CP1604 Coolkeeragh - Strabane Upgrade

Options Report

January 2026

Version history					
Version	**Date**	**Description**	**Prepared by**	**Checked by**	**Approved by**
1.0	25/06/2025	First draft	Bronagh McCaffrey	Niall McClements	
1.1	30/01/2026	Final draft	Finian Hagan	Niall McClements, Michael McClure	

Disclaimer

While all reasonable care has been taken to prepare this document, we can make no guarantee to the quality, accuracy and completeness of the information herein. We do not accept responsibility for any loss associated with the use of this information. Use of this document and the information it contains is at the user's own risk.

Information in this document does not amount to a recommendation as regards to any possible investment. Before taking a business decision based on the content of this document, we advise that interested parties seek separate and independent opinion in relation to the matters covered by this document.

Published January 2026.

Castlereagh House, 12 Manse Road, Belfast, BT6 9RT, Northern Ireland.

Contents

1 Introduction

SONI designs and operates the transmission system to be secure against credible contingencies. The most onerous contingency affecting the majority of generation in Northern Ireland is the potential for the loss of the 275 kV double circuit between Coolkeeragh and Magherafelt, which passes through the Sperrin mountains. At all times, the transmission network must be able to cope with the potential change in power flows resulting from the sudden disconnection of these circuits (or any other network element).

The Needs Report that counterparts this Options Report shows that there is a risk of overloads on the Coolkeeragh- Strabane, Coolkeeragh- Killymallaght and Killymallaght-Strabane circuits in 2035 as seen in the Tomorrow's Energy Scenarios (TES) 2023 and Shaping Our Electricity Future (SOEF) documents published by SONI. This confirms a need for the capacity of the corridor to be increased to allow future renewable generation to connect.

This options report focuses on the 110kV corridor between Coolkeeragh and Strabane.

2 Grid development framework

To ensure transmission system reliability and security, predicted power flows of the network are compared with the requirements of the Transmission System Security and Planning Standards (TSSPS[1]).

The TSSPS establishes a set of design criteria for the transmission system. This includes setting the minimum level of redundancy that should be incorporated into the design to deal with credible faults and outages. The standard includes checking for any circuits that would be overloaded or where voltages would fall below statutory levels.

SONI assesses the present and future transmission system against these standards and, when breaches are forecast, establishes plans to address these breaches.

The planning of new transmission development projects by SONI follows a three-part process, shown in Figure 2.1. The process includes stakeholder and public participation in the development of projects.

Figure 2.1: SONI's Grid Development Process

A need has been identified on the 110kV corridor between Coolkeeragh and Strabane, which is detailed in the ***Coolkeeragh - Strabane Upgrade Needs Report***.

This Options Report for the Coolkeeragh - Strabane Upgrade summarises the process of identifying the preliminary preferred option, and forms part of Part 1 of the grid development process.

[1] Transmission System Security and Planning Standards, SONI, 2023, https://cms.soni.ltd.uk//sites/default/files/2024-09/Transmission-System-Security-and-Planning-Standards-June-2023.pdf

3 Long list of options

To examine the potential impact of reinforcement in the Coolkeeragh to Strabane corridor, an initial longlist of options for network reinforcement was developed. This list represents potential options at differing scales that could impact constraints this study area. The options consider ways of providing additional network capacity, which include:

- Providing additional capacity on existing circuits and route;
- Splitting out circuits to make the most of the infrastructure already there;
- Rebuilding substations to allow more circuit turn-ins;
- Providing additional capacity with new circuits; and
- Building a new switching station to provide more space for bays and circuit turn ins.

For some of these methods, a number of sub options were developed. Table 3.1 provides a brief overview of the long list of options.

Table 3.1: Longlist of options

Summary	Option	Description
None	1	Do nothing
Upgrade circuits	2	Upgrade all existing circuits
Restore double circuit	3A	Restore Coolkeeragh to Strabane double circuit
	3B	Restore and upgrade all circuits
	3C	Restore and upgrade double circuit
Rebuild Killymallaght	4A	Rebuild only
	4B	Rebuild, upgrade Coolkeeragh to Strabane
	4C	Rebuild, upgrade all circuits
New circuit	5	New Coolkeeragh to Strabane circuit
New substation	6	Switching station south of Coolkeeragh

The subsections below provide an overview of the options on the longlist. **Note that any circuit routes shown in diagrams are for illustrative purposes only**. Should the preferred option require a new circuit, the final route would be subject to detailed design taking into consideration a range of criteria and include extensive stakeholder engagement. Any new infrastructure would also require planning permission.

3.1 Option 1: Do nothing

This option would involve not reinforcing the transmission system in the Coolkeeragh to Strabane corridor.

3.2 Option 2: Upgrade circuits

A restring of each of the circuits is a viable option for reducing the capacity issue on these lines. A possible conductor would be an Invar type conductor (rated to 193/191/186 MVA for winter, autumn and summer respectively). An illustration of this new configuration is shown in Figure 3.1 below.

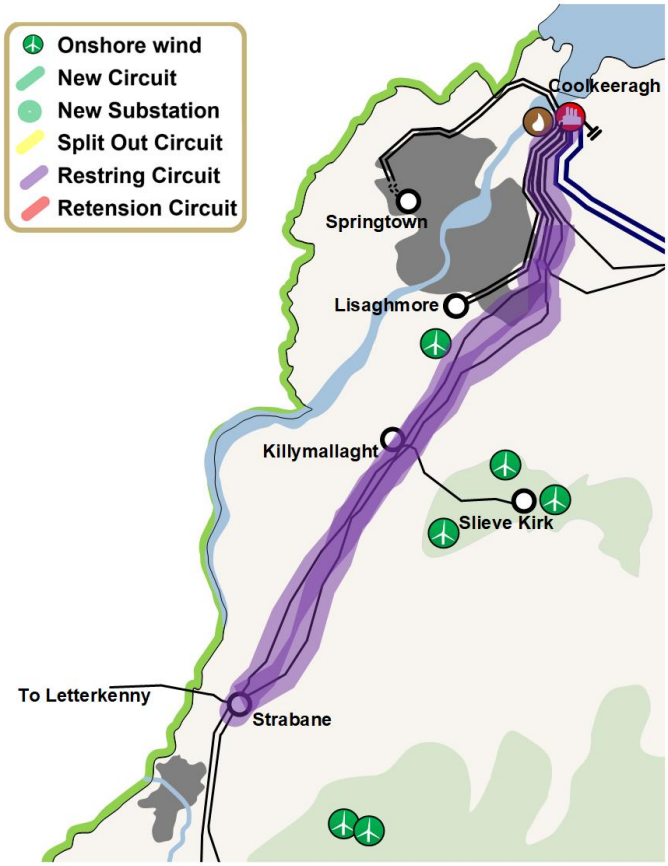

Figure 3.1 Map showing Option 2

Coolkeeragh to Strabane

The 110kV circuit between Coolkeeragh and Strabane comprises two sections. The section from Coolkeeragh to Mobuoy would require to be restrung with an Invar type conductor. The section from Mobuoy to Strabane would not need to be restrung as it comprises two circuits jumpered together and has sufficient capacity.

Coolkeeragh to Killymallaght

The 110kV circuit between Coolkeeragh and Strabane comprises two sections, both of which would require to restrung with an Invar type conductor. Additionally, an earth wire

with fibre/comms provision would be required to be installed to increase protection in this area.

Killymallaght to Strabane

The 110kV circuit between Killymallaght and Strabane would be restrung with an Invar type conductor.

There are no sub-options being considered as part of this option.

3.3 Option 3: Restore double circuit

Option 3 considers the re-establishment of 2 circuits between Coolkeeragh and Strabane. This would involve splitting the currently parallelled double circuit between Coolkeeragh and Strabane. A number of sub options were identified and included.

3.3.1 Option 3A

Re-establishing the 110kV double circuit from Mobuoy to Strabane will provide two 110kV circuits, each rated at 124/119/109 MVA in winter, autumn and summer, respectively. The double circuit tower from Coolkeeragh to Mobuoy will be used to bring the two circuits into Coolkeeragh. As a result, the section of the Coleraine to Coolkeeragh 110kV circuit that presently uses one side of the double circuit tower line from Coolkeeragh to Mobuoy will need to be cabled into Coolkeeragh.

Figure 3.2 provides an indicative overview of the new arrangement.

The existing 110kV mesh at Strabane substation will require an extension to provide an additional bay for the newly established second 110kV circuit between Coolkeeragh and Strabane.

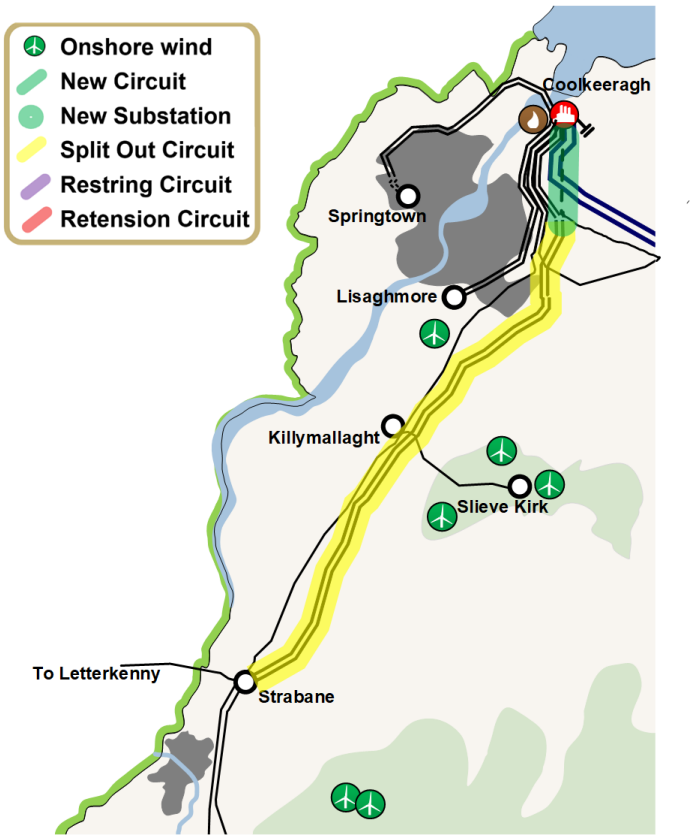

Figure 3.2: Map showing Option 3A.

3.3.2 Option 3B

As with Option 3A, re-establishing the 110kV double circuit from Mobuoy to Strabane will provide two 110kV circuits between Coolkeeragh and Strabane. In Option 3B, these circuits will be restrung with an Invar type conductor, with each circuit rated at 193/191/185 MVA in winter, autumn and summer, respectively.

The double circuit tower from Coolkeeragh to Mobuoy will be used to bring the two circuits into Coolkeeragh. Both circuits on this tower line will be restrung with Invar type conductor. As with Option 3A, the section of the Coleraine to Coolkeeragh 110kV circuit that presently uses one side of the double circuit tower line from Coolkeeragh to Mobuoy will need to be cabled into Coolkeeragh.

The 110kV circuits between Coolkeeragh, Killymallaght and Strabane will also be uprated with Invar type conductor.

Figure 3.3 provides an indicative overview of the new arrangement.

As with Option 3A, the existing 110kV mesh at Strabane substation will require an extension to provide an additional bay for the newly established second 110kV circuit between Coolkeeragh and Strabane.

