Mid Antrim Upgrade

Preliminary Preferred Options Report

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Version: Revision 01

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Rev 01	Preliminary Options Report	N. McClements, Engineer, Current Network	R. Smyth, Team Lead, Current Network	Arthur Moynihan, Manager, Current Network	June 2021

Contents:

Figures:

Tables:

Summary

A case of need report has been prepared for reinforcing the 110 kV network between Kells and Rasharkin.

This report presents SONI's preliminary preferred option which will be used in a TNPP submission to the Utility Regulator.

To date a number of assessments have been completed by consultants commissioned by SONI. These include a feasibility investigation completed by Mott MacDonald and environmental assessments completed by RPS. These assessments have provided information to SONI in identifying the preliminary preferred option.

The options investigated in this report include:

- Option 1: Do nothing
- Option 2: Restringing of existing 110 kV circuit from Kells to Rasharkin with a higher capacity conductor;
- Option 3a: Construction of a new 110 kV circuit from Kells to Rasharkin passing North East of Ballymena;
- Option 3b: Construction of a new 110 KV circuit from Kells to Rasharkin with a cable section through Ballymena town;
- Option 3c: Construction of a new 110 kV circuit from Kells to Terrygowan, uprating a double circuit section between Kells and Terrygowan and construction of a new circuit from Terrygowan to Rasharkin;
- Option 4: Establishing a 6-bay GIS substation near Ballymena Main, uprating both Kells – Ballymena circuits and constructing a new circuit from Ballymena to Rasharkin with a section of cable through Ballymena town;
- Option 5: Construction of a new 110 kV circuit from Creagh to Rasharkin, extending the existing GIS switchboard at Creagh Main and uprating the 110 kV circuit from Creagh to Kells;
- Option 6: Establishing a 4-bay AIS or GIS substation arrangement at Terrygowan, uprating the double circuit section from Terrygowan to Kells and constructing a new 110 kV circuit from Terrygowan to Rasharkin; and
- Option 7: Construction of a full cable option between Kells and Rasharkin and any associated reactive compensation.

The options were appraised in two case years, 2025 and 2030. The 2025 case represented a system which closely resembles that of today. The 2030 case represented a more onerous, challenging system where additional generation would follow the Addressing Climate Change scenario (with 70% renewables) from the SONI Tomorrow's Energy Scenarios, NI (TESNI 2020).

As determined in the associated Needs report, Option 1 – do nothing will result in potential overloads for circuits and a resulting high cost to constrain wind generation - £9.5m by 2030 annually based on a constraints study. The analysis showed that Option 2 – Restring would not address the congestion in 2025 and 2030. All of the other options addressed the

congestion by 2025, however congestion would return in the 2030 case. However it is recognised that significant other additional reinforcements will be required to address the 2030 ACC scenario. A number of options are set out in the SONI Transmission Development Plan, NI (TDPNI); however this will depend on the final outcome of a new Energy Strategy.

The full cable option 7 was also rejected at the assessment of the long list as: it was over twice the cost of several of the lower cost options; would require significant plant and equipment and an extension of Kells 275/110 kV substation and presented other technical risks.

All of the remaining shortlisted options are broadly similar in terms of technical merit. A comparison exercise was completed which assessed the environmental, deliverability and cost aspect of each option. A number of these options would pass through environmental constraints within the study area which could impact on the deliverability of that option.

Based on a multi-criteria analysis of cost (capital and lifecycle) as well as environmental impact, technical merit and deliverability, to date the preliminary preferred option is identified as Option 6 (Terrygowan). This option consists of:

- Establishing a 4-bay AIS or GIS substation arrangement at Terrygowan (close to the Whiteside's corner);
- Uprating the double circuit section between Terrygowan and Kells substation (12.7km) and replacement of the existing earthwire with OPGW; and
- Construction of a new wood pole 110 kV overhead line circuit (21.5km approx.) with sections of cable at each end to accommodate substation entry. This circuit would be constructed within the study area set out in Appendix 4.

This option is the least environmentally constrained as per RPS' assessments and is also the second least expensive option at a cost of £22.5 million.

For the purposes of our stakeholder engagement exercises and TNPP submission this is selected as preliminary preferred option.

1. INTRODUCTION

The need for the reinforcement of the Kells – Rasharkin circuit has been confirmed in the associated Needs Report. Under high wind conditions, with the assumptions as set out in the Transmission System Security and Planning Standards (TSSPS), the Kells – Rasharkin circuit has the potential to be overloaded in 2025, by approximately 140% even after the operation of the Coolkeeragh run back scheme. This is currently managed by constraining wind farms and other renewable generation in Constraint Group 1 using the Wind Dispatch Tool. This in turn leads to congestion.

2. DESCRIPTION OF THE NETWORK

The transmission network, see Figure 1, is based on a strongly meshed 275 kV ring around Lough Neagh with a double circuit spur to Coolkeeragh. There is also an underlying 110 kV network which establishes a meshed ring around the North and West from the 275 kV backbone substations at Kells and Tamnamore.

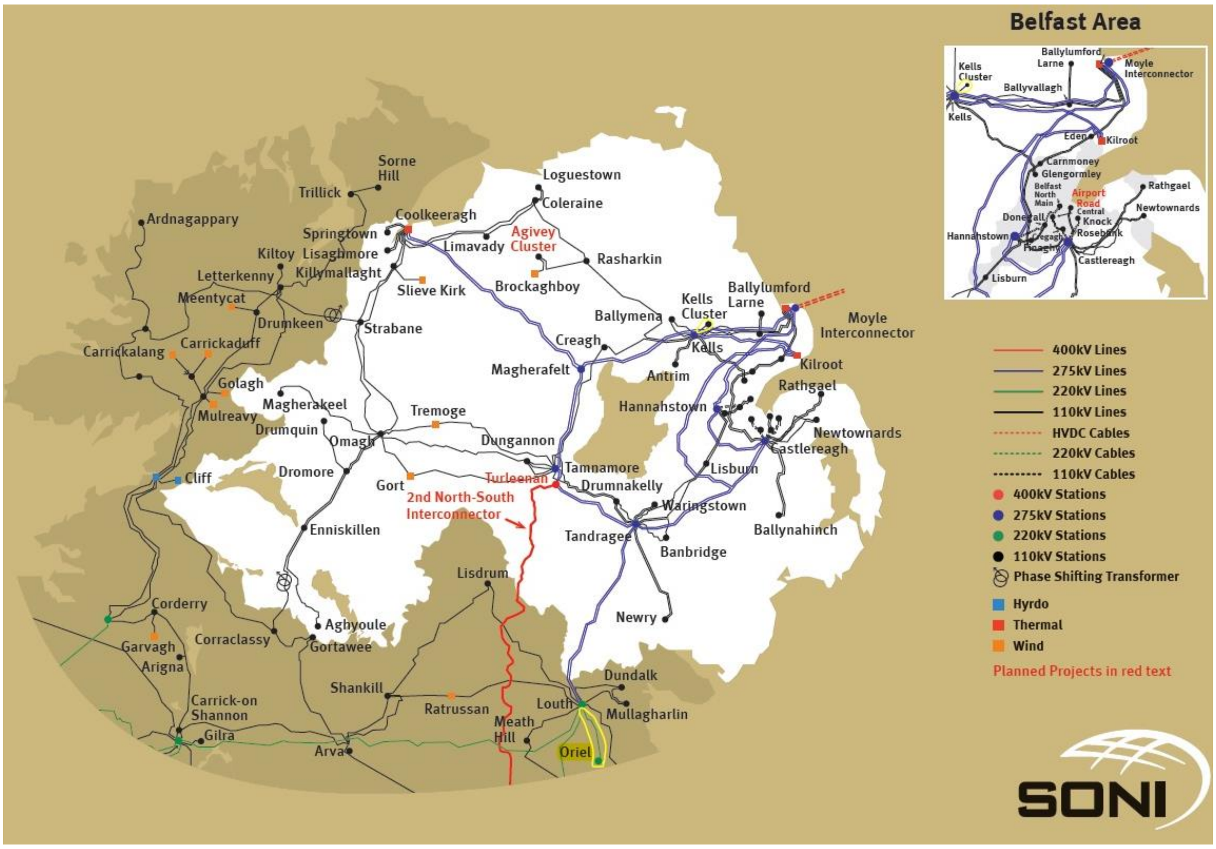

Figure 1 - Existing Transmission Network

The majority of renewable generation has been connected in the North and West of Northern Ireland. This is passed onto the 110 kV system at bulk supply points and cluster substations and onto the 275 kV system at grid supply points.

3. ASSESSMENTS TO DATE

In April 2017 CP1006, Reinforcement of 110 kV circuit: Kells – Rasharkin, was approved by the Management Investment Committee. This approval catered for the preliminary works associated with the investigation of options for the development of a 110 kV circuit to reinforce the transmission network between Kells and Rasharkin.

In August 2017 SONI commissioned Mott MacDonald to carry out a feasibility investigation for a number of options identified by an initial desktop study. Mott Mac Donald investigated these options in greater detail and completed a multi-criteria analysis that assessed each option against the following constraints: Environmental, Social and Cultural (ESC) constraints, technical constraints and Capex costs. The options included:

1. A new overhead line from Kells to Rasharkin, diverting to the North (East) of Ballymena.
2. A new overhead line from Kells to Rasharkin, diverting to the South (West) of Ballymena.
3. A new overhead line from Kells to Ballymena, a new cable route through the town of Ballymena and a new overhead line to Rasharkin,
4. A new cable connection from Kells to an existing 33 kV overhead circuit that passes close to Kells and connects into Ballymena substation, the uprate and rebuild of this 33 kV line to 110 kV specification, a new cable route through Ballymena and a new overhead line to Rasharkin. This also included a new 33 kV cable from Kells to Ballymena Main substation to replace the functionality of the existing 33 kV overhead line.
5. Uprating of both existing 110 kV overhead circuits from Kells to the existing Ballymena Main substation, construction of a GIS substation close to Ballymena Main, installing a new cable route through Ballymena before continuing as a new overhead line to Rasharkin.
6. Uprating of an existing 110 kV connection between Kells and Creagh and constructing a new overhead line from Creagh to Rasharkin to establish a complete connection from Kells to Rasharkin via Creagh.

In May 2018 SONI commissioned RPS to undertake environmental constraint modelling of the proposed options. This was in support of Mott Mac Donald’s overall feasibility investigation.

In September 2018 Mott MacDonald were asked to include an additional option in their investigations. This option involved the uprate of the existing double circuit from Kells to Terrygowan, construction of a new circuit between Kells and Terrygowan (to replace the functionality of the existing Kells – Creagh circuit) and construction of a new circuit from Terrygowan to Rasharkin. Mott MacDonald has completed their feasibility investigation producing a number of reports and corridor maps. These reports have helped in the determination of the preliminary preferred option; they are included in Appendix 1 of this document.

SONI investigated indicative cable routes around Ballymena and from cable sealing ends into all substations. This was a desktop assessment which was incorporated into the work completed by Mott MacDonald and RPS.

In April 2020 SONI commissioned RPS to complete a second environmental constraint modelling of the proposed options and to provide a narrative of each option from a constraints perspective. RPS was asked to use the Environmental, Social and Cultural (ESC) constraints which Mott Mac Donald included in their analysis. This exercise provided the information and figures associated with section 7 of this options report. This written summary of the RPS assessment is included in the appendices of this document.

In June 2020 an additional option was added to the longlist by SONI. This option involved the uprating of the double circuit section from Kells – Terrygowan, the construction of a new 110 kV node at Terrygowan, turning in of the existing Kells – Creagh circuit (to establish a Kells - Terrygowan and Terrygowan – Creagh circuits) and the construction of a new circuit from Terrygowan to Rasharkin. An assessment of this option was available from the work completed to date by both consultants. Both consultants have updated the final versions of the feasibility investigation reports with this option.

Through the development of the preliminary preferred options report the findings from Mott MacDonald and RPS consultants have helped to inform SONI and prepare cost estimates and multi criteria assessments. In reviewing these reports a number of conclusions and actions have been determined.

It was the preference of SONI to use the environmental constraint modelling completed by RPS in 2020 for the option appraisal multi criteria assessment. Through the timeline of this project there was an evolution in the modelling of options, including a refinement of corridors and methodology used.

Through this refinement it was also found that technical constraints determined by Mott MacDonald were not considered problematic for the construction of an overhead line. Other technical constraints such as under crossings of 33 kV, 11 kV and BT overhead lines have been factored into the cost estimate of options. NIE Networks will underground these crossings where it is reasonably practicable to reduce the risk of working above live equipment. This applies for new build circuits and existing circuit uprates. Cost is included in the multi criteria assessment. These cost estimates have been prepared from a unit cost database provided by NIE Networks.

4. TDPNI

4.1. Tomorrow's Energy Scenarios

In July 2020 SONI published the Tomorrow's Energy Scenarios NI 2020 (TESNI 2020). Tomorrow's Energy Scenarios were developed in order to gain a perspective of the long term needs of the transmission system and to inform the energy and climate policy debate focusing on the electricity system.

Following the consultation period in autumn 2019 the "Least Effort" scenario (50% RES-E) was removed and replaced with the new "Accelerated Ambition" scenario. The key characteristics of the three scenarios and of the generation and demand changes are included in Appendix 2. The resulting scenarios can be summarised as follows:

1. Modest Progress (MP) – 60% of electricity demand from renewables by 2030, 40% reduction in CO_2 emissions.
2. Addressing Climate Change (ACC) – 70% of electricity demand from renewables by 2030, 45% reduction in CO_2 emissions.
3. Accelerated Ambition (AA) – 80% of electricity demand from renewables by 2030, 50% reduction in CO_2 emissions.

These final scenarios will be used to conduct a number of different power system studies out to 2040. These studies will help to identify any future needs on the transmission system brought about by changes in generation, demand, storage and interconnection. The results of these studies have been published in June 2021. This information will provide input to future versions of the Transmission Development Plan Northern Ireland (TDPNI).

4.2. Shaping Our Electricity Future

In March 2021 SONI and EirGrid launched the Shaping Our Electricity Future work stream and consultation. This has been the largest consultation that both companies have undertaken and similarly to the Tomorrow's Energy Scenarios publication this report assesses the performance of the transmission network and report on areas of weakness.

Shaping the Electricity Future seeks to develop an integrated approach to developing a reliable and efficient power system and market. It considers three separate areas:

1. The transmission network;
2. System operations; and
3. The electricity markets.

Shaping Our Electricity Future assesses the transmission network performance in Northern Ireland and on an all-island basis in order to find opportunities to minimise the transmission network capital investment cost to consumers. It also considers a single scenario for 2030 based on governmental RES-E targets in both jurisdictions. In Ireland this been agreed as 70% by 2030 and while there is currently no target agreed yet in NI it is anticipated to be similarly 70% by 2030 based on statements from the Economy Minister.

As part of the ‘Networks’ piece of Shaping Our Electricity Future, four possible approaches for future grid development are considered and consulted on as part of the consultation process. These approaches differ in the number of transmission projects that will need to be completed in order to achieve the 70% RES-E target by 2030 and the scale and technology behind these projects. These four approaches can be summarised as follows:

1. Generation Led – Clean electricity generation is located close to where most of the power is used;
2. Developer Led – Developers decide where to locate clean electricity generation;
3. Technology Led – Using new ways to move clean electricity across the country; and
4. Demand Led – Large electricity users are located closer to the sources of clean electricity generation.

Similar to Tomorrow’s Energy Scenarios the outcomes of this work stream will be used to provide input to future versions of the TDPNI and to get a better understanding of which projects will be required to meet the needs of the new energy strategy (in Northern Ireland this is expected in late 2021). This project has been identified as required across all four of these approaches in Shaping Our Electricity Future. For further information please access this consultation from the SONI website.

4.3. Transmission Development Plan Northern Ireland

In assessing the options within this options report a number of other relevant projects are also considered.

The 70% renewables target is expected to require the establishment of reinforcement North of Rasharkin and Agivey. The TDPNI includes a North West 110 kV reinforcement project. A sensitivity study is included in this options report that includes additional reinforcement between Rasharkin and the North West of Northern Ireland. For the purposes of these studies one of the options, namely the Agivey – Limavady option, has been included as a sensitivity study along with our preliminary preferred option, see Appendix 9. This reinforcement will be assessed in a separate options report.

5. LONG LIST OF OPTIONS

5.1. Option 1 – Do Nothing

This option would result in the existing constraint remaining. The Needs Report assessed the level of congestion in the following tables. Table 1 shows the unconstrained loadings on the circuits in the event of the loss of the Coolkeeragh – Magherafelt 275 kV double circuit.

Case year	***Season***	***Before double circuit contingency***	***Before completion of SPS operation***	***After double circuit contingency and SPS operation***
2025	Summer valley Summer peak Winter peak	71% 81% 83%	135% 153% 158%	121% 134% 139%
2030	Summer valley Summer peak Winter peak	97% 113% 116%	171% 189% 208%	157% 176% 192%

Table 1 - Load flows for Do-Nothing Option under loss of Coolkeeragh – Magherafelt DCT

There are also local overload risks. These loadings have been recorded before the proposed transfer of Gruig and Garves windfarms from Coleraine to Rasharkin. This transfer cannot be accommodated at present due to voltage collapse issues at Rasharkin for the loss of the Coleraine – Rasharkin circuit. Table 2 shows the level of loading on the Kells – Rasharkin circuit for the loss of the Coleraine - Rasharkin circuit. Similarly the table also shows the level of loading on the Coleraine – Rasharkin circuit for the loss of the Kells – Rasharkin circuit.

