Options Report
Part A
Capital Project 0966

December 2017

EIRGRID

This page was intentionally left blank.

1 Table of Contents

2 Introduction

EirGrid follow a six step approach when we develop and implement the best performing solution option to any identified transmission network problem. This six step approach is described in the document 'Have Your Say' published on EirGrid's website[1]. The six steps are shown on a high-level in Figure 1. Each step has a distinct purpose with defined deliverables.

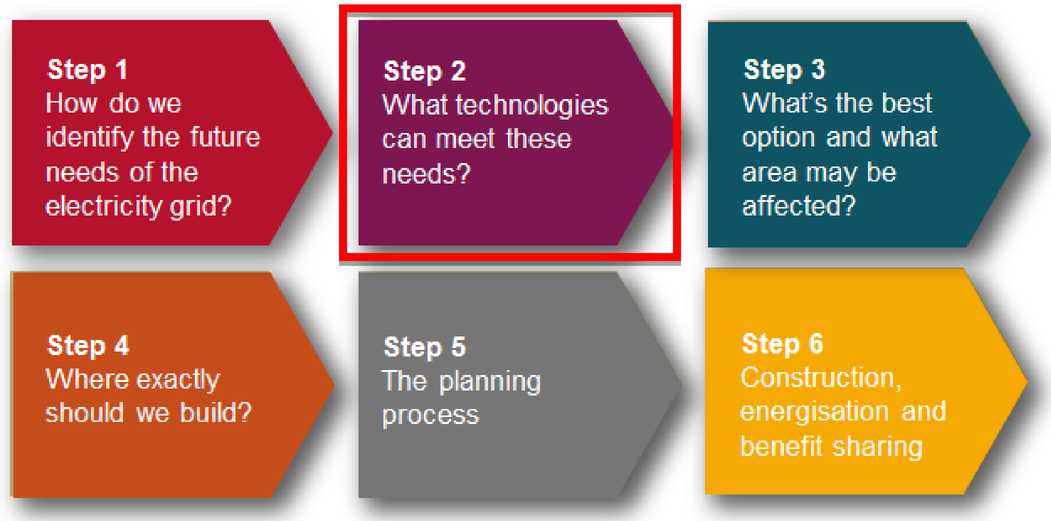

Figure 1 *High Level Project Development Process*

The transmission network problem was identified and described in previous Step 1 and was documented in the Need Report.

The Options Report Part A (this document) is a deliverable for Step 2. In Step 2, a technology overview will be carried out. This will determine the aspects that will be considered when creating any options. All the viable and technically acceptable options created will be shown in a list that is called 'the long list'. This list will be refined in a two-part approach with the aim to establish a shorter list of best performing solution options to bring forward for further investigation in Step 3. The outcome from the first part of refinement of the long list in Step 2 is presented in the Options Report Part A (this document) and the outcome of the second part of refinement of the list is presented in Options Report Part B.

The need, in this case, involves a transmission network problem regarding the transfer of power across the existing 400 kV transmission network from west to east and the transfer of this power within in the transmission network as it reaches the east coast. The issues encountered involve both capacity and voltage.

[1] http://www.eirgridgroup.com/the-grid/have-your-say/

3 Process followed and criteria

3.1 Description of process

The need to improve the transmission network is identified in Step 1. Following on from this step, the process of identifying viable and technically acceptable technology solution options starts. This involves a rigorous process spanning over two steps namely, Step 2 and Step 3. The outcome of Step 2 is a list of best performing solution options which will be taken to Step 3 for further investigation and evaluation. At the end of Step 3 we will have a best performing solution option which will be developed for construction and energisation.

Step 2 can further be broken down into a two-part approach, namely Part A and Part B. This report (Options Report Part A) details the findings of the first part (Part A) of the refinement of the long list. Part B will involve a second refinement of the options list and the findings of this assessment will be presented in the Options Report Part B at the end of Step 2. Between Part A and Part B stakeholder engagement will take place. The stakeholder engagement is project specific and generally at this stage in the development process it is intended to engage with national and regional stakeholders. A project specific web-site will be set up and relevant material about the project will be published. Figure 2 provides an overview of the process and different tasks in Step 2, excluding stakeholder engagement. A more detailed description of the individual tasks is provided below.