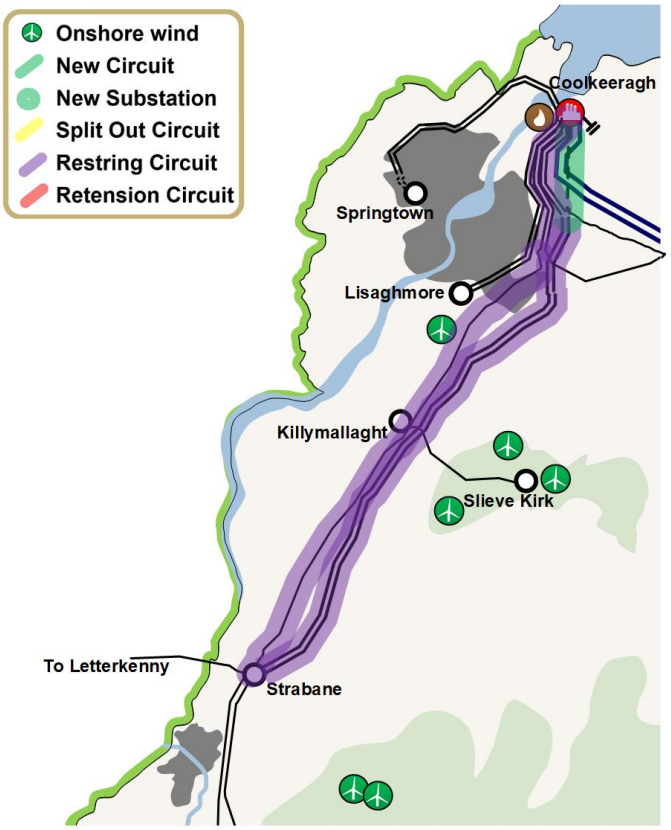

Figure 3.3: Map showing Option 3B

3.3.3 Option 3C

As with Options 3A and 3B, re-establishing the 110kV double circuit from Mobuoy to Strabane will provide two 110kV circuits between Coolkeeragh and Strabane. In Option 3C, these circuits will be restrung with an Invar type conductor, with each circuit rated at 193/191/185 MVA in winter, autumn and summer respectively.

As with Options 3A and 3B, the use of the double circuit tower line from Coolkeeragh to Mobuoy for the two Coolkeeragh to Strabane 110kV circuits requires a section of the Coleraine to Coolkeeragh 110kV circuit to be cabled into Coolkeeragh.

Unlike in Option 3B, the 110kV circuits between Coolkeeragh, Killymallaght and Strabane will be re-tensioned, increasing their capacity from 166/158/143 MVA to approximately 178/171/157 MVA in winter, autumn and summer respectively.

Figure 3.4 provides an indicative overview of the new arrangement.

As with Options 3A and 3B, the existing 110kV mesh at Strabane substation will require an extension to provide an additional bay for the newly established second 110kV circuit between Coolkeeragh and Strabane.

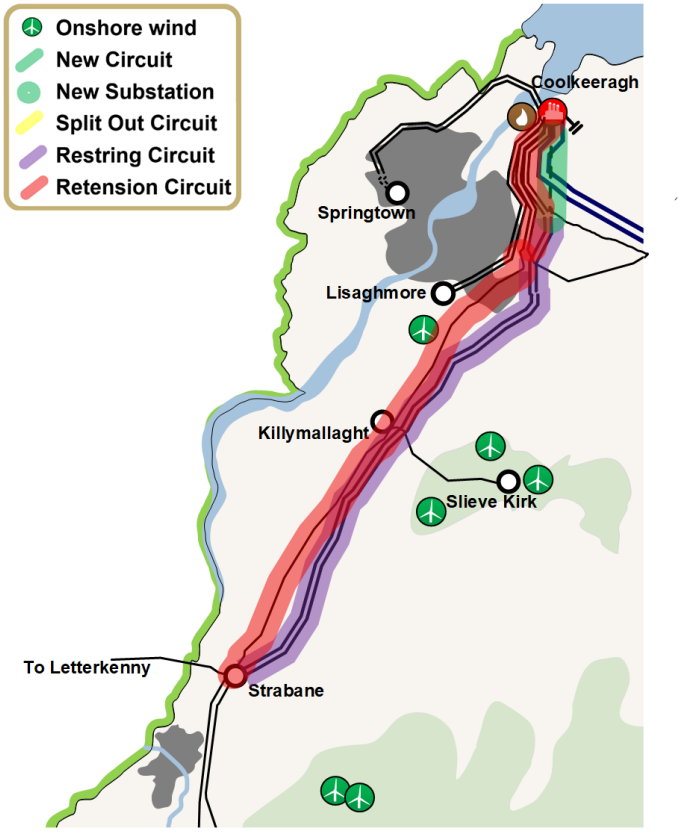

Figure 3.4: Map showing Option 3C.

3.4 Option 4: Rebuild Killymallaght

Option 4 considers a rebuild of the existing Killymallaght substation and a diversion of the other lines in the Coolkeeragh- Strabane corridor into it. A number of sub-options are considered for the configuration of this new substation.

3.4.1 Option 4A

Option 4A creates a new double busbar switching station near to Killymallaght, with all of the 110kV circuits between Coolkeeragh and Strabane diverted into it.

The existing 110/33kV transformer at Killymallaght would remain and be connected into the new site via a 110kV cable as a transformer feeder arrangement.

This option re-establishes the 110kV double circuit from Mobuoy to Strabane to provide two 110kV circuits, with a new 110kV cable required from Mobuoy to Coolkeeragh for the Coleraine to Coolkeeragh circuit. This work is described in more detail in section 3.3.1.

Figure 3.5 provides an indicative overview of the new arrangement.

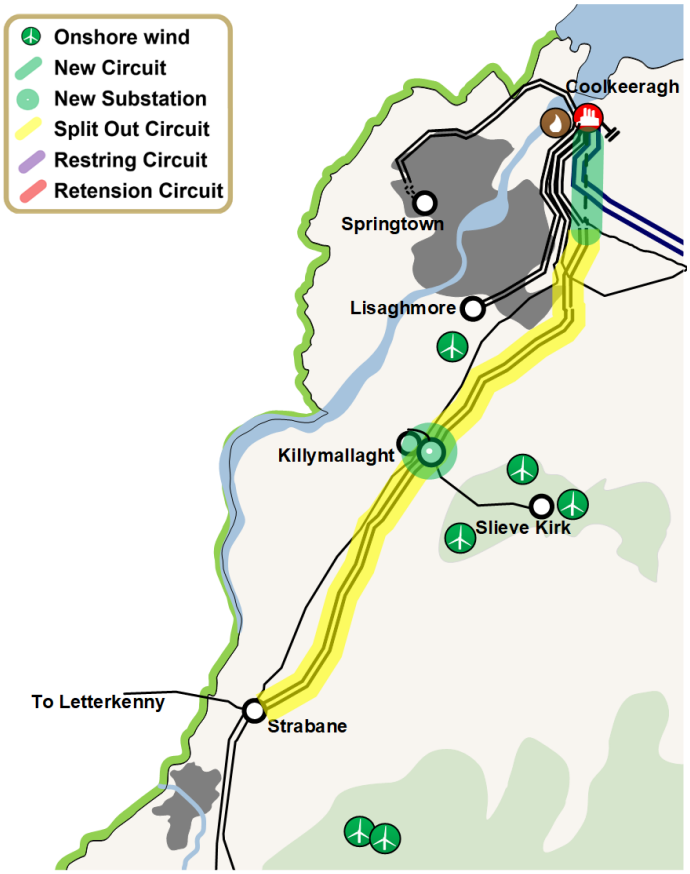

Figure 3.5: Map showing Option 4A.

3.4.2 Option 4B

Option 4B has an identical configuration to that described in Option 4A in **section 3.4.1**.

In this option, however, the two 110kV circuits between Coolkeeragh and Strabane created through the restoration of the double circuit are upgraded with an Invar type conductor, providing additional capacity between Coolkeeragh, Killymallaght and Strabane.

Figure 3.6 provides an indicative overview of the new arrangement.

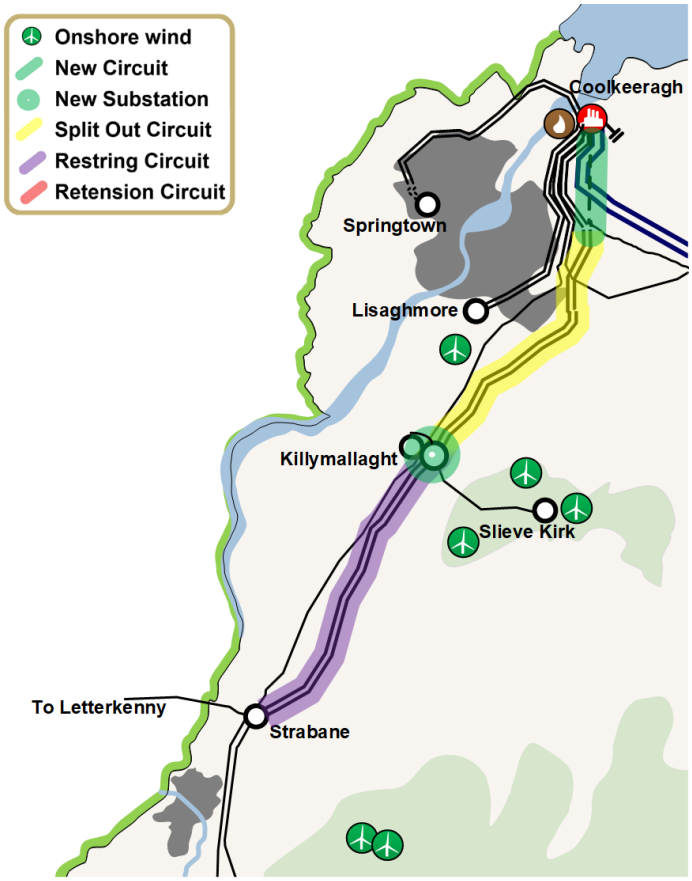

Figure 3.6: Map showing Option 4B.

3.4.3 Option 4C

Option 4C has an identical configuration to that described in Option 4A in **section 3.4.1** and Option 4B in **section 3.4.2**.

In this option, however, all of the circuits in the Coolkeeragh- Strabane corridor are upgraded with an Invar type conductor, providing additional capacity between Coolkeeragh, Killymallaght and Strabane.

Figure 3.7 provides an indicative overview of the new arrangement.

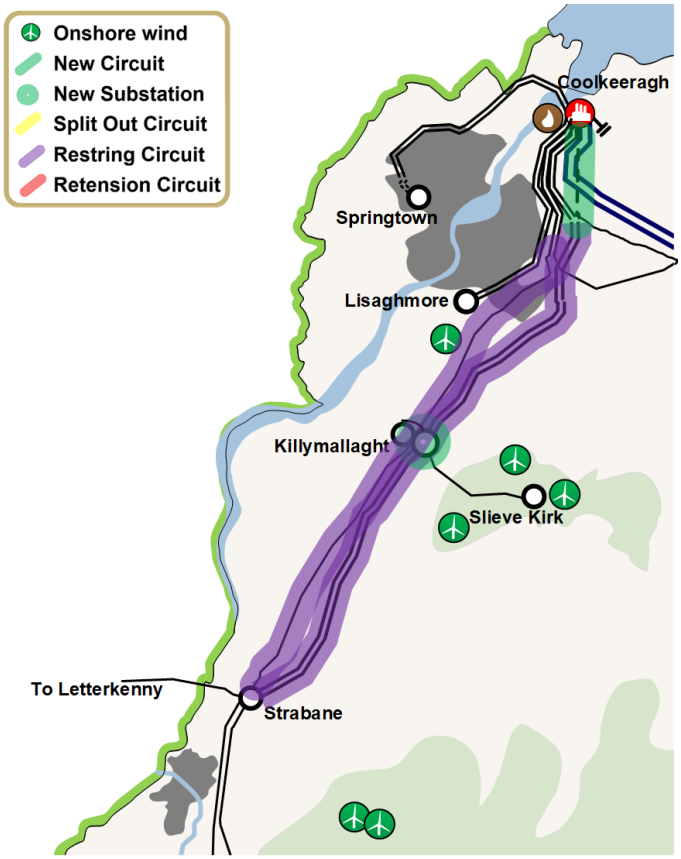

Figure 3.7: Map showing Option 4C.

