# Step 2 – Options Report of Grid Development Framework

## North Connacht Project

April 2018

# Contents

# 1 Introduction

## 1.1 Our Statutory Role

EirGrid is the national electricity Transmission System Operator (TSO) for Ireland. Our role and responsibilities are set out in Statutory Instrument No. 445 of 2000 (as amended); in particular, Article 8(1) (a) gives EirGrid, as TSO, the exclusive statutory function:

*"To operate and ensure the maintenance of and, if necessary, develop a safe, secure, reliable, economical, and efficient electricity transmission system, and to explore and develop opportunities for interconnection of its system with other systems, in all cases with a view to ensuring that all reasonable demands for electricity are met and having due regard for the environment."*

Furthermore, as TSO, we are statutorily obliged to offer terms and enter into agreements, where appropriate and in accordance with regulatory direction, with those using and seeking to use the transmission system. Upon acceptance of connection offers by prospective generators and demand users, we must develop the electricity transmission network to ensure it is suitable for those connections.

## 1.2 'Have Your Say' – Framework for Grid Development

EirGrid's process for developing identified transmission network problems into viable technical solutions, and further into construction and energisation, is known as the Framework for Grid Development ("The Framework"). It is described in our document *'Have Your Say'* published on EirGrid's website (www.eirgridgroup.com).

At a high-level, The Framework has six steps, as outlined below and in Figure 1. Each step has a distinct purpose and deliverables. The steps generally combine technical and other analysis with opportunities for public and stakeholder participation.

In summary:

- **Step 1:** We confirm the need for a project and its scale.
- **Step 2:** After considering a number of technical solutions, we narrow this down to the *Shortlist of Technology Options* – such as a new line and/or substation, or upgrades to existing lines.

- **Step 3:** We consider technology options in more detail. We also look at the broad study areas we may use for possible routes or site locations. We will also provide information on the methods we are using to analyse the technology options and study areas. We then narrow our analysis to a best performing option and its study area – the general area where we could locate the option.

- **Step 4:** We develop a detailed route or site. This will specify the location of any new equipment or infrastructure.

- **Step 5:** We will finalise a design scheme and obtain all necessary consents for the project. The relevant planning authority will decide if the project has permission to proceed, including setting conditions of permission, or modifying the proposal.

- **Step 6:** The project is progressed and handed over to ESB Networks, the Transmission Asset Owner (TAO) to construct and energise.

The North Connacht Project is currently in Step 2 of The Framework. In this Step, following the identification of a need to reinforce the transmission network (Step 1), Step 2 identifies and analyses the various potential technology options that meet the identified need.

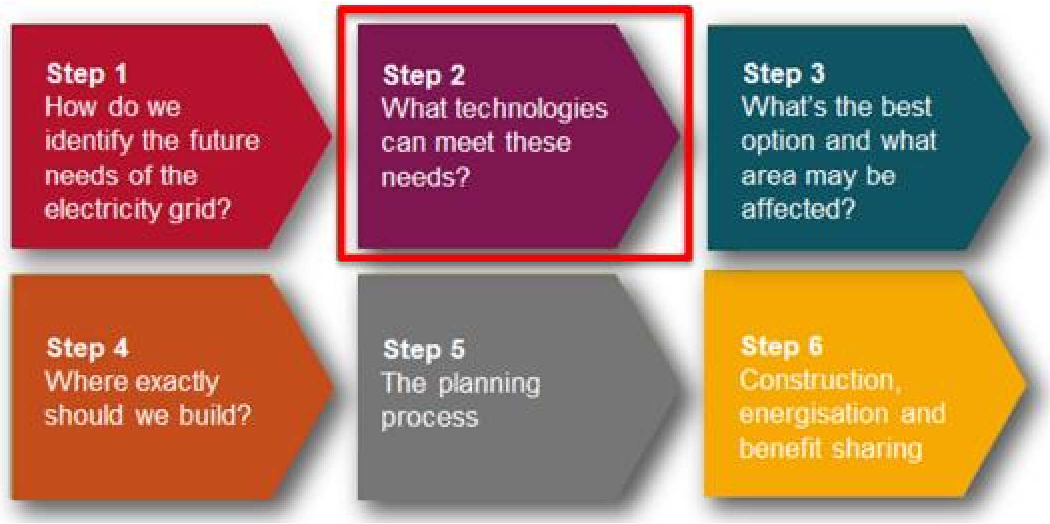


*Figure 1: Overview of EirGrid's Framework for Grid Development.*
*The North Connacht Project is in Step 2 (highlighted with red box)*

As confirmed in the Step 1, the transmission network need for the North Connacht Project arises as a result of the connection of additional Gate 3 electricity generation capacity in the north Connacht area, and the evacuation of that generation from the area via the transmission system to load centres in south or east. Previously there were higher levels of wind generation proposing to connect in the area. These higher levels drove the larger Grid

West project. Now that the levels are lower, it is anticipated that a smaller-scale solution will meet the need. This smaller-scale solution will be known as the North Connacht Project.

