Scottish & Southern Electricity Networks

RIIO-ED2 Engineering Justification Paper

Keith 33kV Circuit Reinforcements

Investment Reference No: 72/SHEPD/LRE/KEITH

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Definitions and Abbreviations

Acronym	Definition
AIS	Air-insulated Switchgear
ASCR	Aluminium Conductor Steel Reinforced
BSP	Bulk Supply Point
CBA	Cost Benefit Analysis
CBRM	Condition Based Risk Management
CEM	Common Evaluation Methodology
CI	Customer Interruptions
CML	Customer Minutes Lost
CT	Consumer Transformation
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
EJP	Engineering Justification Paper
ESA	Electricity Supply Area
EV	Electric Vehicle
FCO	First Circuit Outage
FES	Future Energy Scenarios
GIS	Geographic Information System
GM	Ground Mounted
GSP	Grid Supply Point
HI	Health Index
IDP	Investment Decision Pack
LCT	Low Carbon Technology
LEP	Local Enterprise Partnership
LI	Load Index
LRE	Load Related Expenditure
LW	Leading the Way
NPV	Net Present Value
OHL	Overhead Line
PM	Pole Mounted
PV	Photovoltaics
RSN	Relevant Section of Network
SCO	Second Circuit Outage
SSEN	Scottish and Southern Electricity Networks
SP	Steady Progression
ST	System Transformation
XLPE	Cross-linked Polyethylene

1 Executive Summary

This proposed investment will deliver load related investment of £5.58m during the RIIO-ED2 price control on the Keith 33kV network.

The primary investment driver for this scheme is load, specifically thermal issues on three of Keith GSP's 33kV circuits. The load related issues are apparent under all four of SHEPD's Distribution Future Energy Scenario (DFES) scenarios and this project is required to progress towards net zero and provide sufficient capacity to facilitate renewable generation and the uptake of low carbon technologies (LCT) such as EVs and Heat Pumps in the Moray area.

Moray council are currently working in line with Scottish Government targets to act on climate change locally in the Moray area and aims to reduce carbon emissions through the 2020-2030 period and beyond. SHEPD has considered the view and targets of Moray council through various DFES stakeholder engagement activities.

Moray's climate targets are expected to have a significant impact on demand growth within the area. Without this intervention, the network will experience increased overloading issues which impact our ability to meet the minimum level of security of supply for consumers, and potentially restrict progress towards a Net Zero network in RIIO-ED2 and beyond.

The EJP considers a range of options to address the load related thermal issues, setting out the options that have been considered and rejected prior to the CBA analysis along with clear rationale for including or excluding each option.

The results shown below in Table 1 show the range of options considered within the Cost Benefit Analysis. These options provide cost-effective solutions for the three circuits that deliver the best value for consumers in terms of the 45 years Net Present Value (£m).

Circuits	Options	Net Present Value (NPV) After 45 Years (£k)	Investment (£k)
Keith 303	Option 2 – Smart Solution& Flexibility Solution and Late Reinforcement (The Preferred Option)	-429	[redacted]
	Option 3 – Early OHL Reinforcement	-530	[redacted]
	Option 4 – Deferral of Option 3 to Year 2028	-4,006	[redacted]
Keith 304	Option 2 – Smart Solution& & Flexibility Solution and Late Reinforcement (The Preferred Option)	403	[redacted]
	Option 3 – Early OHL Reinforcement	-176	[redacted]
	Option 4 – Deferral of Option 3 to Year 2028	-568	[redacted]
Keith 307	Option 2 – Smart Solution (The Preferred Option)	-180	[redacted]
	Option 3 – Early OHL Reinforcement	-3,873	[redacted]
	Option 4 – Deferral of Option 3 to Year 2028	-3,197	[redacted]

Table 1: Option Summary

Following the optioneering and detailed analysis, as set out in this paper, the proposed scope of works is:

Asset	Volume	Costs
33kV OHL Increase Temperature (km)	56	[redacted]
33kV OHL (Pole Line) Conductor (km)	34	[redacted]
33kV Pole (No.)	408	[redacted]
Flexible Services Cost		[redacted]
Total		**£5,577k**

Table 2: Investment Summary

This scheme delivers the following outputs and benefits:

- Ensures the 33kV circuits out of Keith GSP continue to operate within thermal ratings and maintain compliance with security of supply standard ER P2.
- Facilitates the continued uptake of low carbon technologies (LCT) within the Keith area and helps support the climate change targets of Moray Council.
- Facilitates the efficient, economic, and co-ordinated development of our Distribution Network for Net Zero.

The cost to deliver the preferred solution is £5.58m and the works are planned to be completed in 2028. This EJP investment sits within our Net Zero Totex ask.

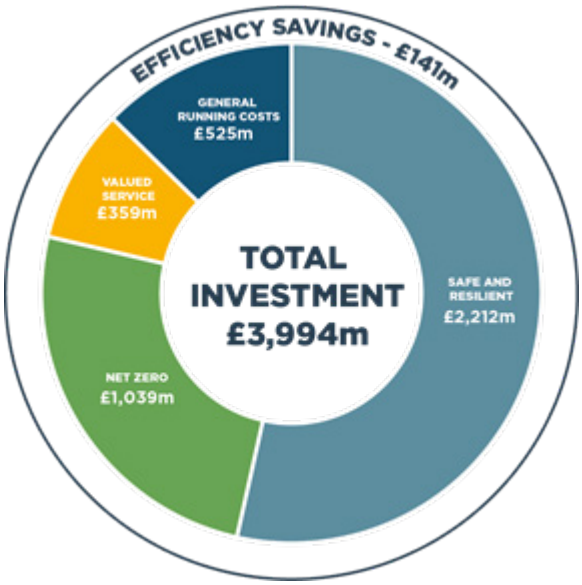


Figure 1: SSEN total investment cost within RIIO ED2

2 Investment Summary Table

The table below provides a high-level summary of this Engineering Justification Paper (EJP) and the Cost and Volume (CV) impacts within SSEN's Business Plan Data Tables.

Engineering Justification Paper Investment Summary				
Name of Scheme	Keith 33kV Circuits			
Primary Investment Driver	Load – Thermal			
Scheme reference	72/SHEPD/LRE/KEITH			
Output reference/type	33kV OHL (Pole Line) Conductor (km) 33kV Pole 33kV OHL (Increase Temp) (km) – Not shown in BPDTs			
Cost	£5.58m			
Delivery year	2023/24 & 2027/28			
Reporting Table	CV1: Primary Reinforcment			
Outputs included in RIIO ED1 Business Plan	No			
Spend apportionment	**(£m)**	**ED1**	**ED2**	**ED3+**
	SHEPD	0	£5.58m	0

Table 3:Investment Summary

3 Introduction

Our ***Load Related Plan Build and Strategy (Annex 10.1)***[1] sets out our methodology for assessing load-related expenditure and describes how we use the Distribution Future Energy Scenarios (DFES) 2020 as the basis for our proposals. We have established a baseline view of demand which provides a credible forward projection of load-related expenditure for the ED2 period and this reflects strongly evidenced support from our stakeholders. Our ex-ante baseline funding request is based on the minimum investment required under all credible scenarios. Our plan will create smart, flexible, local energy networks that accelerate progress towards net zero – with an increased focus on collaboration and whole-systems approaches.

This investment is a component of our strategic goal of 'Accelerating progress towards a net zero world'.

Section 4 of this Engineering Justification Paper (EJP) describes our proposed load related investment plan for the reinforcement of Keith Primary Substation in RIIO-ED2. The primary driver considered within this paper is load related P2/7 compliance issue at Keith primary substation due to forecast demand growth from our Stakeholder supported Distribution Future Energy Scenario (DFES).

This EJP provides high-level background information for this proposed scheme explaining the existing network arrangement, the load growth forecasts through the Distribution Future Energy Scenarios (DFES) and setting out the need for this project. The Detailed Analysis section of the EJP describes the network studies undertaken, detailing the results which further justify the need of the proposed investment.

Section 5 provides an exhaustive list of the options considered through the optioneering process to establish the most economic and efficient solution. Each option is described in detail, with the EJP setting out the justification for those options which are deemed unviable solutions, and therefore not taken forward to the Cost Benefit Analysis.

Section 6, Cost Benefit Analysis (CBA) Summary, provides the comparative results of all the options considered within the CBA and sets out the rationale and justification for the preferred solution. This section also describes how we have established the cost efficiency of the plan with reference to the unit costs that have been chosen.

Finally, **Section 7** of this EJP also sets out the deliverability of the plan for RIIO-ED2 and this proposed investment.

[1] SECTION D: (Chapter 10), Responding to the net zero Opportunity, (Annex 10.1), Load Related Plan Build and Strategy

4 Background Information

4.1 Existing Network Arrangement

Keith GSP is located within the Moray area of Scotland and sits within the North Caledonia region of SHEPD's licence area. This substation is supplied via 4 x 90MVA 132kV/33kV transformers split across 2 x 33kV busbars and supplies 26,902 customers via 7x 33kV circuits and 11x Primary Substations.

The existing 33kV network configuration is shown below. This network is situated in rural North East Scotland with approximately 79% of the 33kV network made up of OHL. Keith 33kV circuits comprise of three closed rings and one radial feeder. GSP Interconnections are present between MacDuff, Elgin, Boat of Garten, Tarland and Kintore (Rothienorman post 2021/22).

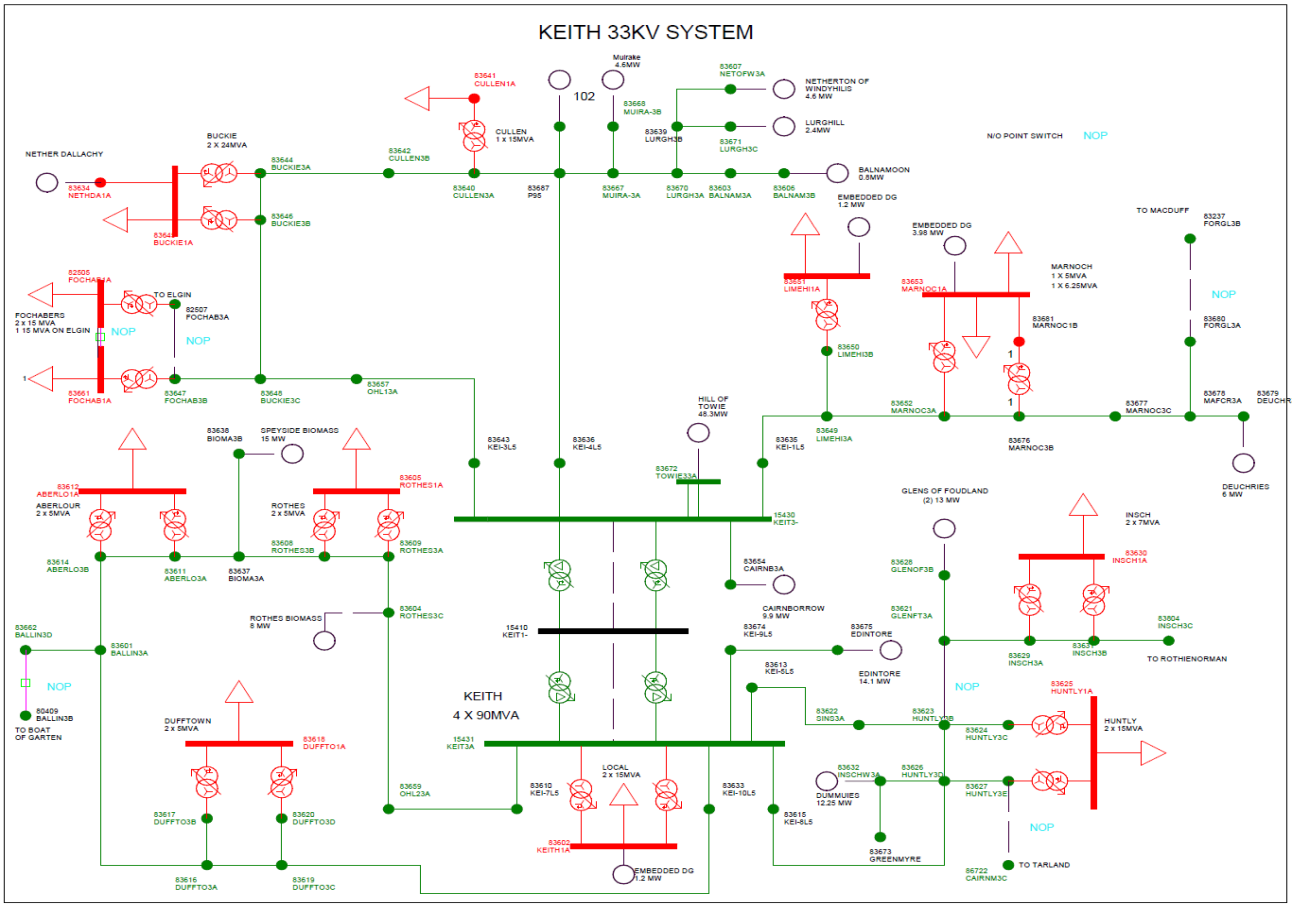


Figure 2: Keith 33kV Network

4.2 Local Area Energy Plan (LAEP)

Keith GSP is located within the North East Region of SHEPD's licence area and in the Local Authority of Moray. In 2019, Moray council declared a climate emergency and acknowledged the need for Climate Change Strategy which they have since published. This strategy marks the commitment to act on climate change locally in the Moray area and aims at reducing carbon emissions through the 2020-2030 period and beyond[2].

[2] https://newsroom.moray.gov.uk/news/moray-council-formally-adopts-climate-change-strategy

Moray has the highest per capita CO_2 emissions of any Local Authority in Scotland. This is attributable in large part to industry and commercial emissions per capita compared to the Scottish average and more specifically, the consumption of gas. These high relative emissions are assignable to Moray's whisky distilling sector, food producers and two MOD military facilities.