3.5 Option 5: New circuit

Option 5 considers building a new circuit from Coolkeeragh to Strabane which will follow closely to the route of the current Coolkeeragh- Strabane circuit. Like in Option 3, described in section 3.3, a new circuit would need to be cabled out of Coolkeeragh for around 7.25km.

The existing 110kV mesh at Strabane substation will require an extension to provide an additional bay for the newly established second 110kV circuit between Coolkeeragh and Strabane.

Figure 3.8 provides an indicative overview of the new arrangement.

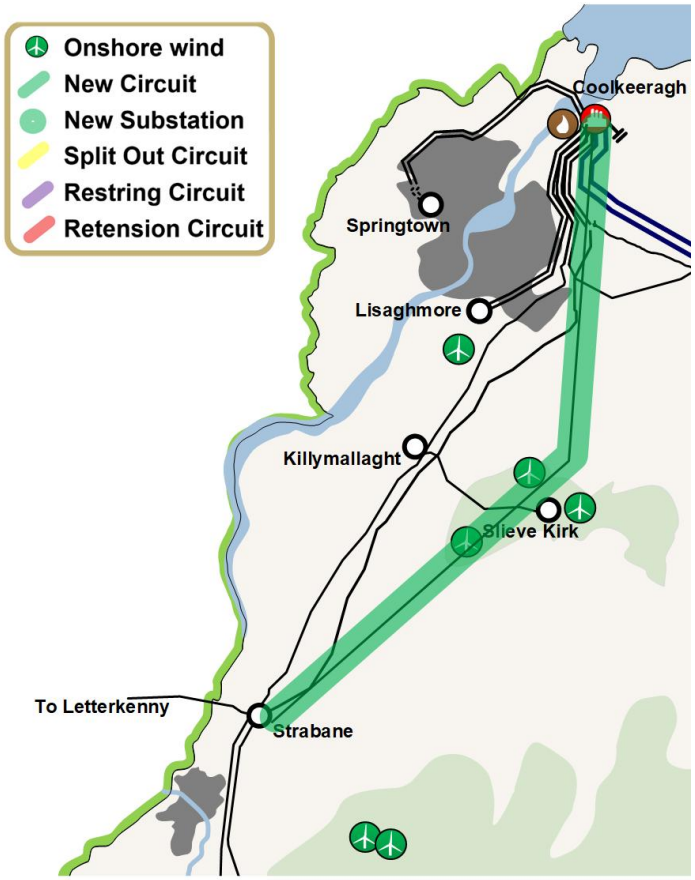

Figure 3.8: Map showing Option 5

There are no sub-options being considered as part of this option.

3.6 Option 6: New substation

Option 6 sees a new 110kV Air Insulated Switchgear (AIS) marshalling substation developed approximately 4km from Coolkeeragh, close to where the 110kV double circuit towers end and the 110kV circuits to the proposed Cam Cluster, Limavady, Coleraine, Killymallaght and Strabane continue as single circuits. All of these 110kV circuits will be turned into the new substation.

This option will re-establish the 110kV double circuit from Mobuoy to Strabane and therefore the existing 110kV mesh at Strabane substation will require an extension to provide an additional bay for the newly established 110kV double circuit between Mobuoy and Strabane.

Figure 3.9 provides an indicative overview of the new arrangement.

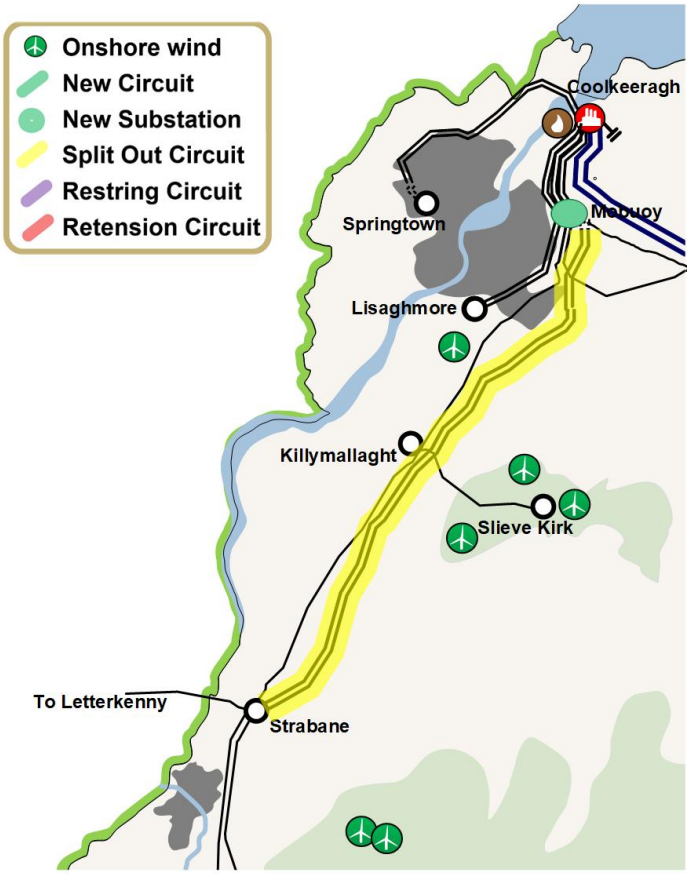

Figure 3.9: Map showing Option 6

There are no sub-options being considered as a part of this option.

4 Comparison of long list of options

4.1 Criteria for comparing the options

The appraisal of the long list is against three criteria:

- A high-level technical assessment of the option;
- A high-level capital cost of the option; and
- A high-level deliverability assessment of the option.

4.2 Technical

As a technical assessment, snapshot studies have been conducted on each of the options of the longlist. A description of what was carried out and the results to these studies can be found in **Appendix A**.

Option 1

Doing nothing results in the existing constraint remaining and increasing in severity as the level of renewable generation connecting increases to meet the 2030 and 2050 targets.

Option 2

By providing additional capacity on the circuits between Coolkeeragh and Strabane, this option results in the reduction of circuit loadings in the intact network condition and following a contingency event. Overloads on the 110kV circuits between the Coolkeeragh and Strabane and Coolkeeragh and Killymallaght circuits are removed; however, each circuit is close to capacity in the event of an outage of the other. This option addresses the immediate problem; however, the risk of overloading is likely to reappear with further renewable generation development and is unlikely to provide long term benefits.

Option 3A

In this option, by creating an additional circuit between Coolkeeragh and Strabane, power flows are shared across more circuits, reducing the loadings on circuits in the intact network condition. are reduced. Overloads following contingency events are removed, however, high power flows close to thermal capacity are observed on all three 110kV circuits. Similarly to Option 2, this option addresses the immediate problem but is unlikely to provide long term benefits.

Option 3B

By not only creating an additional circuit between Coolkeeragh and Strabane but also increasing capacity on all of the circuits in the corridor through uprating the conductor, this option not only addresses the immediate problem, but provides additional capacity for

additional renewable generation in the area. This is one of the strongest performing options technically.

Option 3C

This option preforms almost as strong technically compared to the full restring – the Killymallaght circuits are loaded more under certain contingencies as they are only being re-tensioned but never present overloads or heavy loading.

Option 4A

Splitting the Coolkeeragh - Strabane circuits into Killymallaght proves to be better however still presents the issues Option 3A has. Pre-contingency loading and post-contingency overloads are reduced however the Coolkeeragh – Killymallaght circuits, from the original Coolkeeragh – Strabane circuits that were split, are heavily loaded post-contingency.

Option 4B

This option performs strong in the snapshot studies with circuits never reaching heavy loading pre and post contingencies. This option would facilitate further development in the area post 2030.

Option 4C

This is the strongest option technically. The circuits never get heavily loaded, even under contingency events the circuits remain in a state that will not require any constraining of wind and all the wind energy generated in the west can be passed through these circuits.

Option 5

The third circuit takes some of the flow away from the original circuits however the other circuits; Killymallaght – Strabane and Coolkeeragh – Killymallaght still have similar overloads as the Do Nothing option whenever either of them overloads, so an issue remains for these circuits. This is not a technically complete solution.

Option 6

This solution removes overloads for Coolkeeragh – Strabane but there are still issues with Coolkeeragh – Killymallaght and pushes the problem onto other circuits such as Coolkeeragh – Limavady causing overloads elsewhere. This option essentially moves where the mitigation measure is required rather than removing the need for it.

4.3 Capital cost

Table 4.1 summarises the capital costs of all the options, broken down into TSO (preconstruction and consents) and TO (construction) costs. The options range from £12.29m to £65.74m. A full breakdown of the capital cost of each option is provided in **Appendix B**.

Table 4.1: High level costs of the longlist of options

Option	Description	Cost (£m)		
		TSO	TO	Total
1	Do nothing	0.0	0.0	**0.0**
2	Upgrade all existing circuits		12.29	
3A	Restore Coolkeeragh to Strabane double circuit		19.75	
3B	Restore and upgrade all circuits		44.97	
3C	Restore and upgrade double circuit		35.81	
4A	Rebuild only		40.73	
4B	Rebuild, upgrade Coolkeeragh to Strabane		49.59	
4C	Rebuild, upgrade all circuits		65.74	
5	New Coolkeeragh to Strabane circuit		38.04	
6	Switching station south of Coolkeeragh		39.34	

4.4 Deliverability

Option 2

For restringing NIEN should be able to access all the towers in this corridor. One note is that two of the Coolkeeragh – Killymallaght/ Coolkeeragh – Limavady DCTs are in the Mobuoy Waste site. There is a remediation project underway to rectify the issues, due to illegal dumping at Mobuoy[2], and NIEN have full access to the tower. There are mounds growing under these DCTs and therefore intrusive foundation inspections will be necessary.

Only part of the Coolkeeragh – Strabane circuit is being uprated in this option and therefore the earth wire will not be replaced for this circuit. There is an opportunity to increase protection in this area by installing earth wire with fibre/ comms provision whilst uprating Coolkeeragh – Killymallaght and Killymallaght – Strabane. The existing portal sections may require additional pole sets and angle tower foundation upgrades to be able to carry a new conductor and to establish the earth wire with upward earthing brackets to existing pole sets and steel towers. There are occasions when these two circuits pass homes, whose curtilage are under the circuit and therefore wayleave amendments may be required.

The restring works for these circuits 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. Addition of an earth wire on the portal sections may require planning permission. This will be better understood during Part 1 stakeholder engagement and if necessary full planning permission will be checked for all construction works associated with this proposal.

The deliverability of this option is considered to be deliverable.

Option 3A

A new cable section is required for connecting the Coleraine circuit to Coolkeeragh and splitting out the ‘B’ circuit. This is approximately 6.3 km. This cable section is reliant on connecting into a new bay in the Coolkeeragh extension and requires a new cable sealing end tower to connect in Coleraine where the double circuit begins as well as the removal of the jumper arrangement on the existing double circuit back to Strabane. Coolkeeragh has been approved for an extension meaning and a new bay there has been allocated for the second circuit. The additional cable would require a new route, which would become clearer during the detailed design part of preconstruction.

