Scottish & Southern Electricity Networks

SSEN Transmission

RIIO-T2 Business Plan: T2BP-EJP-0032 Rev 1.1

Kilmorack & Aigas Substation Works

Core Non-Load Engineering Justification Paper

1 Executive Summary

Our paper A Risk Based Approach to Asset Management[1] sets out our approach to network risk and how we subsequently identify assets that require intervention to limit the rise of risk over the RIIO-T2 period.

This paper identifies the need for intervention on the 132/11kV transformers at Kilmorack and Aigas substations. The primary driver for the scheme is the asset condition.

In response to Ofgem's feedback from the Draft Determination document and associated reports, SHE Transmission:

- Commissioned independent assessments of transformer asset condition at Kilmorack & Aigas substations. The reports are included as Appendix 1 of this document.
- Published our Environmental Assessment Report on all SHE Transmission substation sites. An extract of this document, relating to the Kilmorack & Aigas substation sites, is included as Appendix 2 of this document.
- A refurbishment intervention option was also considered to investigate potential end-of-life extension of the assets.

Following a process of optioneering and detailed analysis, as set out in this paper, the proposed scope of works is unchanged from the December submission and is as follows:

- Offline build of a new 132/11kV substation accommodating two transformers and associated plant for the connection of the Kilmorack and Aigas hydro power stations.

This scheme will cost [redacted] and will deliver the following outputs and benefits during the RIIO-T2 period:

- [redacted] A long-term monetised risk benefit of [redacted]
- [redacted] An immediate reduction of total network risk calculated as [redacted]
- Reduced environmental risk and improved visual impact,
- A reduction to the risk of asset failure impacting on the generation customers,
- Improved separation of assets between SHE Transmission and the customer,
- Improved operational flexibility and resilience in line with our goal to aim for 100% transmission network reliability for homes and businesses,

[1] A Risk Based Approach to Asset Management

- Improved coordination with other projects in the Beauly Deanie cluster, improving outage management and reducing impact on generators and customers.

The Kilmorack and Aigas scheme is not flagged as eligible for early or late competition due it being under Ofgem's £50m and £100m thresholds respectively.

Name of Scheme/Programme	Kilmorack & Aigas Substation Works
Primary Investment Driver	Asset Health (Non-Load)
Scheme reference/ mechanism or category	SHNLT207 (Kilmorack) SHNLT206 (Aigas)
Output references/type	NLRT2SH207 (Kilmorack)
Cost	[redacted]
Delivery Year	RIIO T2
Reporting Table	C 0.7 Non-Load Master Data
Outputs included in RIIO T1 Business Plan	No

2 Introduction

This Engineering Justification Paper sets out our plans to undertake condition-related work during the RIIO-T2 period (April 2021 to March 2026). The planned work is associated with Kilmorack and Aigas substations as shown on the map on page 7 of this document.

The Engineering Justification Paper is structured as follows:

Section 3: Need

This section provides an explanation of the need for the planned works. It provides evidence of the primary and, where applicable, secondary drivers for undertaking the planned works. Where appropriate it provides background information and/or process outputs that generate or support the need.

Section 4: Optioneering

This section presents all the options considered to address the need that is described in Section 3. Each option considered here is either discounted at this Optioneering stage with supporting reasoning provided or is taken forward for detailed analysis in Section 5.

Section 5: Detailed Analysis

This section considers in more detail each of the options taken forward from the Optioneering section. Where appropriate the results of Cost Benefit Analysis are discussed and together with supporting objective and engineering judgement contribute toward the identification of a selected option. The section continues by setting out the costs for the selected option.

Section 6: Conclusion

This section provides summary detail of the selected option. It sets out the scope and outputs, costs and timing of investment and where applicable other key supporting information.

Section 7: Price Control Deliverables and Ring Fencing

This section provides a view of whether the proposed scheme should be ring-fenced or subject to other funding mechanisms.

Section 8: Outputs included in RIIO-T1 Business Plan

This section identifies if some or all the outputs were included in the RIIO-T1 Business Plan and provides explanation and justification as to why such outputs are planned to be undertaken in the RIIO-T2 period.

2.1 Post Draft Determination Update

In response to Ofgem's draft determination feedback, SHE Transmission undertook the following actions:

2.1.1 Asset Condition Review

Polaris Diagnostics & Engineering Ltd was commissioned to undertake a review of the SHE Transmission Asset Condition Reports – Aigas 132/11kV Substation[2] and Kilmorack 132/11kV Substation[3] as well as historical oil data for the transformers at both sites.

The conclusions of the Polaris reports on both Aigas GT1[4] and Kilmorack GT1[5] (included within Appendix 1 of this document) identify that:

- both transformers are in a condition commensurate with age (60 years old), but will continue to deteriorate during the RIIO-T2 period;
- analysis of the oil records show that there is an underlying thermal abnormality within each transformer, manifested by contamination of the main tank oil, indicating an increased risk of failure beyond that of age-related deterioration;
- that intervention on these assets is required, within the RIIO-T2 period, to mitigate this risk.

2.1.2 Substation Environmental Assessment

Environmental Resources Management Ltd undertook an assessment of environmental risk for all SHE Transmission substations.

The resulting report[6] and associated data table[7] were published in June 2020 and offer additional information to support analysis of intervention options at this site.

The ERM Ltd report assesses the Kilmorack & Aigas sites as being HIGH Risk from both a vulnerability and sensitivity perspective, for the contamination of groundwater. In addition, both sites sit over the River Beauly and are assessed as being at HIGH flood risk.

[2] Aigas Substation Works Asset Condition Report T2BP-ACR-0020
[3] Kilmorack Substation Works Asset Condition Report T2BP-ACR-0021
[4] Polaris Diagnostics & Engineering Ltd - Summary Report on Aigas GT1 132/11kV Transformer
[5] Polaris Diagnostics & Engineering Ltd - Summary Report on Kilmorack GT1 132/11kV Transformer
[6] SSE Phase 1 Contaminated Land Assessment report
[7] SSE Phase 1 Contaminated Land Assessment Final Risk Review Table

2.1.3 Development & Assessment of Intervention Options

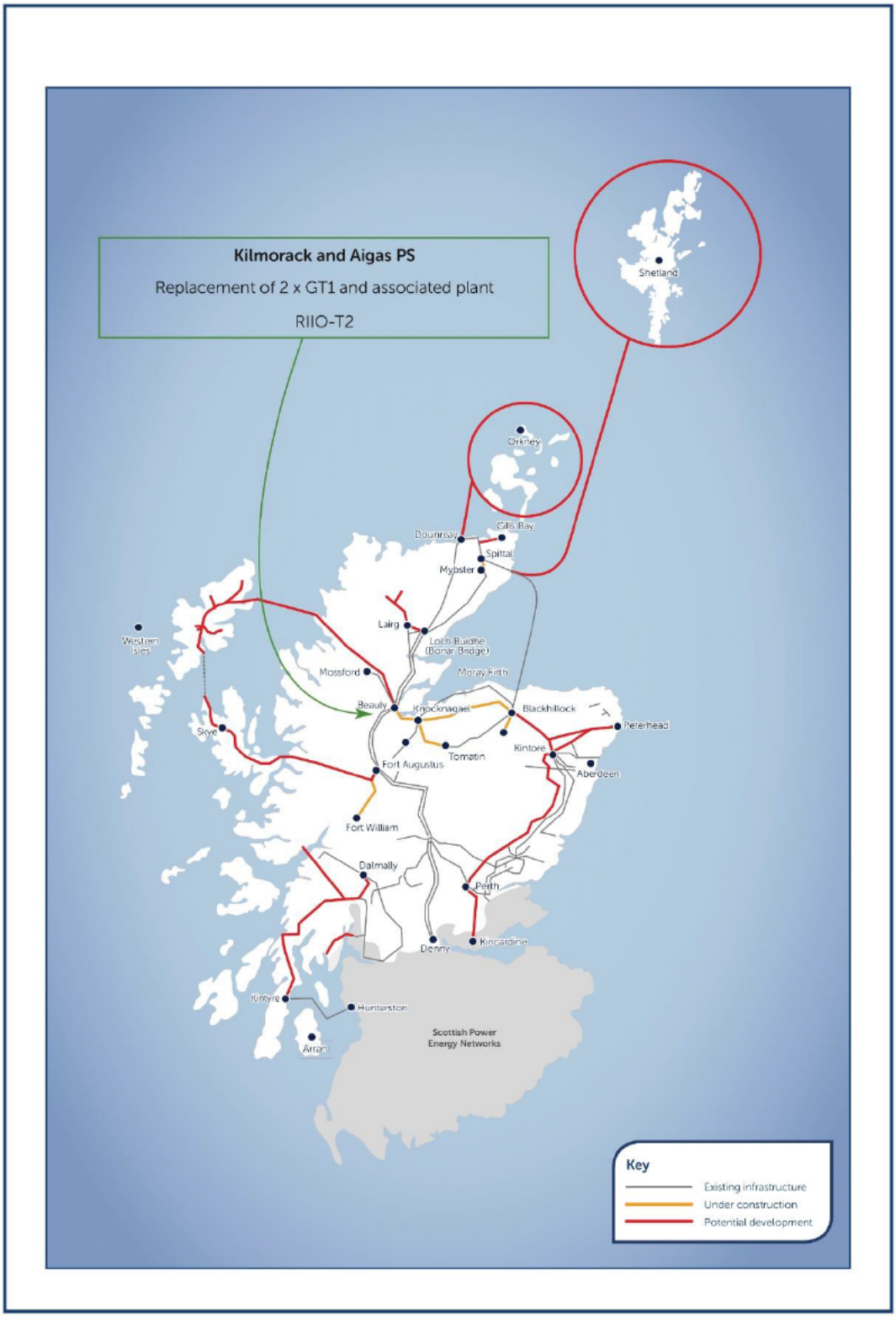
Following the recommendations of the Polaris reports on Aigas GT1 & Kilmorack GT1, SHE Transmission developed the following range of intervention options to mitigate this increased risk of failure during the T2 period:

- **Replacement** – 3 replacement interventions were developed for delivery in T2. These were an 'in-situ' replacement option for each site; an 'offline build – new substation' option for each site, close to the existing substations; and an 'offline build – single combined substation' option, situated between the two sites.

- **Refurbishment** – SHE Transmission developed a refurbishment intervention to address the visual condition & asset performance deterioration factors, identified in the Asset Condition Report for GT1 and its associated non-lead assets at each site.

  The impact of this intervention will ensure that the risk of asset failure during the RIIO-T2 period is mitigated, but further age-related deterioration will require asset replacement to be undertaken during a future regulatory period. Options for future replacement in the RIIO-T3 and RIIO-T4 regulatory periods were developed for consideration.

These interventions are subject to cost benefit analysis to derive the preferred option and optimum intervention time.


Kilmorack and Aigas PS
Replacement of 2 x GT1 and associated plant
RIIO-T2
Shetland
Orkney
Dounreay
Gills Bay
Spittal
Mybster
Lairg
Loch Buidhe (Bonar Bridge)
Western Isles
Mossford
Moray Firth
Beauly
Knocknagael
Blackhillock
Peterhead
Skye
Tomatin
Kintore
Fort Augustus
Aberdeen
Fort William
Dalmally
Perth
Denny
Kincardine
Kintyre
Hunterston
Arran
Scottish Power Energy Networks
Key
Existing infrastructure
Under construction
Potential development

3 Need

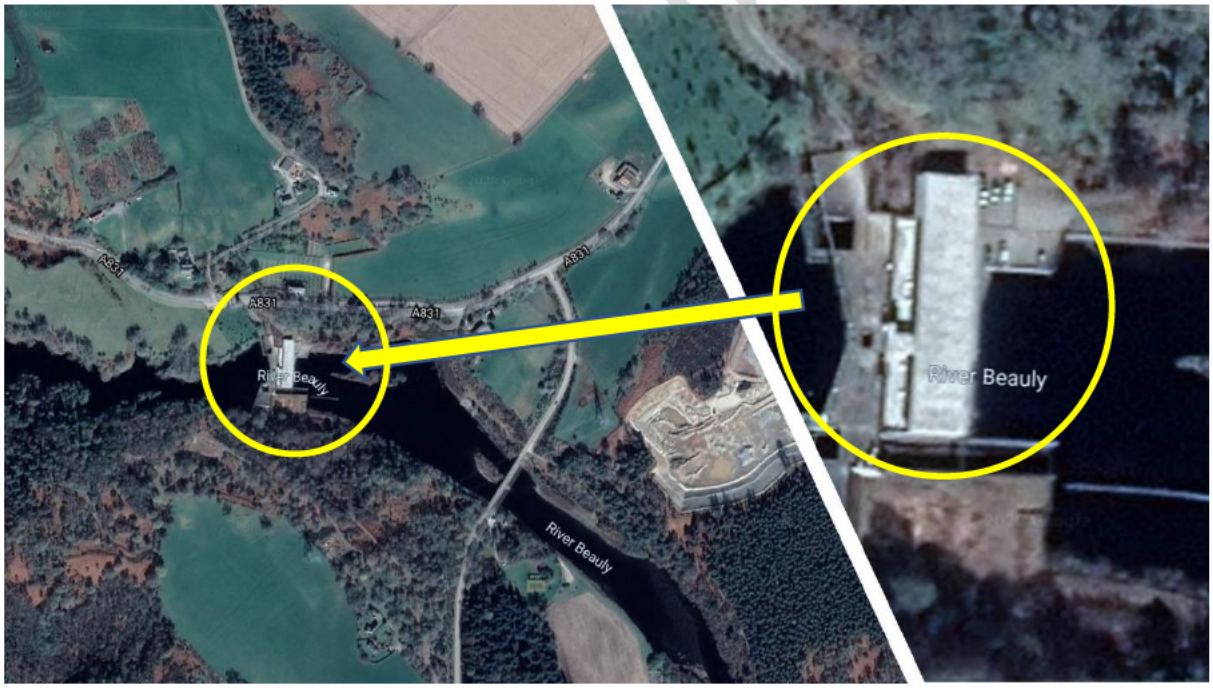
This section provides an explanation of the need for the planned works. It provides evidence of the primary and, where applicable, secondary drivers for undertaking the planned works. Where appropriate it provides background information and/or process outputs that generate or support the need.

3.1 Background

3.1.1 Kilmorack

Kilmorack 132/11 kV substation provides a network connection for Kilmorack hydro generation site which generates 20MW into the transmission system. The unconventionally designed indoor AIS substation is located within the generation building over the River Beauly (see Figure 1 below), approximately 1 mile east of Beauly Substation along the A831. Kilmorack Cable Sealing End remote compound is located on the opposite side of the A831 next to a cemetery. This is the connection onto the 132kV overhead line BDS back to Beauly substation. The site was originally built in 1960 and the transformer was manufactured in 1960 and installed in 1962.

Figure 1 – Kilmorack Site Location on top of the River Beauly

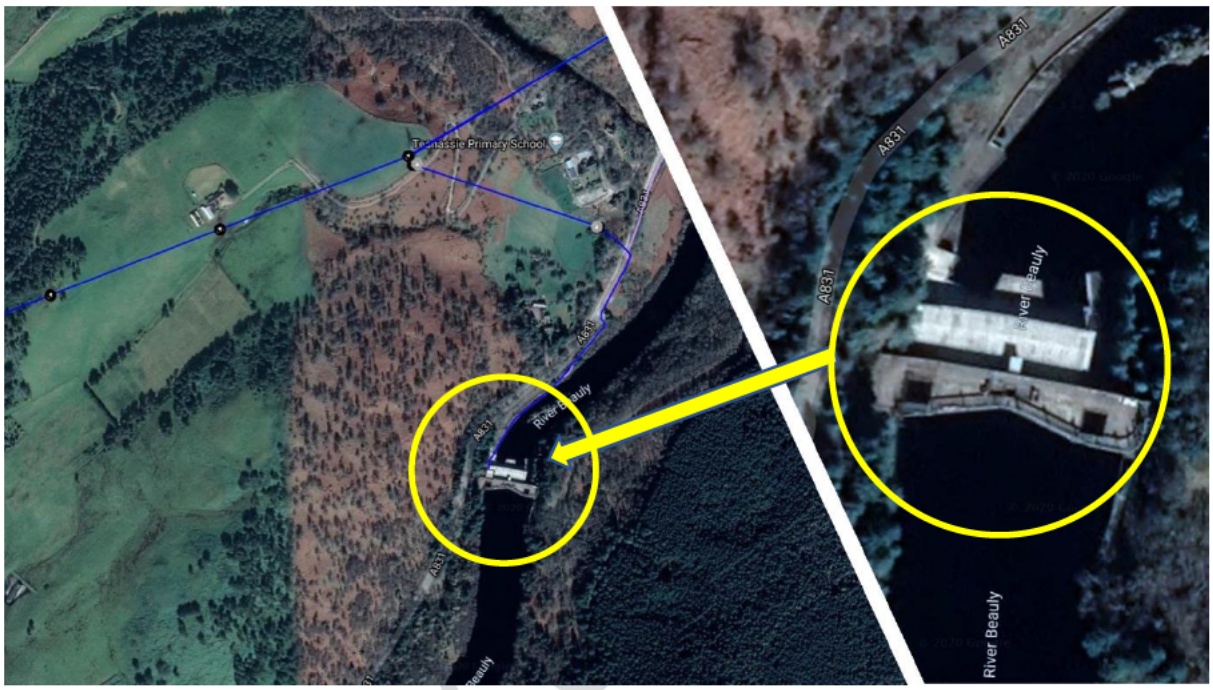


3.1.2 Aigas

Aigas 132/11 kV substation provides a network connection for Aigas hydro generation site which generates 20MW into the transmission system. The unconventionally designed indoor AIS substation is located within the generation building over the River Beauly (see figure 2 below), approximately 2.5