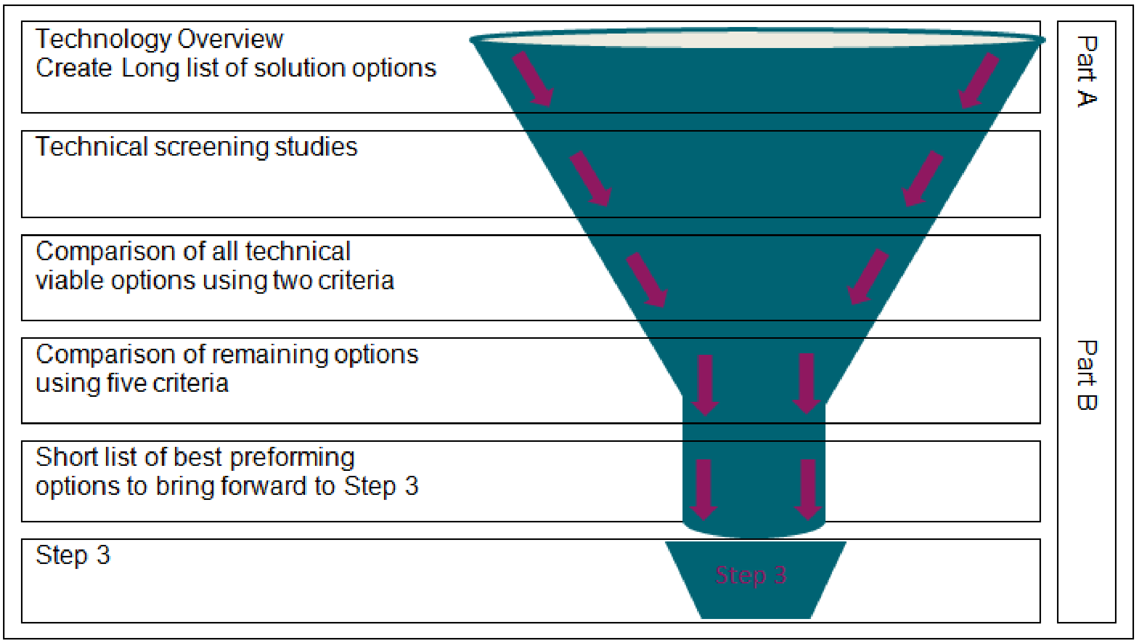

Figure 2 *Illustration of the process of developing of options in Step 2*

3.1.1 Part A

The initial development of viable and technically acceptable options starts with the Technology Overview. This involves consideration of technical aspects which will form the basis of developing the solution options, such as technologies, suitable voltage levels and potential connection points of the solutions. The reasoning and justification for any choices and decisions are outlined. This is discussed in section 4.1 Technology overview in more detail. The findings of the technology overview are then used to create a long list of viable and technically acceptable solution options.

The second task involves high level technical screening studies of the identified solution options to determine if they have a potential to solve the identified need. The solution options will also be assessed on their technical ability, relative to each other, to solve the identified problem. This is discussed in section 4.2.1 Technical screening studies. Further more detailed technical analysis will be carried out later in Part B in Step 2 to determine technical details of options.

The third task involves a multi-criteria comparison of the solution options in the long list using two criteria namely, technical performance and economic performance. This task may involve reducing a vast number of solution options to a more refined list of options to be further investigated. This is discussed in Section 4.3 Comparison of solution options.

3.1.2 Part B

The option list is further refined, this time using a multi-criteria comparison against five criteria. The five criteria are technical performance, economic performance, environmental, deliverability and socio-economic aspects. Each remaining option is assessed against the five criteria. At the end of Step 2 the outcome of this assessment will be available in the Options Report Part B. The outcome of Step 2 is a shorter list of solution options which will be taken to Step 3 for further investigation and evaluation.

3.2 Criteria used for comparison of options

As described in previous section the multi-criteria comparison is carried out twice in Step 2. The first time (Part A) the performance matrix is used only two criteria are compared namely, technical performance and economic performance. The second time (Part B) the performance matrix is used five criteria are compared, namely technical performance, economic performance, environmental, deliverability and socio-economic. Descriptions of the all criteria are outlined below.