Moray Council have also published their action plan which outlines the scope and extent of actions required in order to achieve their stated targets and deliver upon the aspirations within their strategy. This action plan includes multiple targets relevant to the electricity sector including; ensuring new developments in the area make provisions for EV charging facilities, converting 100% of taxi and 70% of plant fleets to ULEV by 2030, converting all fossil-fuelled based heating systems in council buildings to low or zero carbon alternatives and improving the energy efficiency of private sector housing by delivering the Home Energy Efficiency Programme for Scotland (HEEPS).

From a generation perspective, Moray Council is committed to supporting the Scottish Government's aim of increasing the amount of electricity generated from renewable sources and help with the 2GW target of community and locally owned energy by 2030. Moray is already contributing towards meeting these targets, primarily through a number of large-scale wind farms. The Council aims to encourage a wide range of renewable energy projects with the aim of ensuring that the right technologies are supported in the right places, while respecting Moray's environment and the existing infrastructure constraints. Moray Council have published non-statutory guidance on onshore wind energy to help inform developers within the area.

Between the Climate Change Strategy Document, Action Plan and Onshore-Wind Guidance Document, Moray council appear proactive with making a significant change in their local area and progressing towards Scotland's overall 2045 net zero target. Moray Council's targets around EVs and low carbon heating systems are expected to have a significant impact on demand growth within the area. This impact is visible within the SHEPD DFES projections and directly contributes to the need for investment discussed within this paper.

4.3 Rothienorman GSP

SHEPD have requested a new GSP on the Rothienorman site through the introduction of 2x120MVA 275/33kV transformers and a 33kV distribution switchboard. The GSP will be integrated into the existing Aberdeenshire 33kV network to facilitate the connection/transfer of up to 90MW of generation and 14MW of demand. It is contracted for delivery in 2021/22.

The project forms part of a whole system approach to facilitate renewable generator connections in Aberdeenshire through the connection of Rothienorman GSP into the local 33kV network and the transfer of generation and demand from neighbouring GSPs. The proposed integration work avoids more costly reinforcements elsewhere on the transmission and distribution systems and is considered to be the most efficient and economical strategy plan for both SHEPD and SSEN Transmission to develop the electrical infrastructure in West Aberdeenshire.

Rothienorman GSP will remove approximately 8.39MW of demand from Keith GSP with the transfer of Insch Primary Substation. Whilst this transfer will help create demand capacity on the 305 and 308 circuits, the forecasted thermal issues are still apparent on the 303, 304 and 307 (Generation) circuits within this paper.

Geographic views for Rothienorman GSP are provided in Appendix 3

4.4 Demand Forecast for Keith GSP

SHEPD have carried out extensive scenario studies through the Distribution Future Energy Scenarios (DFES) which is based on the National Grid's Future Energy Scenarios (FES) 2020 and local stakeholder input. The DFES comprises of four potential pathways for the future of energy, based on how much energy may be needed and where it might come from. The variables for the four scenarios are driven by government policy, economics and consumer attitudes related to the speed of decarbonisation and the level of decentralisation of the energy industry. SHEPD have worked closely with their partner Regen to develop the forecasts between 2020 and 2050 through enhanced engagement with the local authorities, local enterprise partnerships (LEPs), devolved governments, community energy groups and other stakeholders.

Based on the enhanced stakeholder engagement feedback, SHEPD have chosen Consumer Transformation as the baseline scenario for investment. SHEPD are protecting customers from the impact of forecasting uncertainties through baseline funding only including load related investment required in the first two years in the RIIO-ED2 period unless it is also required by other net zero scenarios. Full details on the DFES methodology, stakeholder input and regulatory treatments of load related investment can be found in the ***Load Related Plan Build and Strategy (Annex 10.1)***[3].

The table below shows the demand projections in MW of each primary within Keith GSP under the CT Scenario and also includes the expected overall forecast demand of Keith and Rothienorman GSPs. These forecasts have been based on the baseline scenario, Consumer Transformation, and show a significant step change in demand over the historically derived forecasts used within the ED1 price control.

Substation	Baseline	ED1			ED2					Future		
	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31
ABERLOUR	4.73	4.75	4.77	4.78	4.80	4.81	4.87	4.96	5.06	5.21	5.39	5.55
BUCKIE	13.14	13.19	13.32	13.44	13.66	13.95	14.35	14.79	15.25	15.97	16.80	17.61
CULLEN	2.49	2.52	2.53	2.54	2.58	2.66	2.79	2.94	3.05	3.29	3.56	3.81
DUFFTOWN	4.44	4.45	4.45	4.47	4.49	4.51	4.55	4.61	4.82	5.02	5.12	5.22
FOCHABERS (33%)	2.11	2.13	2.14	2.16	2.18	2.21	2.25	2.39	2.59	2.81	3.02	3.18
HUNTLY	6.05	6.07	6.09	6.14	6.22	6.34	6.50	6.71	6.94	7.26	7.66	8.03
INSCH	6.26	6.31	6.37	6.51	6.84	7.23	7.62	7.99	8.39	8.94	9.58	10.14
KEITH	6.43	6.48	6.53	6.60	6.67	6.77	7.05	7.22	7.47	7.80	8.30	8.69
LIMEHILLOCKS	1.45	1.45	1.46	1.47	1.47	1.49	1.50	1.52	1.55	1.63	1.76	1.90
MARNOCH	2.80	2.81	2.82	2.84	2.90	3.00	3.10	3.22	3.34	3.63	3.97	4.26
ROTHES	4.99	5.10	5.12	5.13	5.17	5.22	5.28	5.35	5.43	5.56	5.73	5.89
Total	**54.90**	**55.25**	**55.60**	**49.57**	**50.15**	**50.95**	**52.26**	**53.72**	**55.51**	**58.19**	**61.31**	**64.13**
Keith GSP	49.70	50.02	50.33	44.87	45.40	46.12	47.30	48.62	50.24	52.68	55.50	58.05
Rothienorman GSP	N/A	N/A	N/A	14.00	14.33	14.72	15.11	15.48	15.88	16.43	17.07	17.64

*Insch Primary moved from Keith GSP to Rothienorman by the end of 2021/22.

Table 4:Winter Peak Demand forecasts (MW)

The 2019/20 peak demand for Keith was 49.7MW and there is currently 153MW of generation connected with a further 104MW contracted to connect. Diversified Peak demand is expected to increase at Keith GSP by approximately 8.1MW from 2019/20 to 2027/28 when following the CT scenario although this is significantly reduced to 0.6MW by the transfer of Insch Primary to Rothienorman in 2021/22.

The forecast 2027/28 peak demand of 50.2MW is split below by technology. The chart shows the largest impacts on demand in the area are from EVs and Heat Pumps, equating to 7% and 10% respectively with smaller percentages for Non-domestic and Domestic developments.

[3] Load related Plan build & strategy (Annex 10.1)

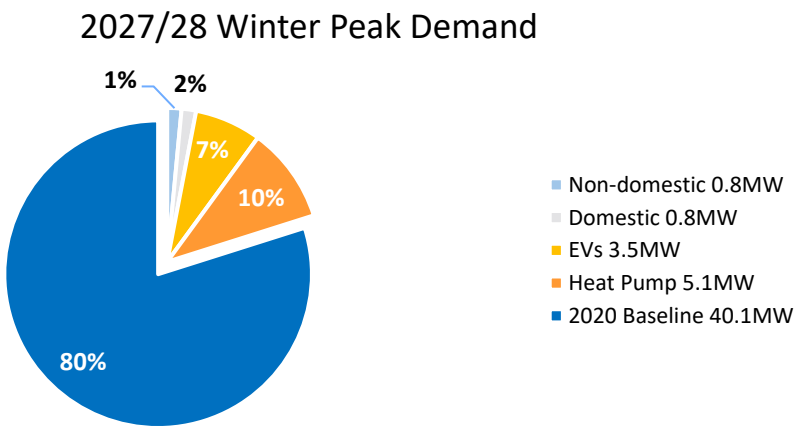


Figure 3: Keith GSP Winter peak demand 2027/28

4.5 Generation Forecast for Keith GSP

The existing 153MW of connected generation is predominantly onshore wind and a mixture of other technologies including Gas, CHP and Anaerobic Digestion with very little Hydro or PV connected in the area. The below charts show the split of generation technologies connected to Keith GSP both in the previous financial year and the forecast values at the end of ED2. The projected figures include all contracted quotations along with projections from the DFES CT scenario.

The total projected generation figure of 398MW by the end of ED2 follows a similar split in generation technologies. Onshore Wind still dominates the area although PV and Battery Storage is expected to develop.

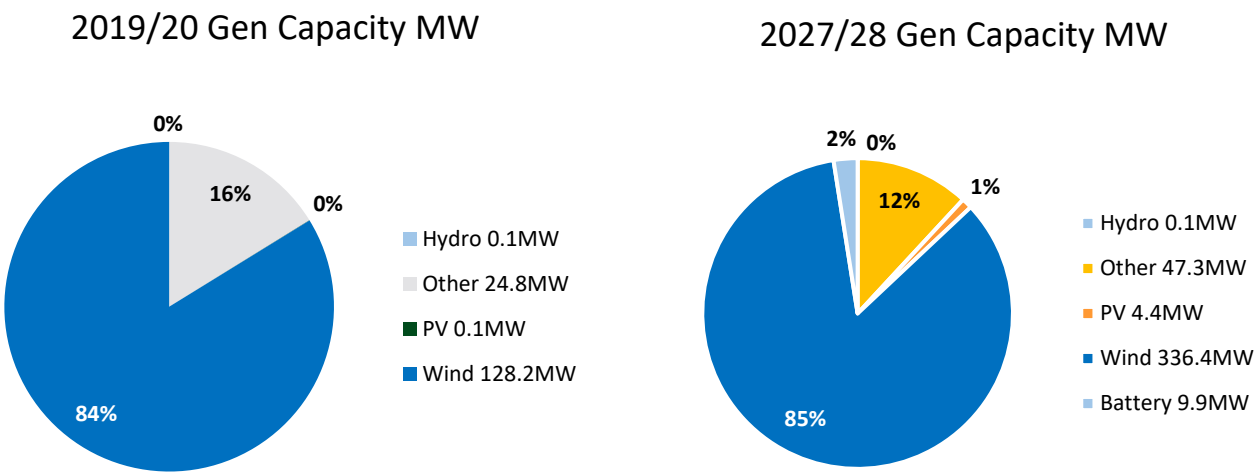


Figure 4: Generation growth.

4.6 Existing Asset Condition

Keith 33kV circuits 303, 304 and 307 issues have been checked against proposed interventions for non-load related drivers during RIIO ED2. This primarily relates to the condition and criticality of each asset as tracked by SSEN's Condition Based Risk Management (CBRM) system.

The CBRM models maintained by SSEN provides a Health, Criticality, and Risk score for each individual asset. The risk score (asset health and criticality) is a key metric that will trigger a need for investment into this asset category. This is calculated using a variety of asset-specific data which includes basic parameters in addition to the observed and measured condition of each asset.

From cross checking the CBRM data with the circuits showing thermal constraints, approximately 36 OHL poles are proposed to be replaced during ED2 period on the relevant circuits. Whilst this information may not directly lead to savings in load or non-load investment, it will create efficiencies in outage planning and minimise customer disruption if linked with the reinforcement within this report.

4.7 Thermal Flow Analysis

The table below shows the non-compliant circuit sections on Keith 303, 304 and 307 from the load flow results and includes the location, conductor type, contingency and first year of overload. The circuit sections have been colour coded to correspond to the highlighted sections on the below network diagram. The analysis revealed a total of 56km of 33kV OHL requiring intervention before the end of ED2. All overloads are apparent under fault conditions rather than network intact which is partly down to the large ring-circuit configuration of the network and limited backfeed options. These overloads, if left, could cause significant increases in CIs and CMLs with associated safety issues resulting from asset failure. These issues could also hinder the LCT deployment within the area fed by Keith GSP, potentially creating a barrier for the net-zero targets outlined by Moray Council. The geographic views of the overloaded sections are shown in Appendix 3.

