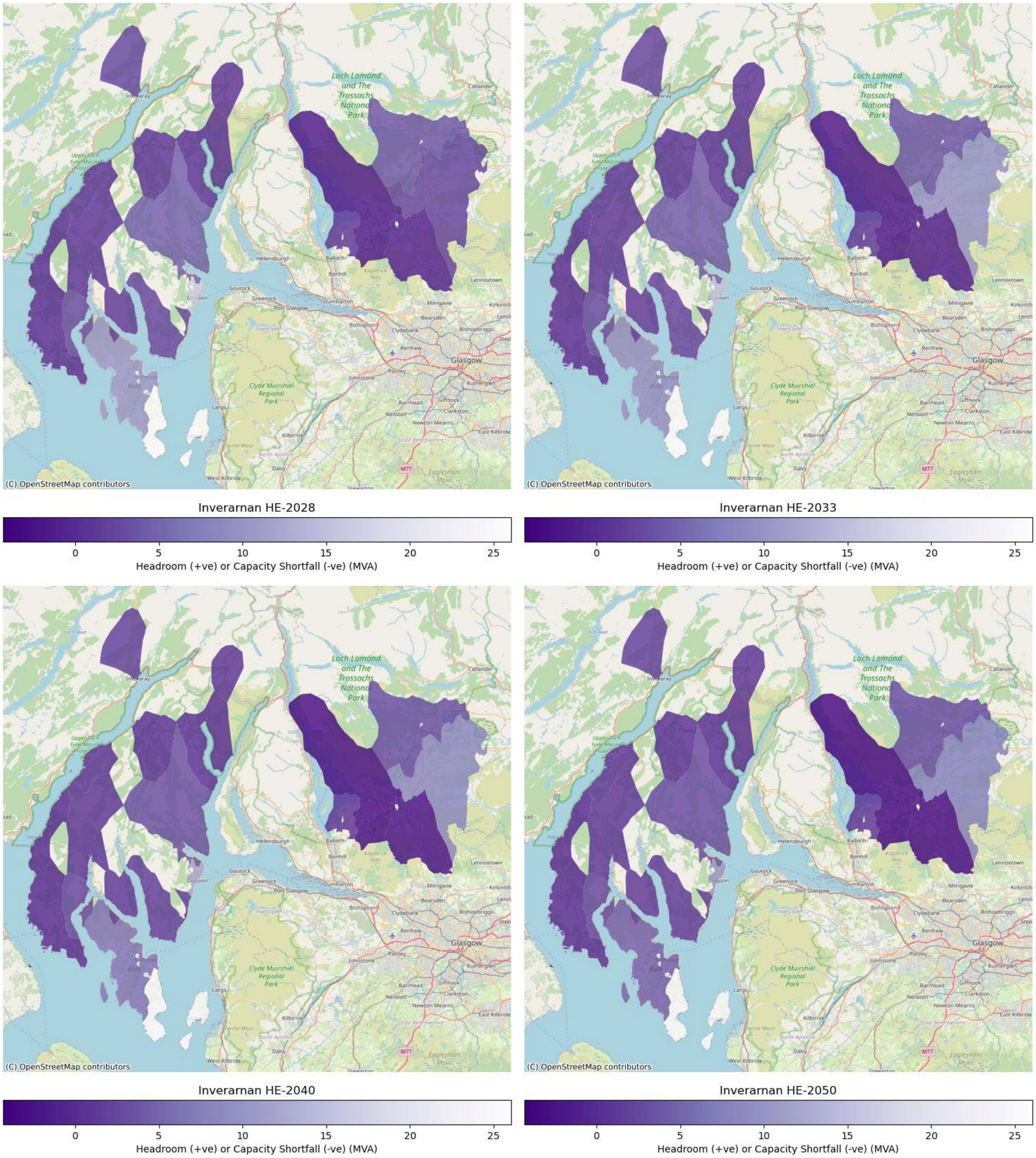

Figure 21: Inverarnan 132kV substation EHV network spatial plans for HE 2028, 2033, 2040, and 2050