Case year	***Season***	***Kells – Rasharkin circuit***		**Coleraine – Rasharkin circuit**	
		Before Coleraine – Rasharkin contingency	*After Coleraine – Rasharkin contingency*	*Before Kells – Rasharkin contingency*	*After Kells – Rasharkin contingency*
2025	Summer valley Summer peak Winter peak	71% 81% 83%	72% 89% 86%	3% 9% 8%	72% 88% 87%
2030	Summer valley Summer peak Winter peak	97% 113% 116%	109% 132% 154%	12% 19% 26%	108% 131% 134%

Table 2 – Load flows for Do-Nothing Option with the loss of the Kells – Rasharkin circuit and with the loss of the Coleraine – Rasharkin circuit

The above potential overload risks are not permitted on the transmission system. To manage this risk, upon real time warnings from the Network Management System state estimator, the renewable generation in the Constraint Group 1 would be constrained. This in turn is what is known as congestion. On the basis that this constraint would be compensated the costs are as detailed in Table 3.

Case year	*Total MWhrs constrained*	*Approx. Constraint costs (£45.7 per MWhr[1])*
2025	46,590	£2,130k
2030	206,840	£9,450k

Table 3 - Cost of constraining renewables to manage congestion

The above constraint costs would accumulate to a net present cost over a 25 year period to £107m.

The total energy consumed in Northern Ireland is approximately 9TWh. In order to reach a target of 70% renewables in Northern Ireland, approximately 6.3TWh will be required to come from renewables. A 2030 constraint of 0.21 TWh is a constraint of over 3% of the required energy coming from renewable sources.

5.2. Option 2 - Upgrade conductor

This option would be based on restringing the existing Kells – Rasharkin with a higher rated conductor. The circuit is currently constructed with two types of high temperature, low sag (HTLS) conductor. The section from Kells – Terrygowan, on the double circuit tower line, is Gap and the section from Terrygowan to Rasharkin is Invar. These conductors are rated at circa 195 MVA.

This proposal would be to replace the conductor on both sections with a composite conductor known as Oslo. A restring with Oslo would increase the rating from 195 MVA to 249 MVA.

This option is expected to cost approximately £14.52m. For a breakdown of this cost estimate see Appendix 3.

5.3. Option 3 - New 110 kV circuit from Kells - Rasharkin

There are three possible study areas to establish a new 110 kV circuit directly from Kells to Rasharkin. The first study area would pass to the Northeast of Ballymena (Option 3a), the second route would pass through Ballymena with cable sections through the town (Option 3b) and the third route would pass to the Southwest of Ballymena (Option 3c).

[1] Based on an Average Day Ahead Market Price (DAM) of €50.26/MWh – SEMOpx market summary for 2019

Option 3a – Northeast study area

The option would be based on an overhead line with cable sections at the approaches to Kells and Rasharkin substations and is equivalent to Option A in the Motts report. The overhead line in this study area would be between 30 and 34 km in length and of wood pole construction (with an earth wire). The cable sections at the approaches to Kells and Rasharkin substations are estimated to be 1km and 800m respectively. The circuit is rated to 200 MVA (all seasons) due to these cable sections.

This circuit would follow the study area set out in figure A4-3a in Appendix 4. The study area avoids the outskirts of Ballymena town and includes the towns of Broughshane and Glarryford. Two sample corridors within the study area have been assessed (i.e. 8 and 9).

This option is estimated to cost £22.36m. For a breakdown of this cost estimate see Appendix 3.

Option 3b – Central Study Area

The option would be based on establishing a new 110 kV circuit from Kells to Rasharkin within the study area in Appendix 3b. This option is based on an overhead line with cable sections at the approaches to Kells (3.2km) and Rasharkin (800m).

The option is equivalent to Option G in the Mott MacDonald feasibility report.

There would also be a section of cable through Ballymena which would include two complex crossings of the railway and rivers.

The two overhead line sections within this study area would be approximately 8.5km and 17.5km in length respectively. The overhead lines would be of wood pole construction (with an earth wire). The circuit is rated to 200 MVA (all seasons) due to the cable sections through Ballymena and to enter Kells and Rasharkin substations.

There would be a requirement to establish special protection arrangements for the cable sections to allow auto-reclose to remain on the overhead line sections whilst inhibiting this for a fault on the underground cable section. Therefore the cable sealing ends would require to be enclosed with sufficient space for current transformers, and a protection / control building.

This circuit would follow the study area set out in figure A4-3b in Appendix 4. The study area includes the western section of Ballymena. Six sample corridors within the study area have been assessed (i.e. 4 and 5 between Kells and Ballymena and 10, 11, 12 and 15 between Ballymena and Rasharkin). Of the potential sub-options that can be made from these corridors this report only considers the following two sub-options: 4 + 15 and 5 + 11.These sub-options have cable sections which are shorter within Ballymena. This may lead to less disruption to the town.

A corridor based on rebuilding an existing 33 kV line from Ballymena Main to Kells 33/11 kV substation was also considered and included as Option F by Motts. However this was rejected as the existing line crosses domestic curtilage and it would not be feasible to obtain wayleaves for a 110 kV circuit along this route.[2]

This option is estimated to cost £30.91m. For a breakdown of this cost estimate see Appendix 3.

Option 3c – Southwest Study Area

The option would be based on establishing a new wood pole 110 kV overhead line (with cable entry at Kells) from Kells to Terrygowan (approx. 12.8km), sample corridor 14. This new overhead line would be connected to the existing single circuit section from Terrygowan to Creagh to provide a full circuit from Kells to Creagh.

The existing Kells – Terrygowan double circuit section would then be used for the new Kells - Rasharkin second circuit and restrung with higher capacity conductor. This circuit would then be extended with a new wood pole overhead line to Rasharkin (approx. 21.5km in length) and a cable section for entry into Rasharkin substation, sample corridors 13A or 13B. This circuit is rated to 195 MVA due to the section of uprated conductor between Kells and Terrygowan. This is equivalent to Option I in the Motts report.

This circuit would follow the study area set out in figure A4-3c in Appendix 4. The study area avoids the outskirts of Ballymena town. Three sample corridors within the study area have been assessed (i.e. 13A, 13B and 14).

This option is estimated to cost approximately £25.69m. For a breakdown of this cost estimate see Appendix 3.

5.4. Option 4 - New GIS Node at 110 kV near Ballymena Main

This option is based on establishing a new 110 kV 6 bay GIS switching station close to Ballymena Main, restringing both existing Kells – Ballymena circuits of length 10km and 11.5km (currently strung with Lynx conductor) and establishing a new 110 kV circuit from Ballymena to Rasharkin. This is equivalent to Option D in the Motts report.

The circuit from the proposed GIS substation at Ballymena Main to Rasharkin would comprise approximately 4.7km of underground cable followed by 18km of overhead line. The cable section through Ballymena would include three complex crossings of the railway and rivers.

There would also be approximately 800m of underground cable on the approach to Rasharkin. The circuit is rated to 200 MVA (all seasons) due to the cable sections.

[2] A desktop assessment of the 33 kV circuit found that it traverses curtilage of domestic housing. The Electricity (Northern Ireland) Order 1992[2]; Paragraph 10(5) of schedule 4 *"Precludes the grant of a necessary wayleave for an overhead electric line where a dwelling covers the land or where valid planning permission exists for a dwelling to be constructed".*

This circuit would follow the study area set out in figure A4-4 in Appendix 4. The study area includes the western section of Ballymena town where underground cables would be used in the residential areas. Four sample corridors within the study area have been assessed (i.e. 10, 11, 12 and 15). Of the potential sub-options that can be made from these corridors this report only considers a sub option using sample corridor 15. This sub-option has a cable section which could be considered potentially easier to deliver due to its location within Ballymena. This may lead to less disruption to the town.

This option has an estimated cost of £32.87m. For a breakdown of this cost estimate Appendix 3.

5.5. Option 5 - New 110 kV circuit from Creagh to Rasharkin

This option is based on the following:

- Restringing the existing Kells – Creagh 110 kV circuit which consists of a 9.6km wood pole section, a 12.7km double circuit tower line section.
- Replace 800m of cable into Creagh Main and construct a new cable sealing end tower.
- Extending the existing Creagh Main 110 kV GIS switchboard; and
- Constructing a new wood pole 110 kV circuit from Creagh to Rasharkin (23.6 km) including cable sections at Creagh and Rasharkin (approx. 1.6km and 1.8km respectively).

It is necessary to restring the circuit from Creagh back to Kells due to the increased power flow on this this circuit after a connection from Creagh to Rasharkin. This option is equivalent to Option H in the Motts report.

The new circuit from Creagh to Rasharkin is rated to 200 MVA (all seasons) due to the cable sections for entry into Creagh and Rasharkin substations.

The existing 110 kV GIS switchboard at Creagh was installed in 2002 with ABB, EXK-D01-HMB-1 type switchgear. This model of switchgear is no longer manufactured by ABB. It would be necessary to have an adaptor panel manufactured specifically to extend this switchboard. The estimated cost of a new bay, adapter panel and civil works is £2.5m. There is no certainty that this approach would be possible.

There is a further disadvantage to this option. The TSSPS requires any new marshalling substation to be of the double busbar type. Creagh Main is a single busbar substation. This means that if there was at a point in the future a busbar fault the circuit could be out of service for a prolonged period of time. A busbar extension would also require the busbar to be disconnected for several days.

This circuit would follow the study area set out in figure A4-5 in Appendix 4. The study area includes the towns of Bellaghy, Clady and Portglenone. This area also includes Lough Beg and the River Maine. Three sample corridors within the study area have been assessed (i.e. 1, 2 and 3).

This option has an estimated cost of £28.45m. For a breakdown of this cost estimate see Appendix 3. A complex crossing has been allowed for in the cost estimate for the cable entry into Creagh Main for the new sections of cable. The new sections of cable can share the same cable trench to cross the A6. The cost estimate also includes a new cable sealing end terminal tower which is required for the existing circuit uprate.

5.6. Option 6 – Terrygowan option

This option was not considered in the Motts reports initially, but was included in the 2020 review once added to the long list and as the overhead line corridors for this option were assessed in a similar option (option 3c). The option is equivalent to Option J in the Mott MacDonald feasibility report.

This option is based on the following:

- Establishing a GIS switchboard or AIS outdoor substation at Terrygowan (close to the Whiteside's Corner where the double circuit tower line terminates into wood pole circuits);
- Restringing the Kells – Terrygowan double circuit section (Creagh circuit side) with higher temperature conductor and replacing the earthwire on this section with OPGW ; and
- Constructing a new wood pole 110 kV circuit from Terrygowan to Rasharkin (21.5 km in length) including a cable section for entry to Rasharkin substation.

The arrangement could be limited to establishing a connection to Rasharkin from the Kells - Creagh circuit. This would limit the number of bays to three plus a bus coupler (four in total). The new circuit from Terrygowan to Rasharkin would be rated to 200 MVA (all seasons) due to the cable sections. The uprated circuit back to Kells would be rated to 195 MVA based on Gap conductor previously used. The replacement of the existing earthwire with optical phase ground wire (OPGW) will provide a communications path from Kells to the new substation at Terrygowan (and to Rasharkin with the new build circuit). This will enhance protection proposals without having to rely on the NIEN Telephone Network.

The estimated cost of this option is £22.53m. For a breakdown of this cost estimate see Appendix 3.

This circuit would follow the study area set out in figure A4-6 in Appendix 4. Two sample corridors within the study area have been assessed (i.e. 13A and 13B).

5.7. Option 7 – New 110 kV underground cable from Kells - Rasharkin

This option was not included in the Motts assessments. However following review a 110 kV underground cable option has been added to the long list for consideration.

This option would be based on establishing a 110 kV cable circuit from Kells Main to Rasharkin. It is estimated that an indicative cable route would be 34 km.

This indicative route was based on the B98 Carncome Road, A26, Cromkill Road (across the NI railway), Tullygarley Road (across the Braid River), Sourhill Road, A43 Galgorm Road, Fenaghy Road, Corbally Road, B93 Cardonaghy Road, Dreen Road, Kilrea Road, Craigs Road, Church Road (through Rasharkin) and Finvoy Road into Rasharkin 110 kV substation. This indicative cable route would follow the study area set out in figure A4-7 in Appendix 4.

This option has technical features and additional requirements that would not be present with an overhead line project. A new circuit comprised of all cable would have an impedance of less than one third that of the overhead line. Load flow studies indicated that the cable would not share power flow equally with the overhead line and would take the majority of the flow. Studies show that it could potentially be overloaded for the loss of the Coolkeeragh – Magherafelt double circuit in the 2025 case. It would also be overloaded for the loss of the Coleraine – Rasharkin circuit.

To balance the power flow between this cable and the existing overhead it would be necessary to install a 200 MVA series reactor in series with the cable circuit. It is estimated that the cost of this device including its connection would be approximately £5m. There would be insufficient space for the device at Kells or Rasharkin. For the purposes of assessing the option it is assumed the device would be installed at Kells after a substation extension and noise assessment.

In addition due to the capacitance of the cable it would inject the equivalent of 45 Mvars of reactive power. This would cause an increase in the high voltage issues being experienced at present and would require compensation. This would require a direct connected 45 Mvar shunt reactor, installed at Kells. This is because the number of available 275/110 kV 22 kV tertiaries has been exhausted. It is estimated that this unit would cost approximately £2m including the 110 kV bay and civils.

There might also be energisation issues with energising a cable and series reactor. There might be a requirement to investigate zero-miss phenomena (ZMP).

With a long cable section there would also be the risk of harmonic resonance. If this option were to be taken forward to the short list it would be necessary to check this using specialist consultancy using the harmonic model. Finally if this option were to be taken forward there would also be a requirement to study temporary overvoltages (TOVs).

The new cable circuit is rated to 200 MVA (all seasons). This option has an estimated cost of £46.17m. For a breakdown of this cost estimate see Appendix 3.

6. COMPARISON OF OPTIONS

6.1. Circuit load flows under normal system operation 2025 and 2030

All options reduce the worst case loading under normal system operation on associated circuits between the Kells and Rasharkin nodes, see Table 4. For the loadings on all the associated circuits in the study area see table A6-1 in Appendix 6.

Circuit	Option								
	1 – Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 - Creagh*	*6 - Terry gowan*	*7 - Cable*
Worst case loading of associated circuits (%)	71-83	58-67	48-59	51-62	49-57	52-66	43-53	48-59	44-51
Coleraine – Rasharkin loading (%)	3-9	3-6	17-22	19-24	15-21	19-25	15-21	18-23	14-20

Table 4 - Percentage loading of key circuits – 2025 range (system normal)

In the 2030 70% renewables scenario there were no overloads under normal system operation except for the do-nothing option, see Table 5 below. For the loadings on all the associated circuits in the study area see table A6-2 in Appendix 6.

Circuit	Option								
	1- Do-nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 - Creagh*	*6 - Terry gowan*	*7 - Cable*
Worst case loading of associated circuits (%)	97-116	82-98	68-86	72-91	69-83	75-97	61-77	69-87	62-75
Coleraine – Rasharkin loading (%)	12-26	21-42	1-25	4-23	1-24	6-24	1-22	3-23	3-26

Table 5 - Percentage loading of key circuits - 2030 range (system normal)

6.2. Load flow following loss of Coolkeeragh – Magherafelt DCT

6.2.1. 2025 Case Year

For the 2025 case the loadings following the loss of the Coolkeeragh – Magherafelt DCT for all options in the long list are shown in Table 6. The loadings on all associated circuits in the study area are also included in tables in Appendix 6.

Circuit loading (Before and After SPS operation)	Option								
	1 Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Ballymena*	*5 – Creagh*	*6 - Terrygowan*	*7 - Cable*
Worst case loading on associated circuits (%)	135-158	110-128	86-105	92-110	89-101	96-117	81-93	87-104	80-92
	121-139	99-110	79-92	83-98	80-88	86-102	73-81	79-91	72-81
Coleraine – Rasharkin loading (%)	55-65	60-71	89-101	91-103	87-99	92-105	88-99	91-102	85-96
	43-48	48-53	79-81	75-83	73-78	77-83	73-78	75-81	70-75

Table 6 - Percentage loading of key circuits – 2025 range (N-DCT before and after completion of SPS operation)

It is noted that for the 2025 case all options that introduce a new circuit, i.e. Options 3-7, address the risk of overload following the loss of the Coolkeeragh – Magherafelt. Option 4 has a very marginal overload (minimal constraint), which is due to the demand at Ballymena Main acting to increase the loading on the circuit that connects through that node. Option 2 Restring indicates a marginal overload (10%).

It is noted that for most options there is also a risk of short term marginal overload before operation of the Coolkeeragh run back scheme. After the operation of the run back scheme in most options the overloads are addressed. This is further discussed in the next section.

Options that introduce a new circuit between Kells and Rasharkin result in reduced impedance between Kells and Coolkeeragh. For the loss of the Coolkeeragh – Magherafelt circuit, that results in an increase in the renewable generation flowing to Kells (via Coleraine) rather than Tamnamore (via Omagh). It is noted that for the options with new circuits, Options 3-7, this also results in a short term marginal overload risk on the Coleraine - Rasharkin circuit before operation of the Coolkeeragh run back scheme.

6.2.2. 2030 Case Year

For the 2030 case the loadings following the loss of the Coolkeeragh – Magherafelt DCT for all options in the long list are shown in Table 7. The loadings on all associated circuits in the study area are also included in tables in Appendix 6.