miles east of Beauly Substation along the A831. Aigas Cable Sealing End remote compound is located on the opposite side of the A831 beside Teanassie Primary School and a small farm holding. This is the connection onto the 132kV overhead line BDS back to Beauly substation. The site was originally built in 1960 and the transformer was manufactured in 1960 and installed in 1962.

Figure 2 – Aigas Site Location on top of the River Beauly



3.1.3 Aigas & Kilmorack Environmental Risk Assessment

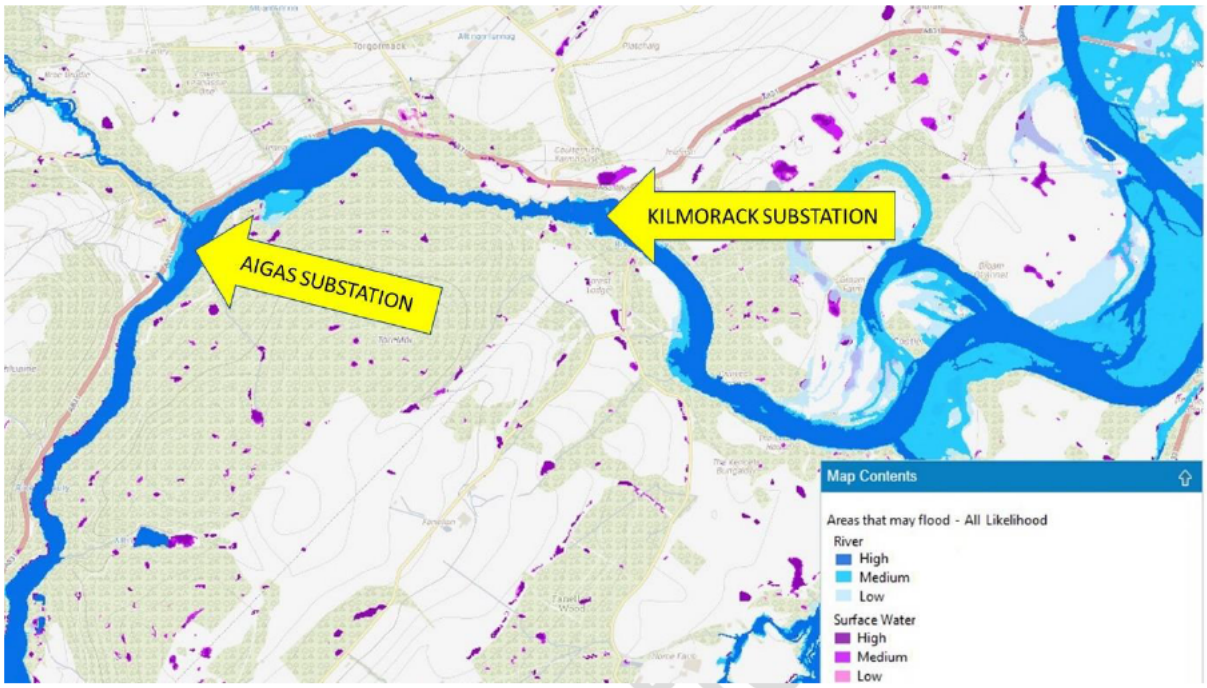
Environmental Resources Management (ERM) Ltd were commissioned to undertake an assessment of environmental risk for all SHE Transmission substations.

The resulting report[6] and associated data table[7] were released in June 2020 and offer additional information to support analysis of the suitability of intervention options, proposed for delivery, within the existing substation locations.

An extract from the above data table, specifically reporting on the hydro-geology and flooding risks for the substation sites at Aigas & Kilmorack, is included in Appendix 2 of this document.

The ERM Ltd report assesses the Kilmorack & Aigas sites as being HIGH Risk from both a vulnerability and sensitivity perspective, for the contamination of groundwater. In addition, both sites sit over the River Beauly and are assessed as being at HIGH flood risk. The Scottish Environmental Protection Agency (SEPA) flood maps (see Figure 3, below) support this independent assessment, with both sites being located in areas with a high likelihood of river flooding risk.

Figure 3 – Scottish Environmental Protection Agency (SEPA) Flood Mapping – River Beauly



Key to Figure 3 - Likelihood of Flooding

High likelihood: A flood event is likely to occur in the defined area on average once in every ten years (1:10). Or a 10% chance of happening in any one year.

Medium likelihood: A flood event is likely to occur in the defined on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year.

Low likelihood: A flood event is likely to occur in the defined area on average once in every thousand years (1:1000). Or a 0.1% chance of happening in any one year.

The likelihood of flooding remains the same in each year. For example, if you experience a flood in year 1 there is the likelihood of it happening in year 2.

The River Beauly is managed by the Beauly Salmon Fishery Board. Salmon fishing rights in Scotland are private heritable titles that are registered separately from land. As such these titles can be bought and sold like any other property. District Salmon Fishery Boards have statutory powers to appoint water bailiffs to enforce salmon fisheries legislation in Scotland. Bailiff's powers are extensive and include powers of seizure, detention entry and search and are similar to the powers of constables. SHE Transmission has a duty of care to the owners of these rights on the river and SHE Transmission would be subject to sanctions from the Beauly Salmon Fishery Board for any pollution caused in the river which damaged the value of the fishing rights. The assets on each site contain circa 29,000 litres of oil.

3.2 Asset Need

3.2.1 Kilmorack

Polaris Diagnostics & Engineering Ltd was commissioned to undertake a review of the SHE Transmission Asset Condition Report – Kilmorack 132/11kV Substation[3] and historical oil data for Kilmorack GT1.

The conclusions of the Polaris report on Kilmorack GT1[5] (included within Appendix 1 of this document) identify that the transformer is in a condition commensurate with age (60 years old), but will continue to deteriorate during the RIIO-T2 period even with additional maintenance work.

Analysis of the oil records show that there is an underlying thermal abnormality within the transformer, manifested by contamination of the main tank oil, indicating an increased risk of failure beyond that of age-related deterioration.

The report concludes that intervention on this asset is required, within the RIIO-T2 period.

The site itself is in poor condition, due in part to access by birds and bats making the environment hazardous to health. Like other substations of this age and purpose there are several ancillary assets which are either shared or are housed in shared space with the customer. There is no transformer LV circuit breaker, leaving the protection of the transformer dependent on third-party equipment. In line with current engineering standards this scheme seeks to achieve correct separation between our assets and the customer's assets by replacing and re-housing these assets in a transmission owned and operated space.

The primary plant compound has an unconventional layout with very limited access and maintenance space. Due to the 1950s design for the power station/substation current environmental standards are not met, for example the floor acts as the transformer bund for the circa 29,000 litres of oil on site with oily water draining in the floor. A fold down barrier across the door way completes the bund. The disconnector and earth switch are suspended from the roof of the compound. The cooler banks for the transformer are wall mounted at a high level and exposed externally to the building. The non-standard layout makes access for maintenance challenging.

In addition, the 132kV disconnector & earth switch are in poor condition and unable to be operated electrically. This means that in the event of failure of the transformer all customers connected to the circuit will lose supply and rely upon manual intervention taking many hours for staff to attend site. Previous work done on site to refurbish or maintain these switches has been unsuccessful and it is uneconomic to pursue this further due to obsolescence and lack of spares.