Circuit	Start Node	End Node	Start Pole	End Pole	Conductor	Length (km)	Rating (MVA)	2027 Flow (MVA)	Contingency	Year	Trigger
KEITH (303)	83646	83648	Pole 1	Pole 83	OH Line - 0.1eq ACSR	12.4	17.80	20.97	N-1	2023	Demand
KEITH (303)	83643	83657	Pole 242	Pole 275	OH Line - 100mm Cu.	2.8	22.30	24.13	N-1	2027	Demand
KEITH (303)	83648	83657	Pole 278	Pole 308	OH Line - 100mm Cu.	3.2	22.30	24.13	N-1	2027	Demand
KEITH (304)	83640	83687	Pole 95	Pole161	OH Line - 0.1in Cu.	6.7	16.90	22.30	N-1	2022	Demand
KEITH (304)	83642	83644	Pole 1	Pole 96	OH Line - 0.1in Cu.	8.9	16.90	17.42	N-1	2028	Demand
KEITH (307)	83659	83610	Pole 19	Pole 141	OH Line - 150mm Cu.	9.9	23.49	24.65	N-1	2024	Generation
KEITH (307)	83604	83659	Pole 141	Pole 233	OH Line - 150mm Cu.	7.9	23.49	24.92	N-1	2024	Generation
KEITH (307)	83608	83637	Pole 95	Pole 143	OH Line - 0.1in Cu.	4.2	13.49	17.83	N-1	2024	Generation

Table 5: The List of the Overloaded Circuits

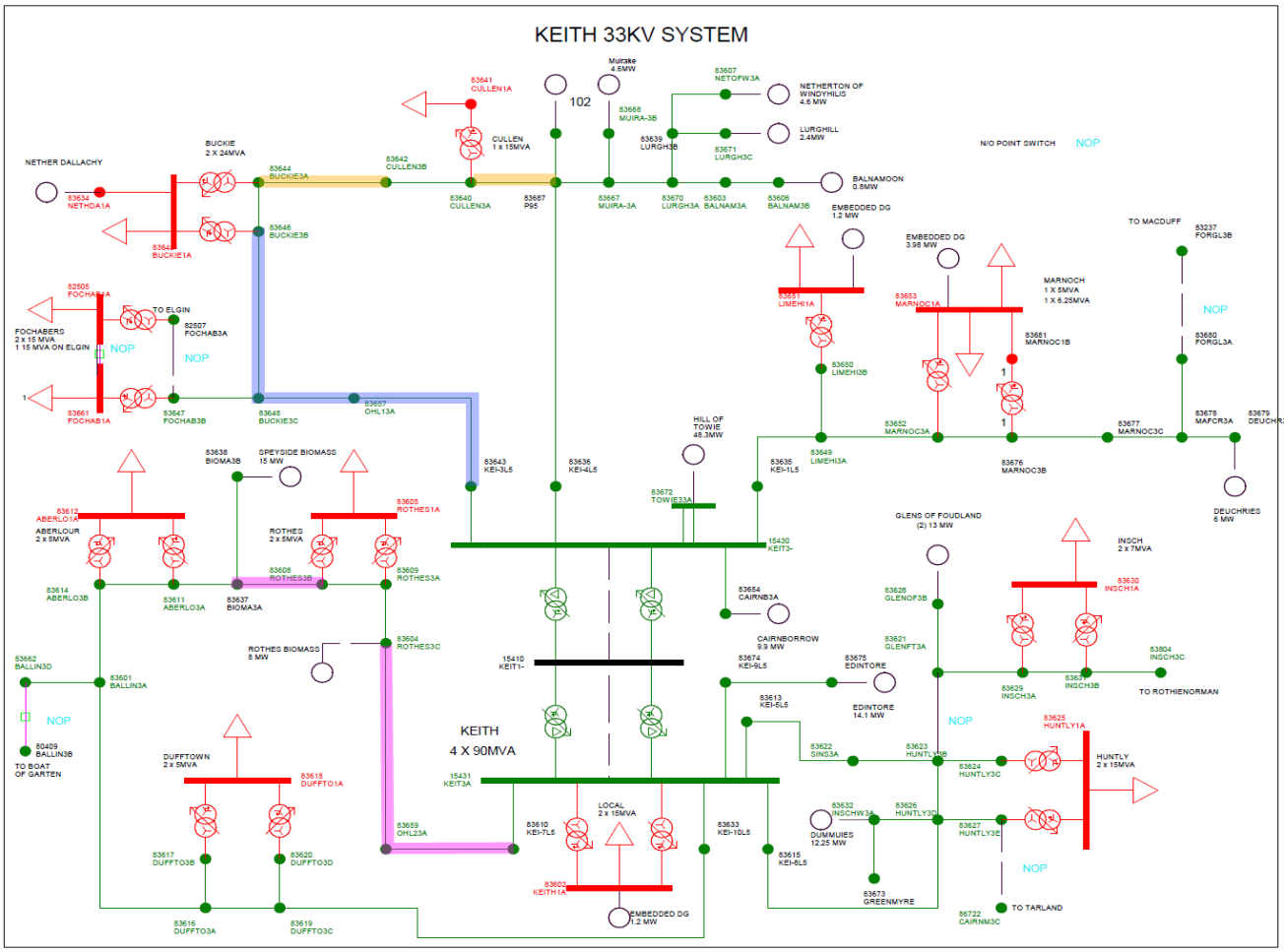
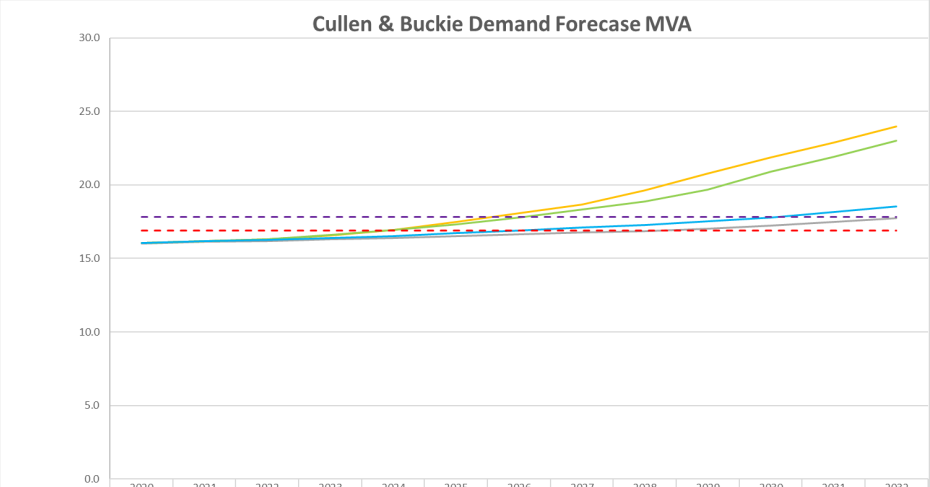


Figure 5: Keith Overloaded Circuits.

4.8 Scenario Modelling

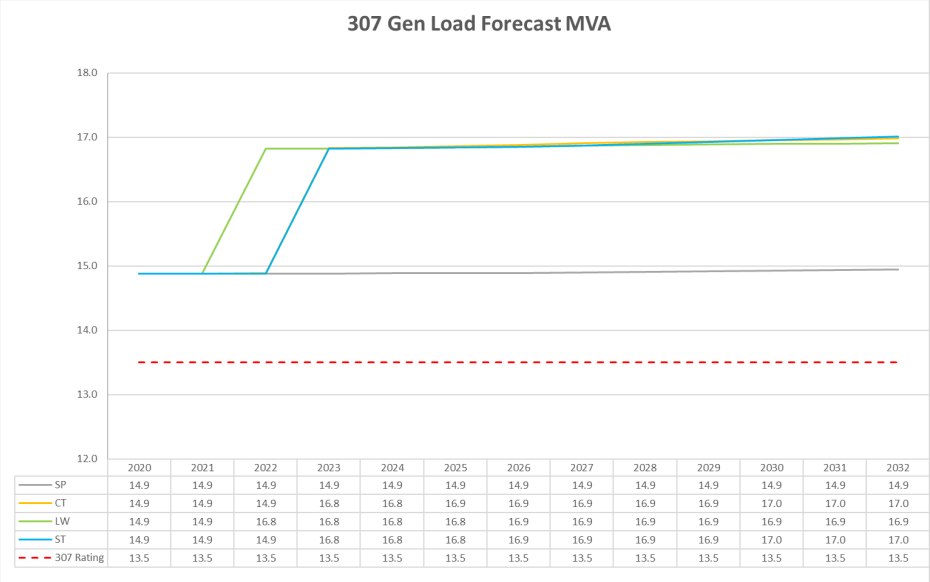
The figures below show the demand projections for Cullen and Buckie, relevant for Keith circuits 303 and 304 for all DFES scenarios for different seasons and the first circuit outage (FCO) ratings of the overloaded conductors. It should be noted that these MVA forecasts assume a nominal voltage of 33kV, the load on the conductor will increase should voltage drop below 1.00pu. In this case, the FCO limit is exceeded for 303 under System Transformation (ST – by 2026), Consumer Transformation (CT – by 2024) and Leading the Way (LW – by 2024) scenarios during ED2. For 304, the rating is exceeded under System Transformation (ST – by 2030), Consumer Transformation (CT – by 2026) and Leading the Way (LW – by 2026) although these are than the power flow from the analysis results when voltage drop has been considered.



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
SP	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.8	16.9	17.0	17.2	17.5	17.7
CT	16.0	16.2	16.3	16.6	17.0	17.5	18.1	18.7	19.7	20.8	21.9	22.9	24.0
LW	16.0	16.2	16.3	16.6	16.9	17.3	17.8	18.3	18.9	19.7	20.9	21.9	23.0
ST	16.0	16.2	16.2	16.4	16.5	16.7	16.9	17.1	17.3	17.5	17.8	18.1	18.5
303 Rating	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9
304 Rating	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8

Figure 6: Cullen & Buckie Demand Forecasts

Considering Keith 307, the below shows the trend for DFES generation forecasts across all the scenarios with the circuit already showing as overloaded in 2020.



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
SP	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9
CT	14.9	14.9	14.9	16.8	16.8	16.9	16.9	16.9	16.9	16.9	17.0	17.0	17.0
LW	14.9	14.9	16.8	16.8	16.8	16.8	16.9	16.9	16.9	16.9	16.9	16.9	16.9
ST	14.9	14.9	14.9	16.8	16.8	16.8	16.9	16.9	16.9	16.9	17.0	17.0	17.0
307 Rating	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5

Figure 7: 307 Net Gen Flow Forecast

4.9 Voltage Assessment

The following table provides the results of the voltage assessment carried out using the 2027/28 DFES demand and generation projections both on the existing network and post investment using the preferred options. The highest or lowest voltage is provided for the Relevant Section of Network (RSN). Circuits 303 and 304 have been assessed under winter max demand conditions and all generation switched off. Circuit 307 has been assessed under summer min demand conditions with all generation switched on.

SYSTEM VOLTAGE LEVELS						
Season	**GSP voltage**	**GSP Demand**	**GSP Generation**	**Study Scenario**	**Highest/ Lowest Voltage**	**33kV Busbar Name**
[-]	[p.u.]	[MVA]	[MVA]	[-]	[p.u.]	[-]
Winter	1.02	51.2	0	Intact	0.97	Buckie 33kV
Winter	1.02	51.2	0	N-1 (303)	0.90	Buckie 33kV
Winter	1.02	51.2	0	N-1 (304)	0.90	Cullen 33kV
Summer	1.00	11.4	224.5	Intact	1.04	Aberlour 33kV
Summer	1.00	11.4	224.5	N-1 (307)	1.04	Aberlour 33kV
Summer	1.00	11.4	224.5	N-1 (310)	1.05	Dufftown 33kV
The above results are within the voltage limits of ± 6% for intact 33KV networks. N-1 voltages are out with intact limits however the tap changers at the 33/11kV transformers to bring 11kV volts within limits. There are no directly connected 33kV customers on the impacted areas of the 33kV network.						

Table 6: Voltage Level Assessment Prior to Investment

4.10 Fault Level Analysis

There are no fault level issues on the Keith GSP network when considering 2027/28 maximum demand and maximum generation conditions. Fault Level results are listed in detailed in Appendix 2.

4.11 Summary

In summary, the forecast increased level of demand and generation on the Keith 33kV network will cause thermal issues in ED2 with the existing network capacity. The need for the network reinforcement works is apparent in ED2 to remove the risk of thermal overloading and maintain network security of supply.

5 Optioneering

This section of the report sets out the investment options that are considered to resolve the forecast overloading issues on the Keith 33kV network. As described below, a holistic approach is taken to ensure investment options that represent best value for money for network customers are identified.

5.1 Whole System Considerations

We have additionally considered the potential for using Whole System solutions (involving collaboration with third parties) to deliver this investment programme. We set out our assessment in Appendix 7. This follows our standardised approach for embedding Whole System considerations into our load and non-load investment decisions (in line with Ofgem's ED2 business plan guidance), as described in our ***Whole System (Annex 12.1)***.

Our assessment enables us to take a proportionate consideration of Whole System options, based on the feasibility of such options existing and materiality of the costs involved.

In this case, our Whole Systems assessment finds that during ED2 specifically, this scheme is not expected to have any wider Whole System interactions and there are no feasible Whole Systems solutions. We note that there are ongoing Whole System interactions between SHEPD and SSEN Transmission to develop a new GSP at Rothienorman, as explained in section 4.2 above. The Rothienorman GSP is contracted for delivery in 2021/22 and will remove approximately 8.39MW of demand from Keith GSP. However, as section 4.2 also notes, this Whole Systems solution will not resolve all of the thermal issues anticipated on the Keith 33kV Circuits during ED2, and therefore further SHEPD-led reinforcement works are required over the ED2 period.

5.2 Summary of Options

The table below provides a high-level summary of the four investment options under consideration along with the advantages and disadvantages associated with each option. A more detailed description of each option is then provided within the proceeding sub-sections.

Option	Description	Advantages	Disadvantages	Results
1. Load Transfer	Load Transfer & Monitor demand development	Low cost and workload.	Does not increase network capacity. Reinforcement may still be required. Need for derogation and justification if P2 compliance breached	Considered but not progressed to CBA
2. Smart Solution & Flexibility Solution with late OHL Reinforcement	Increase operating temperature of existing conductor in early years and reinforce OHL at the end of ED2.	Lower cost compared with conductor reinforcement.	May trigger line rebuild if existing poles cannot be modified to maintain ground safety clearances. Minimum headroom gained. Will not improve volts	Taken forward to CBA Preferred Option for Feeder 303, 304 and 307 (Smart Solution only)
3. Early OHL Reinforcement	Reinforce overloaded conductor in early ED2.	Increase network resilience. Create headroom for new demand. Improve network volts.	May incur long outages for line rebuild. Highest cost.	Taken forward to CBA

4. Flexibility Solution	Consider local generation, storage, smart EV charging etc.	Utilising existing network capacity	Uncertainty of securing participants. Reinforcement may still be required.	Taken forward to CBA

Table 7: Summary of 33kV Circuit Investment Options

5.3 Keith 303

The overloading of the 303 circuit is triggered by the increase in demand at Fochabers, Buckie and Cullen primary substations under winter maximum demand conditions by 2023. The overloaded sections (18.4km) are apparent under the N-1 scenario if a trip at Keith CB 4L5 was to occur. The below provides a high-level summary of options considered, for further details on the study of Keith 303, please see Appendix 1 of this paper.