3.2.1 Technical performance

Technical performance in Part A is based on high level technical screening studies of the identified solution options. This will determine if they have a potential to solve the identified need. The solution options will also be assessed on their technical ability, relative to each other, to solve the identified problem. In this case the initial technical screening study is based on assessing the worst contingency identified in load flow as part of the need analysis. The different options will be compared against identified indicators of the technical performance based on the need identified. This is further discussed in Section 4.2.1 Technical screening studies.

The second time (Part B) the technical performance is assessed the criteria is based on compliance with Transmission System Security and Planning Standards (TSSPS) and policies. Minimum technical requirements based on these have to be met to qualify an option for consideration, but options which extend technical performance margins beyond minimum acceptable levels are favoured over others. Operational flexibility will also be assessed. This will capture the complexity involved in operational switching and risks to operation during maintenance. The extent to which future reinforcement of, and/or connection to, the transmission network is facilitated will also be taken into account.

3.2.2 Economic performance

Economic performance in Part A will be based on high level estimated capital costs for each option for comparison purposes. The primary source for cost estimates have been developed with input from the Transmission Asset Owner (TAO) and are based on desktop designs and costings for similar works. Where costs were not available for a particular technology, the best most recent estimate will be used.

Economic performance in Part B will be based on estimated Total Project Cost (TPC) for comparison purposes. The TPC will comprise both estimated capital costs and an estimated cost for the Transmission System Operator (TSO) element for development the options. The primary source for cost estimates have been developed with input from the Transmission Asset Owner (TAO) and are based on desktop designs and costings for similar works. Where costs were not available for a particular technology the best, most recent estimate will be used.

3.2.3 Environmental

This criteria is used in Part B. Environmental issues are considered at a high level such as potential interactions with Natura 2000 sites (Special Areas of Conservation-SAC, or special Protection Areas-SPAs or other designated sites that may be in the zone of influence for the various options. Impacts on existing land use and landscape including cultural heritage is compared for the various options.

3.2.4 Deliverability

This criteria is used in Part B. Deliverability captures timelines as well as engineering and planning risks which could extend delivery timescales and costs.

3.2.5 Socio-Economic

This criteria is used in Part B. This criterion will consider the general location of the subject site of the substation and adjacent lands with regards to the nature of typical social impacts. This assessment is carried out in accordance with EirGrid's SIA Methodology.

3.3 Scale used to assess each criteria

The effect on each criteria parameter is presented along a range from "more significant"/"more difficult"/"more risk" to "less significant"/"less difficult"/"less risk". The following scale is used to illustrate each criteria parameter:

More significant/difficult/risk   Less significant/difficult/risk

In the text this scale is quantified by text for example mid-level (Dark Green), low-moderate (Green), low (Cream), high-moderate (Blue) or high (Dark Blue).

4 Long list and comparison of options

4.1 Technology Overview

This overview forms the pillars from which the solution options to resolve the identified need are developed. For the technology overview, EirGrid's approved technology toolbox has been used. To determine the possible solution options a number of aspects are considered. A brief discussion regarding these aspects and the decisions made are outlined below.

Prior to developing options for the identified need, it is important to analyse and understand the need. The need in this case, involves a transmission network problem regarding the transfer of power across the transmission 400 kV network from west to east and the transfer of this power within the counties Dublin, Kildare and Meath as it reaches the east coast. The issues encountered involve both capacity and voltage. As indicated by the need assessment, solutions with the best potential to solve the need are very likely to involve connection points on the 400 kV network or other strong nodes in its vicinity. The best performing solution needs to integrate with the existing network and provide a platform for the future expansion of the transmission network.

4.1.1 Technologies

The development of options may involve additional circuits or equipment which may allow for the more efficient use of existing transmission infrastructure on the system.

High Voltage Alternating Current (HVAC) will be considered for the majority of the reinforcement options. HVAC is the same technology as is used in the existing network and would integrate well. High Voltage Direct Current (HVDC) will also be considered when options are developed. HVDC is a suitable technology for the transfer of large amounts of power over long distances from one point to another. The lengths of circuits in the Irish transmission network are relatively small <100 km and this would not usually merit a HVDC solution. HVDC will therefore only been considered for a limited number of options. Only underground cable will be considered for HVDC.