To split these circuits into two live circuits the second circuit will require a bay in Strabane to terminate into and the jumper arrangement connecting the ‘B’ circuit will need to be

[2] The Mobuoy Remediation Project | Department of Agriculture, Environment and Rural Affairs

removed (this includes the cable linking both circuits before entering the existing mesh circuit bay at Strabane). Strabane will need a mesh extension. NIEN have informed that it is not possible to extend the 110kV mesh substation within the existing footprint. They would not be able to achieve the safety clearances from live structures during the construction stage and there would not be sufficient space to set up a crane to allow any new structures or equipment to be erected. This will therefore involve land purchase from the neighbouring field and extension of the mesh to construct two new bays. The existing concrete structures which support the 110kV equipment need to be replaced in the next 10-15 years due to their age. Another factor is that Strabane is a hot earthing site, therefore soil resistivity samples will need to be checked. Other options for Strabane, including a new substation, may need to be considered and evaluated given the planned asset replacement works and the possibility of new 110kV connections in the surrounding area.

The deliverability of this option is considered to be deliverable.

Option 3B

Combined level of deliverability as Option 2 and Option 3A. There is added difficulty with the restring of the Coolkeeragh – Strabane A and B circuits from Mobuoy – Strabane (not included in the restring option of Option 2). These circuits are 22.2km long DCT and go through rural areas so there should not be too many issues in restringing them. Therefore, there will be more undercrossings with 33kV and 11kV circuits.

The deliverability of this option is considered to be challenging.

Option 3C

Combined level of deliverability as Option 2 and the restring of Coolkeeragh – Strabane of Option 3B. A re-tension of the Coolkeeragh – Killymallaght and Coolkeeragh – Strabane should be more deliverable than a restring. Access would be the main consideration with built up areas like Altnagelvin.

The deliverability of this option is considered to be deliverable.

Option 4A

This option is based on establishing a new 110kV switching station at a site nearby the original Killymallaght substation and using the original as a transformer feeder. There would be considerable disruption to turn in the 110kV OHLs. This requires cable to connect the two Killymallaght stations and Killymallaght – Strabane and any other circuit in this project that doesn't pass over the site chosen for this rebuild (as depicted in **Error! Reference source not found.**).

The establishment of a new Killymallaght would involve purchasing land and getting planning permission to build a new substation. The delivery of this would involve extensive stakeholder engagement with landowners, the procurement of an appropriate sites, outline design of the substation, new terminal towers and a planning application. This switching station would be built nearby the original Killymallaght substation which may be difficult to get landowners nearby in agreement for a second station in the vicinity. The split involves similar deliverability to Option 3A.

The deliverability of this option is considered to be challenging.

Option 4B

The deliverability is similar to Option 4A with the added difficulty of restringing the Coolkeeragh – Strabane 'A' and 'B' circuits from Coolkeeragh to Killymallaght.

The deliverability of this option is considered to be challenging.

Option 4C

Option 4C combines the level of deliverability of Option 3B and Option 4A. This option would require 4.5 years, and the estimated completion date is 2037 (starting construction in 2033).

The deliverability of this option is considered to be very challenging due to the volume of construction and access required.

Option 5

Option 5 proposes approximately 24 km of new overhead line and 7.25 km of cable. A study area identified for approximately 31.25 km of circuit would be subject to landowner engagement, environmental appraisal and planning permission.

It is not yet clear of the environmental or technical challenges associated with this option; however, it would be considered that a new circuit would have a larger impact than most options in the longlist. The associated works to extend Strabane (as with the split) are required in order to have a bay to terminate this circuit.

The deliverability of this option is considered to be very challenging.

Option 6

This option is based on establishing a new 110kV substation at a site appropriate to turn in all the adjacent 110kV lines. There would be considerable disruption to the 110kV OHLs for this option. It involves purchasing land and getting planning permission to build a new substation. The delivery of this would involve extensive stakeholder engagement with

landowners, the procurement of an appropriate sites, outline design of the substation, new terminal towers and a planning application.

There is also the added complication of the illegal waste disposal at Mobuoy Road Waste Site which could potentially involve remedial works.

The deliverability of this option is considered to be very challenging.

4.5 Assessment of the longlist

Less favourable **More favourable**

Table 4.x: Comparative performance of longlist of options

Option	Description	Score			
		Technical	Cost	Deliverability	Overall
1	Do nothing				
2	Upgrade all existing circuits				
3A	Restore Coolkeeragh to Strabane double circuit				
3B	Restore and upgrade all circuits				
3C	Restore and upgrade double circuit				
4A	Rebuild Killymallaght only				
4B	Rebuild Killymallaght, upgrade Coolkeeragh to Strabane				
4C	Rebuild Killymallaght, upgrade all circuits				
5	New Coolkeeragh to Strabane circuit				
6	Switching station south of Coolkeeragh				

5 Short list of options

Following assessment of the longlist of options, table 5.1 lists the options shortlisted for further investigation.

Table 5.1: Shortlist of options

Option	Description
1	Do nothing
2	Upgrade all existing circuits
3A	Restore Coolkeeragh to Strabane double circuit
3C	Restore and upgrade double circuit

6 Comparison of short list of options

6.1 Criteria for comparing the options

6.1.1 Technical performance

The shortlisted options will be compared against the reduction in energy constrained and the reduction in constraint costs.

6.1.2 Cost

The shortlisted options will be compared against the following criteria:

- The capital cost of the option
- The Net Present Cost of the option

6.1.3 Deliverability

The shortlisted options will be compared against the following criteria:

- The complexity and potential challenges associated with delivering the option; and
- The estimated year the option can be delivered.

6.1.4 Environmental

Each option will have a high-level assessment of its potential social and environmental impacts.

6.2 Technical performance

6.2.1 Impact on constraints

Table 6.1 shows the reduction in constraints in 2035 for each option, with each option showing a significant reduction in constraints on renewable energy, from constraints of £24.6 million and 321.3GWh in 2035. This reduction is particularly evident in Option 3C and 4B.

Table 6.1: Technical assessment of shortlist of options

Option	Description	Reduction in constraints	
		Energy (GWh)	Cost (£m)
1	Do nothing	N/A	N/A
2	Upgrade all existing circuits	148.0	11.33
3A	Restore Coolkeeragh to Strabane double circuit	171.2	13.10
3C	Restore and upgrade double circuit	299.1	22.89

6.2.2 Summary of technical performance

Table 6.2 shows a summary of the technical performance of each of the shortlisted options.

Table 6.2: Technical assessment of shortlist of options

Option	Description	Score
1	Do nothing	
2	Upgrade all existing circuits	
3A	Restore Coolkeeragh to Strabane double circuit	
3C	Restore and upgrade double circuit	

6.3 Cost

6.3.1 Capital Cost

Table 6.3 shows the capital cost of each of the shortlisted options. Option 4B has a very high cost but Options 2, 3A and 3C have relatively low capital costs.

Table 6.3: Capital cost of shortlist of options

Option	Description	Capital cost of option (£m)
1	Do nothing	0
2	Upgrade all existing circuits	12.29
3A	Restore Coolkeeragh to Strabane double circuit	19.75
3C	Restore and upgrade double circuit	35.81

6.3.2 Net Present Cost

Table 6.4 presents the results of the Net Present Cost (NPC) analysis. The results for both the standard NPC analysis, and the NPC analysis taking the impact of CO_2 emissions into account, are shown. A negative value denotes an improvement over the do-nothing baseline. Option 3C sees the biggest reduction in NPC compared to the baseline do-nothing option for both calculations. The change is from £420.30m without taking carbon pricing into account, and £759.18m with taking it into account. The method for taking carbon pricing into account was the same as is used for the Connect West project, with this method being laid out in the Appendix C of this document.

Table 6.4: Capital cost of shortlist of options

Option	Description	Change in NPC (£m)	
		Without CO_2	With CO_2
1	Do nothing	0	0
2	Upgrade all existing circuits	-146.6	-282.15
3A	Restore Coolkeeragh to Strabane double circuit	-165.1	-338.27
3C	Restore and upgrade double circuit	-281.1	-556.81

6.3.3 Summary of cost

Table 6.5 shows a summary of the cost of each of the shortlisted options.

Table 6.5: Cost assessment of shortlist of options

Option	Description	Score		
		Cost	NPC	Overall
1	Do nothing	N/A		
2	Upgrade all existing circuits			
3A	Restore Coolkeeragh to Strabane double circuit			
3C	Restore and upgrade double circuit			

6.4 Deliverability

6.4.1 Complexities and challenges

Option 2

The complexity of restringing the existing circuits is quite low given that there will be no additional infrastructure required for the grid. As part of the preconstruction of this option, inspections would have to be carried out on the towers on the route, and a conductor assessment would need to be carried out. Depending on the results of these assessments, the complexity of the option could increase.

The outages from restringing can be quite significant with a long return to service. Only one circuit can be taken out at a time and therefore there will be sometime between each restring. This will lead to significant wind generation constraint during the outage of each of these circuits. This option would require less than 3 years for construction and there would be outages with associated constraints for all three circuits. The estimated construction start date would be in 2033.

Option 3A

For all of the sub-options as part of Option 3 there will need to be an extension of Strabane Main substation to accommodate the extra circuit required as part of these options. A cable will need to be laid between Coolkeeragh and Mobuoy (which is where the existing Coolkeeragh- Strabane and Coolkeeragh- Coleraine circuits split off from each other) to accommodate the new circuit too. The cable would have obstacles entering the Coolkeeragh site. Some of the significant projects with planning around Coolkeeragh include:

- A transmission connected data centre;
- A Battery Energy Storage System (BESS); and
- A synchronous condenser.

Coolkeeragh is a congested area. North of Coolkeeragh there are railway tracks and the River Foyle. To the East is an industrial and commercial development and the River Faughan. To the South is the Maydown Road, which has 33kV and 275kV circuits, a transmission gas pipeline and distribution gas pipe. It is highly unlikely that there is room in the Maydown Road or road verges for this cable. The most viable cable route will require easements secured in lands to the South of Maydown Road.

There will also need to be an extension to the Strabane 110kV mesh to the east of the substation, which should not add too much complication. An illustration of this extension can be seen in Figure 6.1 below.

Figure 6.1: Strabane Mesh Extension to the east

Figure 6.2 below shows a Single Line Diagram of what a possible extension to Strabane Main 110kV Substation would look like.