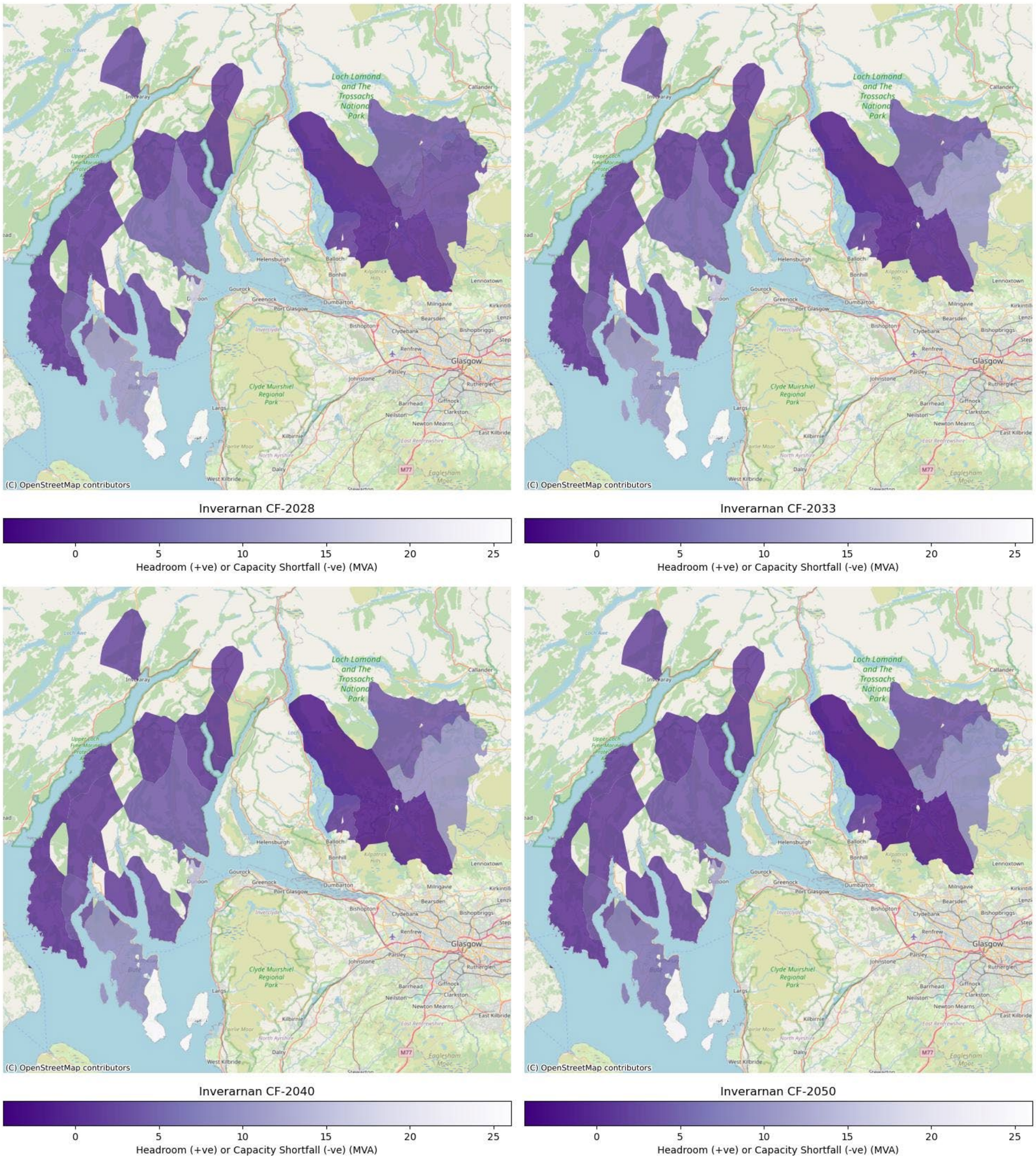

Figure 22: Inverarnan 132kV substation EHV network spatial plans for CF 2028, 2033, 2040, and 2050