In terms of new circuits, both underground cable (UGC) and overhead line (OHL) options will be considered. It should be noted that previous analysis has indicated that long lengths (more than 10 km) of AC 400 kV underground cable cannot be accommodated in the Irish transmission system. There are technical reasons why a longer AC underground cable cannot be accepted. The reasons include voltage control problems and electromagnetic transient phenomena associated with the capacitive characteristics of high voltage underground cables. The issues associated with long cables can only be determined by specialised system analysis and these studies are planned to be carried out if the option is brought forward to Step 3.

Although previous analysis have identified issues we have for completeness included two AC underground cable solution options in the long list, one at 400 kV and one at 220 kV. The cable options will be assessed on the same terms as the other options in Part A. If the cable options remain after the first refinement of the list their technical suitability and acceptability will be investigated further in Part B and in Step 3 if required.

Partial AC undergrounding of any overhead line solution using short lengths of underground cables will be considered as part of mitigation measured in Step 3 and/or Step 4.

As the need partly indicated issues with power transfers within the counties Dublin, Kildare and Meath the consideration of options included in the long list will also extend to circuits within these counties.

As indicated by the need assessment, the solutions with the best potential to solve the need involve connection points on the 400 kV network or other strong 220kV[2] nodes in its vicinity. More remote 220kV nodes were excluded as they would significantly increase the route length of the options which in turn, would result in higher cost, longer deliverability and potential for environmental impact.

The identified connection points, 400kV stations and other strong nodes, are all located far inland. Consequently fully offshore cable solutions are not possible. The use of a partial offshore cable solution has not been specifically identified. The reason is that the onshore cable elements alone would be longer than entirely onshore cable options as the distance to the coast from suitable connection points is substantial. In the event that subsequent detailed routing of cable options increases the route length sufficiently, the use of partial offshore cable will be reconsidered.

We will also consider technologies for voltage support as the need analysis has identified this as an issue. The technologies that provide voltage support will mostly be located in existing stations.

[2] As only 220kV and 400kV stations have sufficient power transfer capacities to be able to resolve the need

4.1.2 Voltage level

For the development of the options the voltage levels 220 kV and 400 kV will be considered. The magnitude of the problem identified, with thermal overloads on 220 kV circuits and voltage collapse the counties Dublin, Kildare and Meath, indicates that a reinforcement using the voltage levels of 220 kV and 400 kV at a minimum is required. Using a 110 kV reinforcement would not contribute with the capacity required and is not considered appropriate.

4.1.3 Connection points

The identified network problems indicate issues with loss of high voltage circuits, in particular the existing 400 kV circuits between the west coast and the east coast. The loss of one of these 400 kV circuits will force the power flow to alternative paths along the paths to the east coast.

Possible connection points for solution options should include connections between the 400 kV stations at Moneypoint, Woodland, Dunstown and other strong nodes on or around the 400 kV network. Figure 3 below highlights some of the identified possible connection points which will be used when creating the potential options.