Circuit loading (Before and After SPS operation)	**Option**								
	1 Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 -Ballymena*	*5 – Creagh*	*6 - Terrygowan*	*7 - Cable*
Worst case loading on associated circuits (%)	171-208	142-172	113-142	118-149	114-136	124-158	100-125	113-142	97-123
	157-192	131-159	104-132	99-137	106-127	114-146	92-117	104-131	90-114
Coleraine – Rasharkin loading (%)	42-66	50-73	83-93	85-95	81-91	88-97	82-92	85-95	77-89
	30-55	37-61	69-79	68-80	67-77	73-82	68-78	71-80	64-75

Table 7 - Percentage loading of key circuits – 2030 range (N-DCT before and after completion of SPS operation)

For the 2030 (70% renewables) case it was necessary to add two Static Var Compensators (Statcom) to the files. These were located at Coleraine and Tamnamore at the 110 kV level.

Table 7 indicates that the loading on the Coleraine – Rasharkin circuit is reduced. This is due to the planned transfer of Gruig and Garves windfarms from Coleraine to Rasharkin.

For all the proposed options the risk of overload increases in the 2030 case and circuits remain overloaded after the operation of the Coolkeeragh run back scheme. It should be noted that the level of constraint is more important than the potential overload for each option as it takes into account the duration. This is assessed in the constraint studies in section 7.3. The new circuit options were based on standard equipment ratings currently available. However the preconstruction phase could include a requirement to investigate improvements to these ratings.

6.2.3. Observations

Option 2 Restring has the highest overloads of all the options for the double circuit contingency in the 2025 and 2030 cases. As per the TSSPS for a double circuit contingency the voltage fall must not exceed 10%. It would be necessary to ensure that sufficient reactive compensation is in place to ensure compliance with voltage step limits in the TSSPS if this option is selected. It is likely that whilst Options 3-7 will also require additional reactive compensation, Option 2 will require a more expansive solution.

6.3. Local contingencies

6.3.1. Coleraine – Rasharkin outage

Table 8 below shows the worst case loadings of the associated circuits from Kells to Rasharkin for the loss of the Coleraine – Rasharkin circuit for each of the options in the longlist.

Circuit loading	Option								
	1 - Do nothing	*2 - Restring*	*3a - North east*	*3b – Centre*	*3c - South west*	*4 - Ballymena*	*5 – Creagh*	*6 -Terrygowan*	*7 - Cable*
Worst case loading (%) 2025 case	71-83	58-67	48-59	51-62	49-57	52-66	44-51	48-59	44-51
	72-86	56-69	38-48	40-50	39-48	40-52	35-44	38-47	37-44
Worst case loading (%) 2030 case	97-116	82-98	68-86	72-91	69-83	75-97	61-77	69-87	62-75
	109-154	Voltage Collapse (V.C.	66-92	68-95	67-90	70-99	59-82	65-91	62-83

Table 8 - Percentage loading for loss of Coleraine - Rasharkin circuit (before and after)

For the 2025 and 2030 cases the loadings following the loss of the Kells – Rasharkin and Coleraine – Rasharkin circuits on all key circuits in the study area are included in tables in Appendix 8.

The key point to note from this table is that voltage collapse in the 2030 ACC scenario can occur for Option 2 restring. This is because whilst this option provides improved thermal capacity, when heavily loaded it consumed a greater extent of reactive power than the other options. This is because loading on the restrung line from Kells to Rasharkin significantly exceeds its surge impedance loading[3]. The other options provide additional circuits to Rasharkin with overall reduced impedance. Also as these options have multiple circuits which are more lightly loaded they are all operating well within their surge impedance loading and do not consume excessive reactive power.

[3] The loading at which its reactive power generated and consumed are equal.

6.3.2. Existing Kells – Rasharkin outage

Table 9 below shows the worst case loadings of the associated circuits from Kells to Rasharkin for the loss of the existing Kells – Rasharkin circuit for each of the options in the longlist.

Circuit loading	**Option**								
	1 - Do nothing	*2 - Restring*	*3a - North east*	*3b – Centre*	*3c - South west*	*4 -Ballymena*	*5 – Creagh*	*6 -Terrygowan*	*7 - Cable*
Worst case loading (%) 2025	71-83	3-6	48-59	51-62	49-57	52-66	43-52	48-59	44-51
	72-87	72-88	72-88	75-91	75-87	75-95	68-83	73-89	66-82
Worst case loading (%) 2030	97-116	21-42	68-86	72-91	69-83	75-97	61-77	69-87	60-74
	108-134	123-153	103-129	106-133	107-127	109-139	97-121	80-130	94-118

Table 9 - Percentage loading for loss of Kells - Rasharkin circuit (before and after)

It is noted that for this contingency, by 2030 ACC scenario, none of the options completely address the congestion.

6.4. Contingencies specific to Options 5 and 6

Option 5 (Creagh) and option 6 (Terrygowan) have two contingencies which were also investigated: loss of the double circuit tower line between Kells and Terrygowan and loss of both interbus transformers are Tamnamore. The resulting circuit loadings have also been included in tables in Appendix 8.

For the 2025 case in option 6 (Terrygowan) there is a slight overload (102%) following loss of the double circuit between Kells and Terrygowan. This overload is manageable.

For the 2030 case in option 5 (Creagh) the loss of the double circuit section from Kells to Terrygowan leads to an overload of approx.140% on the Creagh - Tamnamore circuit. This circuit is currently strung with Lynx conductor (124 MVA). Similarly for option 6 (Terrygowan) this leads to an overload of approx. 150% on the Creagh – Terrygowan circuit (rated 103 MVA) and 130% on the Creagh – Tamnamore circuit. This is due to the renewable generation flowing towards Tamnamore instead of Kells and onto the 275 kV system.

This contingency would be considered a high impact, low probability (HILP) event. It will be necessary to install a special protection scheme (SPS) at Rasharkin to trip the remaining circuit to Creagh or Terrygowan following loss of the double circuit section. Reinforcement will then be required to prevent overloads on the Rasharkin – Coleraine circuit. A study area for a potential 110 kV circuit to reinforce the area between Rasharkin and the North and West of Northern Ireland has been included in the TDPNI which will help address this.

6.5. Phase angle comparison

The trip of the Coolkeeragh – Magherafelt double circuit tower line under high wind generation conditions creates a phase angle difference between the two substations. If this angle exceeds 20° the auto-reclose feature of the protection scheme is blocked to prevent the disturbance to generators. However this also prevents the overhead line from being reclosed and in deteriorating weather could increase the risk of further faults leading to a cascade of tripping. Each of the options has been assessed to examine the effect on the phase angle, a summary is provided in table 10. The full analysis is in Appendix 7.

It is not anticipated that any of these options will address the phase angle issue. It will require a series of reinforcements to address this issue. However each project in turn makes a contribution.

Circuit loading (Before and After SPS operation)	**Option**								
	1 Do nothing	*2 – Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Ballymena*	*5 – Creagh*	*6 - Terrygowan*	*7 - Cable*
Angle difference before SPS	40	39	35	34	35	34	35	35	35
Angle difference after SPS	32	32	28	28	29	28	29	28	29
Change in angle difference (compared to Do nothing option)		0	4	4	3	4	3	4	3

Table 10 - Phase angle difference between Coolkeeragh and Magherafelt substations with longlist options – 2025 winter peak (N-DCT before and after completion of SPS operation)

It is noted that all options that establish a second 110 kV circuit result in a reduced phase angle. In all cases, based on this actual scenario, the angle remained above 20°. However it must be noted that this still results in a significant improvement as the number of hours over the course of a year that the phase angle is breached will reduce significantly.

6.6. Observations

- Except for Option 2 – restring, there were no voltage step violations following the double circuit contingency.
- The Coleraine – Rasharkin circuit is highly loaded in the 2025 case and would have the potential for overload before completion of the SPS runback in some of the options. The transfer of Garves and Gruig windfarms helps reduce this.
- The new and uprated circuits in the 2030 case could avail of a higher capacity conductor selection.
- In terms of reducing the phase angle difference between Coolkeeragh and Magherafelt following the double circuit contingency all of the options (except option 2) are effective and have a similar reduction.
- All of the options will lead to some circuits being overloaded in the 2030 case. This is unavoidable due to the level of expected generation. Additional projects within the TDPNI will be required to prevent this from occurring. Special protection schemes may also be required.

6.7. Comparison on cost

The estimated costs of each the options in the long list are set out in Table 11 and Figure 2 below. For a full breakdown see Appendix 3.

Option	Cost (£m)	Comments
Option 1 - Do nothing	-	-
Option 2 - Restring	14.52	Uprate with Oslo conductor
Option 3a - Northeast	22.36	
Option 3b - Central	30.91	
Option 3c - Southwest	25.69	
Option 4 - Ballymena	32.87	
Option 5 - Creagh	28.45	GIS adaption chamber required
Option 6 - Terrygowan	22.53	Earthwire replaced with OPGW
Option 7 - Underground cable	46.17	Reactive compensation required

Table 11 - Cost estimate for long list options

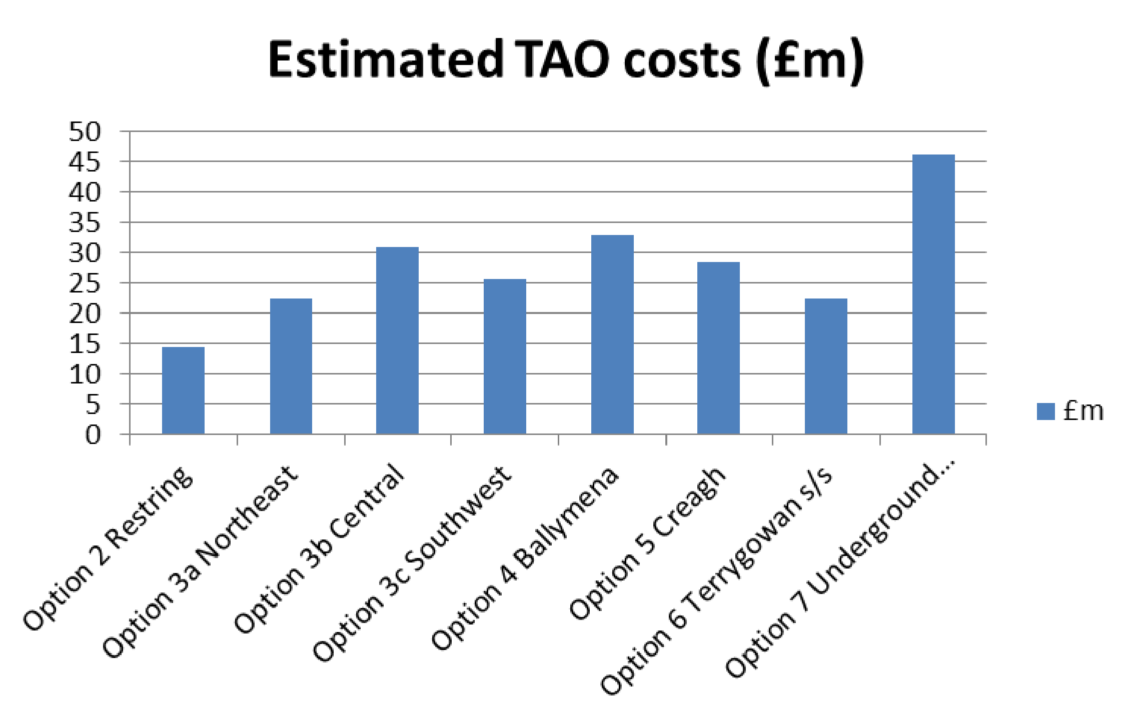

Figure 2 - Comparison of cost estimates for long list options

6.8. Deliverability

An assessment of the deliverability of each option is provided below. This is based on information received from the feasibility investigations and from knowledge in completing other transmission projects.

The deliverability ranges from very good to very poor. For the graphic very poor deliverability would be designated a dark blue colour and very good deliverability would be designated a yellow colour. Tables 12 and 15 show how this representation is used in the long list of options comparison and the short list of options multi criteria assessment.

<u>Option 2 – restring:</u>

- Option 2 - restring involves the uprate of the existing Kells – Rasharkin single circuit with a new type of conductor known as composite conductor. This will require type testing as this conductor type has not been used on the Northern Ireland system previously. There is a risk that these tests are delayed or the conductor does not pass the tests.
- The existing Kells – Rasharkin circuit is comprised of a L4 double circuit tower section and a wood pole section. The existing wood pole section may require additional pole sets and foundation upgrades to be able to carry a conductor of the composite type. The existing L4 double circuit section may require similar work including foundation upgrades and tower steel work. The extent of this is not known.

- This option would require two years for construction and would require a number of outages with associated constraints.
- The restring of this circuit could be carried out under permitted development rights and should not require planning permission. There would need to be access arrangements to allow for stringing points.
- The main issues however that would affect the delivery of this option is the fact that the conductor is not in the technology tool box at present and that it would require a significant outage of the existing Kells – Rasharkin circuit to implement it. An uprate of an existing circuit would still be considered easier to deliver than a new overhead line circuit despite these challenges. Therefore the deliverability of this option is considered as medium.

Option 3a – Northeast:

- Option 3a - Northeast proposes approximately 30-34 km of new overhead line. Cable sections are required for substation entry due to congestion.
- This circuit will encounter other developments such as a PV farm around the outskirts of Ballymena town which could impact on its alignment and ability to ensure a corridor. Additional cable sections are not considered in this option due to the cost of establishing a cable sealing compound with protection arrangements but may be needed.
- This option would require two years of construction and should not impact on the existing network. The deliverability of this option is considered as medium.

Option 3b – Central:

- Option 3b - Central proposes approximately 26km of new overhead line with a cable section through Ballymena town. Cable sections are also required for substation entry due to congestion.
- A cable section of approximately 5.1km is required in Ballymena town between overhead terminal towers. This cable section would encounter at least two complex crossings which will require directional drilling. These crossings include rivers and the NI railway line. There would also be disruption to traffic as the cable would where possible be constructed within the public roads.
- This option would require two years of construction and should not impact on the existing network. There are complexities involved with the cable section. The deliverability of this option is considered as poor.

Option 3c – Southwest:

- Option 3c – Southwest proposes approximately 34km of new overhead line and the uprate of the existing double circuit section between Kells and Terrygowan. Cable sections are required for substation entry due to congestion.
- The corridors for the overhead line section from Terrygowan to Rasharkin scored the best among all the options from an environmental assessment indicating that these corridors should be socially acceptable and achieve planning permission. However with this option another circuit is required to replace the section of the Kells – Creagh circuit. This circuit will be located close to the existing double circuit towerline and this may not be as socially accepted by local residents.

- This option would require two years of construction and will require a detailed outage plan with impact to the existing network. The deliverability of this option is considered as medium.

<u>Option 4 – Ballymena:</u>

- Option 4 – Ballymena proposes the construction of a new GIS substation near Ballymena Main along with approximately 18km of new overhead line and a 5.4km cable section through Ballymena town. A cable section is required for substation entry at Rasharkin due to congestion.
- The existing Kells – Ballymena circuits (21.5km total), comprised of wood pole construction would need to be uprated. This would require additional pole sets and foundation upgrades to be able to carry the new conductor. New intermediate pole sets may not be possible due to dwellings and businesses, therefore diversions of existing circuit alignments may be required.
- The cable section required in Ballymena town would encounter at least three complex crossings which would require directional drilling. These crossings include rivers and the NI railway line. There would also be disruption to traffic as the cable would where possible be constructed within the public roads.
- Ballymena Main has inadequate spacing for an existing AIS extension or a new GIS substation within the existing compound. A new GIS substation would need to be located as close to the existing substation. However the options for a site are limited and if the identified site cannot be obtained the cost of this option will increase significantly.
- The work involved in uprating the existing Ballymena – Kells circuits would require longer outages and can only take place one circuit at a time. This leaves the demand at Ballymena at risk under N-1. This option would require three years for construction. A detailed outage plan will be required as this option will have an impact on the existing network. The deliverability of this option is considered as poor.

<u>Option 5 – Creagh:</u>

- Option 5 – Creagh proposes an extension of the existing GIS arrangement at Creagh with approximately 24km of new overhead line and the uprate of the existing Kells – Creagh circuit. Approximately 3.5km of cable sections are required for substation entry due to congestion and 800m of cable section as part of the existing Kells – Creagh circuit uprate. These cable sections into Creagh will require direction drilling in order to pass across the A6 road which will require establishment of working compounds.
- The new circuit would be situated within the designations of a height restriction (15m) for new infrastructure along the river Bann from Toome to Portglenone. This has been included in the Local Development Plan for Mid and East Antrim council. The new circuit would also enter the designated areas the River Bann SPA/ASSI and this could raise concerns from statutory bodies.
- The existing Kells – Creagh circuit is comprised of a L4 double circuit tower section, a wood pole section and a cable section. The existing wood pole section will require additional pole sets, foundation upgrades to be able to carry the new conductor. New

intermediate pole sets may not be possible due to dwellings and businesses, therefore a diversion of the existing circuit alignment may be required.
- An extension of the existing GIS arrangement at Creagh will require an adaption chamber along with a new panel, as the existing panel type is no longer manufactured. This type of extension has had been completed before on the NI system and poses a risk to the overall project delivery.
- This option would require three years for construction and will require a detailed outage plan with impact to the existing network. The deliverability of this option is considered as poor.