Appendix C HV/LV spatial plans for other DFES scenarios

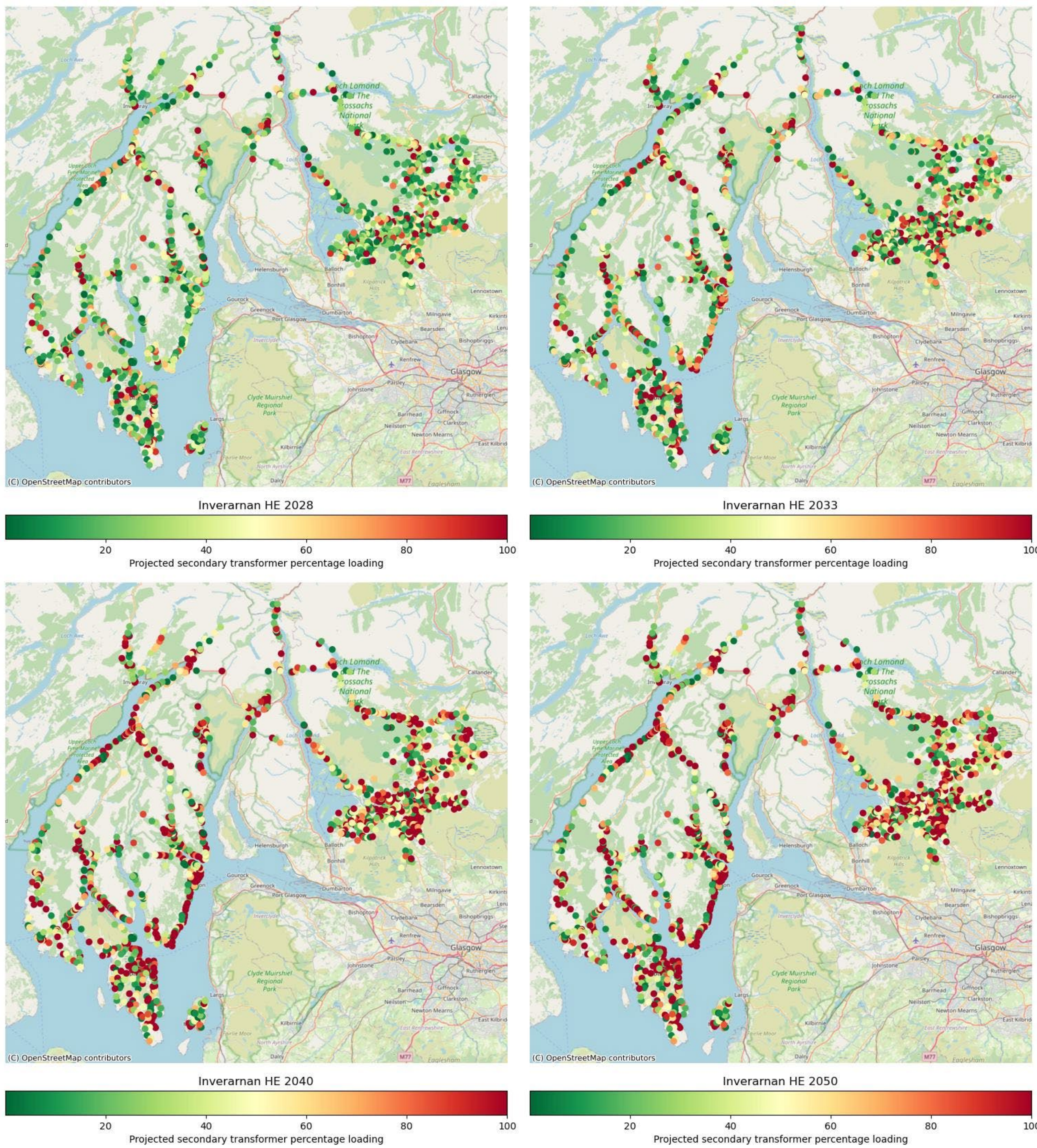

Figure 23: Inverarnan 132kV supply area HV/LV HE spatial plans for 2028, 2033, 2040, and 2050