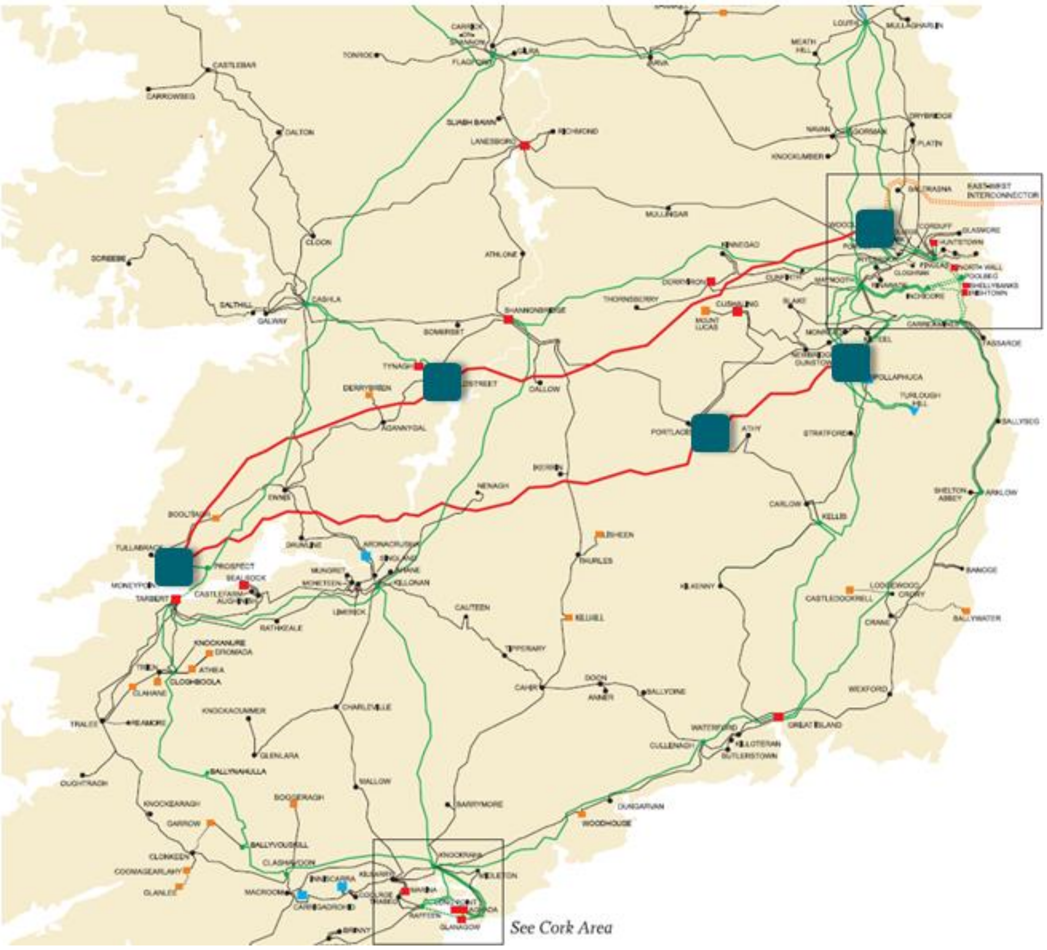

Figure 3 *Some the possible connection points for solutions*

4.2 Assessment of solution options in long list

The long list of solution options was established using the connection points, voltage levels and technologies described in previous section. Knowledge of the identified need and engineering judgement was also used when the long list was created. The long list consists of 15 technically viable and feasible solution options and they are listed in Table 1 in section 4.2.1 Technical screening studies.

The solution options identified in the long list were assessed based on two criteria namely, technical performance and economic performance. The aim of this assessment is to be able to compare the options and reduce the number of solution options that would be brought forward for more detailed evaluation. The sections below describe how these assessments were carried out and the outcome. The effect on each criteria parameter is presented along the following scale.

More significant/difficult/risk Less significant/difficult/risk

4.2.1 Technical screening studies

The technical performances of options, at this stage, is based on high level technical screening studies to determine if the options have a potential to solve the identified need. The solution options will also be assessed on their technical ability relative to each other. The aim of the high level technical screening studies is to reduce the number of solution options that would be brought forward for more detailed evaluation.

The high level technical screening studies are carried out on a network situation where major problems occurred on the transmission system in the needs analysis. The major problems occurred during a network situation representing Winter Peak 2025 with EWIC and Moyle interconnectors exporting with high wind generation in the west and south west. This situation was previously identified in the needs analysis as the worst scenario. This situation creates a cross country power flow on the existing transmission system from the West to the East coast.

The high level technical screening studies are based on assessing the worst contingency, loss of Oldstreet – Woodland 400 kV circuit, identified as part of the need analysis. The need analysis also found that three technical issues had to be addressed as part of the solution to cater for unplanned losses of any of the 400 kV circuits. These issues were:

- thermal overloads
- voltage collapse
- large phase angle differences which would prevent reclosing

It was decided to use these three issues as indicators of the technical performance of the options in the long list. This enabled us to assess the options technical ability to solve the identified issues above in a concise way. It also allowed us to compare the options technical ability relative to each other.

Each solution option in the long list was modelled in the above mentioned network situation and the worst contingency, loss of Oldstreet – Woodland 400 kV circuit, was applied. The impact that the solution option made on the three issues was recorded and compared with a reference case. The reference case represents a network with no solution option included.

Table 1 below highlights the high level technical performance of the options based on the three indicators, compared to the reference case. The table also displays the combined technical performance of the options in Step 2 Part A.