Option 6 – Terrygowan:

- Option 6 – Terrygowan proposes the construction of a new substation near Terrygowan, approximately 21.5km of new overhead line and the uprate of the existing double circuit section between Kells and Terrygowan. The procurement of a site and the establishment of planning permission do present complexities. However there are a number of options for a site location along the double circuit section or the wood pole section of the existing circuits at Terrygowan which may be more achievable than with option 4 – Ballymena for example.
- The uprate of the existing double circuit section will also include the replacement of the existing earthwire, requiring a double circuit outage. However this should be achievable.
- The corridors for the overhead line section from Terrygowan to Rasharkin scored the best among all the options from an environmental assessment indicating that these corridors should be socially acceptable and achieve planning permission.
- This option would require two years of construction and will require a detailed outage plan with impact to the existing network. The deliverability of this option is considered as medium.

Option 7 – Cable:

- Option 7 – Cable proposes an underground cable circuit between Kells and Rasharkin of approximately 34km. Reactive compensation would be required for this circuit which will require a substation extension at Kells Main to accommodate new 110 kV bays. An extension of the existing site would require planning permission and therefore could be subject to delays.
- The circuit would require at least four complex crossings which will require directional drilling. These crossings include rivers and the NI railway line. There will also be disruption to traffic as the cable would be constructed within the public roads, including the A26 between Antrim and Ballymena.
- Due to the capacitance of a cable circuit of this length this must be compensated for to prevent high voltages. A shunt reactor will be required at Kells. Additionally due to the impedance of a cable circuit compared to the existing Kells – Rasharkin circuit which is comprised of overhead line a series reactor would also be required to balance the power flows on both circuits.
- This option will have greater disruption to traffic. It is unlikely that this option could be delivered by 2030 due to the need to extend the compound at Kells. Failure to deliver

the project by 2030 could impact on any new energy targets. The deliverability of this option is considered as very poor.

6.9. Comparison of options from the long list

Table 12 below provides a comparison of the long list of options based on the technical performance, deliverability in the given time frame and to meet the needs of the project and estimated cost. SONI considers these criteria as important in rationalising the long list of options. Additional criteria are used to appraise the short list of options, including environmental impact. The technical performance of each option is based on the loadings for study years 2025 and 2030 and following the contingencies in sections 6.2 – 6.4. This also includes any voltage step violations and the options contribution to reducing the phase angle issue between Coolkeeragh and Magherafelt substations. An option with a very good technical performance is designated a yellow colour and an option with a very poor technical performance is designated a dark blue colour, as per the key in table 12 below.

Key: **Less favourable** **More favourable**

Option	**Technical performance**	**Deliverability**[4]	**Cost of option (£m)**[5]
1 Do nothing		N.A	N/A
2 Restring			14.52
3a Northeast			22.36
3b Central			30.91
3c Southwest			25.69
4 Ballymena			32.87
5 Creagh			28.45
6 Terrygowan			22.53
7 Cable			46.17

Table 12 - Comparison of options in long list

[4] Technical performance and Deliverability colour scale: very good – yellow; good – light green; medium – dark green; poor – blue; and very poor – dark blue.

[5] Cost of option (£m) colour scale: less than £20m – yellow; between £20m and £25m – light green; between £25m and £30m – dark green; between £30m and £35m – blue; and greater than £35m – dark blue.

6.10. Rejection of options from long list

Based on the criteria shown in the previous section the following options have been rejected from the long list.

<u>Option 2 - Restring</u>

Option 2 Restring would provide significant additional thermal capacity along the route. Whilst in the 2025 case the loss of Coolkeeragh – Magherafelt would lead to the potential for a marginal overload (110%) based on application of the TSSPS, this would be minimal in terms of constraints.

However the option does not improve the voltage or phase angular stability of the 110 kV system. Whilst the voltage stability can be managed through constraints in the 2025 case the loss of the Coolkeeragh – Magherafelt double circuit led to voltage collapse in the 2030 case. The extent of reactive compensation for Option 2 Restring would be greater than for the other reinforcement options.

Finally Option 2 Restring also led to a local voltage issue for the loss of the Coleraine – Rasharkin 110 kV circuit in 2030.

This was also after the installation of additional reactive compensation at Tamnamore and Coleraine. All the other options helped to support the voltage in the North West.

In the event of a trip of the Coolkeeragh – Magherafelt double circuit during high wind generation the ability to reclose is important. In deteriorating weather conditions, where most faults are transient, it is normally possible and equally important to restore the system to normal as quickly as possible. Remaining below the 20 Degree limit more often during the course of a year improves systems resilience to unforeseen events. Option 2 does not improve the phase angle stability. All other options reduced the phase angle difference by approx. 4 degrees.

As a result of the above limitations, this option is rejected.

<u>Option 7 – Cable Option</u>

Option 7 is over twice the cost of most of the other options. Due to the requirement to extend the existing Kells 275/110 kV substation and install additional plant and apparatus, technical risk, deliverability and the overall cost this option is therefore rejected.

The other options are between £22m – 33million. As these are broadly similar in terms of technical merit and deliverability they are all shortlisted for the next stage.

7. PRELIMINARY APPRAISAL OF SHORT LISTED OPTIONS

7.1. Short listed options

The following options are shortlisted for further investigation:

- Option 1 - Do nothing;
- Option 3a - Northeast;
- Option 3b - Central;
- Option 3c - Southwest;
- Option 4 - Ballymena;
- Option 5 - Creagh; and
- Option 6 - Terrygowan.

7.2. Desktop Environmental Comparisons

7.2.1. RPS Scoring

RPS was asked to carry out a desktop environmental assessment of the main options based on environmental, social and cultural constraints. For each of the options, for the purposes of making an assessment, a sample corridor (see Appendix 5), was established within each of the main study areas.

The RPS environmental constraints model uses a cell cost surface to represent the various environmental and social constraints that are associated with the study area. Using a cell size of 10m x 10m (100m raster grid) each option was represented by a total number of cost cells which provide an overall cumulative constraint cost. Some of these cells which are more constrained will have a greater cost to cross. If an option has encountered many of these cells it will have received a high score representing many different constraints, some of which could impact of the deliverability of that option.

RPS carried out two assessments of the sample corridors. The first assessment used the full width of the corridors. This assessed every cell within the 500m corridor and cumulatively scored all the constraints encountered. The second assessment used a 100m centreline in the middle of the corridor. This assessed only the cost cells along the centreline. The results of these assessments are shown in table 13 below, including the total score for each option considering all its segments. This has helped identify which options are potentially the most constrained and which are least constrained.

The scoring of the options based on the above is also set out in the multi criteria assessment in table 15 in section 7.5. For this assessment the constraints within the 500m corridor only were used in order to present all of the constraints within each corridor. For the graphic an option with a lower number of constraints is designated a yellow colour and an option with a higher number of constraints is designated a dark blue colour.

Option	Sample corridor within study area	RPS option environmental scores	
		Constraints within 500m OHL corridor[6]	Constraints along 100m centreline of OHL corridor
3a Northeast	8	3,204	911
	9	2,894	818
3b Central	4 +15	3,156	1,031
	5 + 11	2,584	774
3c Southwest	14+13a	1,907	617
	14 + 13b	921	362
4 Ballymena	15	2,986	1,010
5 Creagh	1	724	299
	2	878	367
	3	837	340
6 Terrygowan	13a	1,647	521
	13b	661	266

Table 13: Constraint scoring of options by RPS

7.2.2. Environmental, cultural and social impact of the options

Option 3a: Sample corridors 8 and 9 would pass through the ASSI at Glarryford along the river Maine. Both corridors encounter roughly 4-5km of upland area and a large number of rivers. Additional constraints include various IHRs and SMRs. This option has the highest constraint scores in the assessment. This is the least cost option.

Option 3b: Sample corridors 4 and 5 would pass through few constraints between Kells and Ballymena. Sample corridors 11 and 15 pass through 4-5 km respectively of upland area. Additionally corridor 11 would passes through a number of listed buildings and a scheduled zone whilst corridor 15 encounters a number of rivers. Cumulatively this gives option 3b a higher constraint score compared to other options. This option is also the most expensive of the options.

Option 3c: Sample corridor 14 associated with this option would pass through few constraints. Sample corridor 13a has a higher constraint cost compared to 13b due to passing through approximately 2km of upland area. Both corridors also would pass through a number of rivers. These corridors are less constrained than corridors which pass through the upland areas North and West of Ballymena town. Sample corridor 13b has the lowest score representing the least constrained corridors in the assessment. This option is the third least cost option.

Option 4: Sample corridor 15 would pass through approximately 5km of upland area North and West of Ballymena town and a number of rivers. This option has a high constraint score and is the second most expensive option. Establishing the GIS switchboard and associated

[6] Constraints along 500m corridor colour scale: less than 700 – yellow; between 700 and 1000 – light green; between 1000 and 2000 – dark green; between 2000 and 2500 – blue; and greater than 2500 – dark blue.

cabling is likely to be quite a complicated project with numerous complex cable crossings. This is the second most expensive option.

Option 5: Sample corridors 1, 2 and 3 are relatively close to the Lough Beg SPA/ASSI and pass over the river Bann, therefore passing through the designated areas. These corridors are less constrained than other corridors in the assessment, but due to its proximity to the SPA/ASSI this option could receive feedback at stakeholder engagement stage due to the impact on wildlife, birds and habitats. Additionally these corridors cross a number of rivers, SMRs and IHRs. Compared to some of the other options these corridors are less constrained, but do have additional risk with impact to wildlife near the water sources.

This option is the fourth least cost option and involves a difficult extension to the existing single busbar GIS switchboard at Creagh Main using an adapter panel. There is no certainty that this approach would be possible.

Option 6: Sample corridor 13b is less constrained than corridor 13a. This has been identified as corridor 13b avoids the upland area by passing closer to the outskirts of Portglenone. Sample corridor 13b has the lowest score representing the least constrained corridor in the assessment. This option has the lowest score of the sub options assessed. This is also the second least expensive option.

7.3. Constraint costs of the Options

The load flow analysis indicates that all short listed options address the potential for overload issues in 2025. However by 2030, based on the central Achieving Climate Change scenario, several potential overloads could return and will require management. This will be managed by constraints using the existing Constraint Group. Analysis of the constraints for each of the shortlisted options in 2030 is set out in Table 14 below.

Year	Option						
	1 Do nothing	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 – Creagh*	*6 -Terry gowan*
2025	2129.3	0	0	0	2.5	0	0
2030	9452.5	816.1	1178.0	697.5	1926.1	451.7	506.0

Table 14 - Constraint costs[7] (£k, £45.7 per MW/hr constrained)

It is observed that Options 5 and 6 have the least level of constraints by 2030. Option 4 Ballymena has the highest level of constraint by 2030.

7.4. Lifecycle costs

An assessment of the lifecycle costs of each of the shortlisted options has been undertaken. This has included the capital cost of each of the options, TSO costs, constraint costs and an allowance for operation and maintenance. The constraint costs were ramped up linearly from 2025 to 2030. From 2030 onwards they were considered constant. The discount rate was assumed to be 3.5% and the model was extended to 25 years.

[7] Constraints colour scale: less than £400k – yellow; between £400k and £800k – light green; between £800k and £1200k – dark green; between £1200k and £2500k – blue; and greater than £2500k – dark blue.

The net present cost for each of the short listed options has been included in the option appraisal multi criteria assessment in table 15. For a full breakdown of this analysis see Appendix 10.

7.5. Multi-criteria assessment

Table 15 combines the technical performance, deliverability, capital cost, net present cost and environmental scoring for each of the reinforcement options. The best performing option across the criteria is Option 6, in particular with the sample corridor 13b.

Key: Less favourable [dark blue] [blue] [dark green] [light green] [yellow] More favourable

Option	Sample corridor within study area	Technical Performance	Deliverability	Cost of option (£m)	Net Present Cost (£m)[8]	RPS option environmental scores
1 Do nothing	N/A	[dark blue]	N/A	N/A	107.24 [dark blue]	N/A
3a Northeast	8	[yellow]	[dark green]	22.36 [light green]	30.12 [light green]	3,204 [dark blue]
	9					2,894 [dark blue]
3b Central	4 +15	[light green]	[blue]	30.91 [blue]	40.66 [blue]	3,156 [dark blue]
	5 + 11					2,584 [blue]
3c Southwest	14+13a	[yellow]	[dark green]	25.69 [dark green]	31.53 [light green]	1,907 [dark green]
	14 + 13b					921 [light green]
4 Ballymena	15	[light green]	[blue]	32.87 [blue]	49.55 [dark blue]	2,986 [dark blue]
5 Creagh	1	[light green]	[blue]	28.45 [dark green]	30.77 [light green]	724 [light green]
	2					878 [light green]
	3					837 [light green]
6 Terrygowan	13a	[yellow]	[dark green]	22.53 [light green]	27.03 [yellow]	1,647 [dark green]
	13b					661 [yellow]

Table 15 - Comparison of options

[8] Net present cost colour scale: less than £30m – yellow; between £30m and £35m – light green; between £35m and £40m – dark green; between £40m and £45m – blue; greater than £45m – dark blue.

8. PRELIMINARY PREFERRED OPTION

Option 6 Terrygowan addresses the potential for overloads and the associated congestion within the 2025 case. It is also the second least cost of the short listed options and the least costing option in the net present cost assessment (over 25 years). Finally by using the Corridor 13b it also has the least environmental, social and cultural score of all the options.

It performs as well as the other options in the 2030 Addressing Climate Change scenario and will require further reinforcements as outlined in the TDPNI. Consideration will be given to making provision for a composite conductor on this circuit, which would help to future proof the option for 2030. It would also be proposed that an enhanced cable capacity and the use of dynamic cable rating could be investigated.

The 70% renewables Addressing Climate Change scenario is expected to require the establishment of reinforcement north of Rasharkin and Agivey. The TDPNI includes a North West 110 kV reinforcement project. A sensitivity study has been completed that includes an additional circuit between Agivey and Limavady, along with our preliminary preferred option, see Appendix 9.

Selection of the preferred solution and completion of the Part 1 stage of the SONI Grid Development Process will be subject to stakeholder engagement, which may change the outcome of the assessments.

Due to the level of generation expected some circuits will experience congestion by 2030. This congestion will be managed through constraints, but there will also be the need to implement a number of special protection schemes on the network in this area to manage HILP issues, such as the loss of the 110 kV Kells - Terrygowan double circuit tower line section.

Based on the assessments in this report the preliminary preferred option is Option 6 (Terrygowan). This option has the second least cost, performed best in the environmental assessment and complies fully with the planning standards for the 2025 case. For the purposes of the TNPP preparation this option is selected.

9. NEXT STEPS

This Preliminary Preferred Option Report is prepared as a basis to begin stakeholder engagement with statutory consultees and elected representatives.

The report will be used as the basis for the preparation of the Transmission Network Pre-construction Project (TNPP) submission. The TNPP will also include funding request for the Part 1 stakeholder engagement costs.

It should be noted however that the outcome of the Part 1 stakeholder engagement process may require amendments to the appraisal process. It is possible that the Preferred Option may be different from that identified in this report, in which case an updated TNPP submission will be required.

The next steps for the project will be as follows:

- Plan and progress Part 1 stakeholder engagement;
- Finalise selection of preferred option;
- Prepare and submit TNPP;
- Publish decision and accompanying reports on the SONI website;
- Upon approval of TNPP funding commence Part 1 governance steps; and
- Commence Part 2 of the SONI Grid Development Process.

10. STAKEHOLDER ENGAGEMENT

NIE Networks has provided feedback on the preliminary preferred options report in their role as asset owner and in line with the Transmission Interface Arrangements (TIA). NIE Networks are supportive of the preliminary preferred option and of the conclusions reached in this report.

SONI also discussed this project with the Utility Regulator at the monthly SONI-UR meeting in December 2020.

SONI will carry out a high level stakeholder engagement exercise with the local authorities affected by the project. This will allow the TNPP submission to be finalised and submitted to the Utility Regulator.

The local constituencies that are affected by this project include;

- North Antrim Constituency;
- South Antrim Constituency; and
- Mid Ulster Constituency.

The local authorities that are affected by this project include:

- Antrim and Newtownabbey Borough Council;
- Mid and East Antrim Borough Council;
- Mid Ulster District Council; and
- Causeway Coast and Glens District Council.

SONI will engage with these local representatives and authorities to discuss the project and any concerns that may arise.

Wider stakeholder engagement will be carried out in the latter parts of the SONI Grid Development Process[9]. By then SONI and NIE Networks will have carried out investigations into the detailed design requirements of this project. Stakeholder engagement at this stage will help to inform the public of the project proposals and take on board any feedback to help finalise proposals.

10.1. Stakeholder Engagement Feedback

SONI met with elected representatives and planning officials within the project study area including councillors along the route of the preliminary preferred option. This took place virtually due to restrictions with the pandemic and SONI has also provided a project summary to all stakeholders.

Feedback collated from the stakeholder engagement meetings was analysed and the emergence of three key themes has been identified. The themes and extracts from the meetings with the stakeholders are outlined below. In total, 13 individual stakeholders were consulted as part of the process. The frequency of the issues raised is outlined in Figure 3 below.