As is discussed in the Beauly – Deanie 132kV OHL Engineering Justification Paper[8] for the refurbishment of the BDN/BDS line which connects these substations; there is a need to address the

[8] Beauly – Deanie 132kV OHL Engineering Justification Paper T2BP-EJP-0034

pilot wire and PLC communications used by the intertripping schemes for these sites. Under the refurbishment of BDN/BDS a new Optical Ground Wire (OPGW) will replace the earth wire thereby providing adequate protection on these circuits. As well the consequential improvement in the protection provided by the BDN/BDS works, the necessary outages for tower painting and phase wire replacement present a timely opportunity to undertake the upgrading of the ageing assets served by these circuits. This approach presents a coordinated package of work to the impacted local communities and improves the overall network impact, performance and risk.

Figure 4 – Unconventional cooler design – confined space/suspended

3.2.2 Aigas

Polaris Diagnostics & Engineering Ltd was commissioned to undertake a review of the SHE Transmission Asset Condition Report – Aigas 132/11kV Substation[2] and historical oil data for Aigas GT1.

The conclusions of the Polaris report on Aigas GT1[4] (included within Appendix 1 of this document) identify that the transformer is in a condition commensurate with age (60 years old), but will continue to deteriorate during the RIIO-T2 period even with additional maintenance work.

Analysis of the oil records clearly show that there is an underlying thermal abnormality within the transformer, manifested by contamination of the main tank oil, indicating an increased risk of failure beyond that of age-related deterioration.

The report concludes that intervention on this asset is required, within the RIIO-T2 period.

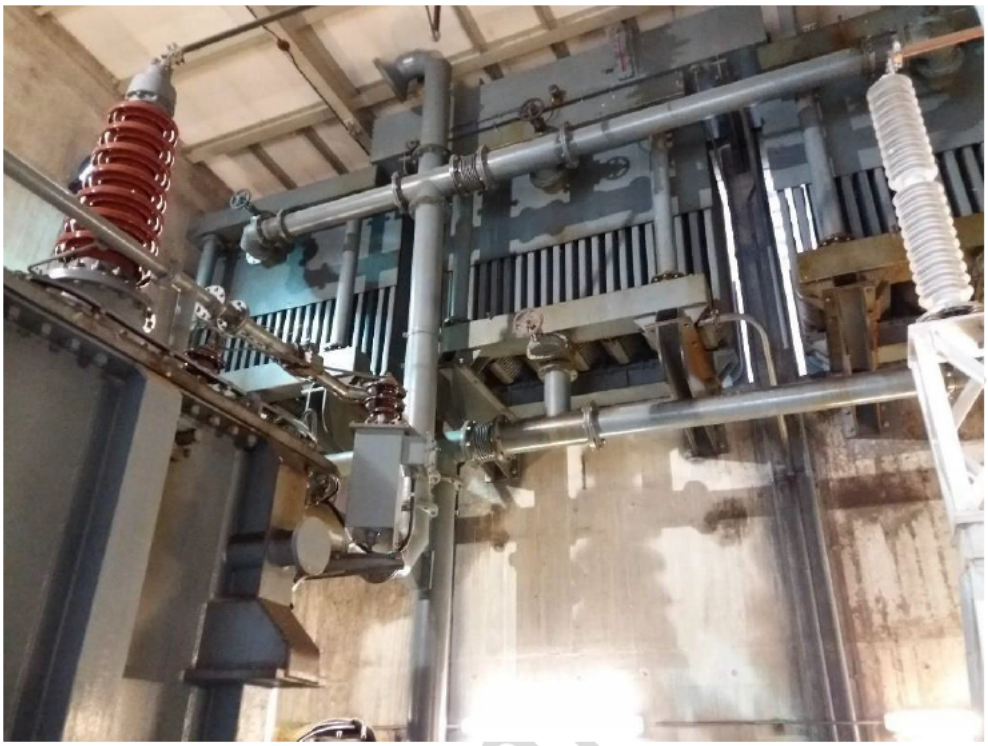
The site itself is in poor condition, due in part to access by birds and bats making the environment hazardous to health. Like other substations of this age and purpose there are several ancillary assets which are either shared or are housed in shared space with the customer. There is no transformer LV circuit breaker, leaving the protection of the transformer dependent on third party equipment. In line with current engineering standards this scheme seeks to achieve business separation by replacing and re-housing these assets in a transmission owned and operated space.

The primary plant compound has an unconventional layout with very limited access and maintenance space. Due to the 1950s design for the power station/substation current environmental standards are not met, for example the floor acts as the transformer bund for the circa 29,000 litres of oil on site with oily water drains in the floor. A fold down barrier across the door way completes the bund. The disconnector and earth switch are suspended from the roof of the compound. The cooler banks for the transformer are wall mounted at a high level and exposed externally to the building. The non-standard layout makes access for maintenance challenging.

In addition, the 132kV disconnector & earth switch are in poor condition and unable to be operated electrically. This means that in the event of failure of the transformer all customers connected to the circuit will lose supply and rely upon manual intervention taking many hours for staff to attend site. Previous work done on site to refurbish or maintain these switches has been unsuccessful and it is uneconomic to pursue this further due to obsolescence and lack of spares.

As is discussed in the Beauly – Deanie 132kV OHL Engineering Justification [redacted] for the refurbishment of the BDN/BDS line which connects these substations; there is a need to address the pilot wire and PLC communications used by the intertripping schemes for these sites. Under the refurbishment of BDN/BDS a new Optical Ground Wire (OPGW) will replace the earth wire thereby providing adequate protection on these circuits. As well the consequential improvement in the protection provided by the BDN/BDS works, the necessary outages for tower painting and phase wire replacement present a timely opportunity to undertake the upgrading of the ageing assets served by these circuits. This approach presents a coordinated package of work to the impacted local communities and improves the overall network impact, performance and risk.

Figure 5 – Unconventional cooler design – confined space/suspended



3.3 Growth Need

There are no known load related capacity increases in the immediate network which would drive upgrade work at this site. Therefore, the asset health of the plant, network operability, resilience and the nature of the site are the main considerations for the replacement work.

A meeting was held with the customers to discuss their portfolio of hydro generation schemes that would be affected by our works during the RIIO-T2 period. There are no plans for increasing output at either power station in the foreseeable future and no capacity increase is proposed or required.

The existing transformers at the power stations are rated at 22.5MVA (naturally) cooled. There is no increase in capacity required by these connections and there is no demand at the sites: there is therefore no driver to install higher rated transformers. The smallest 132/11kV transformer on the transformer framework is rated at 30/36MVA. There will therefore be a consequential capacity increase at the site once replacement is carried out either in the T2 period or in subsequent years. It is more economical to procure a standard transformer from our framework range than to order bespoke units.

4 Optioneering

This section presents all the options considered to address the need that is described in Section 3. Each option considered here is either discounted at this Optioneering stage with supporting reasoning provided or is taken forward for detailed analysis in Section 5.

There is an asset health and condition driver to replace the 132/11kV GTs at Kilmorack and Aigas substations as set out in the Asset Condition reports [redacted]. There is also a requirement for upgrade of the substation compound and auxiliary assets. In addition, due to the 1950s design of the power station/substation current environmental standards are not met and there is a significant risk of environmental pollution and contamination of the River Beauly in the event of a transformer failure. As highlighted before this could lead to significant risk of prosecution from SEPA and the Fisheries Board due to environmental impact and loss of fishing amenity.

The poor asset condition and the need for additional site upgrades means that intervention works in the RIIO-T2 period is required.

Like other substations of this age and purpose there are several ancillary assets which are either shared or are housed in shared space with the customer. In line with current engineering standards this scheme seeks to achieve business separation by replacing and re-housing these assets in a transmission owned and operated space.

The following table captures the options considered:

Table 1 – Options

Option	Option Detail	Cost (£m)	Taken forward to Detailed Analysis?
0	Do Nothing	[redacted]	No
1	In-Situ Replacement (per site)	[redacted]	No
2	Offline Build of Each Site	[redacted]	Yes
3	Offline Combined Build (one site)	[redacted]	Yes
4	T2 Refurbishment and Replacement in T3	[redacted]	Yes
5	T2 Refurbishment and Replacement in T4	[redacted]	Yes

Option 0 - Do Nothing

The assets condition, as detailed in the Asset Condition Reports and the findings of the Polaris Summary Reports, conclude that a 'do nothing' approach will result in further deterioration of asset condition, resulting in an increased likelihood of failure of the transformers and their associated non-lead assets.