5.3.1 Option 1: Load Transfer

The overload can be mitigated by transferring the load at Fochabers primary to Elgin GSP. The load transfer however will only relieve the thermal constraints on part (6km) of the Keith 303 circuit although will contribute to the thermal overload of the Elgin 301 circuit. For this reason, this option is not considered viable.

5.3.2 Option 2: Smart Solution & Flexibility Solution and Late OHL Reinforcement (Preferred Option)

Increasing the operating temperature of 18.4km of OHL from 50°C to 75°C will provide further capacity to the circuit and remove the need to reinforce the conductor. The 75°C rating can only be applied if:

- The lines contain grease suitable for 75°C.
- The lines are provided with removable extension links at the tension insulator sets to allow for conductor creep.
- The lines height can be increased for temperature compensated sags to comply with safety clearance heights to meet statutory regulations.

This option will require a full line survey to access core temperature capability and potentially replacement of poles with associated steelwork. The increase in operating temperature will remove the thermal overload on all sections but will create only 0.41MVA of demand headroom on Cullen and Buckie Primary substations.

With this low amount of demand headroom created, this option will have flexibility solution for 4 years and then the reinforcement required in the year 2027/28 based on DFES projections.

5.3.3 Option 3: Early OHL Reinforcement

Reinforcement of 18.4km of OHL with larger conductor. This will increase the capacity of the circuit and create headroom for future demand. It is proposed that 12.4km would be reinforced from 0.1in ACSR to 150mm Cu, increasing the rating from 17.8MVA to 29.3MVA. This would create approximately 9.3MVA of headroom capacity on top of 2027/28 demand.

The 6km of 100mm Cu would need to be reinforced with 150mm Cu. This would increase the rating of these sections from 22.3MVA to 29.3MVA and leave approximately 5.1 MVA of headroom capacity with 2027/28 demand.

Whilst the option leads to extra costs, it is not preferred.

5.3.4 Option 4: Flexible Solution

This option requires securing flexibility services to reduce peak demand to defer or remove the need for conventional reinforcement if Option 3 cannot be delivered on time in early ED2. The figure below shows that

the peak demand at Feeder 303 exceeds the FCO rating for approximately 18.5 hours over the winter months with a requirement between 0-7MVA. This is a substantial amount of generation capacity to secure and it is estimated that flexibility is not a viable option to alleviate this thermal issue.

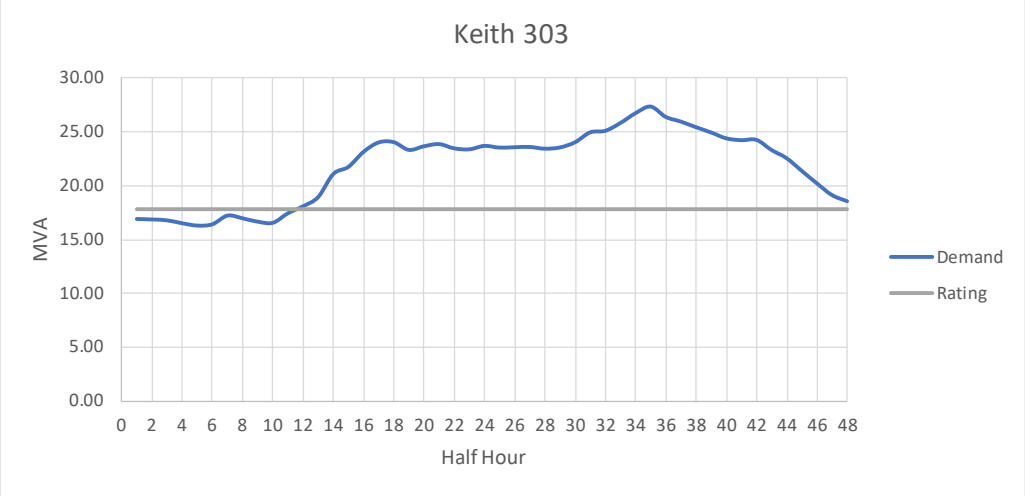


Figure 8: Keith 303 Winter peak demand 2027/28 without flexibility services.

The Common Evaluation Model (CEM) CBA model [4] has been used to assess if there is any benefit on deferring reinforcement of the OHL. The most economically viable conventional solution was obtained from the CBA and input into the Common Evaluation Methodology (CEM) Flexibility CBA to determine if there are economic benefits in deferring the capital investment.

The CEM framework evaluates options around timing of network investments, in particular taking into account:

- the range of different options available (e.g., reinforcing the network, using flexibility, or doing nothing);
- the time periods in which actions can be taken; and
- the existence of uncertainty, and the impact of incremental information which becomes available over time.

The figure below shows the output of the CEM CBA model, estimating that under the CT scenario, there is no benefit of deferring reinforcement.

Overall NPV of deferral	**Optimal length of baseline deferral (years)**	**NPV of optimal deferral**
Flexibility under CT	Baseline	£0
Flexibility under ST	Baseline	£0
Flexibility under SP	Baseline	£0
Flexibility under LW	Baseline	£0

Figure 9: Net benefit of deferring reinforcement Keith 303

Despite our commitment to the Flexibility First approach, in this scenario the current assessment has concluded the required flexibility could not be secured effectively within the allocated investment for the scheme. However, we will need to utilise flexibility to year 2027/28 if there is deliverability issue on option 3.

[4] https://www.energynetworks.org/assets/images/Resource%20library/ON20-WS1A-P1%20Common%20Evaluation%20Methodology-PUBLISHED.23.12.20.pdf

Prior to committing to this investment, we will re-assess the options using the CEM Framework to confirm the optimal solution for this location. Should new services be available, or market prices become favourable, SSEN will market test the Flexibility Services in the affected area to establish the cost, location and technical capabilities of the available flexibility before confirming the optimal route. Flexibility will only be pursued where the economic benefit of deferring the capital investment exceeds the additional cost of the flexibility service, providing an optimised net present value to consumers or potentially delivering additional whole system benefits.

Further to this, flexibility may provide OPEX benefits to SSEN and our customers during scheme delivery by;

a) Avoiding/reducing the risk of outages during planned works through load/generation management
b) Avoiding/reducing the need for Mobile Diesel Generation in planned or unplanned outage scenarios
c) Reducing the scale of the works through the implementation of a 'Hybrid' scheme, part reinforcement and part Flexibility.

These opportunities will be reviewed, and Flexibility secured should the CEM Framework CBA prove a positive benefit, with justification of the decisions/reviews presented as required.

Further detail of our Flexibility First approach and assessment methodology can be found in ***DSO Strategy (Annex 11.1) Appendix F - Delivering Value through Flexibility.***

5.4 Keith 304

The overloading of the 304 circuit is triggered by the increase in demand at Buckie and Cullen primary substations under winter maximum demand conditions. The overloaded sections (15.6km) are apparent under the N-1 scenario if a fault were to occur between Fochabers Primary and Buckie Primary. The below provides a high-level summary of options considered, for further details on the study of Keith 304, please see Appendix 1 of this paper.

5.4.1 Option 1: Load Transfer

The option to do minimum involves monitoring demand increases year on year and taking reactive action once load reaches forecasted values. This option carries a significant amount of risk and may result in increased CIs, CMLs or even non-compliance with ER P2. For this reason, the do-minimum option has been deemed not viable due to the risk associated with this option.

5.4.2 Option 2: Smart Solution & Flexibility Solution and Late OHL Reinforcement (Preferred Option)

Increasing the operating temperature of 15.6km of OHL from 50°C to 75°C will provide further capacity to the circuit and remove the need to reinforce the conductor. The 75°C rating can only be applied if:

- The lines contain grease suitable for 75°C.
- The lines are provided with removable extension links at the tension insulator sets to allow for conductor creep.
- The lines height can be increased for temperature compensated sags to comply with safety clearance heights to meet statutory regulations.

This option will require a full line survey to access core temperature capability and potentially replacement of poles with associated steelwork. The km unit costs for this reinforcement are based around averages from previous project costs of similar work.

The increase in operating temperature will only partially remove the thermal overload and therefore not create any demand headroom on Cullen and Buckie Primary substations. This option will have the flexibility solution for 2 years and the reinforcement required in the year 2027/28 based on DFES projections.

5.4.3 Option 3: Early OHL Reinforcement

Reinforcement of 15.6km of OHL with larger conductor. This will increase the capacity of the circuit and create headroom for future demand. It is proposed that the 6.7km and 8.9km sections are reinforced from 0.1in Cu to 150mm Cu. Increasing the rating from 16.9MVA to 29.3MVA. This would create approximately 4.6MVA of headroom capacity on top of 2027/28 demand.

Whilst the option leads to extra costs, it is not preferred.

5.4.4 Option 4: Flexible Solution

This option requires securing flexibility services to reduce peak demand to defer or remove the need for conventional reinforcement if Option 3 cannot be delivered on time in early ED2. The figure below shows that the peak demand at Feeder 303 exceeds the FCO rating for approximately 17 hours over the winter months with a requirement between 0-5MVA. This is a substantial amount of generation capacity to secure and it is estimated that flexibility is not a viable option to alleviate this thermal issue.

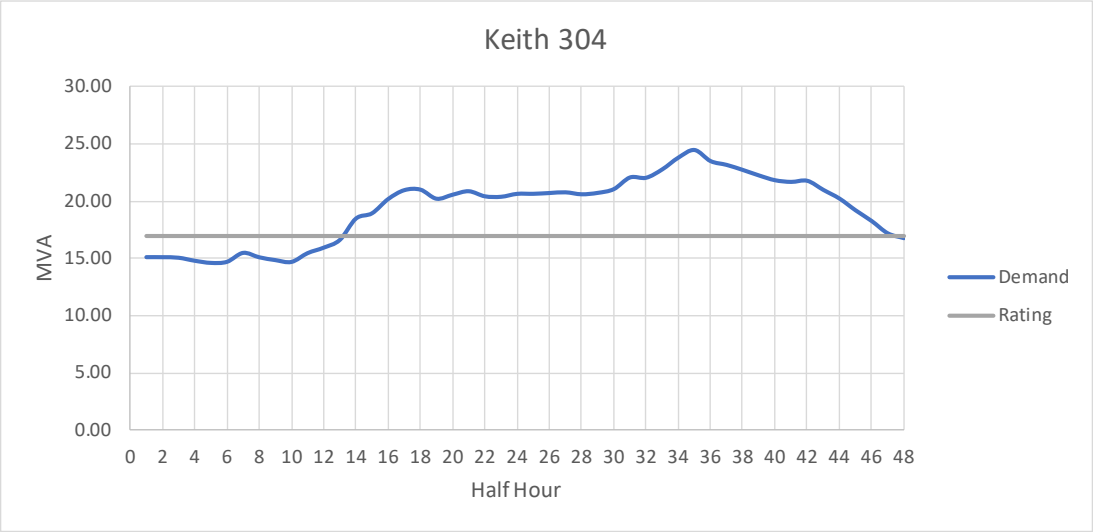


Figure 10: Keith 304 Winter peak demand 2027/28 without flexibility services.

The figure below shows the output of the Baringa CBA model for the 304 reinforcement. This estimates that under the CT scenario, there is no benefit of deferring reinforcement.

Overall NPV of deferral	**Optimal length of baseline deferral (years)**	**NPV of optimal deferral**
Flexibility under CT	Baseline	£0
Flexibility under ST	Baseline	£0
Flexibility under SP	Baseline	£0
Flexibility under LW	Baseline	£0

Figure 112: Net benefit of deferring reinforcement Keith 304

Despite our commitment to the Flexibility First approach, in this scenario the current assessment has concluded the required Flexibility could not be secured effectively within the allocated investment for the scheme. However, we will need to utilise flexibility to year 2027/28 if there is deliverability issue on option 3. Prior to committing to this investment we will re-assess the options using the CEM Framework to confirm the optimal solution for this location. Should new services be available, or market prices become favourable SSEN will market test the Flexibility Services in the affected area to establish the cost, location and technical capabilities of the available flexibility before confirming the optimal route. Flexibility will only be pursued where the economic benefit of deferring the capital investment exceeds the additional cost of the flexibility service, providing an optimised net present value to consumers or potentially delivering additional whole system benefits.

Further to this, flexibility may provide OPEX benefits to SSEN and our customers during scheme delivery by;

a) Avoiding/reducing the risk of outages during planned works through load/generation management
b) Avoiding/reducing the need for Mobile Diesel Generation in planned or unplanned outage scenarios
c) Reducing the scale of the works through the implementation of a 'Hybrid' scheme, part reinforcement and part Flexibility.

These opportunities will be reviewed, and Flexibility secured should the CEM Framework CBA prove a positive benefit, with justification of the decisions/reviews presented as required.

Further detail of our Flexibility First approach and assessment methodology can be found in ***DSO Strategy (Annex 11.1) Appendix F - Delivering Value through Flexibility.***

5.5 Keith 307

The overloading of the 307 circuit is partially apparent under 2019/20 generation capacity and minimum demand at Dufftown and Aberlour. Since generation has last connected in the area, minimum demand has reduced causing thermal issues in worst case export studies. Whilst minimum demand is expected to increase through ED2, embedded generation is also expected to increase, and the thermal issue is expected to worsen.

The increase in generation at Dufftown, Aberlour and Rothes primary substations is expected to increase the thermal overload throughout ED2. The overloaded sections (22km) are apparent under the N-1 condition of trip at CB 10L5 and the below provides a high-level summary of options considered, for further details on the study of Keith 307, please see Appendix 1 of this paper.

5.5.1 Option 1: Load Transfer

This option carries a significant amount of risk and may result in increased CIs, CMLs or even non-compliance with ER P2. Given that 4.2km of the 22km is at risk of overload under 2019/20 demand and generation figures, the do-minimum option has been deemed not viable.

5.5.2 Option 2: Smart Solution (Preferred Option)

Increasing the operating temperature of 22km of OHL from 50°C to 75°C will provide further capacity to the circuit and remove the need to reinforce the conductor. The 75°C rating can only be applied if:

- The lines contain grease suitable for 75°C.
- The lines are provided with removable extension links at the tension insulator sets to allow for conductor creep.
- The lines height can be increased for temperature compensated sags to comply with safety clearance heights to meet statutory regulations.