[9] http://www.soni.ltd.uk/the-grid/grid-development-process/

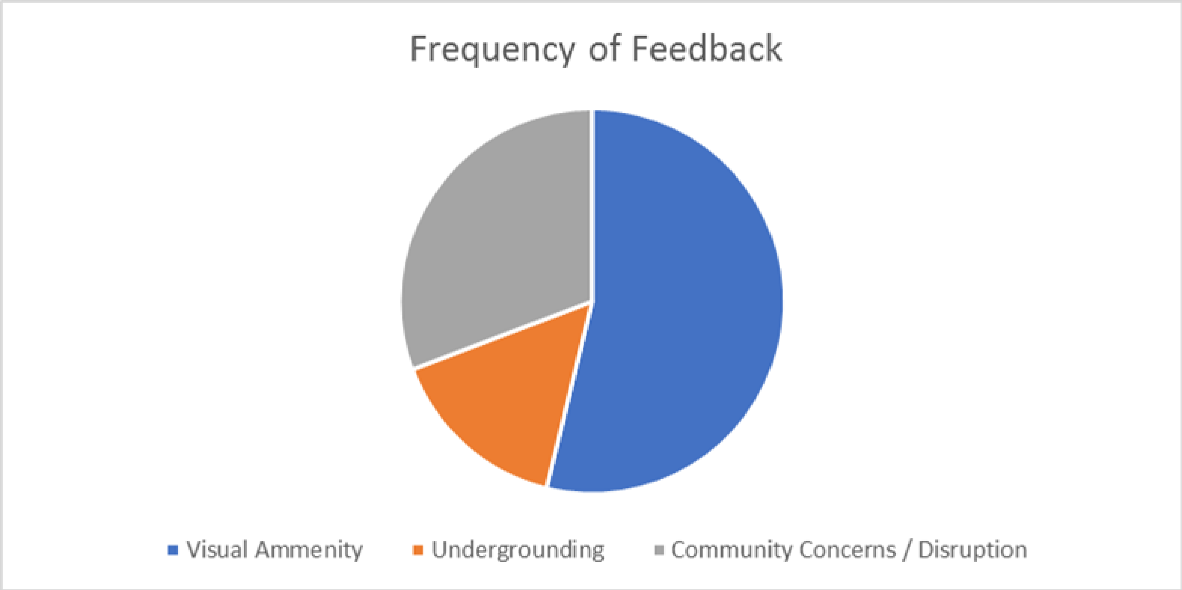

Figure 3 - Key feedback from the Part 1 Stakeholder Exercise

10.2. Project changes since beginning Stakeholder Engagement

The following changes to the project proposals have occurred since beginning stakeholder engagement with elected representatives. The Preliminary Preferred Options report and TNPP submission have been updated with these changes.

- **Estimated completion date (ECD) for the project changed from 2027 to 2028** – due to a review of the programme management requirements in Parts 2 and 3 of the SONI Grid Development Process.
- **Update to the existing cost estimates for options** – an estimate for under crossings has now been included in the cost estimates of all options. NIE Networks will endeavour, where feasible, to underground these under crossings. The various risks presented from working above existing overhead line assets and the consecutive customer outages for each phase of the work outweighs the cost impact of undergrounding them. Subsequently the NPV analysis has also been updated.

11. APPENDICES

APPENDIX 1

Environmental Desktop Report

See attached document produced by RPS:

SONI_Kells_Rasharkin_Constraints Modelling_Report_F01_201111 – Corridor Options Constraint Modelling Report

Feasibility Investigation Reports

See attached documents produced by Mott MacDonald:

386752_001_RevG__- Corridor Selection Assessment Criteria Report

386752-002_Scheme Appreciation Report_RevF_- Scheme Appreciation Report

386752-003_OHL_Routing_Study_RevE_ - Routing Study and Overall Comparison Report

386752-OHL Reutilisation Report – RevC – Overhead line reutilisation report – technical summary

APPENDIX 2

SONI Tomorrow's Energy Scenarios (TES)

Key design characteristics for the three scenarios:

	Modest Progress	Addressing Climate Change	Accelerated Ambition
Decarbonisation	**Medium**	**High**	**High**
RES-E by 2030	60%	70%	80%
Coal generation phase out	2024	2024	2024
Oil generation phase out	2040	2040	2035
Carbon capture and storage	No	Before 2050	2040
Electrification of heat	Low	Medium	High
Electrification of transport	Medium	High	High
Energy efficiency gains	Medium	High	High
GHG reduction by 2030	›35%	›45%	›50%
GHG reduction by 2050	›63%	›78%	›78% [2040]
Decentralisation	**Low**	**Medium**	**High**
Distribution connected generation	Low	Medium	High
Self-consumption	Low	Medium	High
EV charging	Simple	Smart	Smarter

Figure A2-1 - Key design characteristics for TESNI 2020 scenarios

Key generation and demand components of TESNI 2020:

Generation Mix (MW):

	2025			2030			2040		
Technology/Fuel	MP	ACC	AA	MP	ACC	AA	MP	ACC	AA
OCGT (gas)	405	405	405	505	605	805	505	705	905
Distillate oil	258	258	258	158	84	84	0	0	0
CCGT	1,481	1,481	1,001	1,481	1,481	1,001	1,481	1,481	408
CCGT (CCS)	0	0	0	0	0	0	0	0	500
Coal	0	0	0	0	0	0	0	0	0
Renewables	1,896	2,334	2,966	2,261	3,107	4,437	2,753	4,081	5,739
Total	**4,040**	**4,478**	**4,630**	**4,405**	**5,277**	**6,327**	**4,739**	**6,267**	**7,552**

Figure A2-2 - Generation mix (MW) for TESNI 2020 scenarios

Renewable generation mix (MW):

	2025			2030			2040		
Technology	MP	ACC	AA	MP	ACC	AA	MP	ACC	AA
Onshore wind	1,529	1,848	2,212	1,753	2,034	2,542	1,960	2,267	2,762
Offshore wind	0	0	0	0	350	500	0	500	850
Solar PV	284	399	665	421	617	1,169	702	1,185	1,777
Biomass	77	81	83	81	100	120	85	123	144
Hydro	6	6	6	6	6	6	6	6	6
Marine	0	0	0	0	0	100	0	0	200
Total	**1,896**	**2,334**	**2,966**	**2,261**	**3,107**	**4,437**	**2,753**	**4,081**	**5,739**

Figure A2-3 – Renewable generation mix (MW) for TESNI 2020 scenarios

Demand mix (TWh):

	2025			2030			2040		
TER	MP	ACC	AA	MP	ACC	AA	MP	ACC	AA
Transport	0.23	0.24	0.24	0.52	0.73	1.03	1.84	1.88	2.40
Residential	2.67	2.79	3.07	2.61	2.79	3.19	2.95	3.63	4.13
Industrial	2.72	3.35	3.94	2.60	3.54	4.43	2.41	3.83	4.93
Tertiary	1.96	1.90	1.91	1.91	1.82	1.82	1.80	1.80	1.94
Losses	0.94	1.00	1.07	0.93	1.04	1.18	1.04	1.23	1.43
Total	**8.52**	**9.28**	**10.23**	**8.57**	**9.92**	**11.65**	**10.04**	**12.37**	**14.83**

Figure A2-4 - Demand mix (TWh) for TESNI 2020 scenarios

APPENDIX 3

Estimated TAO costs for each option

Option 2: Restring				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Overhead line				
Restring towerline section	0.29	13	3.68	Oslo conductor
Restring portal section	0.29	26	7.48	Oslo conductor
Undercrossings				
33 kV undercrossings	0.06	8	0.48	
11 kV undercrossings	0.03	47	1.41	
BT line undercrossings	0.006	24	0.14	
Estimate of TAO costs			**13.20**	
Contingency (10%)			1.32	
Total			**14.52**	

Figure A3-2 - Option 2 cost estimate

Option 3a: Northeast study area				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Substation works				
110 kV AIS bay (Rasharkin)	0.78	1	0.78	
Equip one bay (Kells)	0.30	1	0.30	
Overhead line				
200 MVA Portal line	0.42	34	14.07	
Cable sections				
200 MVA XLPE Rural	1.50	2	3.00	
Sealing ends	0.08	2	0.16	
Undercrossings				
33 kV undercrossings	0.06	4	0.24	
11 kV undercrossings	0.03	53	1.59	
BT line undercrossings	0.006	31	0.19	
Estimate of TAO costs			**20.33**	
Contingency (10%)			2.03	
Total			**22.36**	

Figure A3-3a - Option 3a cost estimate

Option 3b: Central study area				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Substation works				
110 kV AIS bay (Rasharkin)	0.78	1	0.78	
Equip one bay (Kells)	0.30	1	0.30	
Overhead line				
200 MVA Portal line	0.42	9	3.65	
200 MVA Portal line	0.42	17.5	7.35	
Cable sections				
200 MVA XLPE Urban	1.50	5.1	7.65	
200 MVA XLPE Rural	1.18	4	4.72	
Complex crossings	0.50	2	1.00	
Sealing ends	0.08	4	0.32	
Sealing end compound	0.1	2	0.20	
Protection arrangements	0.15	2	0.3	
Undercrossings				
33 kV undercrossings	0.06	7	0.42	
11 kV undercrossings	0.03	42	1.26	
BT line undercrossings	0.006	25	0.15	
Estimate of TAO costs			**28.10**	
Contingency (10%)			2.81	
Total			**30.91**	

Figure A3-3b - Option 3b cost estimate

Option 3c: South west study area				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Substation works				
110 kV AIS bay (Rasharkin)	0.78	1	0.78	
Equip one bay (Kells)	0.30	1	0.30	
Overhead line				
200 MVA Portal line	0.42	13	5.38	
200 MVA Portal line	0.42	22	9.03	
Restring Kells - Terrygowan	0.17	13	2.13	
Cable sections				
200 MVA XLPE Rural	1.18	3	3.54	
Sealing ends	0.08	2	0.16	
Undercrossings				
33 kV undercrossings	0.06	9	0.54	
11 kV undercrossings	0.03	46	1.38	
BT line undercrossings	0.006	19	0.11	
Estimate of TAO costs			**23.35**	
Contingency (10%)			2.34	
Total			**25.69**	

Figure A3-3c - Option 3c cost estimate

Option 4:Ballymena Main option				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Substation works				
Ballymena Main GIS site purchase	0.50	1	0.50	
Ballymena Main GIS site pre-enabling	0.55	1	0.55	Based on a 90x90m compound
Ballymena Main GIS	0.72	6	4.32	
110 kV AIS bay (Rasharkin)	0.78	1	0.78	
Equip one bay (Kells)	0.30	1	0.30	
Overhead line				
200 MVA Portal line	0.42	18	7.35	
Restring Kells - Ballymena	0.13	22	2.86	
New structures	1.00	1	1.00	
Cable sections				
200 MVA XLPE Urban	1.50	4.7	7.05	
200 MVA XLPE Rural	1.18	0.8	0.94	
Complex crossings	0.50	3	1.50	
Sealing ends	0.08	4	0.32	
Undercrossings				
33 kV undercrossings	0.06	6	0.36	
11 kV undercrossings	0.03	61	1.83	
BT line undercrossings	0.006	37	0.22	
Estimate of TAO costs			**29.89**	
Contingency (10%)			2.99	
Total			**32.87**	

Figure A3-4 - Option 4 cost estimate

Option 5: Creagh Main option				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Substation works				
Extend building	0.25	1	0.25	
Extension to Creagh GIS	2.50	1	2.50	Includes adaption chamber and new GIS panel
110 kV AIS bay (Rasharkin)	0.78	1	0.78	
Overhead line				
200 MVA Portal line	0.42	24	10.12	
Restring Kells - Terrygowan	0.17	13	2.13	
Restring Terrygowan - Creagh	0.13	9.6	1.28	
Replace cable into Creagh	1.50	0.8	1.20	
New cable sealing end tower at Creagh	0.49	1	0.49	
Cable sections				
200 MVA XLPE Rural	1.18	3.4	4.01	
Sealing ends	0.08	2	0.16	
Complex crossing	0.5	1	0.50	
Undercrossings				
33 kV undercrossings	0.06	8	0.48	
11 kV undercrossings	0.03	59	1.77	
BT line undercrossings	0.006	31	0.19	
Estimate of TAO costs			**25.86**	
Contingency (10%)			2.59	
Total			**28.45**	

Figure A3-5 - Option 5 cost estimate

Option 6:Terrygowan option				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Substation works				
Terrygowan AIS site	0.10	1	0.10	
Terrygowan AIS site pre-enabling	0.55	1	0.55	
Terrygowan AIS	0.78	4	3.12	
110 kV AIS bay (Rasharkin)	0.78	1	0.78	
Overhead line				
200 MVA Portal line	0.42	22	9.03	
Restring Kells - Terrygowan	0.17	13	2.13	
Restring earthwire with OPGW	0.25	1	0.25	
Cable sections				
200 MVA XLPE Rural	1.18	2.3	2.71	
Sealing ends	0.08	2	0.16	
Undercrossings				
33 kV undercrossings	0.06	6	0.36	
11 kV undercrossings	0.03	39	1.17	
BT line undercrossings	0.006	19	0.11	
Estimate of TAO costs			**20.48**	
Contingency (10%)			2.05	
Total			**22.53**	

Figure A3-6 - Option 6 cost estimate

Option 7: Underground cable option				
Item Description	**Unit cost (£m)**	**No**	**£m**	**Comments**
Substation works				
110 kV AIS bay (Rasharkin)	0.78	1	0.78	
Equip one bay (Kells)	0.30	1	0.30	
Cable sections				
200 MVA XLPE Rural	0.92	34	31.31	
Complex crossings	0.50	4	2.00	
Reactive compensation				
Procure compound for series reactor	0.25	1	0.25	
Pre-enabling	0.55	1	0.55	
Series reactor (200 MVA)	5.00	1	5.00	
Shunt reactor (45 MVAr)	1.00	1	1.00	
Bay for shunt reactor	0.78	1	0.78	
Estimate of TAO costs			**41.97**	
Contingency (10%)			4.20	
Total			**46.17**	

Figure A3-7 - Option 7 cost estimate

APPENDIX 4 STUDY AREAS

North East study area

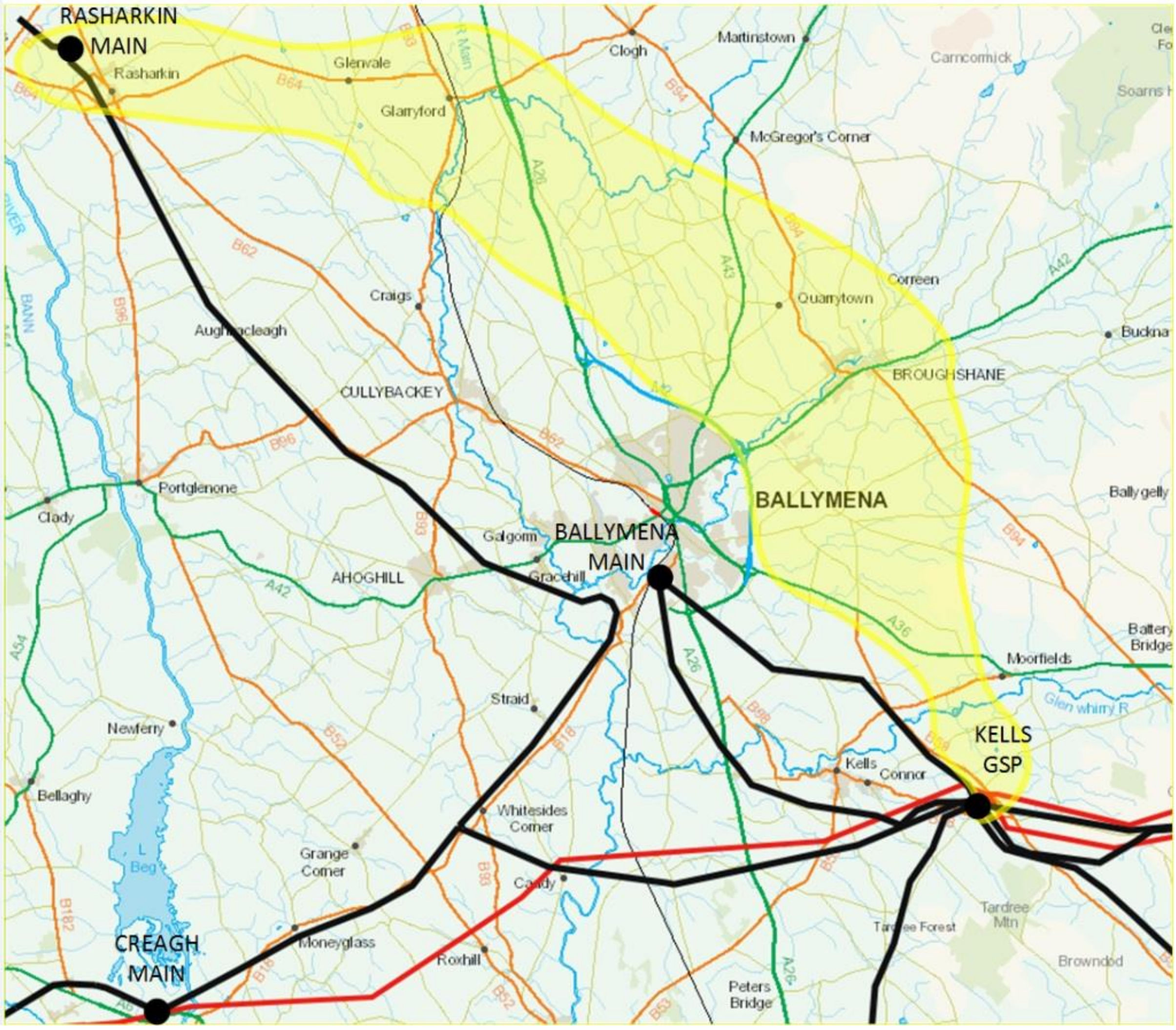

Figure A4-3a – Option 3a North East study area

Yellow shaded area: Study area to establish a new wood pole overhead line circuit with possible underground cable sections at the approach to Kells and Rasharkin substations.