The conclusion drawn from this analysis is that 'do nothing' is not a viable option and that some form of asset intervention is required during the RIIO-T2 period. The potential environmental impact of transformer failure is not acceptable and poses significant risk to customers and users of the River Beauly.

NOT PROGRESSED TO DETAILED ANALYSIS

Option 1 – In-Situ Replacement

Due to the layout of the existing substation arrangements at Kilmorack and Aigas Power Stations, an in-situ replacement of the transformers, disconnectors and earth switches to current engineering and environmental standards cannot be accommodated. Any in-situ replacement would not completely remove the environmental risks described in Section 3 of this document and would deliver a non-compliant substation solution. In addition, the site would remain within a high likelihood SEPA flood zone.

The sites at Kilmorack and Aigas, as well as the sites at Culligran and Deanie, form part of a cascade water management system. As a result, any outages required for an in-situ replacement would be relatively long in duration (9-12 months) and compromise the operability of the hydro sites in terms of water management and loss of generation.

NOT PROGRESSED TO DETAILED ANALYSIS

Option 2 – Offline Build of Each Site

An offline build of both the Kilmorack and Aigas substations allows us to achieve compliant design to current engineering standards for these sites and to mitigate the environmental risks associated with the existing, ageing assets.

KILMORACK

A new substation would be constructed in an area of land near to the existing 132kV cable sealing end compound. The connection to this new substation compound would be facilitated through introduction of a new 11kV cable route, resulting in an increased length of cable between the local generator and transmission connection. Initial cable route assessments conclude that this cable could have a route length of around 0.5km, which is considered achievable with a 22.5MVA generator connection.

This design includes the installation of a new connection to BDS therefore removing the existing cable sealing end compound. The new indoor substation design includes a 132kV circuit switcher, 30/36MVA 132/11kV transformer, 11kV circuit breaker, protection and supplies and ancillary items.

The indoor substation design is proposed in order to mitigate any visual impact on the local landscape and therefore address the consenting risk to this solution. The offline build contributes to minimised outage requirements, and any outages will be coordinated with the reconductoring of the circuit BDS. The BDS works will deliver a fibre communication channel back to Beauly substation providing the means to improve the protection of this circuit and the intertripping to these sites.

AIGAS

A new substation would be constructed in an area of land near to the existing 132kV cable sealing end compound. The connection to this new substation compound would be facilitated through introduction of a new 11kV cable route, resulting in an increased length of cable between the local generator and transmission connection. Initial cable route assessments conclude that this cable could have a route length of around 0.5km, which is considered achievable with a 22.5MVA generator connection.

This design includes the installation of a new connection to BDS therefore removing the existing cable sealing end compound. The new indoor substation design includes a 132kV circuit switcher, 30/36MVA 132/11kV transformer, 11kV circuit breaker, protection and supplies and ancillary items.

The indoor substation design is proposed in order to mitigate any visual impact on the local landscape and therefore address the consenting risk to this solution. The offline build contributes to minimised outage requirements, and any outages will be coordinated with the reconductoring of the circuit BDS. The BDS works will deliver a fibre communication channel back to Beauly substation providing the means to improve the protection of this circuit and the intertripping to these sites.

PROGRESS TO DETAILED ANALYSIS

Option 3 - Offline Combined Build (one site)

This option combines the new substations for Kilmorack and Aigas at a shared site. The development works undertaken for this option have identified 2 potential site locations for the new substation at a point mid-way between the two power stations. There are no significant issues foreseen in obtaining the necessary consents needed for this option. This option proposes the same transformer design for each customer as for the separate sites in Option 2. However, there are economies to be realised with shared infrastructure that do not compromise the commercial connections. This option means a single planning application to satisfy the connection of these two sites which minimises the impact on the local stakeholders. Like the advantages delivered by Option 2 this option proposes an offline build minimising the outage requirements and the opportunity to coordinate works with the reconductoring of BDS. The BDS works will deliver a fibre communication channel back to Beauly

substation providing the means to improve the protection of this circuit and the intertripping to these sites.

PROGRESS TO DETAILED ANALYSIS

Option 4 – T2 Refurbishment and Replacement in T3

This option proposes to undertake the refurbishment of GT1 and the targeted replacement of non-lead assets in poor condition at each site.

The key benefit of this option is a reduced intervention cost during the RIIO-T2 period and deferral of the substation replacement works to RIIO-T3.

The refurbishment will comprise a series of works to improve the external condition of the transformer. This work will include, but is not limited to, the replacement of all gaskets & seals; replacement of the marshalling kiosk; repair of oil leaks from all tanks & coolers; tap-changer refurbishment; regeneration of the insulating oil; and installation of on-line DGA to monitor any further deterioration associated with the underlying thermal abnormality within the transformer.

Targeted replacement of non-lead assets will include the replacement of the 132kV disconnector & earth switch that is in poor condition and unable to be restored to electrical operation, with a 132kV circuit switcher & earth switch. This will have the additional benefit of providing improved system operability.

A review of the protection modifications required at both Aigas & Kilmorack has identified that the very limited space available in existing protection panels will not be suitable for installation of the modern protection relays needed as a result of the works identified in Beauly – Deanie 132kV OHL Engineering Justification Paper4. The refurbishment option therefore includes the provision of a temporary, container-based blockhouse solution at each site. The blockhouse will be located close to the existing transformer compounds and will house the protection, control, telecommunications and ancillary equipment needed to maintain the performance & operation of the 132kV substation assets.

There are significant environmental risks, associated with the delivery of refurbishment intervention options at the Kilmorack & Aigas sites. The flooding, River Beauly and ground-water contamination risks are outlined in Section 3.1.3 and again in Appendix 2 of this document.

There are 29,000 litres of mineral oil contained within the transformers at each of these sites, situated directly over the River Beauly. There is significant concern that any refurbishment intervention on the unconventional designs of the transformers & associated 132kV assets at these sites could lead to the damage of components not readily replaceable. This significantly increases the risk of major oil leaks & contamination of the local water table, during and after any refurbishment intervention option.

Another significant factor to consider for any refurbishment option is the need to dismantle the existing building infrastructure to facilitate access to undertake the refurbishment work scope. There

is a risk that this intervention could cause costly structural damage during the dismantling, refurbishment and reinstatement of the building fabric.

There is also a significant risk from asbestos within buildings of this age. All dismantling works would require to be undertaken in controlled conditions to mitigate against this risk.

These proposed refurbishment works will mitigate the immediate RIIO-T2 risk of failure, but it is clear that there will be a requirement in the near future to undertake replacement of the 132kV assets at these sites as they reach end-of-life condition.

Additional outages will be required at these substation sites and associated remote-ends during the RIIO-T3 period, to facilitate the replacement works. This approach will also have a negative impact on the generation assets connected and on local stakeholders due to sustained construction works, spread over multiple regulatory periods.

In order to fully assess the benefits of this refurbishment option, substation replacement in RIIO-T3 (in line with Option 2, above) will be considered.

PROGRESS TO DETAILED ANAYLSIS

Option 5 - T2 Refurbishment and Replacement in T4

Same as Option 3 but with the asset replacement work carried out in the RIIO-T4 period.

PROGRESS TO DETAILED ANAYLSIS

5 Detailed Analysis

This section considers in more detail each of the options taken forward from the Optioneering section. Where appropriate the results of Cost Benefit Analysis are discussed and together with supporting objective and engineering judgement contributes toward the identification of a selected option. The section continues by setting out the costs for the selected option.

5.1 Cost Benefit Analysis

A Cost Benefit Analysis (CBA) has been carried out in order to assess the preferred choice between Options 2, 3, 4 & 5. Our CBA Methodology[9] sets the process and mechanics of our approach to CBA. In order to carry out this CBA, the following complete solutions were costed to allow comparison:

Table 2: CBA Solutions for Comparison

Option	Description	Cost (£million)
2	T2 replacement – offline build of two new 132kV substations	[redacted]
3	T2 replacement – offline build of a single new 132kV substation	[redacted]
4	T2 refurbishment followed by Option 2 replacement during T3	[redacted]
5	T2 refurbishment followed by Option 2 replacement during T4	[redacted]

[9] Cost Benefit Analysis Methodology

Table 3: CBA Total NPV

CBA Option No.	Total Forecast Expenditure (£m)	Total NPV	Delta (Option to baseline)	Total NPV (Incl. Monetised Risk £m)
Baseline (Option 2)	[redacted]	[redacted]		[redacted]
Option 3	[redacted]	[redacted]	[redacted]	[redacted]
Option 4	[redacted]	[redacted]	[redacted]	[redacted]
Option 5	[redacted]	[redacted]	[redacted]	[redacted]

The resulting CBA calculation has identified that Option 5 (T2 refurbishment, followed by T4 offline build of a new substation) provides a superior total NPV than Options 2, 3 or 4, however once monetised risk is included Option 3 (T2 offline build of a single new 132kV substation) is significantly better.