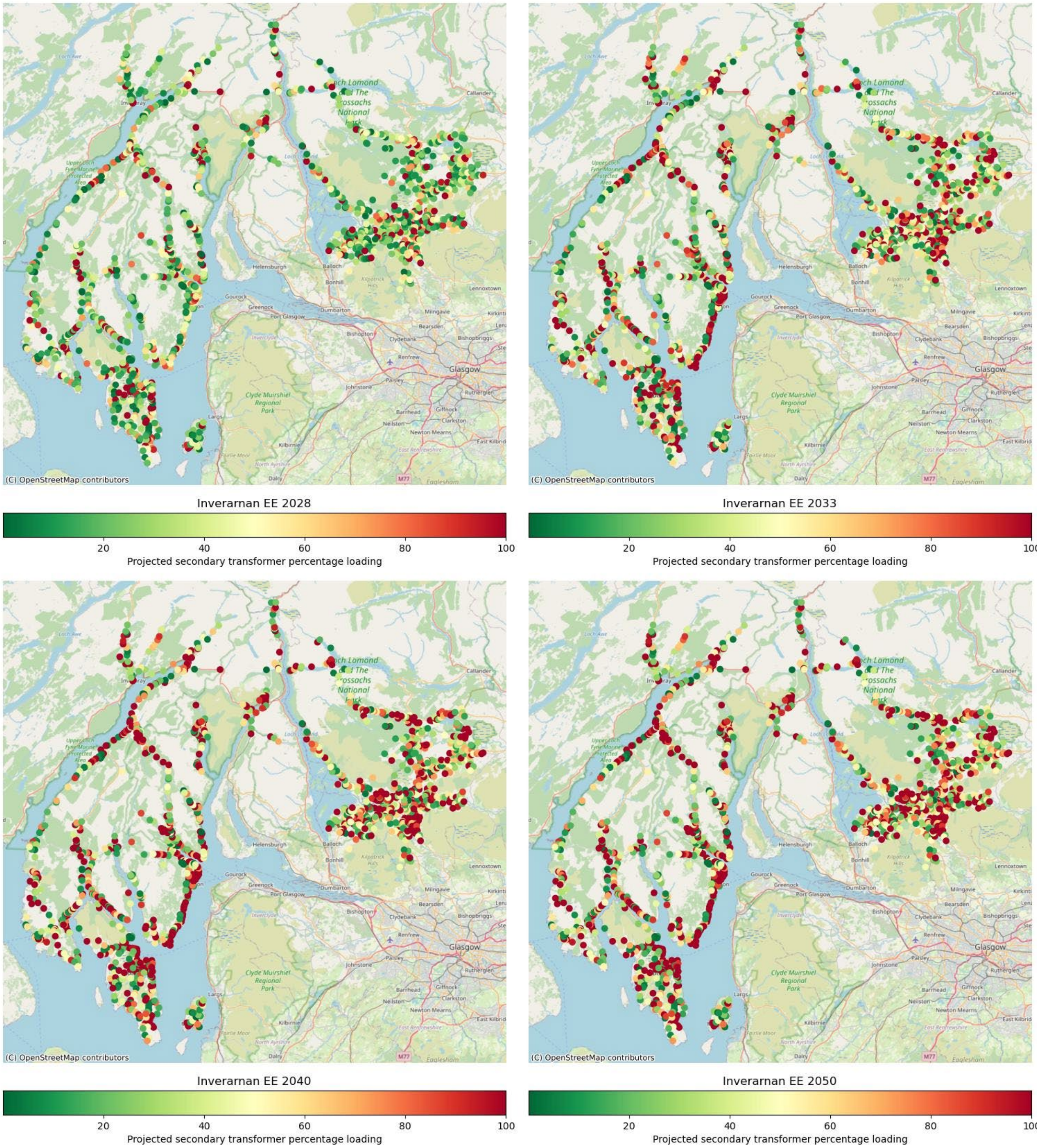

Figure 24: Inverarnan 132kV supply area HV/LV EE spatial plans for 2028, 2033, 2040, and 2050