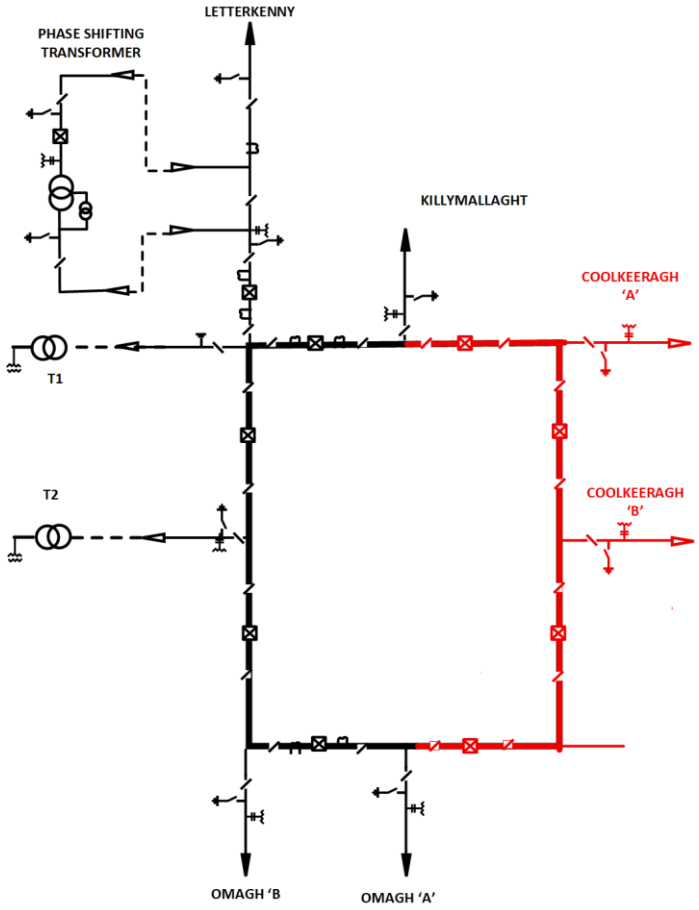

Figure 6.2: Single Line Diagram of possible extended Strabane Main 110kV Substation

This option would require 2 years for construction and there would be outages with associated constraints on the Coleraine line. The estimated construction start date would be in 2033.

Option 3C

Part of the complexity of this option is the same as Option 3A due to a required extension of Strabane 110kV Main Substation, as can be seen in Figures 6.1 and 6.2 above, and the need of a cable between Coolkeeragh and Mobuoy to accommodate the additional circuit without having to build more tower lines. Another smaller layer of complexity to this option is the restring of the Coolkeeragh - Strabane circuits, which has the same complexity as Option 2. Additionally, the retensioning of the Coolkeeragh- Killymallaght and Killymallaght-Strabane circuits, which will be relatively low impact, will add to the overall complexity of the option.

The outages from restringing can be quite significant with a long return to service. Only one circuit can be taken out at a time and therefore there will be considerable time between

each restring. This will lead to significant wind generation constraint during the outage of each of these circuits.

This option would require less than 3 years for construction and there would be several outages with associated constraints. The estimated date for construction starting is 2033.

6.4.2 Estimated date of completions

Table 6.6 shows the estimated year of delivery of each of the options.

Table 6.6: Estimated year of delivery of each of the shortlisted options

Option	Description	Estimated year of delivery
1	Do nothing	N/A
2	Upgrade all existing circuits	2035
3A	Restore double circuit	2035
3C	Restore and upgrade double circuit	2036

6.4.3 Summary of deliverability

Less favourable **More favourable**

Table 6.7 shows a summary of the deliverability of each of the shortlisted options.

Table 6.7: Deliverability assessment of shortlist of options

Option	Description	Score		
		Complexity	Date	Overall
1	Do nothing	N/A	N/A	N/A
2	Upgrade all existing circuits			
3A	Restore double circuit			
3C	Restore and upgrade double circuit			

6.5 Environmental

6.5.1 Environmental assessment of the shortlisted options

Option 2

In Option 2 there is no new infrastructure being built so the environmental impact of the option is quite low. However, there is a possibility that some of the towers would need replaced, depending on which conductor is chosen for the restring following the conductor assessment to be carried out by the TO post project approval. There will be minimal social impact as part of this option.

Option 3A

For Option 3A the main impact on the environment will be the new cable section between Mobuoy and Coolkeeragh which may be via road network and agricultural land. There will be crossings of the River Faughan, the A2 and a golf course and would be considered a constraint as they require horizontal directional drilling (HDD) during the construction stage. SONI and NIE Networks will include for this during detailed design in Part 2 of the Grid development process. There may also be a social and environmental impact to the option due to cabling (via HDD) under the golf course and also the extension of Strabane 110kV substation which will be into an adjacent field.

Option 3C

The environmental impact of Option 3C is a partial combination of Option 2 and Option 3A, as there will be a restring in this option alongside the creation of the cable section between Mobuoy and Coolkeeragh. As there is a retensioning of the Coolkeeragh- Killymallaght and Killymallaght- Strabane circuits this might have a lesser environmental impact as there is less chance of a need to replace any towers of either circuit. The social impact of this option will be the same as for Option 3A.

6.5.2 Summary of environmental assessment

Table 6.8 shows the environmental assessment of each of the shortlisted options.

Table 6.8: Environmental assessment of shortlist of options

Option	Description	Score
1	Do nothing	N/A
2	Upgrade all existing circuits	
3A	Restore double circuit	
3C	Restore and upgrade double circuit	

6.6 Assessment of the shortlist

Table 6.9 shows the combined performance of each of the shortlisted options.

Table 6.9: Combined performance of shortlist of options

Criteria	Option			
	0	2	3A	3C
Technical				
Cost				
Deliverability	N/A			
Environmental	N/A			
Overall score				

7 Preliminary preferred option

Option 3C: Split Coolkeeragh – Strabane into two live circuits, extend Strabane 110kV mesh substation, restring the two Coolkeeragh- Strabane circuits, cable from Coolkeeragh to Mobuoy to connect into Coleraine and retension Coolkeeragh – Killymallaght and Killymallaght – Coolkeeragh is the preferred option. This option has the fourth least cost involved (estimated £35.8 million) and has the lowest net present value cost over a 40-year period (considering the capital costs, wind farm constraints, carbon costs, operation and maintenance). This option performs well in reducing wind farm constraints by providing a significant increase in thermal capacity and redundancy for the Coolkeeragh – Strabane 110kV circuits.

The restring conductor has been modelled with Invar for this report, however NIE Networks will investigate suitable conductors which may have a significantly higher rating and reduction in line losses. This is a part of their preconstruction works and will be reviewed at Part 2 of the project.

Selection of the preferred solution and completion of the Part 1 stage of the SONI Grid Development Process was subject to stakeholder engagement.

8 Summary of stakeholder engagement

SONI has carried out a high-level stakeholder engagement exercise with the local authorities affected by the project. This has allowed the TNPP submission to be finalised and submitted to the Utility Regulator.

The local constituencies that are affected by this project include:

- Foyle;
- East Londonderry; and
- West Tyrone

The local authorities that are affected by this project include:

- Derry City and Strabane District Council

SONI has engaged 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[3]. 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.

8.1 Part 1 stakeholder engagement

In accordance with SONI's Three Part Process for Grid Development for Northern Ireland this stakeholder engagement was commenced during Part 1 of project development.

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

Appendix A: Thermal Network Analysis

The results of the network analysis are presented for all circuits between Coolkeeragh and Strabane associated with each option. Three scenarios are considered:

- **Intact network**- the loading on the normal network configuration with no planned or unplanned outages;
- **N-1**- the highest loading observed on the network following the outage of any single circuit; and
- **N-DC**- the highest loading observed on the network following the outage the 275 kV double circuit between Coolkeeragh and Magherafelt.

For each of the three scenarios, three demand scenarios are assessed: winter peak (**WP**), summer peak (**SP**) and summer minimum (**Sm**).

All results are presented as a percentage of the rated capacity of each circuit.

Table A.1: Load flow analysis for Option 1

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	74	78	74	112	119	114	24	24	27
Coolkeeragh – Strabane 'A'	59	64	61	115	124	118	52	51	59
Killymallaght – Strabane 'A'	17	16	7	87	89	80	80	79	78

Table A.2: Load flow analysis for Option 2

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	62	59	56	94	89	87	17	17	19
Coolkeeragh – Strabane 'A'	50	49	48	97	93	90	40	40	46
Killymallaght – Strabane 'A'	16	13	7	74	68	62	60	60	59

Table A.3: Load flow analysis for Option 3A

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	70	74	72	90	90	84	25	25	26
Coolkeeragh – Strabane 'A'	41	43	43	77	80	77	31	31	40
Coolkeeragh – Strabane 'B'	47	49	49	86	89	86	35	35	46
Killymallaght – Strabane 'A'	19	17	10	97	89	80	75	75	73

Table A.4: Load flow analysis for Option 3B

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	59	56	52	75	69	63	17	18	16
Coolkeeragh – Strabane 'A'	27	26	25	48	46	44	19	20	22
Coolkeeragh – Strabane 'B'	31	30	29	55	53	50	21	23	26
Killymallaght – Strabane 'A'	18	16	10	74	68	62	55	57	56

Table A.5: Load flow analysis for Option 3C

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	67	69	65	80	82	77	25	30	25
Coolkeeragh – Strabane 'A'	27	26	25	50	47	45	21	22	24
Coolkeeragh – Strabane 'B'	27	26	25	50	47	45	21	22	24
Killymallaght – Strabane 'A'	17	16	8	80	81	73	60	69	68

Table A.6: Load flow analysis for Option 4A

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	54	57	54	81	85	81	21	23	30
Coolkeeragh – Killymallaght 'B'	66	69	66	93	98	93	37	30	38
Coolkeeragh – Killymallaght 'C'	44	47	45	66	71	67	17	19	25
Killymallaght – Strabane 'A'	25	27	25	37	40	37	50	55	59
Killymallaght – Strabane 'B'	25	27	25	37	40	37	50	55	59
Killymallaght – Strabane 'C'	20	22	21	28	31	29	40	45	48

Table A.7: Load flow analysis for Option 4B

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	44	50	50	81	85	81	13	13	17
Coolkeeragh – Killymallaght 'B'	53	61	61	76	87	86	18	18	23
Coolkeeragh – Killymallaght 'C'	36	42	41	53	63	62	14	14	18
Killymallaght – Strabane 'A'	17	19	20	24	28	30	50	55	59
Killymallaght – Strabane 'B'	17	19	20	24	28	30	50	55	59
Killymallaght – Strabane 'C'	13	16	17	19	22	24	40	45	48

Table A.8: Load flow analysis for Option 4C

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	35	33	32	52	50	48	13	13	17
Coolkeeragh – Killymallaght 'B'	43	41	40	59	56	54	18	18	23
Coolkeeragh – Killymallaght 'C'	37	35	33	55	53	50	14	14	18
Killymallaght – Strabane 'A'	16	16	15	23	23	21	33	33	35
Killymallaght – Strabane 'B'	16	16	15	23	23	21	33	33	35
Killymallaght – Strabane 'C'	16	16	15	23	23	21	33	33	35

Table A.9: Load flow analysis for Option 5

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Killymallaght 'A'	65	68	64	86	90	81	25	25	24
Coolkeeragh – Strabane 'A'	45	48	46	77	81	78	39	38	44
Coolkeeragh – Strabane 'B'	25	23	22	41	38	36	19	19	21
Killymallaght – Strabane 'A'	23	22	16	87	89	80	71	71	69

Table A.10: Load flow analysis for Option 6

Circuit	Intact network (%)			N-1 (%)			N-DC (%)		
	WP	SP	Sm	WP	SP	Sm	WP	SP	Sm
Coolkeeragh – Mobuoy 'A' (Strabane turn in)	60	66	65	80	85	85	24	28	35
Coolkeeragh- Mobuoy 'B' (Killymallaght turn in)	46	50	50	67	73	71	19	22	26
Coolkeeragh- Mobuoy 'C' (Cam turn in)	51	60	60	75	89	86	20	26	32
Coolkeeragh- Mobuoy 'D' (Limavady turn in)	69	82	81	102	120	116	28	35	43
Strabane- Mobuoy 'A'	38	41	39	79	82	78	33	38	42
Strabane- Mobuoy 'B'	38	41	39	79	83	78	33	38	43
Mobuoy- Killymallaght	79	82	77	90	95	88	27	31	29
Killymallaght- Strabane	14	14	4	87	89	80	70	70	69