This option will require a full line survey to access core temperature capability and potentially replacement of poles with associated steelwork. The km unit costs for this reinforcement are based around averages from previous project costs of similar work.

This option increases the summer rating of the 0.1in Cu from 13.49MVA to 17.89MVA and will meet the required capacity of the projected generation figures although it will create approximately 0.06MVA of capacity to 307 following 2027/28 generation forecasts.

Whilst this option is preferred for ED2, it is advised that the generation and demand is closely monitored on this ring circuit and flexibility services are utilised should generation capacity continue to rise past the 2027/28 forecasts.

5.5.3 Option 3: Early OHL Reinforcement

This option looks to reinforce 22km of existing OHL with a larger conductor. The new conductor is required to meet a power flow of 24.92MVA on Keith 307.

The 4.2km of 0.1in Cu should be reinforced with 150mm Cu, increasing the summer rating from 13.5MVA to 23.5MVA. This would create approximately 5.7MVA of headroom capacity on top of 2027/28 generation projections. Potential issues for this option are the maximum conductor size used by SHEPD for 33kV OHL is 150mm Cu so 17.8km of 150mm Cu would need to be reinforced with 400mm Al cable to meet the 24.92MVA power flow requirement.

Given the high cost associated with reinforcing 17.8km of OHL with cable, this option is not preferred.

5.5.4 Option 4: Flexible Solution

This option considers utilising both customer demand and generation capacity to actively manage the peak power flow on existing assets if Option 2 cannot be delivered on time in early ED2. This will allow SHEPD to utilise the existing network effectively and may defer or remove the need for reinforcement action.

The figure below shows that the peak demand at Feeder 307 exceeds the FCO rating for 24 hours over the summer months with a requirement between 0-4MVA. This option is not the preferred choice due the requirement to secure permanent flexibility services and this option not creating any capacity headroom compared with the low-cost option of increasing the operating temperature. This option is to be considered in future for this circuit should generation capacity continue to rise past the 2027/28 forecasts and approach overloading the 75°C conductor rating.

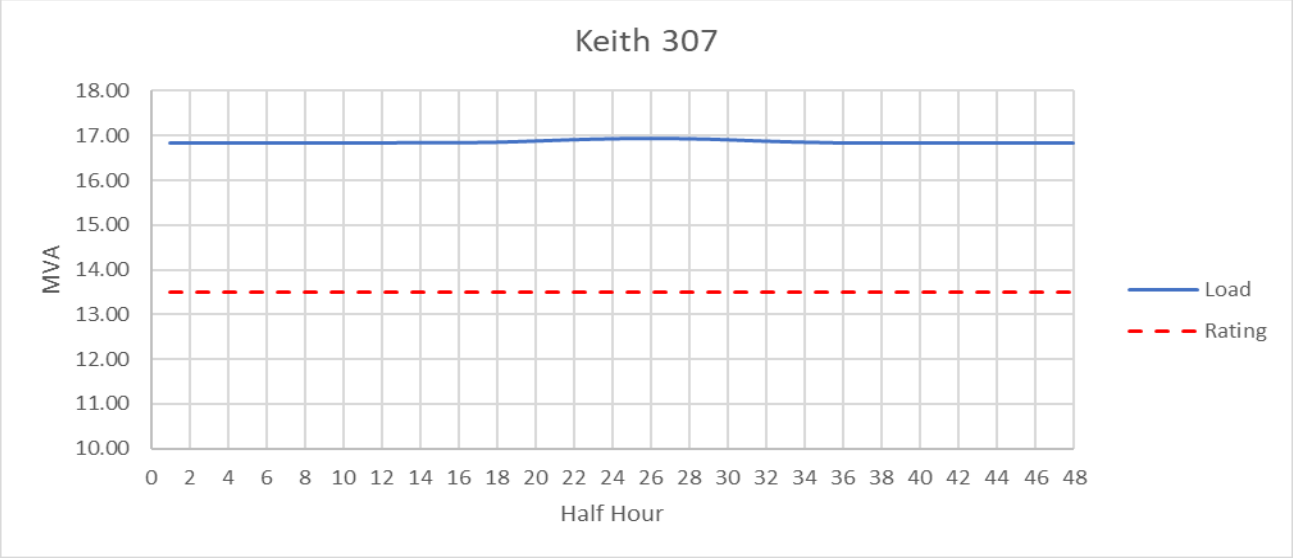


Figure 12: Keith 307 Summer min demand, max generation 2027/28 without flexibility services

The figure below shows the output of the Baringa CBA model for the 307 reinforcement. This estimates that under the CT scenario, there is no benefit of deferring reinforcement.

Overall NPV of deferral	**Optimal length of baseline deferral (years)**	**NPV of optimal deferral**
Flexibility under CT	Baseline	£0
Flexibility under ST	Baseline	£0
Flexibility under SP	Baseline	£0
Flexibility under LW	Baseline	£0

Figure 13: Net benefit of deferring temperature increase on Keith 307

Despite our commitment to the Flexibility First approach, this project is not technically compatible with a Flexible Solution due to the expected Thermal constraint being constant throughout the year. However,, we will need to utilise flexibility to year 2027/28 if there is deliverability issue on preferred option 2.
Prior to committing to this investment, we will re-assess the options using the CEM Framework to confirm the optimal solution for this location. Should new services or solutions become available SSEN will market test the Flexibility Services in the affected area to establish the cost, location and technical capabilities of the available flexibility before confirming the optimal route. Flexibility will only be pursued where the economic benefit of deferring the capital investment exceeds the additional cost of the flexibility service, providing an optimised net present value to consumers or potentially delivering additional whole system benefits.

Further to this, flexibility may provide OPEX benefits to SSEN and our customers during scheme delivery by;

a) Avoiding/reducing the risk of outages during planned works through load/generation management
b) Avoiding/reducing the need for Mobile Diesel Generation in planned or unplanned outage scenarios
c) Reducing the scale of the works through the implementation of a 'Hybrid' scheme, part reinforcement and part Flexibility.

These opportunities will be reviewed, and Flexibility secured should the CEM Framework CBA prove a positive benefit, with justification of the decisions/reviews presented as required.

6 Analysis and Cost

This section provides an overview of the results from the Cost Benefit Analysis (CBA). This detailed exercise has been undertaken to support the investment strategies discussed within this EJP.

6.1 CBA of investment options

Ofgem's RIIO-ED2 standard CBA template was used to assess costs and benefits of the conventional options for each circuit individually. Capital reinforcement costs, CI/CML penalties, network losses and other societal benefits are the key parameters used in the options progressed. The customer interruptions / customer minutes lost (CI/CML) were calculated based on the improvement of health conditions of the assets and the probability of a failure.

This scheme was initially proposed to be constructed in 2023/24. The concept of premium pricing has been developed by the Commercial and Deliverability workstream to provide a way to capture the cost of delivering a project earlier than is feasible to help with deliverability of the plan. The premium cost has been based upon tender returns for representative model projects across a variety of asset categories. The premium cost is the difference between evaluated tender rates for lowest submitted tender and highest submitted tenders. In this EJP, the premium price relates to OHL works and attracts a 35% uplift on the lowest submitted tender. For Cable works, we have undertaken a bottom up analysis of a representative sample of ED1 projects to calculate the premium cost, which is the difference between the internal and external delivery rates of historic cable projects. Due to the complexity of this scheme and our assessment of delivery constraints, we have also considered the use of flexibility to defer the investment to the end of ED2 and maintain compliance with P2. From the outcome of CBA analysis, we revised our investment phasing accordingly to ensure our Business Plan is deliverable, meets our consumers' needs and is most cost efficient for our consumers. Further information on our Cost Benefit Analysis (CBA) approach is set out within our ***Cost Benefit Analysis Process (Annex 15.8)***.

6.2 CBA Results

The CBA results below show the cost of each viable option and associated NPV. The preferred option has been determined based on the least NPV unless stated otherwise.

Where premium cost has been applied, the option title below will contain (*).

6.2.1 Keith 303 CBA Results

Summary of Cost

Options	Unit	2024	2025	2026	2027	2028	ED3+	Total £k
Option 2 – Smart Solution& Flexibility Solution and Late Reinforcement (The Preferred Option)	**£k**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0	[redacted]
Option 3 – Early OHL Reinforcement *	**£k**	[redacted]	0	0	0	0	0	[redacted]
Option 4 – Deferral of Option 3 to Year 2028	**£k**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0	[redacted]

Cost Benefit Analysis comparisons

Options	Net Present Value (NPV) After 45 Years (£k)	Investment (£k)
Option 2 – Smart Solution & Flexibility Solution and Late Reinforcement (The Preferred Option)	-429	[redacted]
Option 3 – Early OHL Reinforcement *	-530	[redacted]
Option 4 – Deferral of Option 3 to Year 2028	-4,006	[redacted]

For Keith 303, the investment and NPV value of Option 2 is the lowest and therefore is taken forward as the preferred solution.

6.2.2 Keith 304 CBA Results

Summary of Cost

Options	Unit	2024	2025	2026	2027	2028	ED3+	Total £k
Option 2 – Smart Solution& Flexibility Solution and Late Reinforcement (The Preferred Option)	**£k**	[redacted]	0	[redacted]	[redacted]	[redacted]	0	[redacted]
Option 3 – Early OHL Reinforcement*	**£k**	[redacted]	0	0	0	0	0	[redacted]
Option 4 – Deferral of Option 3 to Year 2028	**£k**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0	[redacted]

Cost Benefit Analysis comparisons

Options	Net Present Value (NPV) After 45 Years (£k)	Investment (£k)
Option 2 – Smart Solution & Flexibility Solution and Late Reinforcement (The Preferred Option)	403	[redacted]
Option 3 – Early OHL Reinforcement*	-176	[redacted]
Option 4 – Deferral of Option 3 to Year 2028	-568	[redacted]

For Keith 304, the investment and NPV value of Option 2 is the lowest and therefore is taken forward as the preferred solution.

6.2.3 Keith 307 CBA Results

Summary of Cost

Options	Unit	2024	2025	2026	2027	2028	ED3+	Total £k
Option 2 – Smart Solution (The Preferred Option)	**£k**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0	[redacted]
Option 3 – Early OHL Reinforcement *	**£k**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0	[redacted]
Option 4 – Deferral of Option 3 to Year 2028	**£k**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]

Cost Benefit Analysis comparisons

Options	Net Present Value (NPV) After 45 Years (£k)	Investment (£k)
Option 2 – Smart Solution (The Preferred Option)	-180	[redacted]
Option 3 – Early OHL Reinforcement *	-3,873	[redacted]
Option 4 – Deferral of Option 3 to Year 2028	-3,197	[redacted]

For Keith 307, the investment and NPV value of Option 2 is the lowest and therefore is taken forward as the preferred solution.

6.3 CBA Summary

For Keith 33kV circuits 303 and 304, the CBA shows the most economical solution is to increase the operating temperature of the conductor and replace at the end of ED2 (Option 2). This solution does however trigger investment during 2023/24. Option 2 has proved the cheapest option due to the benefit of differing reinforcement to a later date although the CBA has not considered the costs associated with circuit outages or setup of CDM. Increasing the operating temperature would also not fix the poles from non-load or improve the voltage of the network.

For Keith 307, the cost to increase the operating temperature is substantially lower than reinforcement due to the long cable sections required. It is proposed that the temperature increase is combined with potential securement of flexibility should generation capacity continue to grow in ED3.

6.4 Costing Approach

Our RIIO ED2 Business Plan costs are derived from our outturn RIIO ED1 expenditure. We have modified costs per activity, capturing and reporting those adjustments in our cost-book. By tying our costs back to reported outturn, real life data has been used which provides multiple data points both SSEN and the Regulator can use to benchmark costs efficiently.

It provides a high level of cost confidence in our Business Plan cost forecast for RIIO ED2. Through our benchmarking analysis, we recognised that not all Non-Load related RIIO-ED1 actual unit costs sit within the upper quartile efficiency band. Where this is the case, we have applied a catch-up efficiency to those cost categories.

Further detail on our unit cost approach, cost efficiency and cost confidence for RIIO-ED2 can be found within our ***Cost Efficiency (Annex 15.1)***[5]. Following our draft Business Plan, we have continued to develop project scopes and costs, utilising valuable stakeholder feedback. We have included developments of our Commercial Strategy within the updated project scope and delivery strategy.

[5] ***Cost Efficiency (Annex 15.1)***

7 Deliverability and Risk

Between our draft and final Business Plans we have carried out a more detailed deliverability assessment of our overall plan as a package and its component investments. Using our draft Business Plan investment and phasing as a baseline, we have followed our deliverability assessment methodology. We have assessed any potential delivery constraints to our plan based on:

- In-house workforce capacity and skills constraints based on our planned recruitment and training profile and planned sourcing mix as well as the efficiencies we have built into our Business Plan. ***(detailed in our Workforce Resilience Strategy in (Annex 16.3)*** and ***Cost Efficiency (Annex 15.1)***
- Assessment of the specific lead and delivery timelines for the asset classes in our planned schemes
- We have evaluated our sourcing mix where there were known delivery constraints to assess opportunities to alleviate any constraints through outsourcing
- We have engaged our supply chain detailed in our ***Supply Chain Strategy (Annex 16.2)*** to explore how the supply chain could support us to efficiently deliver greater volumes of work and how we could implement a range of alternative contracting strategies to deliver this
- We have also engaged with the supply chain on the delivery of work volumes that sit within Uncertainty Mechanisms to ensure we have plans in place to deliver this work if and when the need arises
- Specific to load schemes: We have carried out flexibility assessments at all voltage levels in order to understand when we can defer reinforcement through paying for flexibility services, therefore ensuring our investment profile is deliverable and at the lowest cost to consumers see ***Flexibility within Load Related Plan Build and Strategy (Annex 10.1***)
- We have assessed the synergies between our planned load, non-load and environmental investments to most efficiently plan the scheduling of work and minimise disruption to consumers
- Based on our assessment of delivery constraints and the results of CBA analysis, the revised investment phasing for Keith 303 and 304 is proposed to be 2027/28 with lower levels of temporary reinforcement in 2023/24. The investment phasing for Keith 307 is proposed to be 2023/24.