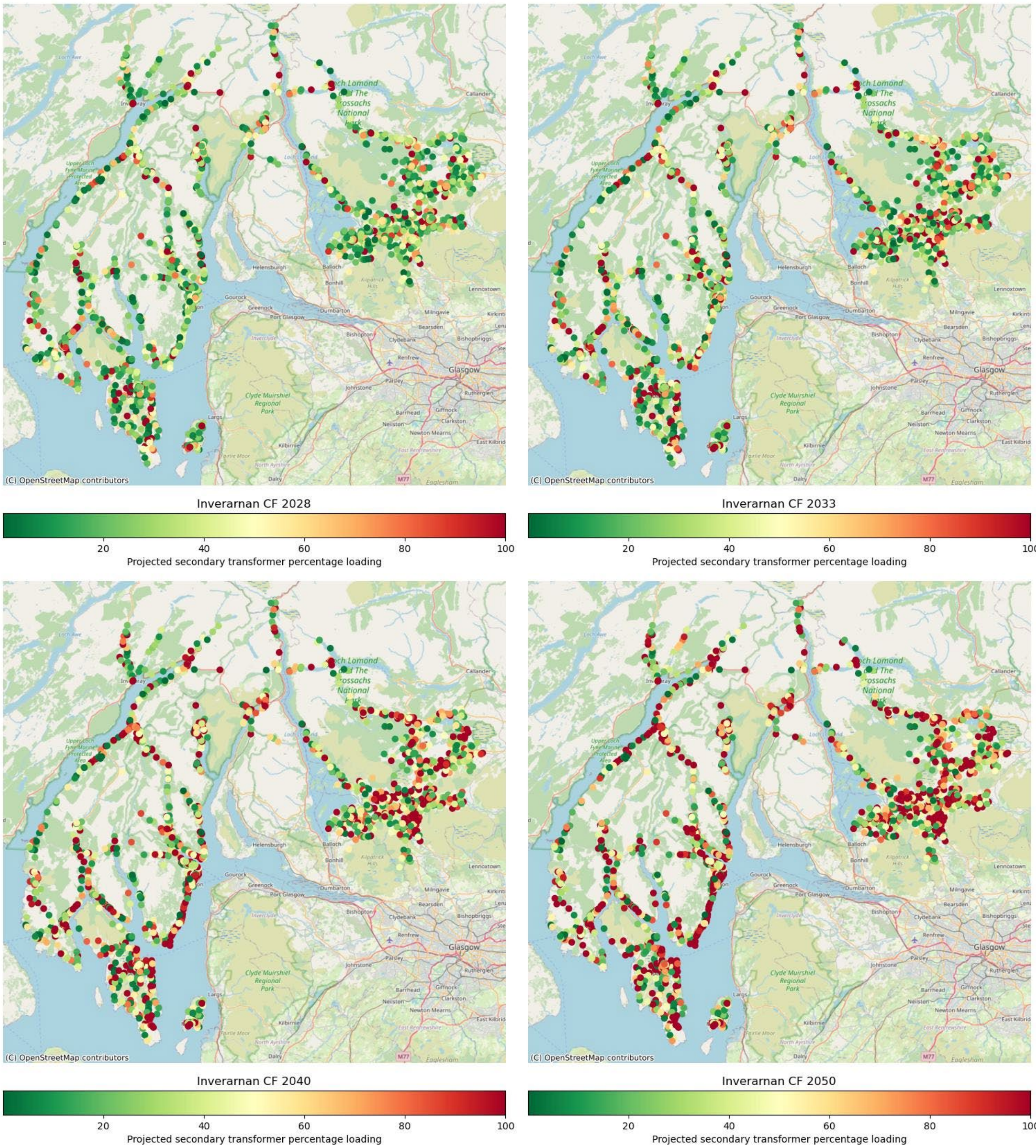

Figure 25: Inverarnan 132kV supply area HV/LV CF spatial plans for 2028, 2033, 2040, and 2050