Appendix B: Estimated Costs

Table B.1: Estimated costs for Option 2

Item description	Unit cost (£m)	No.	£m	Notes
Overhead line works: Coolkeeragh to Killymallaght				
Uprate with Invar conductor	0.172	5.8	1.00	Restring portal section
Uprate with Invar conductor	0.172	8.75	1.51	Restring tower line section
Earth wire with fibre/Comms provision	0.06	14.55	0.92	From other project cost estimates
CT changes for protection upgrade	0.10	1.00	0.10	110kV, 40 kA.
Overhead line works: Coolkeeragh to Strabane				
Uprate with Invar conductor	0.172	4.8	0.83	Coolkeeragh - Mobuoy section
Overhead line works: Killymallaght to Strabane				
Uprate with Invar conductor	0.172	11.2	1.93	
Earth wire with fibre/Comms provision	0.06	11.2	0.71	From other project cost estimates
CT changes for protection upgrade	0.10	1.00	0.10	110kV, 40 kA.
Refurbishment				
Refurbish existing structures	3.08	1	3.08	Estimate from recent projects
Undercrossings				
33 kV undercrossings - Coolkeeragh - Mobuoy	0.06	3	0.18	
33 kV undercrossings - Coolkeeragh - Killymallaght	0.06	7	0.42	
11 kV undercrossings - Coolkeeragh - Mobuoy	0.03	3	0.09	
11 kV undercrossings - Coolkeeragh - Killymallaght	0.03	6	0.18	
11 kV undercrossings -Strabane - Killymallaght	0.03	5	0.15	
TO costs				
Estimate of TO costs			**11.18**	
Contingency (10%)			**1.12**	
Total			**12.29**	
TSO costs (Preconstruction and consents)				
Preconstruction				
Total				
Combined TSO and TO costs				
Total				

Table B.2: Estimated costs for Option 3a

Item description	Unit cost (£m)	No.	£m	Notes
Strabane substation works				
Land purchase	0.53	1	0.53	From other project cost estimate
Mesh extension pre-enabling works	3.06	0.5	1.53	Restring tower line section
Mesh extension	1.28	3	3.84	From other project cost estimates
Equip new mesh bays	0.09	3	0.27	From other project cost estimates
New terminal towers	0.09	2.00	0.176	Portal terminal towers
Cable to new terminal towers	0.16	1.00	0.16	Approx. 50m for each circuit
110kV protection on new circuit	0.08	1.00	0.08	Main distance, overcurrent
Coolkeeragh substation works				
110kV AIS DBB Bay	0.79	1	0.79	
Coleraine circuit works				
200 MVA cable	1.58	6.3	9.92	
Directional drilling	0.58	1	0.58	From other project cost estimates
Cable sealing end tower	0.09	1	0.09	
TO costs				
Estimate of TO costs			**17.96**	
Contingency (10%)			**1.80**	
Total			**19.75**	
TSO costs (Preconstruction and consents)				
Preconstruction				
Total				
Combined TSO and TO costs				
Total				

Table B.3: Estimated costs for Option 3b

Item description	Unit cost (£m)	No.	£m	Notes
Strabane substation works				
Purchase of land beside existing 110kV substation	0.53	1	0.53	Approximate based on other project cost estimate with inflation
Mesh extension pre-enabling works	3.06	0.5	1.53	Only a fraction of the cost provided from the database is necessary.
110kV mesh extension Strabane	1.28	3	3.84	Mesh extension for 2 new bays (equipping 1), moving 2 bays and replacement of 4S0 and 7S0.
110kV AIS DBB Bay Coolkeeragh	0.79	1	0.79	
Equip bays in mesh extension Strabane	0.09	3	0.27	SONI estimate based on other project cost estimate
Terminal towers for Coolkeeragh - Strabane circuit split	0.09	2	0.18	Establish two new 110kV portal terminal towers and downdroppers at Strabane
2000 mm^2 Al XLPE (200 MVA)	0.16	1	0.16	Cable allowed from terminal tower into Strabane for both circuits, approximately 50 m each.
Coleraine cable works				
New 200 MVA cable section	1.58	6.3	9.92	Approx. estimate of cable (3 km to river, 0.3km for directional drill and another 3km to Mobuoy) for Coolkeeragh - Coleraine circuit.
Directional drill under river and golf course	0.58	1	0.58	SONI estimate from other project cost estimate. Approximately 300m.
New cable sealing end tower for the new 200 MVA cable section connection to the existing portal sections	0.09	1	0.09	SONI estimate based on Drumnakelly
Overhead line works: Coolkeeragh – Strabane				
110kV Line Uprate with Invar conductor	0.172	54	9.30	Restring tower line section - A and B circuit
Earth wire with fibre/Comms provision - double circuit section	0.06	27	1.62	Estimate from Other project cost estimate
110kV Main Distance protection and directional overcurrent protection	0.08	1	0.08	For the new Coolkeeragh-Strabane
Overhead line works: Killymallaght – Strabane				
110kV Line uprate with Invar conductor	0.172	11.2	1.93	Restring portal section
Earth wire with fibre/Comms provision - double circuit section	0.06	11.2	0.67	Estimate from Other project cost estimate
CT changes associated with upgrading the protection	0.10	1.00	0.10	Estimate based of previous projects, 110kV and 40 kA.

Table B.3: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
Overhead line works: Coolkeeragh- Killymallaght				
110kV Line uprate with Invar conductor	0.172	5.8	1.00	Restring portal section
110kV Line Uprate with Invar conductor	0.172	8.75	1.51	Restring tower line section
Refurbishment				
Refurb existing tower line and portal sections for restring works	4.82	1	4.82	Approx. cost estimate for double circuit tower line and portal section foundation replacements - based off recent transmission projects
Undercrossings				
33 kV undercrossings - Coolkeeragh - Strabane	0.06	6	0.36	
33 kV undercrossings - Coolkeeragh - Killymallaght	0.06	7	0.42	
33 kV undercrossings - Strabane - Killymallaght	0.06	1	0.06	
11 kV undercrossings - Coolkeeragh - Strabane	0.03	27	0.81	
11 kV undercrossings - Coolkeeragh - Killymallaght	0.03	6	0.18	
11 kV undercrossings - Strabane - Killymallaght	0.03	5	0.15	
TO costs				
Estimate of TO costs			**40.88**	
Contingency (10%)			**4.09**	
Total			**44.97**	
TSO costs (Preconstruction and consents)				
Total				
Combined TSO and TO costs				
Total				

Table B.4: Estimated costs for Option 3c

Item description	Unit cost (£m)	No.	£m	Notes
Strabane substation works				
Purchase of land beside existing 110kV substation	0.53	1	0.53	Approximate based on other project cost estimate with inflation
Mesh extension pre-enabling works	3.06	0.5	1.53	Only a fraction of the cost provided from the database is necessary.
110kV mesh extension Strabane	1.28	3	3.84	Mesh extension for 2 new bays (equipping 1), moving 2 bays and replacement of 4S0 and 7S0.
110kV AIS DBB Bay Coolkeeragh	0.79	1	0.79	
Equip bays in mesh extension Strabane	0.09	3	0.27	SONI estimate based on other project cost estimate
Terminal towers for Coolkeeragh - Strabane circuit split	0.09	2	0.18	Establish two new 110kV portal terminal towers and cable sealing ends at Strabane.
2000 mm^2 Al XLPE (200 MVA)	0.16	1	0.16	Cable allowed from terminal tower into Strabane for both circuits, approximately 50 m each.
Coleraine cable works				
New 200 MVA cable section	1.58	6.3	9.92	Approx. estimate of cable (3 km to river, 0.3km for directional drill and another 3km to Mobuoy) for Coolkeeragh - Coleraine circuit.
Directional drill under river and golf course	0.58	1	0.58	SONI estimate from other project cost estimate. Approximately 300m.
New cable sealing end tower for the new 200 MVA cable section connection to the existing portal sections	0.09	1	0.09	SONI estimate based on Drumnakelly
Overhead line works: Coolkeeragh – Strabane				
110kV Line Uprate with Invar conductor	0.172	54	9.30	Restring tower line section - A and B circuit (including span at Mobuoy)
Earth wire with fibre/Comms provision - double circuit section	0.06	27	1.62	Estimate from Other project cost estimate
110kV Main Distance protection and directional overcurrent protection	0.08	1	0.08	For the new Coolkeeragh-Strabane
Overhead line works: Killymallaght – Strabane				
Retension	0.50	0.3	0.16	Based on a scale of Omagh - Strabane Retension with inflation
Overhead line works: Coolkeeragh- Killymallaght				
Retension	0.50	0.4	0.20	Based on a scale of Omagh - Strabane Retension with inflation

Table B.4: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
Refurbishment				
Refurb existing tower line and portal sections for restring works	2.15	1	2.15	Approx. cost estimate for double circuit tower line and portal section foundation replacements - based off recent transmission projects
Undercrossings				
33 kV undercrossings - Coolkeeragh - Strabane	0.06	6	0.36	
11 kV undercrossings - Coolkeeragh - Strabane	0.03	27	0.81	
TO costs				
Estimate of TO costs			**32.55**	
Contingency (10%)			**3.26**	
Total			**35.81**	
TSO costs (Preconstruction and consents)				
Total				
Combined TSO and TO costs				
Total				

Table B.5: Estimated costs for Option 4a

Item description	Unit cost (£m)	No.	£m	Notes
Killymallaght substation works				
New Killymallaght AIS site	0.53	1	0.53	Assumed cost of site purchase
New Killymallaght AIS site pre-enabling	3.06	1	3.06	110kV Substation pre-enabling
New Killymallaght AIS Substation	0.79	11	8.74	New AIS double busbar arrangement for 9 circuits and 2 bus couplers
110kV main distance protection and directional overcurrent protection.	0.08	7	0.55	For 7 circuits
Control building	0.20	1	0.20	SONI estimate
Strabane substation works				
Purchase of land beside existing 110kV substation	0.53	1	0.53	Approximate based on other project cost estimate with inflation
Mesh extension pre-enabling works	3.06	0.5	1.53	Only a fraction of the cost provided from the database is necessary.
110kV mesh extension Strabane	1.28	3	3.84	Mesh extension for 2 new bays, 1 equipped for new circuit connection.
110kV AIS DBB Bay Coolkeeragh	0.79	1	0.79	
Equip bays in mesh extension Strabane	0.09	3	0.27	SONI estimate based on other project cost estimate
Terminal towers for Coolkeeragh - Strabane circuit split	0.09	2.00	0.18	Establish two new 110kV portal terminal towers and cable sealing ends at Strabane
2000 mm2 Al XLPE (200MVA)	0.16	1.00	0.16	Cable allowed from terminal tower into Strabane for both circuits, approximately 50 m each.
Coleraine cable works				
New 200 MVA cable section	1.58	6.3	9.92	Approx. estimate of cable (3 km to river, 0.3km for directional drill and another 3km to Mobuoy) for Coolkeeragh - Coleraine circuit.
Directional drill under river and golf course	0.58	1	0.58	SONI estimate from other project cost estimate. Approximately 300m.
New cable sealing end tower for the new 200 MVA cable section connection to the existing portal sections	0.09	1	0.09	SONI estimate based on Drumnakelly
Overhead line works: Coolkeeragh - Strabane A&B				
Coolkeeragh - Strabane A + B Circuits Turn in	1.055	2	2.11	
110kV Main Distance protection and directional overcurrent protection	0.08	1.00	0.08	For the new Coolkeeragh-Strabane
Overhead line works: Killymallaght - Strabane				
110kV Single circuit wood pole portal with 400mm^2 ACSR	0.45	0.53	0.24	