This Step 2 – Options Report is a deliverable for Step 2 of The Framework. In this step, a technology overview is carried out. This will identify the technical and economic issues that have been considered in creating the *Longlist of Technology Options* which meet the identified need for the project. This longlist is then refined by means of further technical and economic analysis, as well as a high-level consideration of other environmental, social and deliverability criteria.

The conclusion of this Step 2 – Options Report is the establishment of the *Shortlist of Technology Options* to bring forward for further investigation in Step 3.

As such, it should be understood that this Step 2 – Options Report does not identify a preferred technology solution. This is the deliverable of Step 3 of The Framework and will be carried out for this project in the next Step. However, the analysis undertaken in Step 2, and all stakeholder feedback occurring therein, assists in the multi-criteria analysis process for identifying of the *Shortlist of Technology Options*.

This Step 2 – Options Report has been written in as non-technical a language as possible. However, given its technical subject matter, and the fact that technical analysis forms a cornerstone of the Step 2 shortlisting process, there are parts of this Step 2 – Options Report that are necessarily technical in content. However, the conclusions arising from such technical analysis have been prepared using non-technical language to the greatest extent possible or appropriate.

# 2 Methodology

## 2.1 Description of the Process

Having identified a transmission network need in Step 1 of The Framework, Step 2 process commences with identification of the *Longlist of Technology Options* which has the potential to meet or overcome that identified need. The longlist is then refined based on a relatively high-level technical and economic analysis, using technical judgement and high-level costings. The *Refined List of Technology Options* is further reduced in the latter part of Step 2 to the *Shortlist of Technology Options*. This analysis is based on ongoing technical judgement, a more detailed (though still high-level) analysis of costs and benefits, and also including a high level review of environmental, social and deliverability issues. A performance matrix is the tool used to assist this qualitative analysis. The Step 2 process is detailed in Figure 11 in the appendix C.1.

It should be noted that the technology options are not spatially or geographically specific, other than identifying the existing nodes involved – i.e. the substations between which a new circuit might extend. Any new circuit options are identified as a straight line plus additional 25% for routing around constraints for the purposes of comparative multi-criteria analysis and evaluation. However, this should not be considered to be representative of any particular spatial definition of that technology option.

## 2.2 Longlist of Technology Options

The procedure to establish the *Longlist of Technology Options* includes a technology overview and a high level technology assessment.

A review of the equipment and technology available is conducted, giving due consideration to higher value and higher risk technologies. Alternative and bespoke technical solutions are also considered. Preliminary technology assessments are undertaken to inform recommendations for technology options which meet the identified need for the North Connacht Project.

Using these high-level technology assessments, the *Longlist of Technology Options* is identified. Where relevant, connection points, voltage levels, and required capacity are established and justification and rationale for each technology option is documented.

## 2.3 Evaluation of Longlist of Technology Options

### 2.3.1 Technical Performance

A preliminary screening of the *Longlist of Technology Options* and their technical performance is carried out. The options are assessed using expert judgement and taking into account matters such as security standards, reliability characteristics and operational practice.

### 2.3.2 Indicative Capital Costs

Indicative capital cost estimates for each of the technology options in the longlist are established. The estimates are adequate for the comparison of technology options, based on outline designs (straight line plus additional 25% for routing around constraints). The cost estimates are based on standard development costs.

### 2.3.3 Decision-Making

Using a two-criteria (technical performance and indicative capital costs) performance matrix, the *Longlist of Technology Options* is reduced to the *Refined List of Technology Options*. This *Refined List of Technology Options* is subsequently reduced to the *Shortlist of Technology Options* using further technical and economic analysis, but also introducing high-level environmental, socio-economic and deliverability analysis. The *Shortlist of Technology Options*, to be taken forward for further analysis in Step 3, must provide an adequate technical performance at a reasonable cost, and should not profoundly impact upon the receiving natural, built and human environment.