The table below sets out the revised investment phasing based on the outcome of our deliverability assessment:

	2023/24	2024/25	2025/26	2026/27	2027/28
Revised Investment Phasing	Keith 303 (Temp) Keith 304 (Temp) Keith 307				Keith 303 Keith 304

This investment scheme is part of the wider load-related investment portfolio in RIIO-ED2. SSEN have developed a strategy to deliver a much larger volume of work in comparison with the level of investment in ED1. We have engaged with our supply chain to negotiate the most effective unit costs and we have taken measures to ensure we secure a future workforce with the right skills and competencies to deliver capital projects in ED2.

In RIIO-ED1, SHEPD have delivered a number of 33kV and 11kV OHL projects using internal workforce. The experience and skills acquired from these projects lay the foundation for the delivery of the proposed option within this paper.

The specific considerations for deliverability based on the scope of Keith 33kV Circuits are detailed below:

- Training
- Location including access issues and civils

- Supply chain
- Work phasing and project interdependencies
- System interfaces for controls, Network operation and SCADA
- Flex requirement potential risk. Flex has not been chosen as the preferred solution however may be required should generation capacity continue to rise on Keith 307.

8 Conclusion

This EJP has raised the need for load related investment on Keith 33kV circuits 303, 304 and 307 within the ED2 price control period. This need for investment is triggered by the forecasted increase in demand and generation on the Keith 33kV network. This load increase is driven by a combination of EV and HP uptake along with increasing capacity of embedded renewable generation. Reinforcement is required to avoid the risk of non-compliance in RIIO-ED2.

Four investment options have been considered for each circuit separately and the preferred solution involves a combination of flexibility, increasing the operating temperature of 56km of existing OHL, reinforcement of 34km OHL conductor with 150mm Cu and the replacement of approximately 408 33kV poles. All viable options are supported by a CBA which provides further breakdown of economic viability over a 45-year period.

The proposed ED2 investment with the combined scheme total of £5.58m. It is proposed that all reinforcement is carried out in the 2027/28 financial year to minimise the risk of thermal overload and network non-compliance.

Appendix 1: Detailed Analysis

Keith 303

Under the N-1 condition of a breaker trip at Keith 4L5, the only 33kV backfeed for the customers on this circuit is Keith 303. Under this fault scenario and the 2027/28 demand, three sections of OHL are overloaded. As shown below, the 12.4km of 0.1in ACSR is overload to 116% of its 17.8MVA rating. The 2.8km and 3.2km sections of 100mm Cu are overloaded to 105% of their 22.3MVA rating. The following section will go over the investment options in more detail.

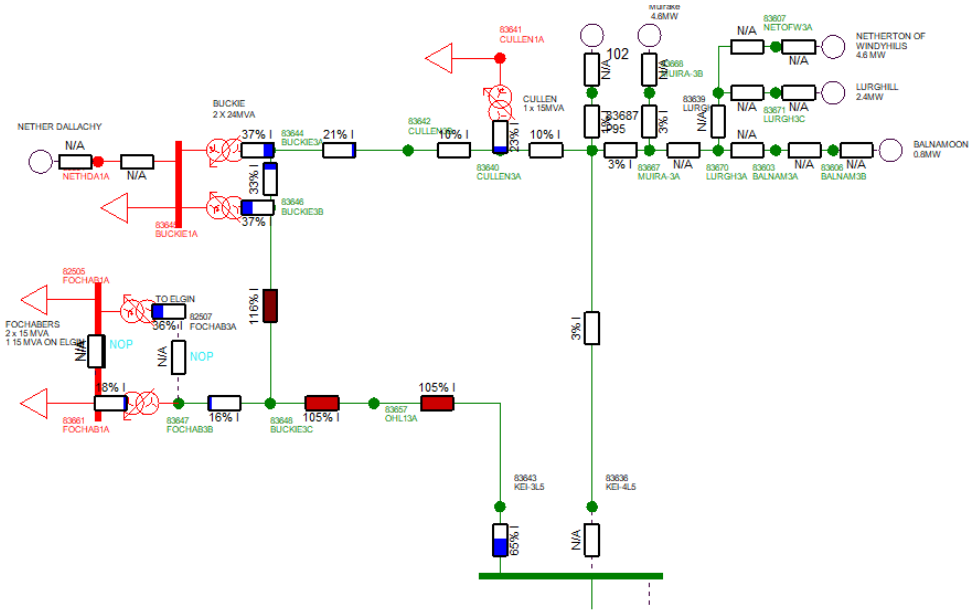


Figure 14: Keith 303 with 2027/28 demand (N-1 4L5)

Option 1: Load Transfer

Currently, Fochabers Primary is fed from both Elgin and Keith GSPs and is split by two NOPs. Approximately one third of the customers are fed by Keith with projected load of 2.57MVA by 2027/28.

The do minimum proposal is to move all Fochabers demand over to Elgin GSP by closing the current 33kV NOP at 1S8 and opening the isolator at 4L7. This would relieve the loading on the 6km of 100mm Cu to 92% of the 22.3MVA rating. This option leaves only the 12.4km section of 0.1in ACSR overloaded but also contributes to the overload of Elgin 33kV circuit 301 under a separate N-1 scenario.

For this reason, the do minimum scenario has been deemed not viable.

Option 2: Smart Solution& Flexibility Solution and Late OHL Reinforcement (The Preferred Option)

The option to increase the operating temperature will vary in cost depending on the construction of the existing OHL sections and their capability to run at 75°C which will require a full line survey to access. Whilst this option will solve the thermal loading issue of the sections, it will not change the circuit impedance and therefore not improve the voltage.

Circuit	Start Node	End Node	Start Pole	End Pole	Conductor	Length (km)	Rating (MVA)	2027 Flow (MVA)	75oC Rating (MVA	Headroom (MVA)	Contingency	Year	Trigger
KEITH (303)	83646	83648	Pole 1	Pole 83	OH Line - 0.1eq ACSR	12.4	17.80	20.97	21.38	0.41	N-1	2023	Demand
KEITH (303)	83643	83657	Pole 242	Pole 275	OH Line - 100mm Cu.	2.8	22.30	24.13	26.92	2.79	N-1	2027	Demand
KEITH (303)	83648	83657	Pole 278	Pole 308	OH Line - 100mm Cu.	3.2	22.30	24.13	26.92	2.79	N-1	2027	Demand

When increasing the operating temperature, the rating of the 0.1in ACSR will increase from 17.8MVA to 21.4MVA and the rating of the 100mm Cu will increase from 22.3MVA to 26.9MVA. The increase in operating temperature will remove the thermal overload on all sections but will create only 0.41MVA of demand headroom Cullen and Buckie Primary substations. The reinforcement is required in year 2018 for this option.

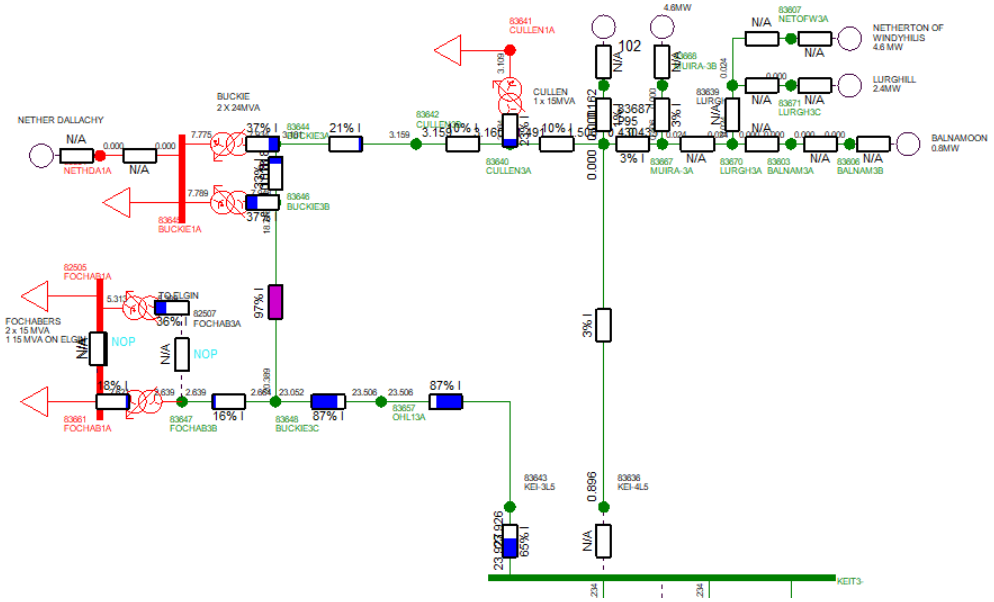


Figure 15: Option 2 Keith 303 with 2027/28 demand (N-1 4L5)

Option 3: Early OHL Reinforcement

Reinforcement of 18.4km of OHL with larger conductor. This will increase the capacity of the circuit and create headroom for future demand. It is expected 12.4km would be reinforced from 0.1in ACSR to 150mm Cu. Increasing the rating from 17.8MVA to 29.3MVA. This would create approximately 9.3MVA of headroom capacity on top of 2027/28 demand for this section.

The 6km of 100mm Cu is should also be reinforced with 150mm Cu. This would increase the rating of these sections from 22.3MVA to 29.3MVA and leave approximately 5.1 MVA of headroom capacity with 2027/28 demand with a joining 185mm Cu cable section being the weak point.

Both reinforcements improve the N-1 volts at Cullen Primary.

These increases in OHL conductor size would trigger a full line rebuild as anything above 100mm requires heavier OHL construction. In addition to the conductor cost, this option would trigger all poles and associated steelwork to be replaced for the 18.4km section.

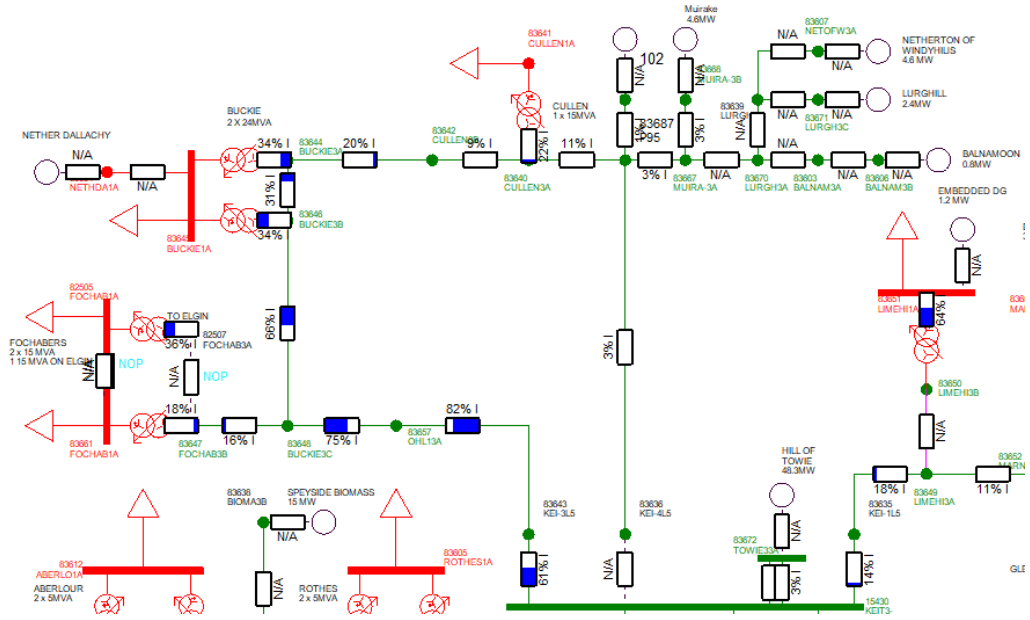


Figure 16: Option 3 Keith 303 with 2027/28 demand (N-1 4L5)

Keith 304

Under the N-1 condition of a fault on Keith 303 between Fochabers Primary and Buckie Primary, the only 33kV backfeed for this circuit is Keith 304. Under this fault scenario and the 2027/28 demand, two sections of OHL are overloaded totalling 15.6km. As shown below, the 6.7km and 8.9km sections of 0.1in Cu are overloaded to 125% and 105% respectively. The following section will go over the investment options in more detail.