Table B.5: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
Circuit section removal of part of portal section from circuit (100m)	0.30	1	0.30	SONI estimate based on other project cost estimate
New angle tower for the new OHL connection to the existing portal sections	0.09	2	0.18	SONI estimate
Overhead line works: Coolkeeragh - Killymallaght				
110kV Single circuit wood pole portal with 400mm^2 ACSR	0.45	0.25	0.11	
Circuit section removal of part of portal section from circuit (100m)	0.30	1	0.30	SONI estimate based on Drumnakelly
New angle tower for the new OHL connection to the existing portal sections	0.09	2	0.18	SONI estimate
Overhead line and cable works: Killymallaght - Slieve Kirk				
New cable sealing end tower	0.09	1	0.09	For the new 200 MVA cable section connection to the existing portal sections
Removal of AP1 section from circuit (340m)	0.30	1	0.30	SONI estimate based on other project cost estimate
New 200 MVA cable section - rural	1.35	0.45	0.61	Approx. estimate of 200 MVA cable (450m)
Cable works: Killymallaght - Killymallaght new				
New 200 MVA cable section	1.58	0.65	1.02	Approx. estimate of 200 MVA single cable (650m)
Directional drill under river	0.58	1	0.58	Directional drilling for new single cable section under river
Sealing end including tower	0.09	2	0.18	
TO costs				
Estimate of TO costs			**37.03**	
Contingency (10%)			**3.70**	
Total			**40.73**	
TSO costs (Preconstruction and consents)				
Total				
Combined TSO and TO costs				
Total				

Table B.6: Estimated costs for Option 4b

Item description	Unit cost (£m)	No.	£m	Notes
Killymallaght substation works				
New Killymallaght AIS site	0.53	1	0.53	Assumed cost of site purchase
New Killymallaght AIS site pre-enabling	3.06	1	3.06	110kV Substation pre-enabling
New Killymallaght AIS Substation	0.79	11	8.74	New AIS double busbar arrangement for 9 circuits and 2 bus couplers
110kV main distance protection and directional overcurrent protection.	0.08	7	0.55	For 7 circuits
Control building	0.20	1	0.20	SONI estimate
Strabane substation works				
Purchase of land beside existing 110kV substation	0.53	1	0.53	Approximate based on other project cost estimate with inflation
Mesh extension pre-enabling works	3.06	0.5	1.53	Only a fraction of the cost provided from the database is necessary.
110kV mesh extension Strabane	1.28	3	3.84	Mesh extension for 2 new bays, 1 equipped for new circuit connection.
110kV AIS DBB Bay Coolkeeragh	0.79	1	0.79	
Equip bays in mesh extension Strabane	0.09	3	0.27	SONI estimate based on other project cost estimate
Terminal towers for Coolkeeragh - Strabane circuit split	0.09	2.00	0.18	Establish two new 110kV portal terminal towers and cable sealing ends at Strabane
2000 mm2 Al XLPE (200MVA)	0.16	1.00	0.16	Cable allowed from terminal tower into Strabane for both circuits, approximately 50 m each.
Coleraine cable works				
New 200 MVA cable section	1.58	6.3	9.92	Approx. estimate of cable (3 km to river, 0.3km for directional drill and another 3km to Mobuoy) for Coolkeeragh - Coleraine circuit.
Directional drill under river and golf course	0.58	1	0.58	SONI estimate from other project cost estimate. Approximately 300m.
New cable sealing end tower for the new 200 MVA cable section connection to the existing portal sections	0.09	1	0.09	SONI estimate based on Drumnakelly
Overhead line works: Coolkeeragh - Strabane A&B				
Coolkeeragh - Strabane A + B Circuits Turn in	1.005	2	2.01	
110kV Main Distance protection and directional overcurrent protection	0.08	1.00	0.08	For the new Coolkeeragh-Strabane
Restring A and B to Killymallaght	0.17	30.8	5.31	Invar conductor
Earth wire with fibre/Comms provision - double circuit section	0.06	15.4	0.92	Earth wire for Coolkeeragh - Killymallaght. Estimate from - Other project cost estimate

Table B.6: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
Overhead line works: Killymallaght - Strabane				
New Killymallaght AIS site	0.53	1	0.53	Assumed cost of site purchase
New Killymallaght AIS site pre-enabling	3.06	1	3.06	110kV Substation pre-enabling
New Killymallaght AIS Substation	0.79	11	8.74	New AIS double busbar arrangement for 9 circuits and 2 bus couplers
Overhead line works: Coolkeeragh - Killymallaght				
110kV Single circuit wood pole portal with 400mm2 ACSR	0.45	0.25	0.11	
Circuit section removal	0.30	1	0.30	SONI estimate based on Drumnakelly
New angle tower for the new 230 MVA OHL connection to the existing portal sections	0.09	2	0.18	For the new 230 MVA OHL connection to the existing portal sections
Overhead line and cable works: Killymallaght - Slieve Kirk				
New cable sealing end tower	0.09	1	0.09	For the new 200 MVA cable section connection to the existing portal sections
Removal of AP1 section from circuit (340m)	0.30	1	0.30	SONI estimate based on other project cost estimate
New 200 MVA cable section - rural	1.35	0.45	0.61	Approx. estimate of 200 MVA cable (450m)
All overhead lines				
Refurb existing tower line and portal sections for restring works	1.18	1	1.18	
Cable works: Killymallaght - Killymallaght new				
New 200 MVA cable section	1.58	0.65	1.02	Approx. estimate of 200 MVA single cable (650m)
Directional drill under river	0.58	1	0.58	Directional drilling for new single cable section under river
Sealing end including tower	0.09	2	0.18	
Undercrossings				
33 kV undercrossings - Coolkeeragh - Killymallaght	0.06	5	0.30	
11 kV undercrossings - Coolkeeragh - Killymallaght	0.03	15	0.45	
TO costs				
Estimate of TO costs			**45.08**	
Contingency (10%)			**4.51**	
Total			**49.59**	

Table B.6: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
TSO costs (Preconstruction and consents)				
Total				
Combined TSO and TO costs				
Total				

Table B.7: Estimated costs for Option 4c

Item description	Unit cost (£m)	No.	£m	Notes
Killymallaght substation works				
New Killymallaght AIS site	0.53	1	0.53	Assumed cost of site purchase
New Killymallaght AIS site pre-enabling	3.06	1	3.06	110kV Substation pre-enabling
New Killymallaght AIS Substation	0.79	11	8.74	New AIS double busbar arrangement for 9 circuits and 2 bus couplers
110kV main distance protection and directional overcurrent protection.	0.08	7	0.55	For 7 circuits
Control building	0.20	1	0.20	SONI estimate
Strabane substation works				
Purchase of land beside existing 110kV substation	0.53	1	0.53	Approximate based on other project cost estimate with inflation
Mesh extension pre-enabling works	3.06	0.5	1.53	Only a fraction of the cost provided from the database is necessary.
110kV mesh extension Strabane	1.28	3	3.84	Mesh extension for 2 new bays, 1 equipped for new circuit connection.
110kV AIS DBB Bay Coolkeeragh	0.79	1	0.79	
Equip bays in mesh extension Strabane	0.09	3	0.27	SONI estimate based on other project cost estimate
Terminal towers for Coolkeeragh - Strabane circuit split	0.09	2.00	0.18	Establish two new 110kV portal terminal towers and cable sealing ends at Strabane
2000 mm2 Al XLPE (200MVA)	0.16	1.00	0.16	Cable allowed from terminal tower into Strabane for both circuits, approximately 50 m each.
Coleraine cable works				
New 200 MVA cable section	1.58	6.3	9.92	Approx. estimate of cable (3 km to river, 0.3km for directional drill and another 3km to Mobuoy) for Coolkeeragh - Coleraine circuit.
Directional drill under river and golf course	0.58	1	0.58	SONI estimate from other project cost estimate. Approximately 300m.
New cable sealing end tower for the new 200 MVA cable section connection to the existing portal sections	0.09	1	0.09	SONI estimate based on other project cost estimate
Overhead line works: Coolkeeragh - Strabane A&B				
Coolkeeragh - Strabane A + B Circuits Turn in	1.005	2	2.01	
Circuit section removal	0.30	1	0.30	SONI estimate based on Drumnakelly
Restring A and B full	0.17	54	9.30	Invar conductor
Earth wire with fibre/Comms provision - double circuit section	0.06	15.4	0.92	Earth wire for Coolkeeragh - Killymallaght. Estimate from other project cost estimate

Table B.7: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
110kV Main Distance protection and directional overcurrent protection	0.08	1.00	0.08	For the new Coolkeeragh-Strabane
Overhead line works: Killymallaght - Strabane				
110kV Single circuit wood pole portal with 400mm^2 ACSR	0.45	0.53	0.24	
Circuit section removal	0.30	1	0.30	SONI estimate based on other project cost estimate
New angle tower	0.09	2	0.18	SONI estimate
Restring tower line section	0.17	11	1.89	Invar conductor
Earth wire with fibre/Comms provision - double circuit section	0.06	11	0.66	Estimate from Other project cost estimate
CT changes associated with upgrading the protection	0.10	2.00	0.20	Estimate based of previous projects, 110kV and 40 kA, and a live tank breaker. 1 x Strabane 1 x Killymallaght
Overhead line works: Coolkeeragh - Killymallaght				
110kV Single circuit wood pole portal with 400mm2 ACSR	0.45	0.25	0.11	
Circuit section removal	0.30	1	0.30	SONI estimate based on other project cost estimate
New angle tower for the new 230 MVA OHL connection to the existing portal sections	0.09	2	0.18	For the new 230 MVA OHL connection to the existing portal sections
Restring portal section	0.17	14.3	2.46	Invar conductor
Overhead line and cable works: Killymallaght - Slieve Kirk				
New cable sealing end tower	0.09	1	0.09	For the new 200 MVA cable section connection to the existing portal sections
Removal of AP1 section from circuit (340m)	0.30	1	0.30	SONI estimate based on Drumnakelly-Tamnamore
New 200 MVA cable section - rural	1.58	0.45	0.71	Approx. estimate of 200 MVA cable (450m)
All overhead lines				
Refurb existing tower line and portal sections for restring works	4.82	1	4.82	
Undercrossings				
33 kV undercrossings - Coolkeeragh - Strabane	0.06	3	0.18	
33 kV undercrossings - Coolkeeragh - Killymallaght	0.06	7	0.42	
33 kV undercrossings - Strabane - Killymallaght	0.06	1	0.06	
11 kV undercrossings - Coolkeeragh - Strabane	0.03	27	0.81	

Table B.7: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
11 kV undercrossings - Coolkeeragh - Killymallaght	0.03	6	0.18	
11 kV undercrossings - Strabane - Killymallaght	0.03	5	0.15	
TO costs				
Estimate of TO costs			**59.76**	
Contingency (10%)			**5.98**	
Total			**65.74**	
TSO costs (Preconstruction and consents)				
Total				
Combined TSO and TO costs				
Total				