## 2.4 Evaluation of Refined List of Technology Options

### 2.4.1 Technical

The technical performance of the *Refined List of Technology Options* is assessed taking into account matters such as security standards, reliability characteristics and operational practice, and applying expert judgement. The analysis also involves detailed loadflow analysis. The corresponding outline conceptual designs and equipment requirements are identified.

### 2.4.2 Economic

Indicative capital cost estimates for each option in the *Longlist of Technology Options* are established. The estimates are adequate for the comparison of technology options, based on outline designs (straight line plus additional 25% for routing around constraints). The cost estimates are based on standard development costs.

### 2.4.3 Environmental (only applicable to Tier 2 & 3)

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 considered to be in a general zone of influence for the various options. Impacts on existing land use and landscape including cultural heritage is compared for the various options, again at a high-level of analysis.

### 2.4.4 Socio-Economic (only applicable to Tier 2 & 3)

This criterion will consider a broad area that might be associated with each option in the *Refined List of Technology Options*, with regard to the nature of typical social impacts. This consideration is carried out in accordance with EirGrid's Social Impact Assessment (SIA) Methodology[1].

### 2.4.5 Deliverability

Deliverability captures high-level issues, such as timelines, and engineering and planning risks which could extend delivery timescales and costs.

### 2.4.6 Decision-Making

Multi-Criteria Analysis, based upon use of a performance matrix, is used to reduce the *Refined List of Technology Options* to the *Shortlist of Technology Options* to be taken into Step 3 of The Framework. The performance matrix is a qualitative evaluation that assesses the relative (comparative) performance of technology options across a standard set of five (5) criteria, namely: technical, economic, environmental, socio-economic and deliverability.

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

More significant/difficult/risk/costly — Less significant/difficult/risk/costly

In this Step 2 – Options Report, this scale is colour-illustrated for example high (Dark Blue). , mid-level (Dark Green), low-moderate (Green) or low (Yellow) The rationale for selecting a particular colour coding is supported by an accompanying explanatory text.

## 2.1 Project Complexity

Tiering is used to define the level of analysis and other activities undertaken for a project. The Framework uses three Tiers, namely Tier 1, Tier 2 and Tier 3. The least complicated

[1] https://buzz.grid.ie/sites/GridDevelopment/ServPol/PlanEnv/Projects/SIA/SIA%20METHODOLOGY%20-%20FINAL%20OCT2015.pdf

projects are assigned to Tier 1, while Tier 3 is assigned to complex projects such as linear development. Depending on the Tier the development will follow different strategies of project development.

The Tier determination is made collectively by an EirGrid cross-functional team assembled by the project manager for the project. A Tier is defined by the most complex of the identified options in the *Shortlist of Technology Options*.

In other words, following the conclusion of the Step 2 multi-criteria analysis (see section 2.4.6 below), and the identification of the *Shortlist of Technology Options*, a Tier is assigned to the project, which in turn influences a project development strategy and engagement strategy for the development of the project in subsequent steps of The Framework.

## 2.1 Stakeholder Engagement

Stakeholder engagement generally takes place for Tier 2 and Tier 3 projects in Step 2. The level and nature of stakeholder engagement generally reflects the level of knowledge at this relatively early stage in the project development process, and is primarily focussed on statutory and non-statutory authorities and agencies.

However, as noted in Section 1 of this Step 2 – Options Report, this is something of a "legacy" project, with the fundamental need for the project shared with the previous Grid West project. As such, it must be understood that, notwithstanding the normal level and focus of stakeholder engagement in Step 2, previous public, community and other stakeholder engagement associated with the Grid West project, has also been considered in this Step. The feedback arising from the previous project remains of relevance, and as such, the supporting information that informs the conclusions of this Step 2 – Options Report (and this project in general) will be somewhat different for this project than for other EirGrid projects in this Step.

Furthermore the findings of specific stakeholder engagement in Step 2 have fed into the decision-making process and the identification of the *Shortlist of Technology Options*.

# 3 Analysis

## 3.1 Project Background

In September 2017, EirGrid announced plans to replace the former extra-high voltage (EHV) solution known as Grid West[2], with a smaller-scale development. The decision to replace that EHV project was made due to a significant reduction in the amount of wind generation in north Connacht to be connected onto the national transmission grid, from that originally identified under the Gate 3 group processing scheme in 2008.

In particular, the generation capacity of the so-called Bellacorick subgroup has now reduced from the initial Gate 3 figure of 647 MW in 2008 to 301 MW in 2017 (see Figure 2).