Options	Amount of voltage support required	No. of overloads observed on top of option	Phase Angle observed across open breaker on Oldsteet - Woodland	Combined Technical Performance in Part A
Reference case without any solution				
New Coolnabacky – Dunstown 400 kV OHL				
New Dunstown – Moneypoint 400 kV OHL				
New second Oldstreet – Woodland 400 kV OHL				
New Moneypoint – Woodland 400 kV OHL				
Upvoltage existing 220 kV circuits to 400 kV to create new Dunstown –Woodland 400 kV OHL				
New Dunstown – Woodland 400 kV OHL				
Upvoltage existing 220 kV circuits to 400 kV to create new Kilpaddoge-Killonan-Shannonbrige 400 kV OHL				
New Coolnabacky – Oldstreet 400 kV OHL				
New Dunstown – Woodland 220 kV OHL				
New Moneypoint – Woodland 220 kV OHL				
New Maynooth – Woodland 220 kV OHL				
New Dunstown – Woodland 220 kV UGC				
New Dunstown – Woodland 400 kV UGC				
New HVDC circuit between Moneypoint – Woodland				
New HVDC circuit between Dunstown – Woodland				

Table 1 *Result of the high level technical screening studies in Step 2 Part A for options in long list*

4.2.2 Economic performance

Economic Performance in Part A in Step 2 is based on estimated capital costs for each option for comparison purposes. Table 2 below summaries the estimated capital cost for the long list of options and provides a colour code relative to each other for comparison purposed.

Options	**Economic Performance**	
	Capital cost (€m)	**Colour code**
New Coolnabacky – Dunstown 400 kV OHL	56	
New Dunstown – Moneypoint 400 kV OHL	249	
New second Oldstreet – Woodland 400 kV OHL	151	
New Moneypoint – Woodland 400 kV OHL	371	
Upvoltage existing 220 kV circuits to 400 kV to create new Dunstown –Woodland 400 kV OHL	68	
New Dunstown – Woodland 400 kV OHL	64	
Upvoltage existing 220 kV circuits to 400 kV to create new Kilpaddoge-Killonan-Shannonbrige 400 kV OHL	203	
New Coolnabacky – Oldstreet 400 kV OHL	117	
New Dunstown – Woodland 220 kV OHL	38	
New Moneypoint – Woodland 220 kV OHL	159	
New Maynooth – Woodland 220 kV OHL	18	
New Dunstown – Woodland 220 kV UGC	98	
New Dunstown – Woodland 400 kV UGC	130	
New HVDC circuit between Moneypoint – Woodland	645	
New HVDC circuit between Dunstown – Woodland	258	

Table 2 *Economic performance of option in long list*

4.3 Comparison of solution options

Table 3 provides a summary of the performance of each option against the two evaluation criteria.

Options	Technical Performance	Economic Performance	Combined Performance in Part A
New Coolnabacky – Dunstown 400 kV OHL			
New Dunstown – Moneypoint 400 kV OHL			
New second Oldstreet – Woodland 400 kV OHL			
New Moneypoint – Woodland 400 kV OHL			
Upvoltage existing 220 kV circuits to 400 kV to create new Dunstown –Woodland 400 kV OHL			
New Dunstown – Woodland 400 kV OHL			
Upvoltage existing 220 kV circuits to 400 kV to create new Kilpaddoge-Killonan-Shannonbrige 400 kV OHL			
New Coolnabacky – Oldstreet 400 kV OHL			
New Dunstown – Woodland 220 kV OHL			
New Moneypoint – Woodland 220 kV OHL			
New Maynooth – Woodland 220 kV OHL			
New Dunstown – Woodland 220 kV UGC			
New Dunstown – Woodland 400 kV UGC			
New HVDC circuit between Moneypoint – Woodland			
New HVDC circuit between Dunstown – Woodland			

Table 3 *Multi criteria assessment based on two criteria in Step 2 Part A*

In terms of technical performance, options which included duplication of the existing 400 kV circuits or improved connectivity between the 400 kV circuits, to create a loop or circle, were found to have a very favourable performance. It is also evident that the duplication or part duplication of the more southern existing 400 kV circuit has a less favourable technical performance then a duplication or part duplication of the northern existing 400 kV circuit. In part this is due to the worst contingency being loss of part of the upper circuit. It should also be noted that any solution option using a 220 kV solution has a less preferential technical performance than a solution using a 400 kV.