Table B.8: Estimated costs for Option 5

Item description	Unit cost (£m)	No.	£m	Notes
Strabane substation works				
Purchase of land beside existing 110kV substation	0.53	1	0.53	Approximate based on other project cost estimate with inflation
Mesh extension pre-enabling works	3.06	0.5	1.53	Only a fraction of the cost provided from the database is necessary.
110kV mesh extension Strabane	1.28	3	3.84	Mesh extension for 2 new bays, 1 equipped for new circuit connection.
110kV AIS DBB Bay Coolkeeragh	0.79	1	0.79	
Equip bays in mesh extension Strabane	0.09	3	0.27	SONI estimate based on other project cost estimate
110kV Main Distance protection and directional overcurrent protection	0.08	1.00	0.08	For new Coolkeeragh-Strabane
2000 mm2 Al XLPE (1km, 200MVA)	0.16	0.50	0.08	Cable allowed from terminal tower into Strabane for moving original Coolkeeragh - Strabane.
Overhead line				
230 MVA Portal line	0.45	11	4.92	Zebra conductor cable out of Coolkeeragh to Killymallaght
230 MVA Portal line	0.45	12.79	5.73	Zebra conductor cable out of Coolkeeragh to Killymallaght
Cable sections				
2000sqmm Al XLPE (1km, 200MVA)	1.58	8.73	13.75	Approx. estimate of 200 MVA cable (8.73 km) for Coolkeeragh - Mobuoy
2000sqmm Al XLPE (1km, 200MVA)	1.58	0.66	1.04	Approx. estimate of 200 MVA cable undercrossing Limavady circuit and Slieve kirk
New cable sealing end tower	0.09	3	0.26	For the 200 MVA cable section connections to the existing portal sections.
CTs for changing between OHL and Cable	0.10	2	0.20	Protection for going OHL to underground
Directional drill under river and golf course	0.58	1	0.58	SONI estimate from other project cost estimate. Approx 300m
Undercrossings				
33 kV undercrossings - A circuit	0.06	4	0.24	
11 kV undercrossings - A circuit	0.03	25	0.75	
TO costs				
Estimate of TO costs			**34.58**	
Contingency (10%)			**3.46**	
Total			**38.04**	

Table B.8: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
TSO costs (Preconstruction and consents)				
Total				
Combined TSO and TO costs				
Total				

Table B.8: Estimated costs for Option 6

Item description	Unit cost (£m)	No.	£m	Notes
Works at Mobouy				
Land purchase	1.00	1	1.00	SONI estimate based on recent projects with similar land size.
Substation pre-enabling	3.06	1	3.06	Assume 90mx90m green field site, cut and fill, drainage, stoning, screening, fencing, entrance, earthing, fence and gates. Assumes good ground and access road of 500m.
110kV AIS DBB Bay	0.79	13	10.33	9 circuits (4 links to Coolkeeragh from two existing tower lines), 2 couplers, 2 future spares, space for bus sections
110kV Main Distance protection and directional overcurrent protection for 9 circuits at Mobuoy	0.08	9.00	0.71	2 x Strabane, 1 x Killymallaght, 1 x Limavady, 1 x Cam, 4 x Coolkeeragh
Control building	0.20	1	0.20	SONI estimate
Strabane substation works				
Purchase of land beside existing 110kV substation	0.53	1	0.53	Approximate based on other project cost estimate with inflation
Mesh extension pre-enabling works	3.06	0.5	1.53	Only a fraction of the cost provided from the database is necessary.
110kV mesh extension Strabane	1.28	3	3.84	Mesh extension for 2 new bays, 1 equipped for new circuit connection.
110kV AIS DBB Bay Coolkeeragh	0.79	1	0.79	
Equip bays in mesh extension Strabane	0.09	3	0.27	SONI estimate based on other project cost estimate
Terminal towers for Coolkeeragh - Strabane circuit split	0.09	2.00	0.18	Establish two new 110kV portal terminal towers and cable sealing ends at Strabane
2000 mm2 Al XLPE (1km, 200MVA)	0.16	1	0.16	Cable allowed from terminal tower into Strabane for both circuits
110kV Main Distance protection and directional overcurrent protection	0.08	1.00	0.08	For new Coolkeeragh-Strabane
Turn in of Killymallaght/ Limavady double circuit				
Coolkeeragh - Killymallaght/Limavady dual cable into Mobuoy	2.68	1.5	4.02	2 x 2000sqmm Al XLPE (1km)
Turn in cost (assume cable sealing ends are needed at an existing angle tower)	1.06	1	1.06	Turn in of the DCT
Mobuoy - DCT tower line link cable	2.68	1.5	4.02	2 x 2000sqmm Al XLPE (1km)
Undercrossings				
Turn in cost of Strabane A/B DCT (assume cable sealing ends needed)	1.06	1	1.06	
Turn in cost of Cam circuit (assuming cable sealing ends needed)	0.25	1	0.25	SONI estimate for single portal based off recent projects

Table B.9: ctd.

Item description	Unit cost (£m)	No.	£m	Notes
Cam circuit cable into Mobuoy	1.35	0.59	0.80	
Mobuoy - DCT towerline link cable (600m, using Cam DCT)	2.68	0.6	1.61	2 x 2000sqmm Al XLPE (1km)
Circuit section removal-removal of unused tower line for Coolkeeragh Strabane - 2 towers	0.30	1	0.30	SONI estimate based on Drumnakelly
TO costs				
Estimate of TO costs			**35.76**	
Contingency (10%)			**3.576**	
Total			**39.34**	
TSO costs (Preconstruction and consents)				
Total				
Combined TSO and TO costs				
Total				

Appendix C

Net Present Cost assumptions

The following assumptions were used in these assessments:

- A reasonable programme of works was assumed, taking into account the difficulty of obtaining outages for uprating works.
- 2025, 2030 and 2035 constraints were modelled and were assumed the same in subsequent years.
- No allowance was made for changes in constraints due to completion of subsidiary parts of an option, or increased constraints from outages.

The following reinforcements were assumed complete:

- The Mid Antrim Upgrade project;
- The second North-South Interconnector; and
- The Tamnamore-Drumnakelly uprate project.

Cost of carbon

Carbon costs were calculated on the basis of constrained energy being met by gas generation with average carbon emissions of 539 kg CO_2/MWh and carbon costs as recommended by UK Department for Business, Energy & Industrial Strategy publication Valuation of Energy Use and Greenhouse Gas.

When conducting Net Present Cost assessments on options for network development projects chiefly associated with renewables integration, a cost is included for the energy constrained from renewable sources. This represents future Firmness of this generation (either commercial or physical). This is based on a future estimate of the Average Day Ahead Market Price in the SEM taken from Shaping Our Electricity Future, which for 2030 was €92.13/MWh (approx. £78/MWh).

Renewable generation is promoted as a way of reducing CO_2 emissions associated with electricity generation. In the UK, climate change impacts are increasingly being factored into infrastructure development – for example, in 2020, the proposed 3rd runway at Heathrow Airport was ruled illegal as it did not adequately consider the UK government's commitments to climate change mitigation, and the UK government's road building plan has been challenged over its climate change impacts.

Under the Climate Change Act (Northern Ireland) 2022, the region has a legally binding target of 80% electricity generation from renewable sources, with full decarbonisation by 2050. SONI has included several projects in the Transmission Development Plan NI that will be vital to achieving this aim, and in order to fully account for the impact of the options

being assessed for these projects a carbon cost is included in the Cost-Benefit Analysis/Net Present Value assessment of these projects.

UK Government guidance

An approach to this is outlined in HM Treasury's Green Book[4], and is as follows:

1. Quantify energy use in MWh.
2. Value energy or fuel use (Market price of electricity).
3. Convert energy use into Greenhouse Gas (GHG) emissions (tonnes of CO_2 equivalent [tCO_2e] x value of carbon).
4. Value to society of emissions (GHG values are based on the economic cost of mitigating a unit of carbon. For power generation, this depends on the market price for carbon, under the UK Emissions Trading System).

Further detail on the valuation of Carbon is included in the UK Department for Business, Energy & Industrial Strategy publication Valuation of Energy Use and Greenhouse Gas[5]. This document includes guidelines on the analysing of CO_2 costs arising from electricity projects (section 3.27):

When a policy or project results in a switch from using one fuel to another, this may be analysed in a similar way as when only one fuel is affected. In such situations, it is necessary to consider the impact on the consumption of each fuel separately and apply the appropriate emissions factor to the change in consumption of each fuel (an increase in one, and a reduction in the other).

Applying this to the assessment of options in a SONI network development project, this would mean assessing the CO_2 emissions of any plant required to run to make up for constrained zero-emissions renewable generation under each option under appraisal.

On providing a cost for Carbon, section 3.35 states:

Changes in emissions which occur in the traded sector are valued at the Traded Price of Carbon. The value placed on changes in greenhouse gas (GHG) emissions is currently under review, now the UK has increased its domestic and international ambitions. Accordingly, current central carbon values are likely to undervalue GHG emissions, though the scale of undervaluation is under review. The potential impact of placing a higher value on GHG emissions can be illustrated by using the existing high carbon values series, in addition to the central values.

---

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf

[5] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Valuation of Energy Use and Greenhouse Gas includes a table of estimates for the Traded Price of Carbon out to the year 2100. From the extract above, in the absence of further detail on Carbon pricing, a reasonable assumption is to use the high estimate in table 1 of the data tables.

Assessing the carbon cost of constrained energy

Constrained renewable generation is zero-carbon energy that is available but cannot be transmitted due to network constraints. This represents energy that must rather come from conventional (non-renewable) sources. In order to assess the carbon cost of constrained, assumptions must be made about the nature of the generation that is required to meet this shortfall.

If renewable generation is being curtailed in Northern Ireland, some or all of this shortfall may be made up by increasing imports on the North-South interconnector(s) and on the Moyle HVDC interconnector. Both the Republic of Ireland and Great Britain have high penetrations of renewable energy – therefore it is reasonable to assume that much of this interconnector flow would come from renewable sources. However, importing electricity into NI by any of these methods serves to increase demand in the source jurisdiction, thus either alleviating renewables curtailment in the source region or increasing generation from non-renewable sources. However, due to the global nature of climate change, all electricity system operators are seeking to minimise the dispatch down of zero carbon generation – thus it is sensible to assume that in the event of curtailment in NI there is no surplus zero carbon generation that can be availed of over the interconnectors, and this energy must come from other sources.

In both the GB and island of Ireland electricity system, peaking generation is provided by gas turbines. In both the Republic of Ireland and Northern Ireland all non-gas fossil fired generation is being replaced by gas-fired units over the coming years. Gas turbine power generators come in two forms: Combined Cycle Gas Turbines (CCGTs) an Open-Cycle Gas Turbines (OCGTs). CCGTs are more efficient while OCGTs are more flexible. CCGTs emit approx. 490 kg CO_2e/MWh, while OCGTs emit approx. 588 kg CO_2e/MWh. A 50/50 mix of both is assumed, giving a CO_2 value for constrained energy of 539 kg CO_2e/MWh.

Methodology for assessing the value of avoided CO_2 emissions

For including the value of avoided CO_2 emissions in the NPC analysis, the following methodology was applied:

1. The magnitude (MWh) of curtailment of renewables is determined for the study area under investigation for all years of the NPC using reasonable assumptions.
2. The total curtailment is multiplied by 0.539 (tCO_2e/MWh of generation 'constrained on') to estimate the CO_2 emissions relating to constrained generation.
3. The total CO_2 emissions in the year is multiplied by a carbon price figure published[6] by the UK government. For this analysis, the 'Market Traded Values' are used.
4. For each year, subtract the emissions associated with constrained generation for the do-nothing baseline case from that associated with the option under assessment.

[6] https://www.gov.uk/government/publications/traded-carbon-values-used-for-modelling-purposes-2024/traded-carbon-values-used-for-modelling-purposes-2024