Appendix D Glossary

ACRONYM	DEFINITION
ANM	Active Network Management
BAU	Business as Usual
BSP	Bulk Supply Point
CER	Consumer Energy Resources
CMZ	Constraint Managed Zone
CT	Consumer Transformation
DEG	Diesel Embedded Generation
DER	Distributed Energy Resources
DFES	Distribution Future Energy Scenarios
DGAD	Distributed Generation Automatic Disconnection
DNO	Distribution Network Operator
DNOA	Distribution Network Options Assessment
DSR	Demand Side Response
EHV	Extra High Voltage
EJP	Engineering Justification Paper
ER P2	Engineering Recommendation P2
ESO	National Grid Energy System Operator
EV	Electric Vehicle
FES	Future Energy Scenarios
FS	Falling Short
GSPs	Grid Supply Points
HV/LV	High Voltage/Low Voltage
HOWSUM	Hebrides and Orkney Whole System Uncertainty Mechanism
HVO	Hydrotreated Vegetable Oil
LAEP	Local Area Energy Planning
LENZA	Local Energy Net Zero Accelerator
LW	Leading the Way

OHL	Overhead Line
PV	Photovoltaic
MW	Megawatt
MVA	Mega Volt Ampere
NESO	National Energy System Operator
NRS	National Records of Scotland
RIIO-ED1/2	RIIO Electricity Distribution Price Control periods 1 and 2
SBTs	Science Based Targets
SDP	Strategic Development Plan
SHEPD	Scottish Hydro Electric Power Distribution
SLC	Standard Licence Condition
SSEN	Scottish and Southern Electricity Network
ST	System Transformation
SWA	Scottish Whisky Association
WSC	Worst Served Customers

Appendix E DNOA Outcome Reports

This annex shows the published DNOA Outcome Reports which are relevant to the Inverarnan 132kV supply area.

DNOA Outcome Report

Dunoon & Isle of Bute (33kV circuits) Ref. 0724-08

Scheme description

- Dunoon GSP supplies customers in Argyll & Bute and North Ayrshire. Postcode(s): KA28, PA20, PA23, PA28, PA31, PA75
- Load Related – Voltage compliance issues under network intact conditions.

Proposed option

- Asset Solution: Reinforcement of both 33kv overhead line circuits from Dunoon GSP to Craigagoul switching station on Bute. Installation of new 33kv switchboard at Craigagoul switching station and installation of voltage regulating equipment to correct voltage issues on the Isle of Bute at Bruchag primary substation.
- Flexibility is not viable due to nature of voltage constraint.
- Capacity Released: 3.8MVA

System need requirement

J	F	M	A	M	J	J	A	S	O	N	D

DNOA History

2024/25	2025/26	2026/27	2027/28	2028/29
Initial assessment				

Indicative flexibility price (if available):

- Availability: N/A
- Utilisation: N/A

Reinforcement timeline

- Substation will be operationally managed to ensure voltage compliance, until reinforcement delivery.
- Reinforcement delivery by 2028/29.

Estimated peak MW outside firm network capacity under each scenario
Grey text relates to estimated peak MW without reinforcement delivery

	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31
CT	-	-	-	-	-	-	-
ST	-	-	-	-	-	-	-
LTW	-	-	-	-	-	-	-
FS	-	-	-	-	-	-	-

Constraint management timeline

17 | Scottish and Southern Electricity Networks Distribution | DNOA Outcomes Report July 2024

CONTACT

whole.system.distribution@sse.com

Scottish & Southern Electricity Networks