The introduction of a new HVDC circuit has not been modelled as part of the initial technical screening studies. It is assumed that the HVDC solution and its control system can be designed as required to meet the system needs including required reactive support. Therefore the technical performance for the HVDC options has been assumed to be optimal for the purpose of the high level screening studies.

In accordance with our strategy to maximise the use of our existing infrastructure before developing new circuits, EirGrid has been investigating the possibility of modifying existing 220 kV towers in order to accommodate 400 kV circuits. One option will use this technology and the initial studies found that this option performs almost as well as the introduction of a new 400 kV overhead line. The better technical performance of a new 400 kV is due to the fact that it provides a net increase in the number of circuits compared to the upvoltaging solution, which involves the replacement of existing 220 kV circuits with 400 kV circuits.

Previous analysis has indicated that long lengths of AC 400 kV underground cable cannot be accommodated in the Irish transmission network. Although previous analysis have identified issues we have for completeness included two AC underground cable solution options in the long list, one at 400 kV and one at 220 kV. The cable options are assessed on the same terms as the other options in the high level screening studies in Part A. AC cable solutions will require very detailed specific technical analysis to determine if they are technically feasible. These detailed specific technical analyses will be carried out in Step 3 if the cable options remain. Partial AC undergrounding of any overhead line solution using short lengths of underground cables will be considered as part of mitigation measured in Step 3 and/or Step 4.

Load flow analysis of a 220 kV underground cable between Dunstown and Woodland stations indicated that the new cable became overloaded for the loss of Oldstreet-Woodland 400 kV circuit. The low impedance of the 220 kV cable caused the power to be directed through this new cable instead of using the parallel existing overhead lines. To alleviate this issue, Woodland 400 kV busbar had to be operated split. This may not be optimal from an operations point of view, and may reflect on the options technical performance at a later stage.

The economic performance has a dependence on the length of the proposed circuit and this is evident from the options that stretch across the country. Long circuits perform economically less favourably compared to the options which have a shorter length. The HVDC circuits have also proven to be prohibitively expensive when compared with the other candidate solutions.

It should be noted that almost all of the options required some additional voltage support devices. The most optimal location for these and their size will be determined when the refined list are analysed in more detail in Part B.

4.4 Proposed solution options to be brought forward

The proposed options that will be taken through for further investigation are marked with the two lighter colours on the scale, **Cream** and **Green,** in Table 3. The proposed options can be influenced by stakeholders if reasonable justification is provided for modification of the proposed list of options. Based on the analysis to date, below is a proposed refined list of solution options to be brought forward for more detailed evaluation in Part B:

- Upvoltage existing 220 kV circuits to 400 kV to create new Dunstown – Woodland 400 kV OHL
- New Dunstown – Woodland 400 kV OHL
- New Dunstown – Woodland 220 kV OHL
- New Dunstown – Woodland 220 kV UGC
- New Dunstown – Woodland 400 kV UGC

5 Conclusion of Step 2 Part A

After completing a technology overview, a long list of 15 viable and technically feasible solution options was presented. The solution options identified in the long list were assessed based on two criteria namely, technical performance and economic performance.

The aim of the assessment in Part A is to be able to compare the options and reduce the number of solution options that would be brought forward for more detailed evaluation. Based on the analysis to date, below is a proposed refined list of solution options to be brought forward for more detailed evaluation in Part B:

- Upvoltage existing 220 kV circuits to 400 kV to create new Dunstown –Woodland 400 kV OHL
- New Dunstown – Woodland 400 kV OHL
- New Dunstown – Woodland 220 kV OHL
- New Dunstown – Woodland 220 kV UGC
- New Dunstown – Woodland 400 kV UGC

The proposed list of options can be influenced by stakeholders if reasonable justification is provided for modification of the refined list.

All options involve a new connection between Dunstown 400/220 kV station and Woodland 400/220 kV station.

Almost all of the options required some additional voltage support devices and the most optimal location for these and their size will be determined when the refined list are analysed in more detail in Part B.

In Part B the remaining options will be assessed under five criteria;

- Technical Performance
- Economic Performance
- Deliverability
- Environmental
- Socio-economic

This assessment will allow the refined long list to be further reduced to create a shorter list to bring forward to Step 3.