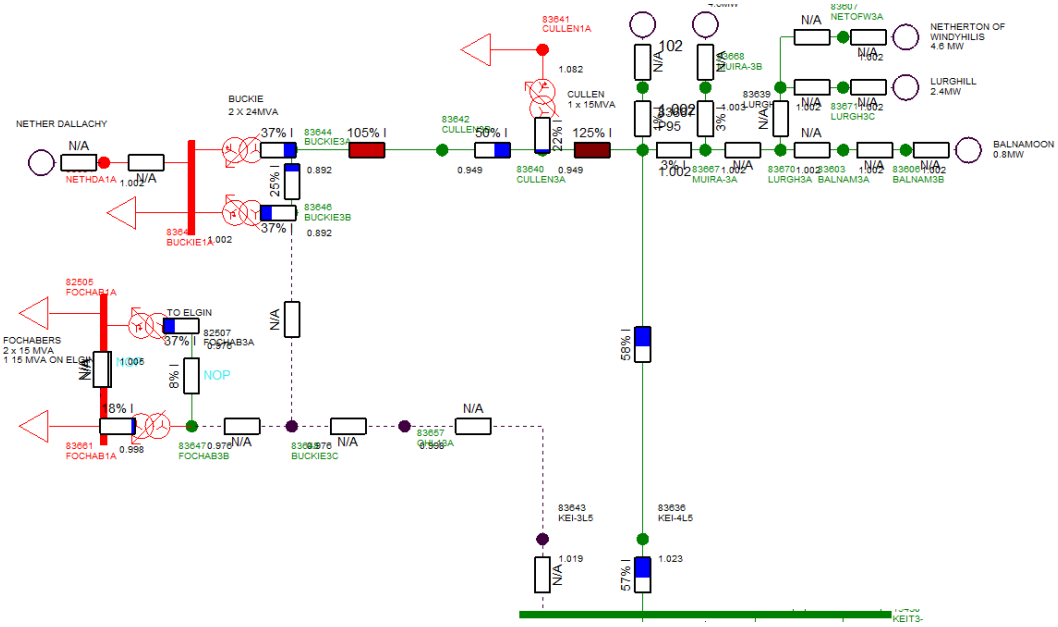


Figure 17: Keith 304 with 2027/28 demand (N-1 3L5)

Option 1: Load Transfer

The overloading of the circuits is caused by the increase in demand at Cullen and Buckie primary substations under maximum winter demand conditions. The option to do minimum involves monitoring demand increases year on year and taking reactive action once load reaches forecasted values. This option carries a significant amount of risk and may result in increased CIs, CMLs or even non-compliance with ER P2. For this reason, the do-minimum option has been deemed not viable due to the risk associated with this option.

Option 2: Smart Solution & Flexibility Solution and Late OHL Reinforcement (The Preferred Option)

The option to increase the operating temperature will vary in cost depending on the construction of the existing OHL sections and their capability to run at 75°C which will require a full line survey to access. For the 6.7km section on Keith 304, this option will not solve the thermal loading issue following the 2027/28 demand projections.

Circuit	Start Node	End Node	Start Pole	End Pole	Conductor	Length (km)	Rating (MVA)	2027 Flow (MVA)	75oC Rating (MVA	Headroom (MVA)	Contingency	Year	Trigger
KEITH (304)	83640	83687	Pole 95	Pole161	OH Line - 0.1in Cu.	6.7	16.90	22.30	20.35	-1.95	N-1	2022	Demand
KEITH (304)	83642	83644	Pole 1	Pole 96	OH Line - 0.1in Cu.	8.9	16.90	17.42	20.35	2.93	N-1	2028	Demand

Increasing the operating temperature to 75°C increases the rating of the 8.9km section of 0.1in Cu from 16.9MVA to 20.35MVA. Whilst this could potentially defer the need for reinforcement, this would still require reinforcement in 2028 based on DFES forecasts.

Option 3: Early OHL Reinforcement

It is proposed the 15.6km of 0.1in Cu is reinforced with 150mm Cu. This would increase the rating of these sections from 16.9MVA to 29.3MVA and create 7MVA of headroom capacity over 2027/28 demand. This increase in OHL conductor size would trigger a full line rebuild as anything above 100mm requires heavier OHL construction. In addition to the conductor cost, this option would trigger all poles and associated steelwork to be replaced for the 15.6km.

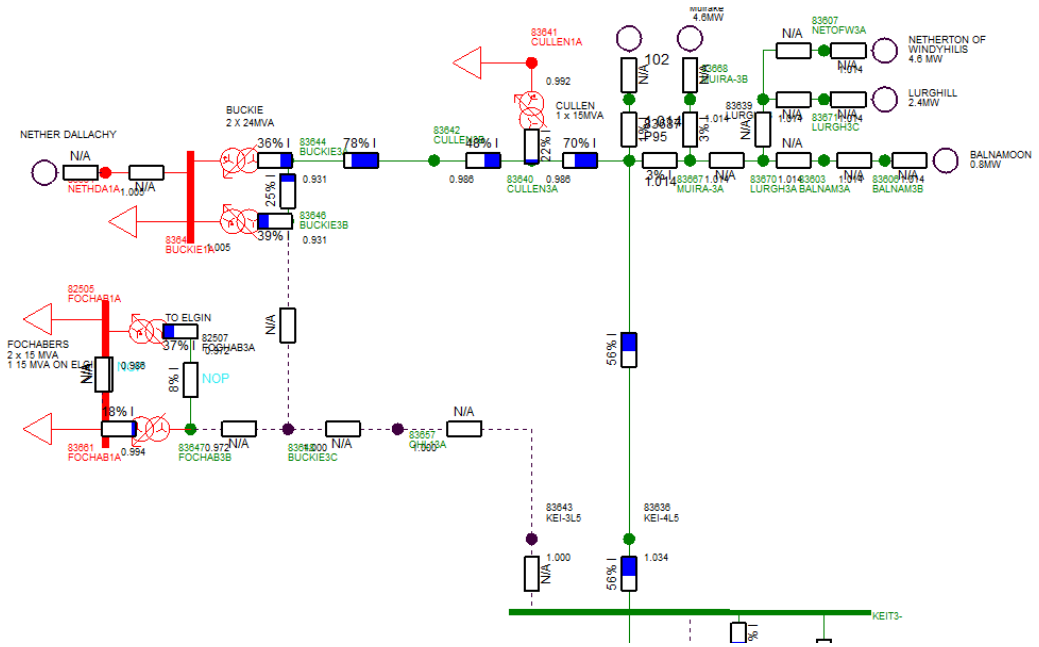


Figure 18: Option 3 Keith 304 with 2027/28 demand (N-1 3L5)

Keith 307

The overloaded sections on 307 (22km) are apparent under the N-1 scenario if a trip at CB 10L5 was to occur and all generation connected on the closed ring circuit is fed through Keith 307. The overloaded sections include a 4.2km of 0.1in Cu, loaded to 132% of its rating and 17.8km of 150mm Cu, loaded to 106% depending on scenario.

The overloading of the circuit is caused by existing 33kV connected generators and 2027/28 embedded forecast generation on Dufftown, Aberlour and Rothes primary substations under minimum demand conditions. There is currently 23MW of generation connected between Keith 307 and Keith 310 with a projected figure of 3.8MW additional generation capacity by 2027/28 under the CT scenario.

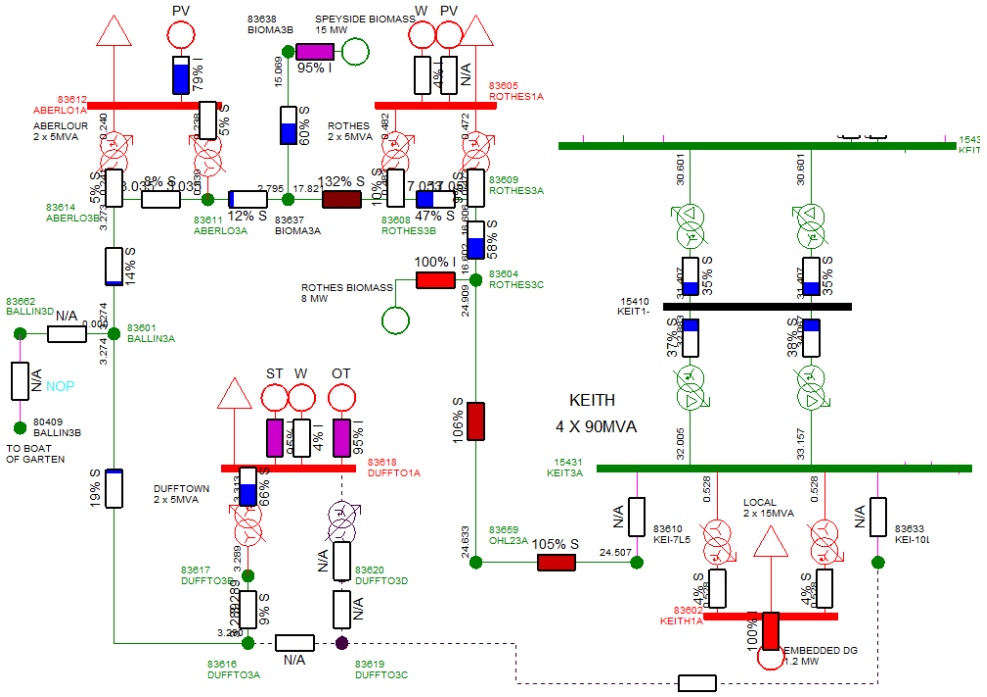


Figure 19: Keith 307 with 2027/28 generation (N-1 10L5)

Option 1: Do-Minimum

As previously stated, this option carries a significant amount of risk and may result in increased CIs, CMLs or even non-compliance with ER P2. Given that 4.2km of the 22km is at risk of overload under 2019/20 demand and generation figures, the do-minimum option has been deemed not viable.

Option 2: Smart Solution (Preferred Option)

The option to increase the operating temperature will vary in cost depending on the construction of the existing OHL sections and their capability to run at 75°C which will require a full line survey to access. Whilst this option will solve the thermal loading issue of the sections, it will not change the circuit impedance and therefore not effect network voltage.

Circuit	Start Node	End Node	Start Pole	End Pole	Conductor	Length (km)	Rating (MVA)	2027 Flow (MVA)	75oC Rating (MVA	Headroom (MVA)	Contingency	Year	Trigger
KEITH (307)	83659	83610	Pole 19	Pole 141	OH Line - 150mm Cu.	9.9	23.49	24.65	31.20	6.55	N-1	2028	Generation
KEITH (307)	83604	83659	Pole 141	Pole 233	OH Line - 150mm Cu.	7.9	23.49	24.92	31.20	6.28	N-1	2028	Generation
KEITH (307)	83608	83637	Pole 95	Pole 143	OH Line - 0.1in Cu.	4.2	13.49	17.83	17.89	0.06	N-1	2028	Generation

Increasing the operating temperature to 75°C increases the summer rating of the 0.1in Cu from 13.49MVA to 17.89MVA and increases 150mm Cu from 23.49MVA to 31.20MVA.

This option will meet the required capacity of the projected generation figures although it will create approximately 0.06MVA of capacity to 307 following 2027/28 generation forecasts.

Whilst this option is preferred for ED2, it is advised that the generation and demand is closely monitored on this ring circuit and flexibility services are utilised should generation capacity continue to rise past the 2027/28 forecasts.

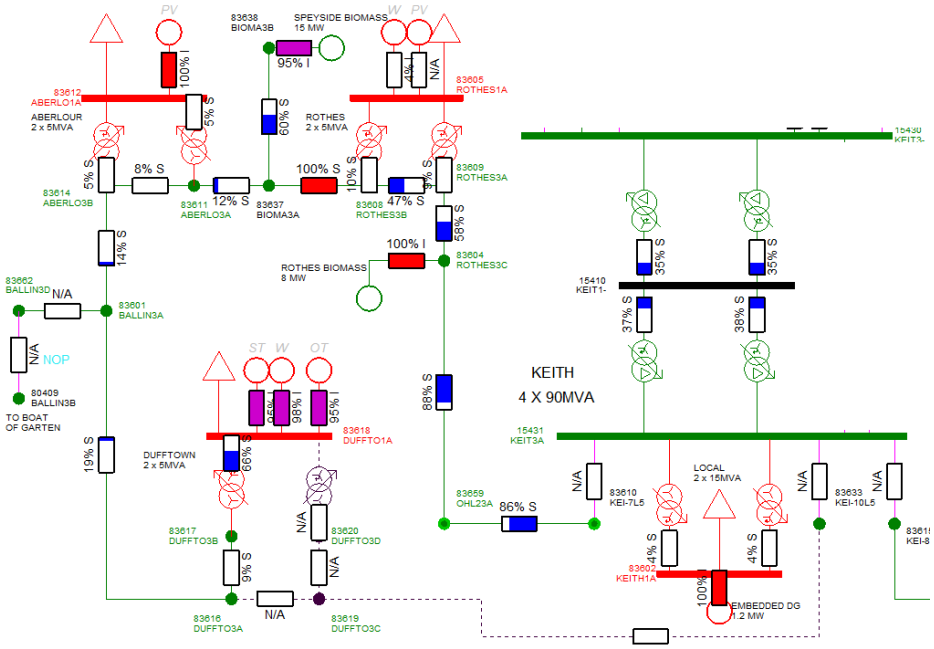


Figure 20: Option 2 Keith 307 with 2027/28 generation (N-1 10L5)

Option 3: Reinforcement

This option looks to reinforce existing OHL with a larger conductor. The new conductor is required to meet a power flow of 24.92MVA on Keith 307.

The 4.2km of 0.1in Cu should be reinforced with 150mm Cu, Increasing the summer rating from 13.5MVA to 23.5MVA. This would create approximately 5.66MVA of headroom capacity on top of 2027/28 generation projections. Potential issues for this option are the maximum conductor size used by SHEPD for 33kV OHL is 150mm Cu so 17.8km of 150mm Cu would need to be reinforced with cable to meet the need for 24.92kVA.

Given the high cost associated with reinforcing 17.8km of OHL with cable, this option is not preferred.

All Circuits - Flexible Solution

For demand constrained assets (303&304), flexibility requirements outlined in Section 5 were calculated by combining dependant primary demands and comparing against the asset rating. Assuming generation remains switched off, as there are no current contracts in place to secure generation capacity, the timeframe of demand above the asset ratings was used to obtain a MWh value for flexible requirement.

For generation constrained assets (307), flexibility requirements outlined in Section 5 were calculated by combining 33kV connected generation along with dependant primary net demand with generation operating at full output. The timeframe of generation load above the asset rating was used to obtain a MWh value for flexible requirement.