Red lines: 275 kV network

Black lines: 110 kV network

Central study area

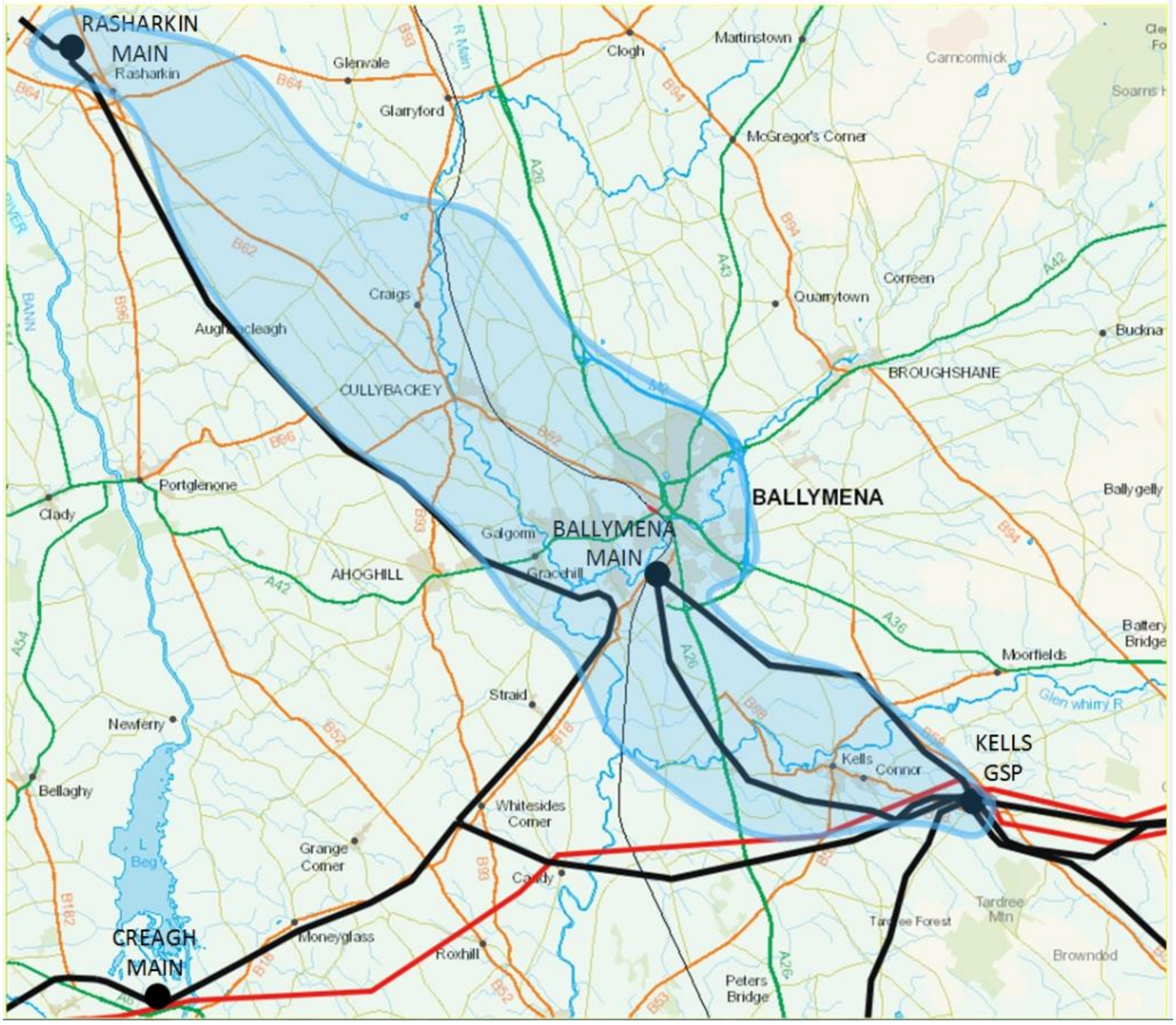

Figure A4-3b – Option 3b Central study area

Blue shaded area: Study area to establish a new wood pole overhead line circuit with possible underground cable sections in Ballymena and at the approach to Kells and Rasharkin substations.

Red lines: 275 kV network

Black lines: 110 kV network

South West study area

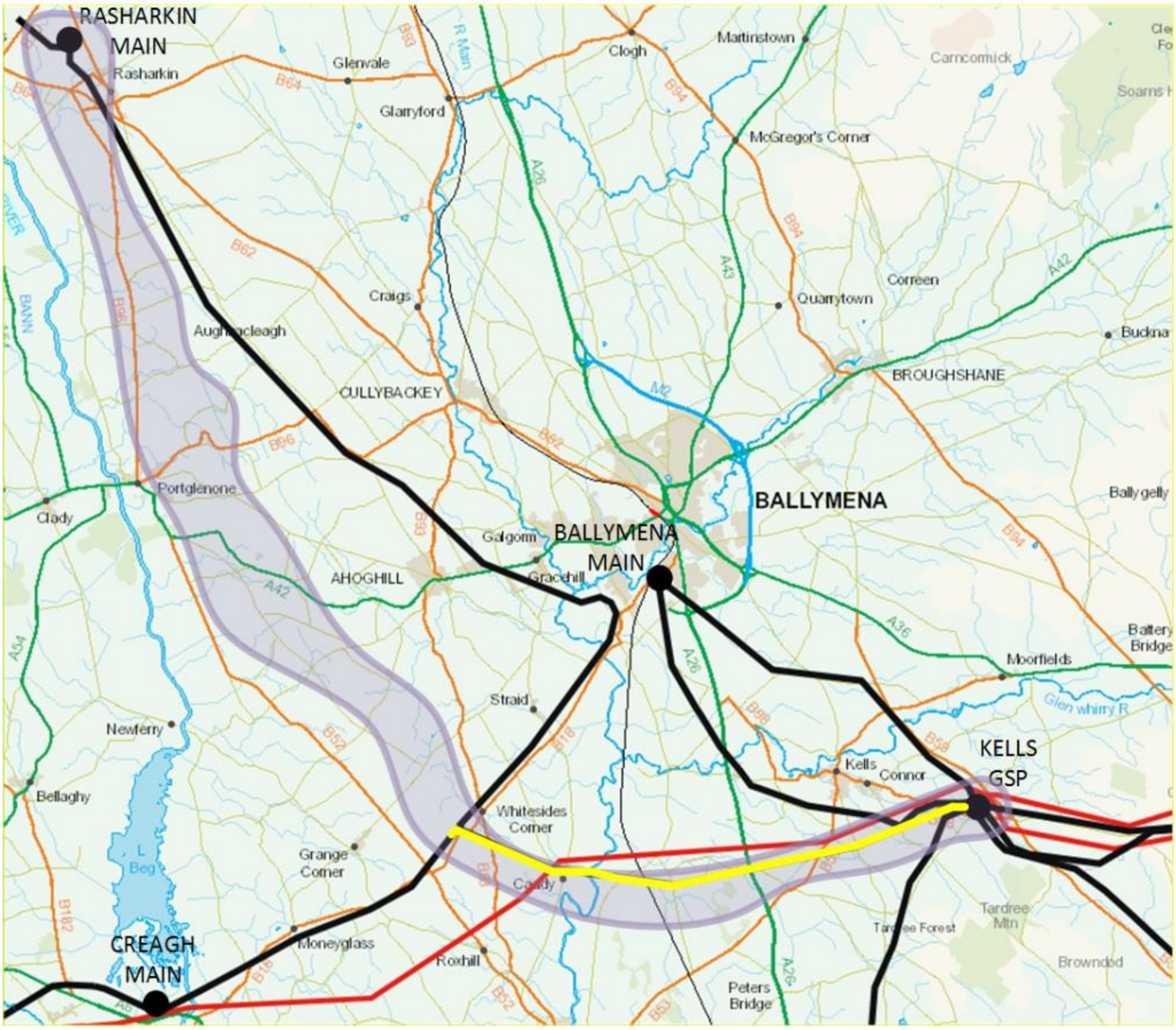

Figure A4-3c – Option 3c South West study area

Purple shaded area: Study area for new wood pole overhead line circuits: includes a wood pole circuit from Kells – Terrygowan (which will connect with the Creagh – Terrygowan section of existing Kells – Creagh circuit) and a wood pole circuit from Terrygowan – Rasharkin (which will connect with the Kells – Terrygowan tower section forming a new Kells – Rasharkin circuit)

Red lines: 275 kV network

Black lines: 110 kV network

Yellow line: Circuit uprate: Existing Kells - Creagh side of double circuit tower line (Kells – Terrygowan) to be restrung with high capacity conductor.

Ballymena, uprates and North West study area

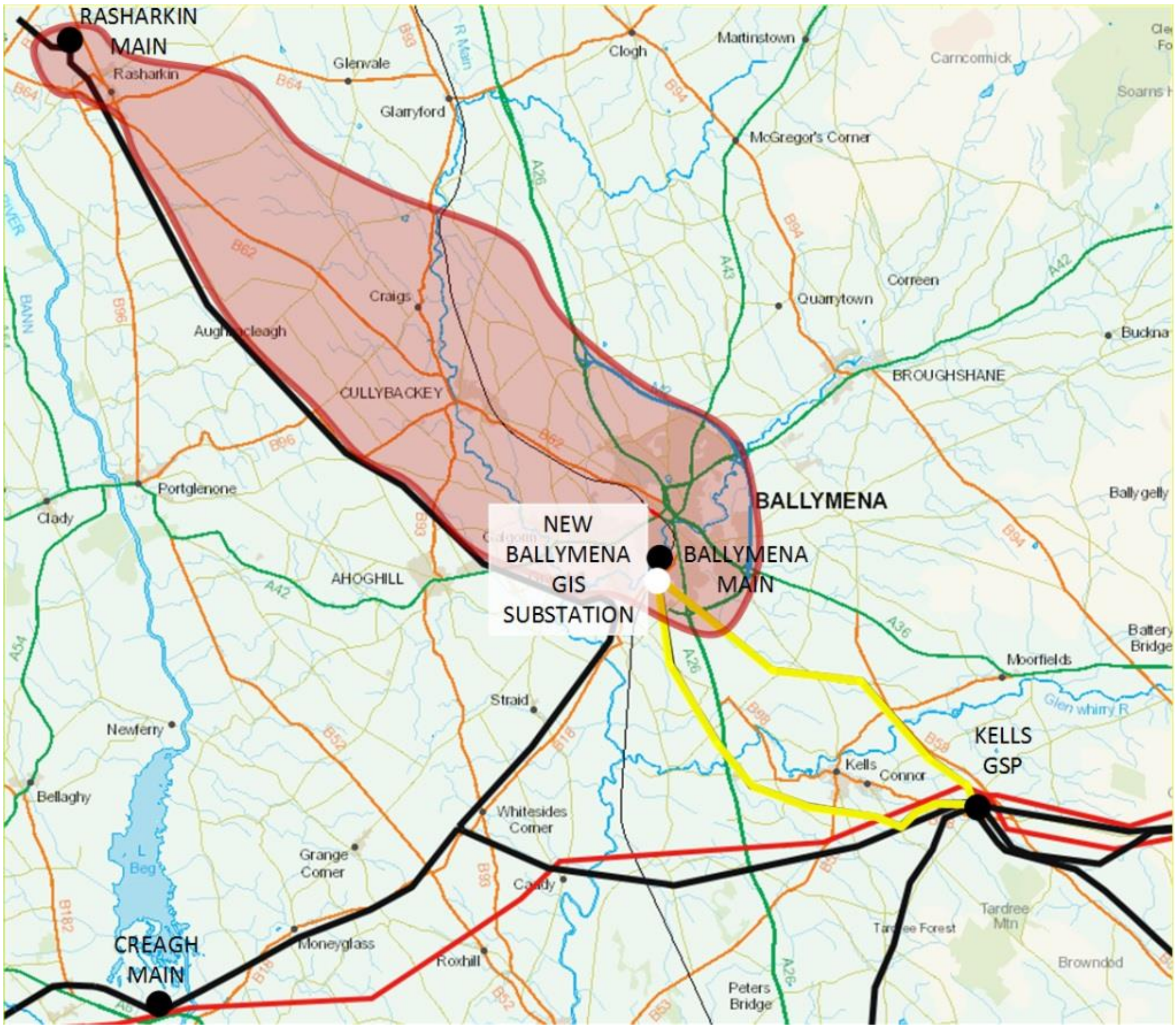

Figure A4-4 – Option 4 Ballymena and North West study area

Red shaded area: Study area for a new cable circuit throughout Ballymena town and a wood pole overhead line circuit to Rasharkin with a possible underground cable section at the approach to Rasharkin substation.

Red lines: 275 kV network

Black lines: 110 kV network

Yellow lines: Circuit uprates: Existing Ballymena – Kells 110 kV circuits to be restrung with high capacity conductor.

White circle: New GIS substation at Ballymena

Creagh Main to Rasharkin West study area

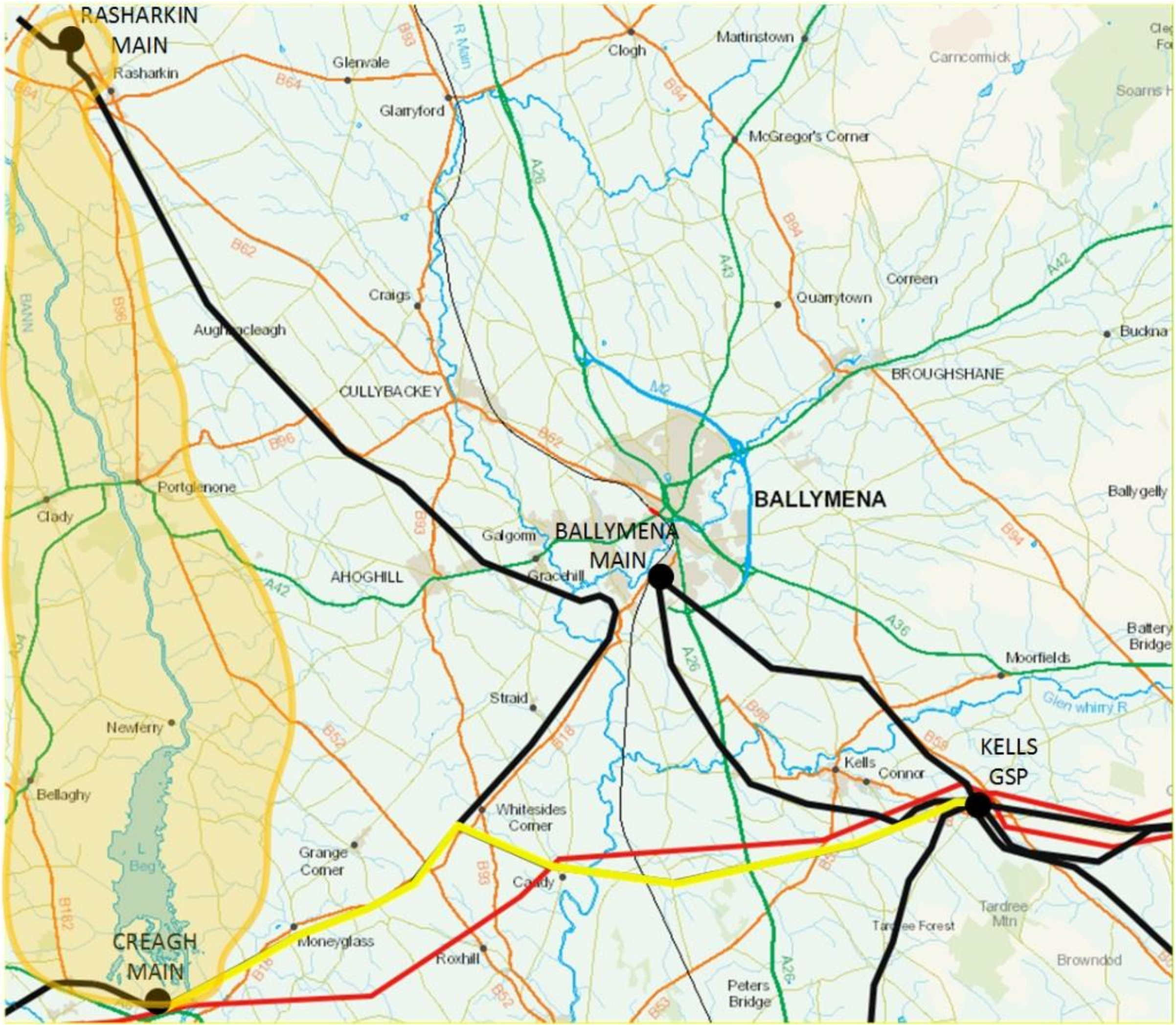

Figure A4-5 – Option 5 Creagh to Rasharkin study area

Yellow shaded area: Study area for a new wood pole overhead line circuit to Rasharkin and possible underground cable sections at the approach to Creagh and Rasharkin substations.

Red lines: 275 kV network

Black lines: 110 kV network

Yellow lines: Circuit uprates: Existing Kells - Creagh 110 kV circuit to be restrung with high capacity conductor.