It is important to note:

- The difference in total NPV between Option 3 and of Option 5 is marginal (£0.39m). However, Option 5 poses significant environmental and safety risks which are difficult to mitigate.
- The cost of mitigating the significant environmental risks introduced by Option 5 are NOT included within this assessment and would further reduce the difference in NPV between Options 5 & 3.
- When Monetised Risk Benefit is considered within the calculations, Option 3 (T2 offline build of a single new 132kV substation) provides a superior total NPV score (by £5.68m) than Option 5.
- Having demonstrated that replacement is a cost-effective and less-risky solution than refurbishment, Option 3 – 'T2 replacement with a single combined substation' is the solution proposed by SHE Transmission.

5.2 Project Sensitivity

As outlined in our core RIIO-T2 business plan document, "A Network for Net Zero", we believe we have a critical role to play in delivering Net Zero ambitions in both the UK and Scotland. Therefore, our plan has been carefully designed with the flexibility to deliver pathways to Net Zero. Our policy

paper "A Risk-Based Approach to Asset Management" outlines our approach to monitoring and assessing the condition of our assets to maintain the reliable and resilient network that is expected by our stakeholders. Where asset condition deteriorates, we undertake a programme of cost-effective, risk-based interventions to maintain the longevity and performance of the transmission network. Each of our non-load related projects for T2 is underpinned by Asset Condition Reports which clearly outline that the works are necessary and driven by reliability.

Table 4: Sensitivity Analysis table

Sensitivity	Test and impact observed – switching inputs
Asset Performance / deterioration rates	Switching deterioration assumption: The asset performance / deterioration rates can only improve or deteriorate. As the need for this project is driven by an asset condition report (as outlined in Section 3), the asset condition will not improve in the intervening period. The second option is for the asset performance to deteriorate and therefore the need remains, and the project would be considered for advancement within available outages.
Ongoing efficiency assumptions	Switching efficiency assumption: increased or decreased. Test would have no impact on (feasible) option selection, only one option was taken forward to detailed analysis and therefore there is no impact on the preferred solution.
Demand variations	No demand at this site and none forecast
Energy scenarios	Sensitivity considered in Section 3 (Need) already. As this is a non-load project and the need is driven by the asset condition, the work would be required regardless of any changes to the energy scenarios.
Asset utilisation	Our policy paper "A Risk-Based Approach to Asset Management" outlines our approach to monitoring and assessing the condition of our assets to maintain the reliable and resilient network that is expected by our stakeholders. Where asset condition deteriorates, we undertake a programme of cost-effective, risk-based interventions to

	maintain the longevity and performance of the transmission network. Each of our non-load related projects for T2 is underpinned by Asset Condition Reports which clearly outline that the works are necessary and driven for reliability.
Timing / delivery	We have considered timing of investments as part of our CBAs.
Consenting / stakeholders	Where applicable we have considered consenting and stakeholder engagement as part of section 5 (Detailed Analysis) and the impact which this has had on the selection of the preferred solution.
Public policy / Government legislation	We have considered the impact of public policy, government legislation and regulations as part of the need (section 3), optioneering (section 4) and detailed analysis (section 5) and the impacts this has on the selection of the preferred solution. For example, the projects have considered the impact of the UK Governments' Net Zero emission by 2050 target, SQSS and ESQCR.

5.3 Proposed Solution

The scope of the selected solution is to build an offline 132/11kV substation to house the transformers for the connection of both Kilmorack and Aigas hydro power stations. The project will be energised within the RIIO-T2 period.

Table 5 – Outputs from Preferred Option

Plant	Size of new plant	Replacement for
132/11kV Transformer	2 x 30/36MVA	2 x 22.5MVA
132kV Circuit Switcher	2 x 132kV circuit switcher (2000A)	NA
11kV Circuit breaker	4 x 11kV circuit breakers (1250A)	NA

5.4 Competition

The Kilmorack and Aigas scheme is not flagged as eligible for early or late competition due it being under Ofgem's £50m and £100m thresholds respectively.

5.5 Risk Benefit

A Risk Benefit Analysis has been carried out in order to compare "no intervention" against the selected "with intervention" option. Please note that while monetised risk is denoted as a financial figure, it is important to note that it is not "real" money and does not correspond to the cost that SHE Transmission would incur if an asset was to fail and these values are thus identified with R£ prefix (for more details please refer to A Risk Based Approach to Asset Management[1]).

The long-term benefit is derived by consideration of the risk of the asset experiencing a catastrophic failure weighted by the probability that the asset will survive for the Options and "no intervention" scenarios. The long-term benefit is an aggregation of the risk of all assets being considered within the option. The risk of each Option is then compared with the "no intervention" scenario. The "no intervention" scenario assumes that when the asset experiences a catastrophic failure the asset is replaced.

Table 6 – Long Term Monetised Risk Benefit

Option	LTMRB – R£ million
Option 2 – Replacement by offline build in RIIO-T2 – 2 sites	[redacted]
Option 3 – Replacement by offline build in RIIO-T2 – single combined site	[redacted]
Option 4 – Refurbishment in T2, followed by Replacement in T3	[redacted]
Option 5 – Refurbishment in T2, followed by Replacement in T4	[redacted]

The highest value of long-term monetised risk benefit for this project is delivered by Options 2 & 3 'Replacement by offline build during RIIO-T2', with a value [redacted]e LTMRB for these options is the same, because the same number of lead assets are included in the scope of works which makes them identical from a long-term risk basis. This preferred solution delivers [redacted] more benefit to Consumers than the Option 5 - T2 Refurbishment/T4 Replacement option it was compared and assessed against. Figures 6 & 7, below, illustrate the difference in LTMRB between the options at each site when they are assessed against the 'No Intervention' baseline.

In addition to assessing the long-term risk benefit, an immediate monetised risk benefit has also been determined. The immediate monetised risk benefit which would be realised through the completion of this project is R[redacted] (the sum of the Kilmorack and Aigas benefits calculated for the intervention at each site).