Appendix 2: Fault Level Results

GSP	Node	Name	kV	MAKE FL kA	BREAK FL kA	Make Rating kA	Break Rating kA	% Make	% Break
KEITH	15430	KEIT3-	33	37.86	12.74	44.60	17.50	84.88	72.82
KEITH	15431	KEIT3A	33	40.72	14.45	62.50	25.00	65.15	57.81
KEITH	83602	KEITH1A	11	23.16	8.00	33.41	13.10	69.34	61.08
KEITH	83605	ROTHES1A	11	12.31	4.38	33.41	13.10	36.85	33.42
KEITH	83609	ROTHES3A	33	9.71	3.69	33.40	13.10	29.07	28.16
KEITH	83612	ABERLO1A	11	10.82	4.13	33.41	13.10	32.39	31.51
KEITH	83614	ABERLO3B	33	7.67	3.13	33.40	13.10	22.95	23.87
KEITH	83616	DUFFTO3A	33	7.25	3.14	33.41	13.10	21.72	24.00
KEITH	83618	DUFFTO1A	11	11.72	4.40	33.41	13.10	35.07	33.59
KEITH	83624	HUNTLY3C	33	10.37	4.36	62.50	25.00	16.60	17.44
KEITH	83625	HUNTLY1A	11	15.30	5.53	33.41	13.10	45.81	42.18
KEITH	83628	GLENOF3B	33	6.62	2.64	62.50	25.00	10.59	10.57
KEITH	83629	INSCH3A	33	4.05	1.89	33.41	13.10	12.12	14.46
KEITH	83630	INSCH1A	11	8.77	3.85	33.41	13.10	26.25	29.37
KEITH	83632	INSCHW3A	33	7.14	3.09	62.50	25.00	11.43	12.36
KEITH	83638	BIOMA3B	33	9.18	3.50	62.50	25.00	14.68	13.99
KEITH	83641	CULLEN1A	11	8.79	3.33	50.00	20.00	17.58	16.64
KEITH	83644	BUCKIE3A	33	7.03	3.23	22.19	8.70	31.67	37.08
KEITH	83645	BUCKIE1A	11	14.40	6.12	33.41	13.10	43.10	46.75
KEITH	83647	FOCHAB3B	33	3.99	1.90	22.19	8.70	17.98	21.89
KEITH	83651	LIMEHI1A	11	4.17	1.58	31.25	12.50	13.35	12.62
KEITH	83652	MARNOC3A	33	7.20	2.68	25.00	10.00	28.78	26.81
KEITH	83653	MARNOC1A	11	11.07	3.85	33.41	13.10	33.13	29.38
KEITH	83661	FOCHAB1A	11	6.75	2.97	33.41	13.10	20.20	22.66
KEITH	83668	MUIRA-3B	33	5.18	2.35	62.50	25.00	8.29	9.40
KEITH	83671	LURGH3B	33	7.45	3.23	62.50	25.00	11.92	12.92
KEITH	83672	TOWIE33A	33	27.28	8.87	62.50	25.00	43.65	35.48

Appendix 3: Geographic Views

Figure 21: 303 (Orange) and 304 (Blue) Investment

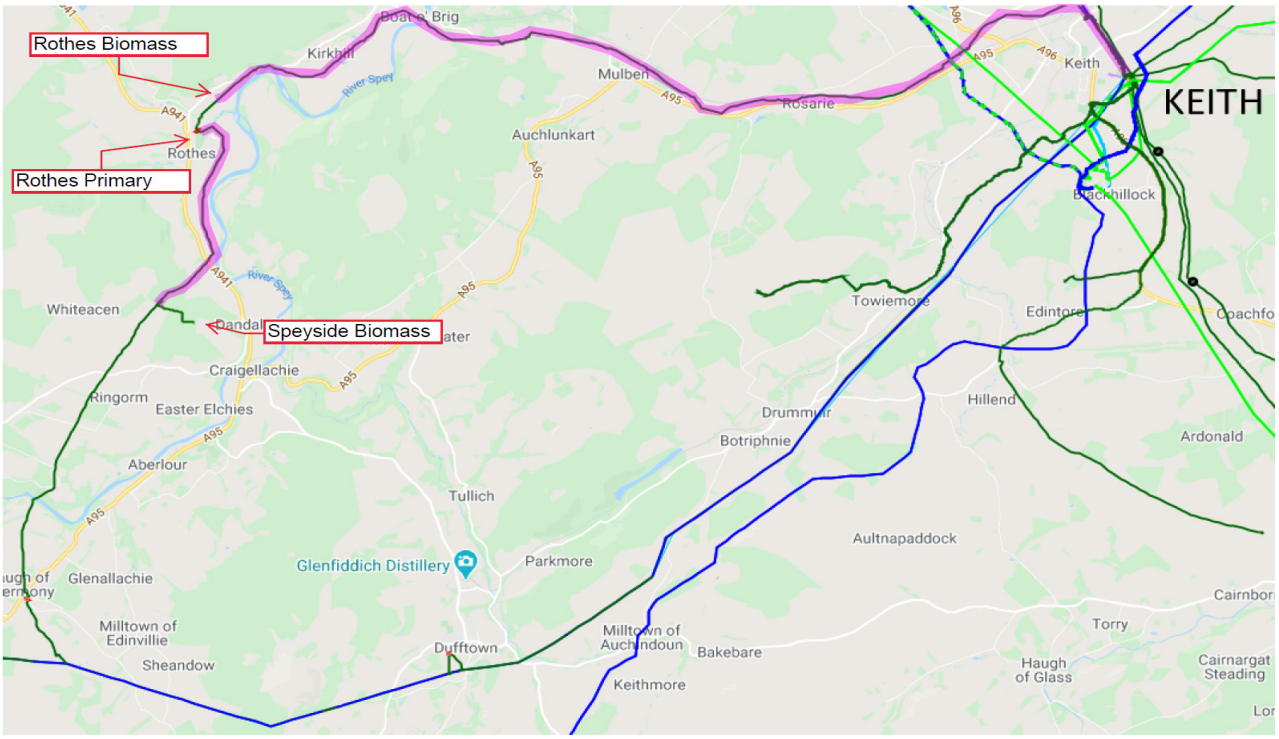


Figure 22: 307 (Pink) Investment

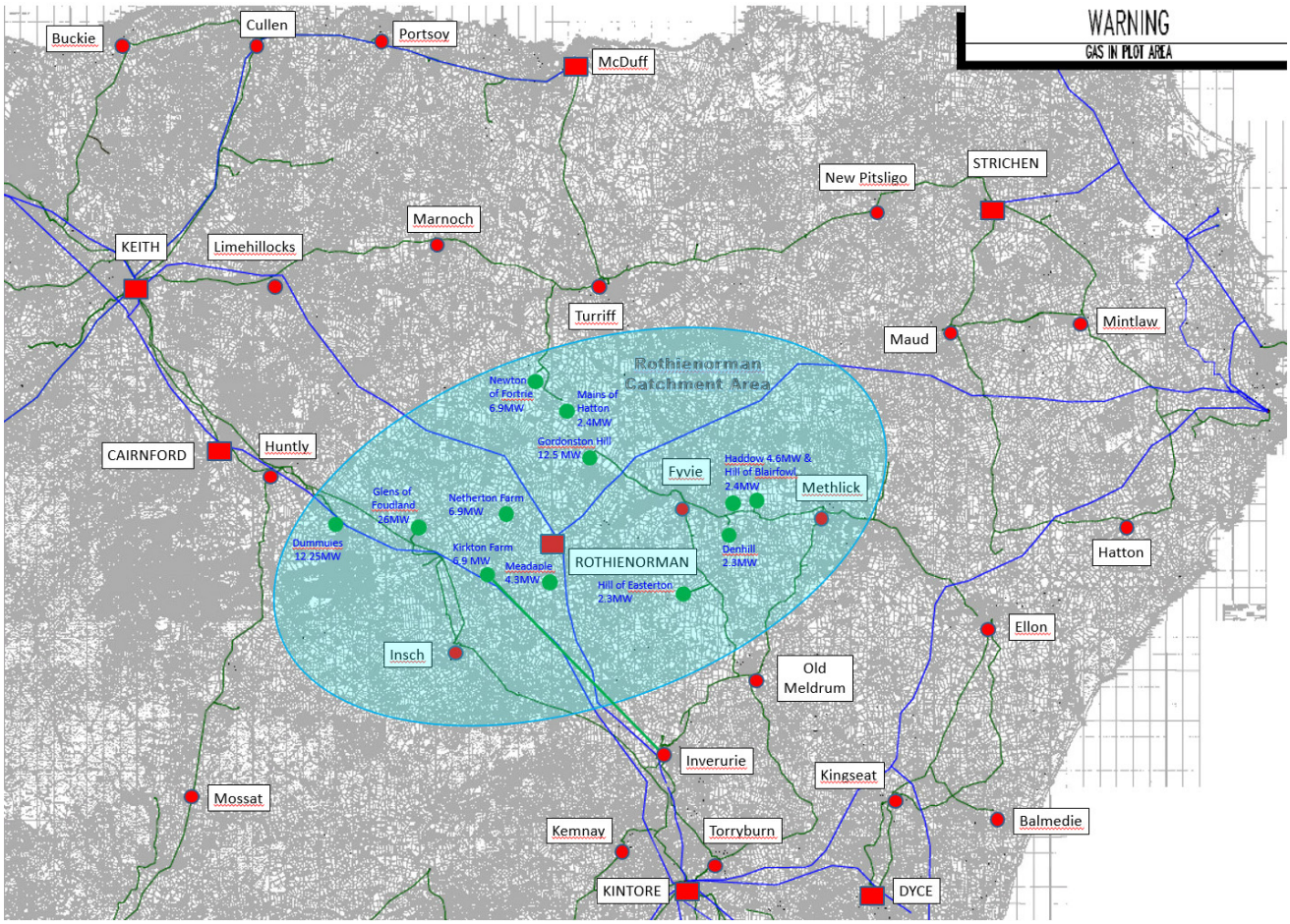


Figure 23: Rothienorman Integration

Appendix 4: Customer Numbers

Substation	Customer Numbers
Aberlour	1123
Buckie	6421
Cullen	2093
Dufftown	1685
Fochabers	895
Huntly	3625
Insch	3344
Keith	3598
Keith 33kV Network	42
Limehillocks	874
Marnoch	1794
Rothes	1408
Total	**26902**

Appendix 5: Business Plan Data Table References

BPDT Reference No	BPDT Title	BPDT Revision	Date
CV1	Primary Reinforcement	V4.1	08-04-2021

Appendix 6: Relevant Policy, Standards, and Operational Restrictions

The policies, manuals and standards and operational restrictions relevant to the content of this paper.

Policy Number	Policy Name / Description
TG-NET-OHL-010	Load Ratings of Overhead Lines – Data Sheet
TG-NET-OHL-012	Short Circuit Ratings of Overhead Lines – Data Sheet
TG-NET-OHL-104	Electrical Constants for Overhead Lines- Data Sheet
TG-NET-CAB-009	Load Ratings of LV to 33kV Underground Cables – Design Data
TG-NET-CAB-010	Electrical Constants for LV to 33 kV Underground Cables- Data Sheet
TG-NET-CAB-011	Short Circuit Ratings of 6.6kV to 33kV Underground Cables - Design Data

Appendix 7: Whole Systems consideration

In augmenting our decision-making processes to consider Whole System solutions, we have introduced an assessment to identify where a Whole Systems CBA would be a useful decision-making tool for ED2 load and non-load schemes. While our work with the ENA to undertake Whole Systems CBAs is ongoing, we have introduced the 'Whole Systems CBA test' to identify where a scheme may be suitable for a Whole Systems CBA to be conducted. Where a Whole Systems CBA is determined to be a useful decision-making tool, these would be conducted in addition to the standard Ofgem CBA and/or SSEN's flexibility CBA. We have introduced this test in line with Ofgem's expectations for "proportionality when submitting a Whole System CBA. For example, smaller or simple projects following the standard CBA template, whereas larger or more complex projects requiring bespoke analytical approaches" (Ofgem BPG, section 4.28, p.34).

The 'Whole Systems CBA test' involves assessing each investment scheme of over £2m (the threshold to develop an EJP for load and non-load investments) against 5 tests. These 5 tests help determine whether a Whole Systems CBA is a useful decision-making tool based on the characteristics of the scheme, including whether it will have wider cross sector or societal impacts.

Details on each of the tests are provided in case study 6 in our ***Whole System (Annex 12.1)***. Tests 1-3 are aligned with the ENA's guidance for Whole System CBA tests. We have added Tests 4 and 5 to clarify whether a Whole Systems CBA is required based on the materiality / proportionality of the investment (Test 4) and whether a flexibility CBA only is sufficient (Test 5). The table below outlines our Whole Systems CBA test for Keith 33kV Circuit Reinforcements.

Scheme	Test 1: Are there Whole Systems interactions, or is there potential for it?	Test 2: Could a Whole Systems CBA drive you to make a different decision?	Test 3: Is a Whole Systems CBA reasonable?	Test 4 - Is the project valued at over £2m?	Test 5 - Is the investment plan related to procuring flexible solutions only?
Keith 33kV Circuit Reinforcements	No – We consider there to be limited potential for Whole Systems interactions with third parties to deliver this investment programme, and accordingly we do not consider there to be potential for Whole Systems solution(s).	No – As noted under Test 1 we do not consider there to be potential for Whole Systems solution(s) in this case.	No – As noted under Test 1 we do not consider there to be potential for Whole Systems solution(s) in this case.	Yes	No

Table 8: Whole Systems CBA test for Keith 33kV Circuit Reinforcements

As the result of tests 1, 2 and 3 above is “No”, a Whole Systems CBA is not required for this investment. It is not expected to have any wider Whole System interactions or potential Whole Systems solutions.

We note that there are ongoing Whole System interactions between SHEPD and SSEN Transmission to develop a new GSP at Rothienorman, as explained in section 4.2 above. The Rothienorman GSP is contracted for delivery in 2021/22 and will remove approximately 8.39MW of demand from Keith GSP. However, as section 5.2 also notes, this Whole Systems solution will not resolve all of the thermal issues anticipated on the Keith 33kV Circuits during ED2, and therefore further SHEPD-led reinforcement works are required over the ED2 period.