Terrygowan, uprate and Mid-West study area

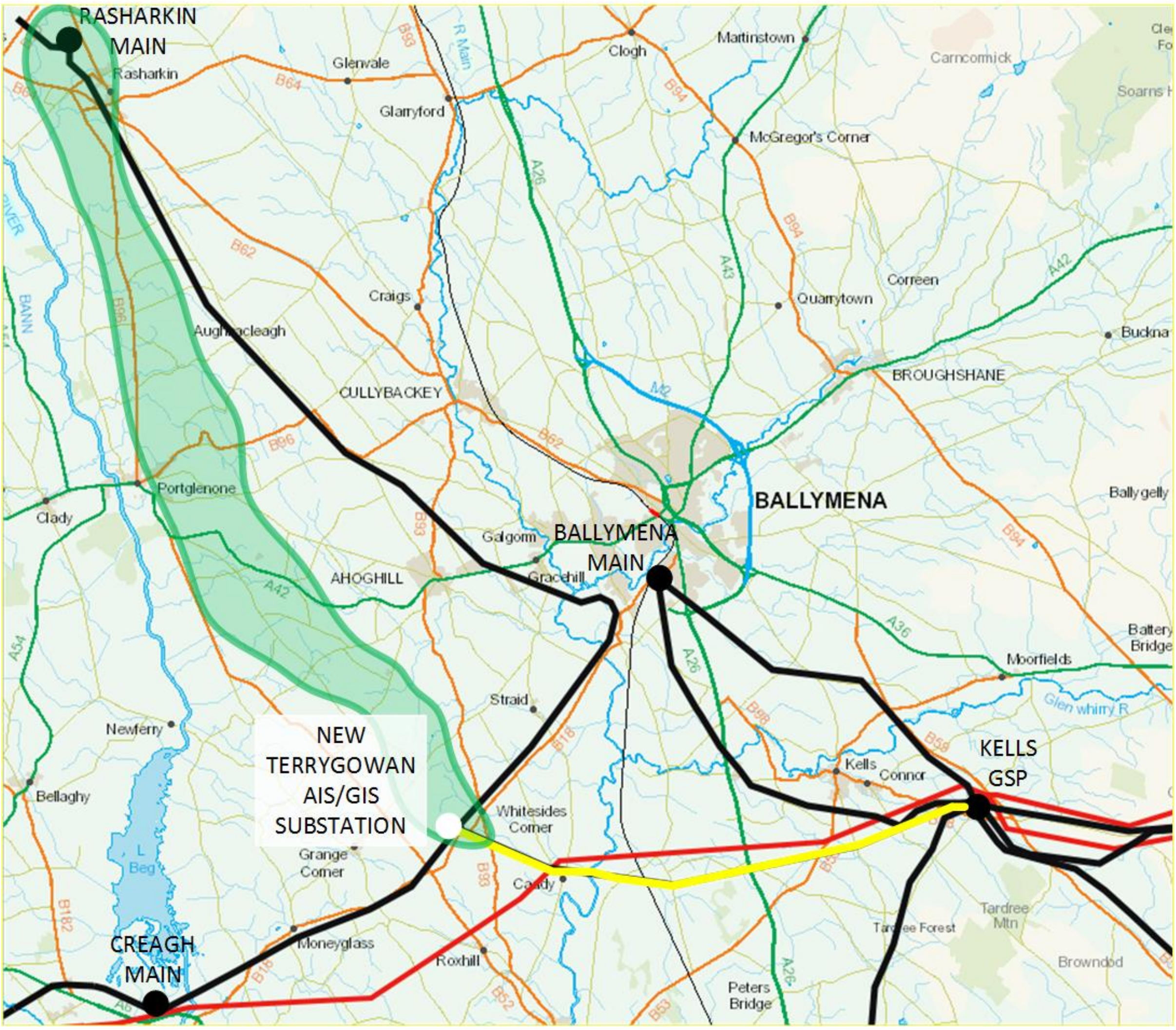

Figure A4-6 – Option 6 Terrygowan and South West study area

Green shaded area: Study area for a new wood pole overhead line circuit to Rasharkin with possible underground cable sections at the approach to Rasharkin and the proposed Terrygowan substations.

Red lines: 275 kV network

Black lines: 110 kV network

Yellow line: Circuit uprate: Existing Kells - Creagh side of double circuit tower line (Kells – Terrygowan) to be restrung with high capacity conductor.

White circle: New AIS or GIS substation arrangement at Terrygowan (end of double circuit tower line section)

Underground cable from Kells – Rasharkin – indicative cable route

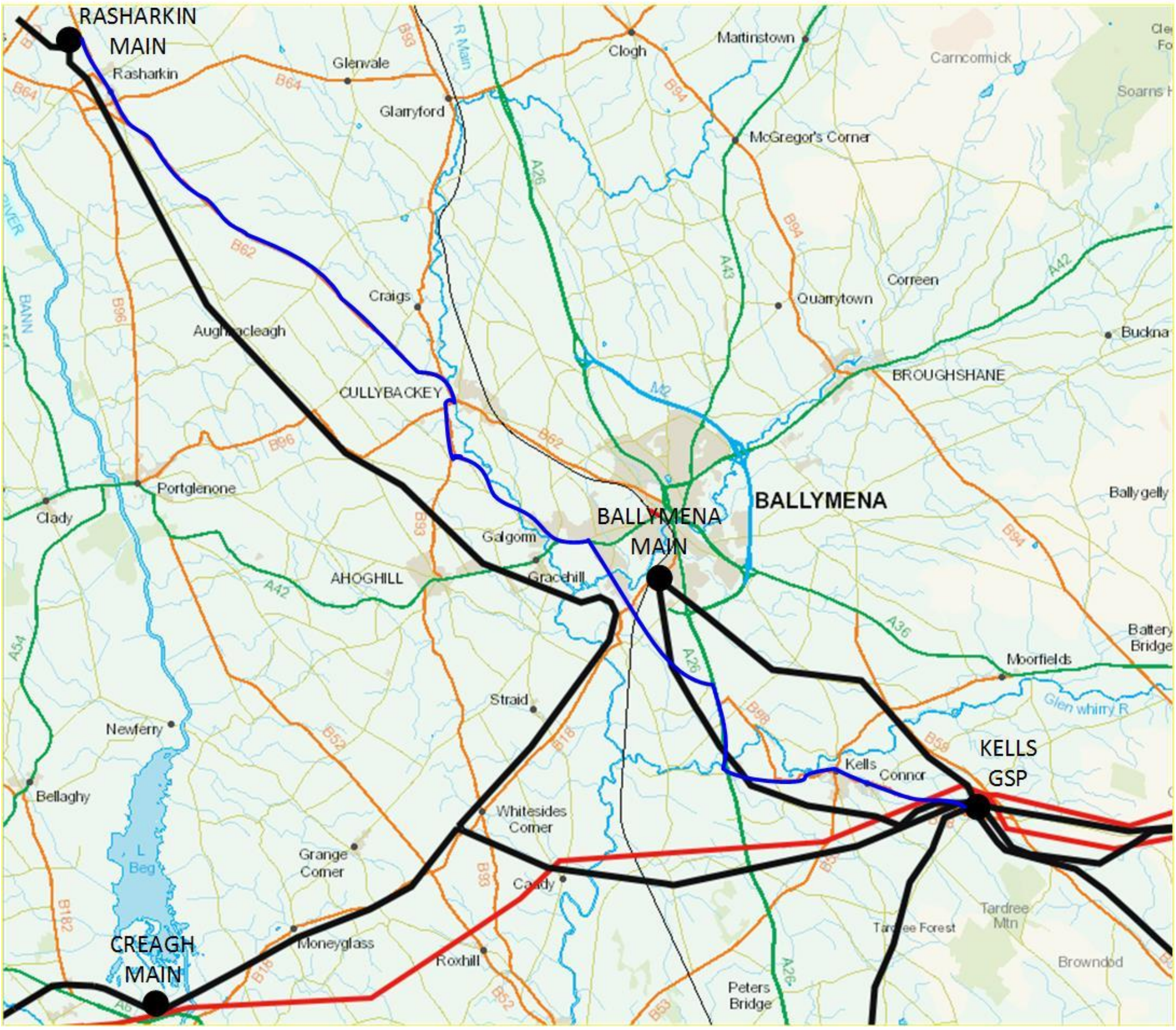

Figure A4-7 – Option 7 Underground cable indicative route

Red lines: 275 kV network

Black lines: 110 kV network

Blue line: Indicative cable circuit route from Kells to Rasharkin: B98 Carncome Road, A26, Cromkill Road (across the NI railway), Tullygarley Road (across the Braid River), Sourhill Road, A43 Galgorm Road, Fenaghy Road, Corbally Road, B93 Cardonaghy Road, Dreen Road, Kilrea Road, Craigs Road, Church Road (through Rasharkin) and Finvoy Road into Rasharkin Main.

APPENDIX 5

Sample corridors within study area

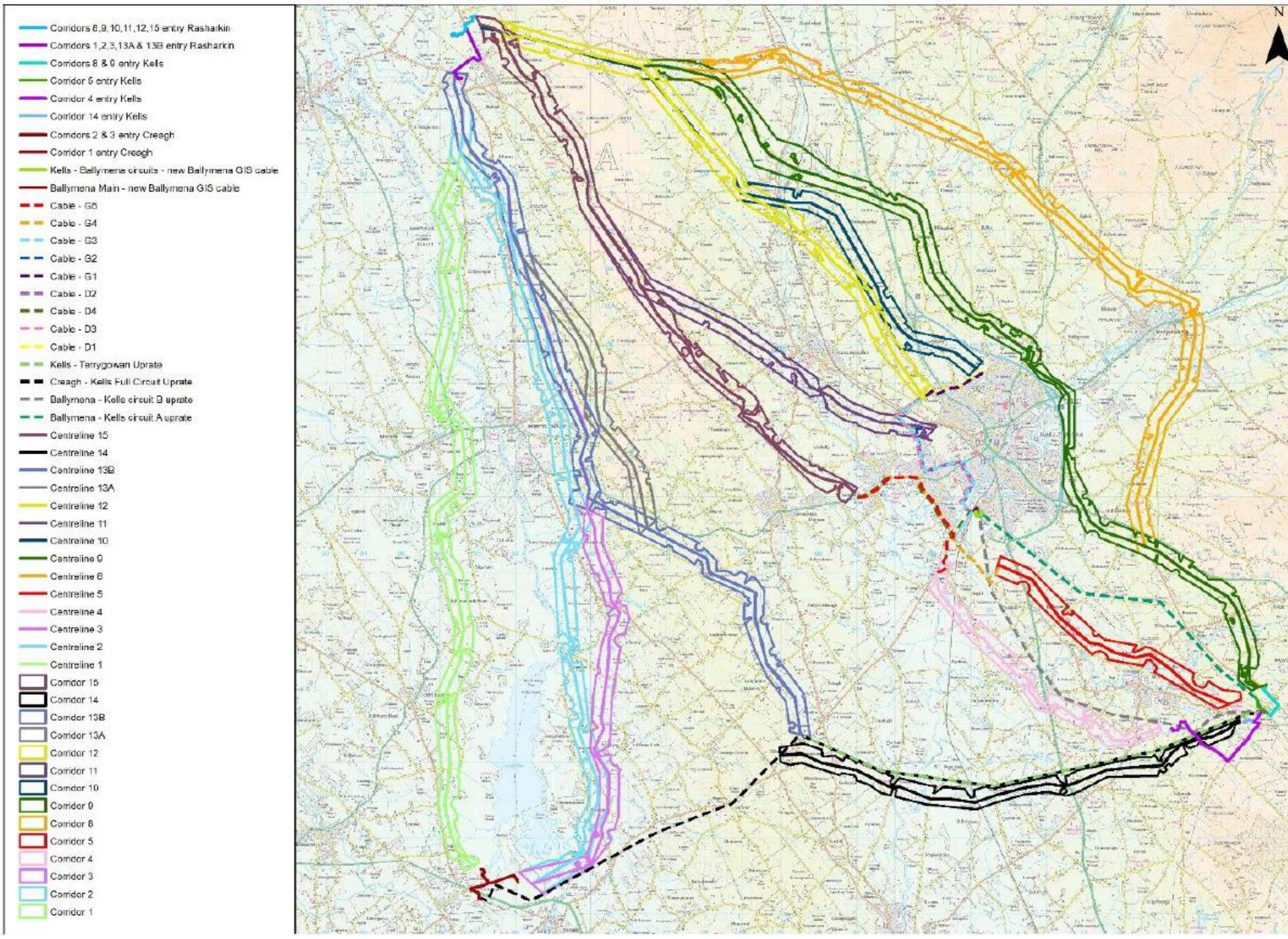

Figure A4 - Sample corridors within study area (assessed by both Mott MacDonald and RPS consultancies)

APPENDIX 6

Percentage loading of key circuits

Circuit	Option								
	1 – Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 - Creagh*	*6 -Terry gowan*	*7 - Cable*
Kells – Rasharkin A (existing)	71-83	58-67	39-46	37-43	41-48	36-41	44-51	40-46	44-51
Kells - Rasharkin B			48-59	51-62	49-57				44-51
Kells - Terrygowan								39-46	
Terrygowan - Rasharkin								48-59	
Creagh - Terrygowan								22-26	
Kells – Ballymena A	10-12	10-12	10-12	16-20	10-12	37-41	16-20	10-12	16-19
Kells – Ballymena B	10-11	9-11	9-11	15-19	9-11	32-35	15-19	10-11	15-19
Ballymena - Rasharkin						52-66			
Kells – Creagh	4-13	6-14	10-16	11-16	10-16	10-16	27-33		12-18
Creagh - Rasharkin							43-52		
Coleraine – Rasharkin	3-9	3-6	17-22	19-24	15-21	19-25	15-21	18-23	14-20

Table A6-1 - Percentage loading of key circuits – 2025 range (system normal)

Circuit	Option								
	1 – Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 - Creagh*	*6 - Terry gowan*	*7 - Cable*
Kells – Rasharkin A (existing)	97-116	82-98	55-67	53-64	58-70	51-60	62-74	56-67	62-75
Kells - Rasharkin B			68-86	72-91	69-83				60-74
Kells - Terrygowan								55-65	
Terrygowan - Rasharkin								69-87	
Creagh - Terrygowan								35-38	
Kells – Ballymena A	9-11	9-11	10-11	16-19	10-11	53-55	17-19	10-11	16-19
Kells – Ballymena B	9-11	9-11	10-11	16-18	10-11	46-57	16-18	9-11	16-18
Ballymena - Rasharkin						75-97			
Kells – Creagh	8-16	10-18	16-22	17-21	16-22	17-22	39-46		16-19
Creagh - Rasharkin							61-77		
Coleraine – Rasharkin	12-26	21-42	1-25	4-23	1-24	6-24	1-22	3-23	3-26

Table A6-2 - Percentage loading of key circuits - 2030 range (system normal)

Circuit loading (Before and After SPS operation)	**Option**								
	1 – do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 -Ballymena*	*5 – Creagh*	*6 -Terrygowan*	*7 - Cable*
Kells – Rasharkin A (existing)	135-159	110-128	71-81	67-77	75-86	65-73	81-93	73-84	80-92
	121-139	99-110	64-71	61-68	67-75	59-63	73-81	66-73	72-81
Kells Rasharkin B			86-105	92-110	89-101				76-91
			79-92	83-98	80-88				68-80
Kells - Terrygowan								75-85	
								68-75	
Terrygowan - Rasharkin								87-104	
								79-91	
Creagh - Terrygowan								33-35	
								30-31	
Kells – Ballymena A	11-12	11-12	10-12	16-21	10-12	65-67	17-21	10-12	16-21
	10-12	10-12	10-12	16-21	10-12	58-61	16-21	10-12	16-20
Kells – Ballymena B	10-12	10-12	10-12	16-20	10-12	56-58	16-20	10-12	16-20
	10-12	10-12	10-12	16-20	10-12	50-53	16-20	10-12	16-20
Ballymena - Rasharkin						96-117			
						86-102			
Kells – Creagh	8-17	8-17	9-16	10-16	9-16	10-16	54-62		12-20
	7-16	7-16	9-15	10-16	8-15	9-16	49-54		12-20
Creagh - Rasharkin							77-92		
							69-80		
Coleraine – Rasharkin	55-65	60-71	89-101	91-103	87-99	92-105	88-99	91-102	85-96
	43-48	48-53	79-81	75-83	73-78	77-83	73-78	75-81	70-75

Table A6-3 - Percentage loading of key circuits – 2025 range (N-DCT before and after completion of SPS operation)

Circuit loading (Before and After SPS operation)	**Option**								
	1 – do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 - Creagh*	*6 - Terry gowan*	*7 - Cable*
Kells – Rasharkin A (existing)	171-208	142-172	91-110	87-105	96-115	83-98	104-125	93-112	103-125
	157-192	131-159	84-102	87-97	89-107	77-90	96-116	86-103	95-116
Kells Rasharkin B			113-142	118-149	114-136				97-123
			104-132	99-137	106-127				90-114
Kells - Terrygowan								94-111	
								87-103	
Terrygowan - Rasharkin								113-142	
								104-131	
Creagh - Terrygowan								48-53	
								44-49	
Kells – Ballymena A	9-12	9-12	10-12	17-20	10-12	82-87	17-20	10-12	17-20
	10-12	10-12	10-12	17-20	10-12	77-81	17-20	10-12	17-19
Kells – Ballymena B	9-11	9-11	10-11	17-19	10-11	72-76	17-19	10-11	16-19
	10-11	10-11	10-11	16-19	10-11	67-70	16-19	10-11	16-19
Ballymena - Rasharkin						124-158			
						114-146			
Kells – Creagh	3-13	3-13	13-21	14-20	12-20	14-21	68-81		13-17
	2-14	2-14	12-20	13-20	11-20	13-21	62-75		14-16
Creagh - Rasharkin							100-125		
							92-117		
Coleraine – Rasharkin	42-66	50-73	83-93	85-95	81-91	88-97	82-92	85-95	77-89
	30-55	37-61	69-79	68-80	67-77	73-82	68-78	71-80	64-75