Figure 6: Long Term Benefit of Proposed Intervention – Kilmorack

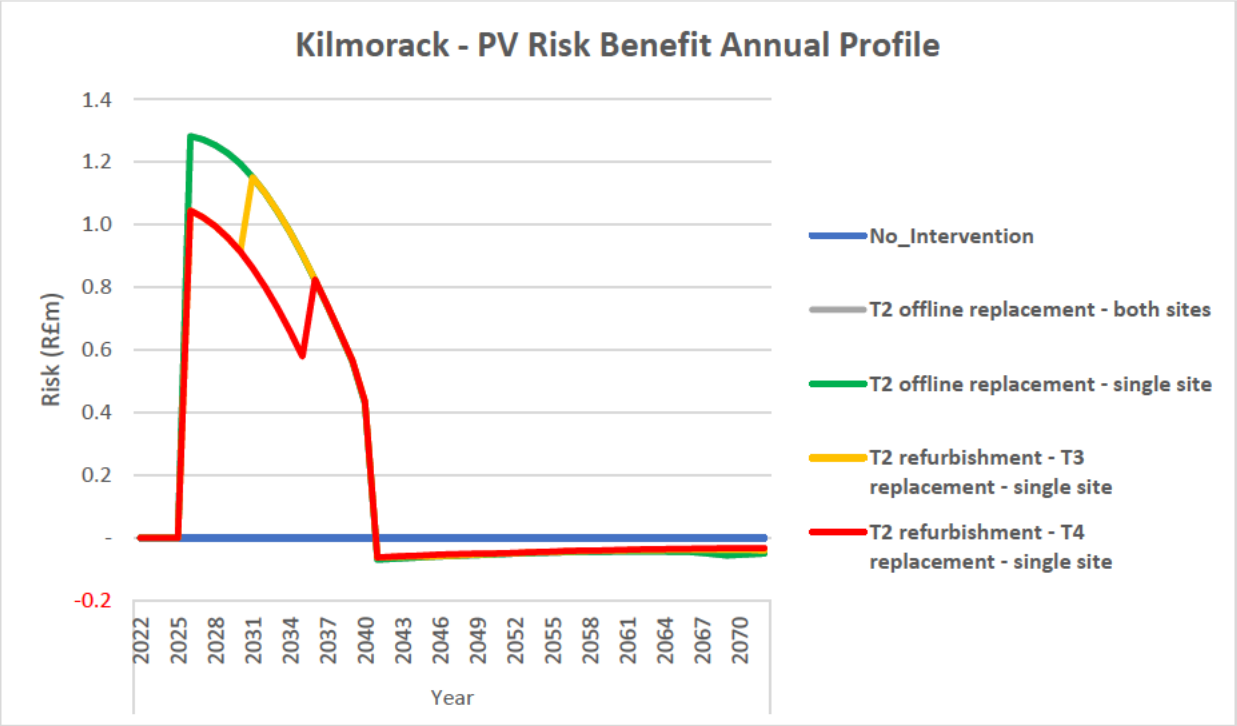
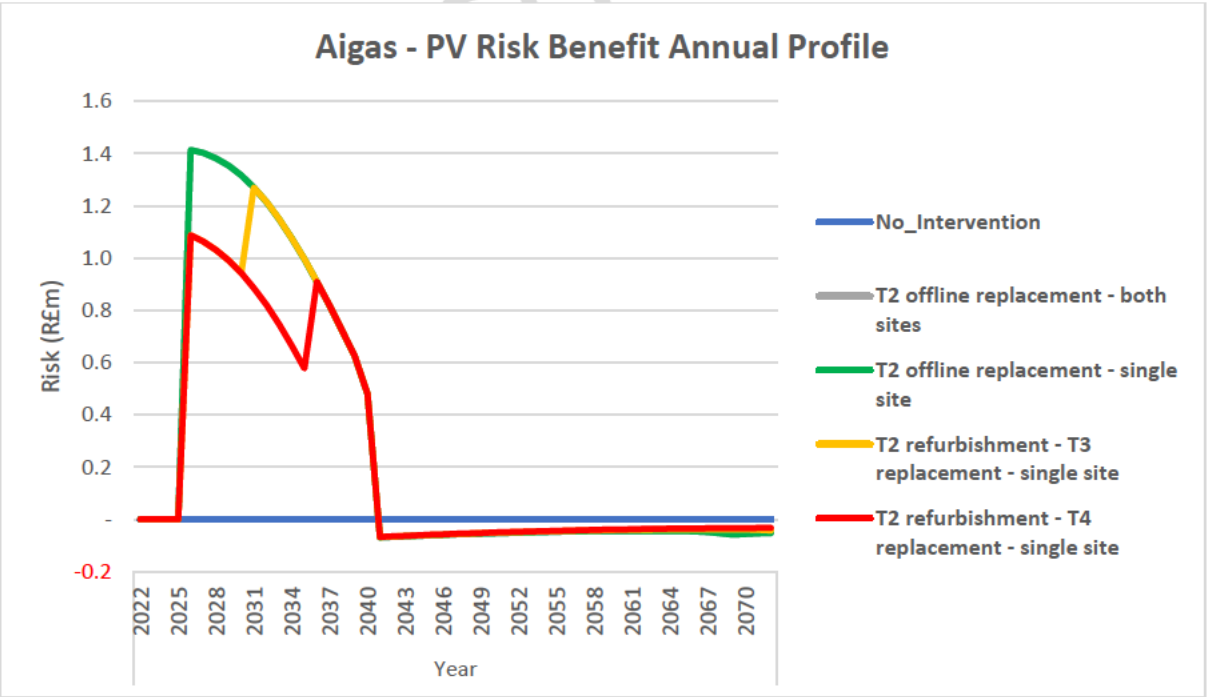


Figure 7: Long Term Benefit of Proposed Intervention – Aigas



5.6 Carbon Modelling

We are committed to managing resources over the whole asset lifecycle – i.e. including the manufacturing of assets, construction, operations and decommissioning activities – to reduce our greenhouse gas emissions in line with climate science and become a climate resilient business. It is our aspiration that the carbon lifecycle cost of investment options plays a key role within our project development and is considered in the selection of a preferred solution. We have therefore developed an internal carbon pricing model that estimates a carbon cost for each option considered in our CBA through deriving values for:

1. Embodied carbon, which relates to the carbon emissions associated with the manufacturing and production of the materials use in production of the lead assets (transformer, reactors, underground cables and Overhead lines. Overhead line is made up of tower/wood pole/composite pole, conductor and fittings) procured and installed as part of the project.

2. The carbon emissions associated with the main stages of the project lifecycle (construction, operations and decommissioning).

It is our vision to embed carbon considerations within our strategic optioneering and project development processes, which will require us to determine a way of flagging high carbon options within our CBA outputs. We will continue to develop our thinking in this space, which will involve our model being validated by a third party, so the results included in this EJP are indicative and subject to change.

The results of the analysis for this project, are captured in the carbon footprint results table,

Table 7 – Carbon Calculation Summary

	Project Information	Baseline
Project info	Project Name/number	0
	Construction Start Year	2026
	Construction End Year	2028
Cost estimate £GBP	Embodied carbon	£ 260,861
	Construction	£ 458,433
	Operations	£ 39,206
	Decommissioning	£ 209,883
	Total Project Carbon Cost Estimate	**£ 968,384**
Carbon footprint tCO2e	Embodied carbon	3,483
	Construction	6,030
	Operations	171

	Decommissioning	603
	Total Project Carbon (tCO2e)	**10,288**
Project Carbon Footprint by Emission Category	Total Scope 1 (tCO2e)	86
	Total Scope 2 (tCO2e)	85
	Total Scope 3 (tCO2e)	10,116
SF_6 Emissions	Total SF_6 Emissions 3 (tCO2e)	68

5.7 Cost Estimate

The cost of the preferred option for works for Kilmorack and Aigas has been developed using rates from existing substation framework contracts and benchmarks from delivered RIIO-T1 projects. The total cost for delivering the scope of works for the proposed solution is [redacted].

6 Conclusion

The primary driver for the replacement of the transformers at Kilmorack and Aigas substations is the condition of both units. There are consequential benefits of this of work, as this would deliver a substation which meets our current engineering standards as well as delivering improved asset separation between SHE Transmission and the customer.

In response to Ofgem's feedback from the Draft Determination document and associated reports, SHE Transmission:

- Commissioned independent assessments of transformer asset condition at Kilmorack & Aigas substations. The reports are included as Appendix 1 of this document.
- Published our Environmental Assessment Report on all SHE Transmission substation sites. An extract of this document, relating to the Kilmorack & Aigas substation sites, is included as Appendix 2 of this document.
- A refurbishment intervention option was also considered to investigate potential end-of-life extension of the assets.

Following a process of optioneering and detailed analysis, as set out in this paper, the proposed scope of works is unchanged from the December submission and is as follows:

- Offline build of a new 132/11kV substation accommodating two transformers and associated plant for the connection of the Kilmorack and Aigas hydro power stations.

This scheme will cost [redacted]nd will deliver the following outputs and benefits during the RIIO-T2 period:

- A long-term monetised risk benefit of [redacted],
- An immediate reduction of total network risk calculated as R[redacted],
- Reduced environmental risk and improved visual impact,
- To reduce the risk of asset failure impacting on the generation customers,
- Improved separation of assets between SHE Transmission and the customer,
- Improved operational flexibility and resilience in line with our goal to aim for 100% transmission network reliability for homes and businesses,
- Improved coordination with other projects in the Beauly Deanie cluster, improving outage management and reducing impact on generators and customers.

The Kilmorack and Aigas scheme is not flagged as eligible for early or late competition due it being under Ofgem's £50m and £100m thresholds respectively.

7 Price Control Deliverables and Ring Fencing

As set out in our Regulatory Framework paper (section 1.12 and Appendix 3) we support a key principle from Citizens Advice – one that guarantees delivery of outcomes equivalent to the funding received - to ensure that RIIO-T2 really deliver for consumers.

For our core non-load projects this means that we commit to delivering our overarching NARMs target. If we do not deliver the NARMS target, or a materially equivalent target, then we should be subject to a penalty. Equally, if we over-deliver against our target and are able to justify that the over-delivery is in the consumers interests and could not have been reasonably factored into our business plan at the time of target setting then we should be made cost neutral for this work.

Core non load projects should not be ring fenced. This is to allow for substitution of projects in order to meet that NARMs target. We need flexibility to respond to up to date asset data information or external influences on our network during the price control; this information might drive us to substitute one project for another in order to ensure a reliable and resilient network. Ring fencing projects may result in sub-optimal decisions, having adverse consequences for the health of our network, which will ultimately be reflected in the NARMs target.

8 Outputs included in RIIO-T1 Plans

There are no outputs associated with this scheme included in our RIIO-T1 plans.

Appendix 1 – Polaris Diagnostics & Engineering Ltd Summary Report – Kilmorack GT1

Polaris Diagnostics & Engineering Ltd has been commissioned by Scottish Hydro Electric Transmission (SHE Transmission), to carry out a Level 1 condition assessment of Kilmorack GT1 132/11kV Transformer.

The level 1 condition assessment has been carried out, based on a review and independent assessment of the historic oil data and SSEN Report SSEN Report T2BP-ACR-0021 Revision 1.1 dated October 2019 both supplied by SHE Transmission.

Based on the assessment of the historical & current asset condition data, GT1 is in a condition commensurate with age and the transformer condition will continue to deteriorate, by ageing, during the RIIO T2 period. There is an increased risk of failure of the asset within this period due to an underlying thermal abnormality and oil leakage. Further intervention will be required within the RIIO-T2 period to mitigate this increased risk of failure.

There is evidence that the transformer has externally deteriorated and requires further inspection and evaluation. Given that the transformer is located in close proximity to the River Beauly, the transformer should be considered as an environmental hazard until such times as the oil leaks have been repaired or the transformer is replaced.

There is an underlying low level thermal abnormality as evidenced by the presence of dissolved ethylene levels in both the main tank and tap changer selector. These are communicating and in equilibrium. To identify the source of the dissolved ethylene electrical testing would be required. Whilst these magnitudes of dissolved gases are still at low level, the dissolved ethylene should be kept under surveillance, in order to check for further manifestation on what could become degenerative thermal abnormality.

The transformer having an estimated 56% residual life remaining in the paper insulation. This suggests that the paper insulation is in a good condition given its age.

This transformer is internally in "reasonable condition" but has an underlying thermal abnormality and will require monitoring in the form of increased oil surveillance and may require enhanced maintenance within this period to prevent deterioration that may lead to failure. The external condition is aged. The transformer has active oil leaks and presents a significant environmental hazard. A 'mid-life' refurbishment should be considered in order to return the asset to a condition such that it will extend the asset life.

In order to mitigate the risk of an increased likelihood of failure during the RIIO T2 period and to understand the scope of work for a "mid-life" refurbishment, the following recommendations are made:

- Frequency of oil sampling should be increased to monitor dissolved ethylene, moisture content and dielectric breakdown voltage. This should be done every 6 months.
- The transformer will require to be cleaned down to mitigate the health and safety risk from bird droppings to facilitate a detailed inspection.
- Detailed inspection of the asset – outage required – to identify the source of the oil leaks.
- Inspection and assessment of the moisture management system.
- 132kV bushings should be oil sampled for DGA and moisture analysis and assessed by the criteria set out in National Grid TGN 82. In addition the bushing power factor and capacitance should be measured. This would require an outage and the removal of the 132kV and 11kV bushings to facilitate the testing.
- Detailed condition assessment of the transformer to include Sweep Frequency Response Analysis (SFRA), Dielectric Frequency Response (DFR), 10kV Power Factor, 5kV Insulation Resistance and DC Winding Resistance testing. This would require an outage and the removal of the 132kV and 11kV bushings to facilitate the testing.
- Following detailed inspection continue with routine inspection.
- Continue with routine maintenance.
- Detailed load flow monitoring.

Author	Issue Authority
Ian B B Hunter Technical Director	Ian B B Hunter Technical Director
	

Appendix 1 – Polaris Diagnostics & Engineering Ltd Summary Report – Aigas GT1

Polaris Diagnostics & Engineering Ltd has been commissioned by Scottish Hydro Electric Transmission (SHE Transmission), to carry out a Level 1 condition assessment of Aigas GT1 132/11kV Transformer.

The level 1 condition assessment has been carried out, based on a review and independent assessment of the historic oil data and SSEN Report T2BP-ACR-0020 Revision 1.1 dated November 2019,both supplied by SHE Transmission.

Based on the assessment of the historical & current asset condition data, GT1 is in a condition commensurate with age and the transformer condition will continue to deteriorate, by ageing, during the RIIO T2 period. There is an increased risk of failure of the asset within this period due to an underlying thermal abnormality and oil leakage. Further intervention will be required within the RIIO-T2 period to mitigate this increased risk of failure.

There is evidence that the transformer has externally deteriorated and requires further inspection and evaluation. Given that the transformer is located in close proximity to the River Beauly, the transformer should be considered as an environmental hazard until such times as the oil leaks have been repaired or the transformer is replaced.

There is an underlying thermal abnormality as evidenced by the presence of dissolved ethylene levels in both the main tank and tap changer selector. These are communicating and in equilibrium. To identify of the source of the dissolved ethylene electrical testing would be required. Whilst these magnitudes of dissolved gases are still at low level, the dissolved ethylene should be kept under surveillance, in order to check for further manifestation on what could become degenerative thermal abnormality.

Oil processing or topping up of the main tank oil has had a dilution effect on the measured 2FAL concentrations and as this is used to predict the condition of the paper insulation and "estimated residual life remaining" of that insulation, the estimate of 55% life remaining is considered optimistic.

This transformer is internally in "reasonable condition" but has an underlying thermal abnormality and will require monitoring in the form of increased oil surveillance and may require enhanced maintenance within this period to prevent deterioration that may lead to failure. The external condition is aged. The transformer has active oil leaks. A 'mid-life' refurbishment should be considered in order to return the asset to a condition such that it will extend the asset life.

In order to mitigate the risk of an increased likelihood of failure during the RIIO T2 period and to understand the scope of work for a "mid-life" refurbishment, the following recommendations are made:

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- Following detailed inspection continue with routine inspection.
- Continue with routine maintenance.
- Detailed load flow monitoring.

Author	Issue Authority
Ian B B Hunter Technical Director	Ian B B Hunter Technical Director
	

Appendix 2 – Extract from Environmental Resources Management Ltd – Environmental Risk Assessment of SHE Transmission Sites

						Immediate Surrounding Land Use					Hydrogeology						Distance to nearest…	Surface Watercourse…	Surface Water Classificatio…	Potential Flood risk o…	Vulnerabilit…	Sensitivity
No.	Substation Code	Substation	Nearest Postcode	Approximate Site Area (hectares)	Year of Installation (No. of transformers)	North	East	South	West	Private Water Supplies within 500m of site	Aquifer Permeability	Groundwater Level (m below ground level)	Groundwater Quality Classification	Groundwater Drinking water Protected Areas	Vulnerability	Sensitivity	Distance to nearest surface water feature (m)	Surface Watercourse Name	Surface Water Classification	Potential Flood risk on site	Vulnerability	Sensitivity
3	AIGA	Aigas Grid	IV4 7AE	0.13	1960 (1)	Dam and river	Woodlands	River	Woodlands	30m north: Aigas Power Station	Moderately productive	Dam - River	Good	Muir of Ord	High	High	0m (adjacent south and north)	River Beauly	Good	High (rivers and surface water)	High	High
20	CULL	Culligran Grid	IV4 7JX	0.10	1962 (1)	Woodlands	River Farrar	Woodlands and River Farrar	Woodlands	100m east: Culligran Power Station	Low productivity	None	Good	Northern Highlands	Moderate	High	90m east	River Farrar	Good	High (rivers)	High	High
22	DEAN	Deanie Grid	IV4 7JX	0.07	1962 (1)	Undeveloped	Loch Beannacharan	Undeveloped and Woodlands	Undeveloped	10m west: East Culligran - domestic 30m southwest: Deanie Power Station 450m northeast: Beannacharan Lodge	Low productivity	Unknown	Good	Northern Highlands	Moderate	High	210m southwest	River Beauly	Good	No risk	Moderate	High
33	KIOR	Kilmorack Grid	IV4 7AL	0.15	1960 (1)	Woodlands and agricultural	Woodlands and River Beauly	Woodlands and agricultural	River Beauly	None	Moderately productive	Unknown	Good	Muir of Ord	Moderate	High	20m east	River Beauly	Good	High (rivers)	High	High