Table A6-4 - Percentage loading of key circuits – 2030 range (N-DCT before and after completion of SPS operation)

APPENDIX 7

Phase angle issue between Coolkeeragh and Magherafelt (following loss of 275 kV double circuit tower line)

Substation	Before N-DCT	After N-DCT, before SPS operation	After N-DCT, after SPS operation
Coolkeeragh	10.96	39.08	27
Magherafelt	7.55	-0.86	-5.12
Total difference	3.41	39.94	32.12

Table A7-1 - Existing phase angle problem between Coolkeeragh and Magherafelt substations (before Kells – Rasharkin reinforcement)

Substation Phase angle (before and after N-DCT - before and after SPS operation)	**Option**							
	2 - Restring	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 - Creagh*	*6 - Terry gowan*	*7 - Cable*
Coolkeeragh (before N-DCT)	11.04	11.04	11.07	11.01	11.01	10.97	11	11.94
Magherafelt (before N-DCT)	7.65	7.83	7.88	7.79	7.83	7.73	7.8	7.92
Total difference	3.39	3.21	3.19	3.22	3.18	3.24	3.2	3.22
Coolkeeragh (N-DCT, before SPS operation)	38.93	35.75	35.46	35.81	35.26	36.01	35.73	36.31
Magherafelt (N-DCT, before SPS operation)	0.29	1.19	1.37	1.01	1.26	0.8	1.08	1.29
Total difference	39.22	34.56	34.09	34.8	34	35.21	34.65	35.02
Coolkeeragh (N-DCT, after SPS operation	26.85	24.51	24.32	24.58	24.09	24.75	24.51	25.03
Magherafelt (N-DCT, after SPS operation)	-4.75	-3.85	-3.77	-3.98	-3.78	-4.14	-3.93	-3.76
Total difference	31.6	28.36	28.09	28.56	27.87	28.89	28.44	28.79

Table A7-2 - Phase angle difference between Coolkeeragh and Magherafelt substations with longlist options – 2025 winter peak (N-DCT before and after completion of SPS operation)

APPENDIX 8

Localised circuit contingencies – 2025 case

Rasharkin – Coleraine 110 kV circuit trip

Circuit loading (Before and after circuit trip)	Option								
	1 – Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 – Creagh*	*6 - Terry gowan*	*7 - Cable*
Kells – Rasharkin A (existing)	71-83	58-67	39-46	37-43	41-48	36-41	44-51	40-46	44-51
	72-86	56-69	31-38	29-36	33-40	29-34	35-44	31-39	36-43
Kells Rasharkin B			48-59	51-62	49-57				44-51
			38-48	40-50	39-48				37-44
Kells - Terrygowan								39-46	
								32-40	
Terrygowan - Rasharkin								48-59	
								38-47	
Creagh - Terrygowan								22-26	
								15-22	
Kells – Ballymena A	10-12	10-12	10-12	16-20	10-12	37-41	16-20	10-12	16-19
	10-12	10-12	10-12	16-20	10-12	29-34	16-20	10-12	16-19
Kells – Ballymena B	10-11	9-11	9-11	15-19	9-11	32-35	15-19	10-11	15-19
	10-11	9-11	9-11	15-19	9-11	25-29	16-19	10-11	15-19
Ballymena - Rasharkin						52-66			
						40-52			
Kells – Creagh	4-13	6-14	10-16	11-16	10-16	10-16	27-33		12-18
	4-13	5-14	6-16	7-16	7-16	7-16	23-30		10-19
Creagh - Rasharkin							43-52		
							34-43		
Coleraine – Rasharkin	3-9	3-6	17-22	19-24	15-21	19-25	15-21	18-23	14-20
	0	0	0	0	0	0	0	0	0

Table A8-1 - Rasharkin – Coleraine 110 kV contingency (Percentage loading of key circuits – 2025 range)

Kells – Rasharkin circuit 110 kV circuit trip

Circuit loading (Before and after circuit trip)	**Option**								
	1 – Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 – Creagh*	*6 - Terry gowan*	*7 - Cable*
Kells – Rasharkin A (existing)	71-83	58-67	39-46	37-43	41-48	36-41	44-51	40-46	44-51
	0	0	0	0	0	0	0	0	0
Kells Rasharkin B			48-59	51-62	49-57				44-51
			72-88	75-91	75-87				66-82
Kells - Terrygowan								39-46	
								63-74	
Terrygowan - Rasharkin								48-59	
								73-89	
Creagh - Terrygowan								22-26	
								27-31	
Kells – Ballymena A	10-12	10-12	10-12	16-20	10-12	37-41	16-20	10-12	16-19
	10-12	10-12	10-12	16-20	10-12	46-48	16-20	10-12	16-19
Kells – Ballymena B	10-11	9-11	9-11	15-19	9-11	32-35	15-19	10-11	15-19
	10-11	9-11	9-11	15-19	9-11	53-55	15-19	10-11	15-19
Ballymena - Rasharkin						52-66			
						75-95			
Kells – Creagh	4-13	6-14	10-16	11-16	10-16	10-16	27-33		12-18
	18-24	18-30	7-15	8-15	6-14	8-15	48-57		11-19
Creagh - Rasharkin							43-52		
							68-83		
Coleraine – Rasharkin	3-9	3-6	17-22	19-24	15-21	19-25	15-21	18-23	14-20
	72-87	72-88	4-9	6-11	4-7	8-14	3-6	4-9	4-6

Table A8-2 – Kells - Rasharkin 110 kV contingency (Percentage loading of key circuits – 2025 range)

Other option specific contingencies

Option 5 - Creagh (loss of DCT: Kells - Rasharkin and Kells - Creagh)

Option	Circuit loading (before and after circuit trip)						
	Kells – Rasharkin A (existing)	Kells – Ballymena A	Kells – Ballymena B	Kells – Creagh	Creagh - Rasharkin	Coleraine – Rasharkin	Creagh – Tamnamore
5 – Creagh	44-51	16-20	15-19	27-33	43-52	15-21	15-25
	0	16-20	15-19	0	52-64	16-24	83-91

Table A8-3 - Option 5 (Creagh) - loss of DCT: Kells - Rasharkin and Kells - Creagh 110 kV circuits (Percentage loading of key circuits – 2025 range)

Option 6 - Terrygowan (loss of DCT: Kells – Rasharkin and Kells – Terrygowan)

Option	Circuit loading (before and after circuit trip)							
	Kells – Rasharkin A (existing)	Kells – Bally mena A	Kells – Bally mena B	Kells – Terry gowan	Terry gowan - Rashar kin	Creagh – Terry gowan	Coleraine – Rasharkin	Creagh – Tamnamore
6 – Terry gowan	40-46	10-12	10-11	39-46	48-59	22-26	18-23	16
	0	10-12	9-11	0	49-60	90-102	19-28	77-85

Table A8-4 - Option 6 (Terrygowan) - loss of DCT: Kells - Rasharkin and Kells - Terrygowan 110 kV circuits (Percentage loading of key circuits – 2025 range)

Option 5 – Creagh and Option 6 - Terrygowan (loss of both Interbus transformers at Tamnamore)

Option	Circuit loading (before and after Tx trip)						
	Kells – Rasharkin A (existing)	Kells – Ballymena A	Kells – Ballymena B	Kells – Creagh	Creagh - Rasharkin	Coleraine – Rasharkin	Creagh – Tamnamore
5 - Creagh	44-51	16-20	15-19	27-33	43-52	15-21	15-25
	48-54	16-20	16-19	42-43	37-48	14-20	12-16

Table A8-5 - Option 5 (Creagh) - loss of both Txs at Tamnamore (Percentage loading of key circuits – 2025 range)

Option	Circuit loading (before and after Tx trip)							
	Kells – Rasharkin A (existing)	Kells – Ballymena A	Kells – Ballymena B	Kells – Terrygowan	Terrygowan - Rasharkin	Creagh – Terrygowan	Coleraine – Rasharkin	Creagh – Tamnamore
6 – Terrygowan	40-46	10-12	10-11	39-46	48-59	22-26	18-23	16
	44-48	10-12	10-11	52-57	45-57	11-18	17-23	17-20

Table A8-6 - Option 6 (Terrygowan) - loss of both Txs at Tamnamore (Percentage loading of key circuits – 2025 range)

Localised circuit contingencies – 2030 case

Rasharkin – Coleraine 110 kV circuit trip

Circuit loading (Before and after circuit trip)	Option								
	1 – Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Ballymena*	*5 – Creagh*	*6 - Terrygowan*	*7 - Cable*
Kells – Rasharkin A (existing)	97-116	82-98	55-67	53-64	58-70	51-60	62-74	56-67	62-75
	109-154	**V.C.**	53-72	50-66	56-76	48-62	59-79	53-71	62-83
Kells Rasharkin B			68-86	72-91	69-83				60-74
			66-92	68-95	67-90				59-82
Kells - Terrygowan								55-65	
								52-68	
Terrygowan - Rasharkin								69-87	
								65-91	
Creagh - Terrygowan								35-38	
								33-40	
Kells – Ballymena A	9-11	9-11	10-11	16-19	10-11	53-55	17-19	10-11	16-19
	9-11	**V.C.**	10-11	17-19	10-11	44-48	17-19	10-11	17-19
Kells – Ballymena B	9-11	9-11	10-11	16-18	10-11	46-57	16-18	9-11	16-18
	9-11	**V.C.**	10-11	16-18	10-11	51-56	16-18	10-11	16-18
Ballymena - Rasharkin						75-97			
						70-99			
Kells – Creagh	8-16	10-18	16-22	17-21	16-22	17-22	39-46		16-19
	9-20	**V.C.**	16-22	17-19	16-22	16-21	38-49		17-20
Creagh - Rasharkin							61-77		
							59-82		
Coleraine – Rasharkin	12-26	21-42	1-25	4-23	1-24	6-24	1-22	3-23	3-26
	0	0	0	0	0	0	0	0	0

Table A8-7 - Rasharkin – Coleraine 110 kV contingency (Percentage loading of key circuits – 2030 range)

Kells – Rasharkin circuit 110 kV circuit trip

Circuit loading (Before and after circuit trip)	**Option**								
	1 – Do nothing	*2 - Restring*	*3a - North east*	*3b - Centre*	*3c - South west*	*4 - Bally mena*	*5 – Creagh*	*6 - Terry gowan*	*7 - Cable*
Kells – Rasharkin A (existing)	97-116	82-98	55-67	53-64	58-70	51-60	62-74	56-67	62-75
	0	0	0	0	0	0	0	0	0
Kells Rasharkin B			68-86	72-91	69-83				60-74
			103-129	106-133	107-127				94-118
Kells - Terrygowan								55-65	
								65-104	
Terrygowan - Rasharkin								69-87	
								80-130	
Creagh - Terrygowan								35-38	
								35-46	
Kells – Ballymena A	9-11	9-11	10-11	16-19	10-11	53-55	17-19	10-11	16-19
	9-11	10-11	10-11	17-19	10-11	64-67	17-19	10-11	16-19
Kells – Ballymena B	9-11	9-11	10-11	16-18	10-11	46-57	16-18	9-11	16-18
	9-11	9-11	10-11	16-18	10-11	73-77	16-18	9-11	16-18
Ballymena - Rasharkin						75-97			
						109-139			
Kells – Creagh	8-16	10-18	16-22	17-21	16-22	17-22	39-46		16-19
	20-34	20-33	12-18	13-17	11-18	14-20	67-81		10-20
Creagh - Rasharkin							61-77		
							97-121		
Coleraine – Rasharkin	12-26	21-42	1-25	4-23	1-24	6-24	1-22	3-23	3-26
	108-134	123-153	17-40	13-35	19-40	10-31	20-41	3-37	28-55

Table A8-8 – Kells - Rasharkin 110 kV contingency (Percentage loading of key circuits – 2030 range)

Other option specific contingencies

Option 5 - Creagh (loss of DCT: Kells - Rasharkin and Kells - Creagh

Option	Circuit loading (before and after circuit trip)						
	Kells – Rasharkin A (existing)	Kells – Ballymena A	Kells – Ballymena B	Kells – Creagh	Creagh - Rasharkin	Coleraine – Rasharkin	Creagh – Tamnamore
5 - Creagh	62-74	17-19	16-18	39-46	61-77	3-23	33-43
	0	16-19	16-18	0	75-93	42-64	129-140

Table A8-9 - Option 5 (Creagh) - loss of DCT: Kells - Rasharkin and Kells - Creagh 110 kV circuits (Percentage loading of key circuits – 2030 range)

Option 6 - Terrygowan (loss of DCT: Kells – Rasharkin and Kells – Terrygowan)

Option	Circuit loading (before and after circuit trip)							
	Kells – Rasharkin A (existing)	Kells – Bally mena A	Kells – Bally mena B	Kells – Terry gowan	Terry gowan - Rashar kin	Creagh – Terry gowan	Coleraine – Rasharkin	Creagh – Tamna more
6 – Terry gowan	56-67	10-12	10-11	60-74	69-87	35-38	3-23	18-31
	0	10-11	9-11	0	71-87	130-148	47-68	120-131

Table A8-10 - Option 6 (Terrygowan) - loss of DCT: Kells - Rasharkin and Kells - Terrygowan 110 kV circuits (Percentage loading of key circuits – 2030 range)

Option 5 – Creagh and Option 6 - Terrygowan (loss of both Interbus transformers at Tamnamore)

Option	Circuit loading (before and after circuit trip)						
	Kells – Rasharkin A (existing)	Kells – Ballymena A	Kells – Ballymena B	Kells – Creagh	Creagh - Rasharkin	Coleraine – Rasharkin	Creagh – Tamnamore
5 - Creagh	62-74	17-19	16-18	39-46	61-77	3-23	33-42
	67-78	16-19	16-19	56-60	54-72	2-22	4-13

Table A8-11 - Option 5 (Creagh) - loss of both Txs at Tamnamore (Percentage loading of key circuits – 2030 range)

Option	Circuit loading (before and after Tx trip)							
	Kells – Rasharkin A (existing)	Kells – Bally mena A	Kells – Bally mena B	Kells – Terry gowan	Terry gowan - Rashar kin	Creagh – Terry gowan	Colerain e – Rasharki n	Creagh – Tamna more
6 – Terry gowan	56-67	10-12	10-11	60-74	69-87	35-38	3-23	18-31
	59-70	10-11	9-11	73-79	65-84	9-15	2-24	12-17

Table A8-12 - Option 6 (Terrygowan) - loss of both Txs at Tamnamore (Percentage loading of key circuits – 2030 range)

APPENDIX 9

Sensitivity – Option 6 Terrygowan (preliminary preferred option) with an additional 110 kV circuit from Agivey – Limavady – 2030 case

Circuit	**Circuit loading following contingency (%)**				
	System normal	*Coolkeeragh - Magherafelt 275 kV double circuit trip (before and after SPS completion)*	*Coleraine – Rasharkin 110 kV single circuit trip*	*Kells – Rasharkin 110 kV single circuit trip*	*Kells – Rasharkin and Kells – Terrygowan 110 kV double circuit trip*
Kells – Rasharkin A (existing)	52-63	95-113 87-104	48-60		
Kells - Terrygowan	52-61	96-112 88-103	49-58	81-95	
Terrygowan - Rasharkin	64-80	115-143 105-132	59-77	94-117	60-75
Creagh - Terrygowan	32-34	50-54 46-50	29-32	37-39	110-125
Creagh - Tamnamore	14-27	33-44 29-40	11-24	20-32	99-108
Agivey - Limavady	22-29	18-25 11-18	11-21	31-39	45-57
Coleraine – Rasharkin	20-24	72-81 63-72		6-18	9-23

Table A9-1 - Option 6 Terrygowan (preliminary preferred option) contingencies with an additional 110 kV circuit from Agivey – Limavady in the 2030 case

APPENDIX 10

Net Present Cost Assessment and Assumptions

Assumption	Option						
	1 – Do nothing	*3a -North east*	*3b -Centre*	*3c -South west*	*4 -Bally mena*	*5 -Creagh*	*6 -Terry gowan*
Capital Cost of Assets	-	£22.36m	£30.91m	£25.69m	£32.87m	£28.45m	£22.53m
Duration of construction	-	2 years, starting in 2027	2 years, starting in 2027	2 years, starting in 2027	3 years, starting in 2027	3 years, starting in 2027	2 years, starting in 2027
Estimated Completion Date and Energisation	-	2028	2028	2028	2029	2029	2028
TSO costs	-	£4.38m	£4.38m	£4.38m	£4.38m	£4.38m	£4.38m
Operation and Maintenance (Based on 0.2% capital value)	-	£53k	£71k	£60k	£75k	£66k	£54k
Wind constraint costs	£2.13m by 2025. £9.45m after 2030	No constraints until after 2025. £0.82m after 2030	No constraints until after 2025. £1.18m after 2030	No constraints until after 2025. £0.7m after 2030	Minimal constraints up to 2025. £1.93m after 2030	No constraints until after 2025. £0.45m after 2030	No constraints until after 2025. £0.51m after 2030
TOTAL NET PRESENT COST	£107.24m	£30.12m	£40.66m	£31.53m	£49.55	£30.77m	£27.03m