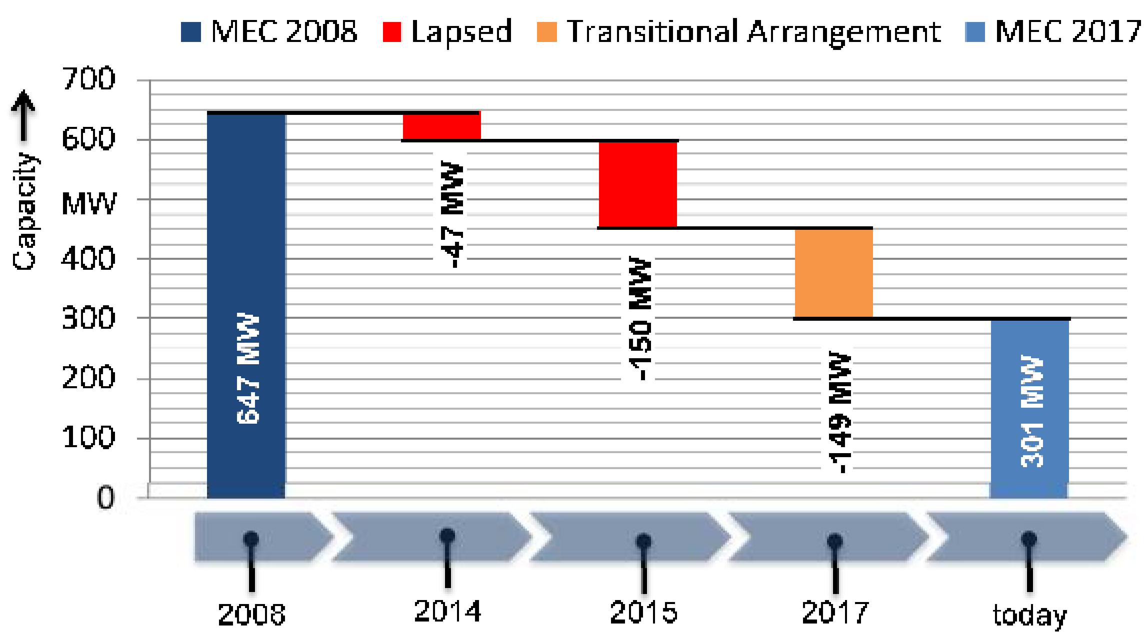


*Figure* 2: Development of Generation Capacity of Bellacorick Subgroup

In 2008 the anticipated wind generation formed the genesis and development of the Grid West project. Although there has been a significant reduction in anticipated wind generation there still remains a need to connect generators with a total combined capacity of 301 MW. This amount of additional generation is still significant; however, it can be met through the development of 110 kV electricity infrastructures, rather than requiring the EHV 220 kV, 400 kV nor HVDC infrastructure that was proposed under Grid West.

[2] http://www.eirgridgroup.com/the-grid/projects/grid-west/whats-happening-now/

Whilst such EHV infrastructure would meet the need for the level of generation currently expected, and in addition would provide a level of future-proofing for further increases in generation, no such further future generation has committed to connecting in the area. In the absence of such commitment, EirGrid has opted to focus on optimising the use of the existing 110 kV electricity infrastructure to minimise the need for new infrastructure.

The two existing 110 kV overhead line circuits extending from the existing Bellacorick 110 kV substation (Bellacorick – Castlebar and Bellacorick – Moy) have already been, or are planned to be, uprated. This is as part of the overall grid development for exporting renewable generation from the north Connacht area. These works alone are not sufficient for the levels of renewable generation still proposed. This Step 2 – Options Report assumes that both of these uprates are completed as a starting position.

## 3.2 Need for Grid Development

Prior to developing technology options, it is important to analyse and understand the need that is being addressed in Step 1. The pre Gate 3 generation capacity in the north Connacht area totals 174 MW. In addition, 401 MW of Gate 3 wind generation have agreements in place to connect to the grid. 301 MW of this Gate 3 generation is located in the vicinity of Bellacorick 110 kV substation (depicted as a red zone in the red square in Figure 3). Including the other generation of 163 MW with Firm Access Quantity (FAQ) and 14 MW without FAQ in the area, a total generation capacity of 752 MW is connected or anticipated to be connected with Firm Access Quantities[3] (FAQ) in the future. The total generation capacity is detailed in Table 15 in Appendix C.2.

[3] http://www.eirgridgroup.com/customer-and-industry/general-customer-information/operational-constraints/

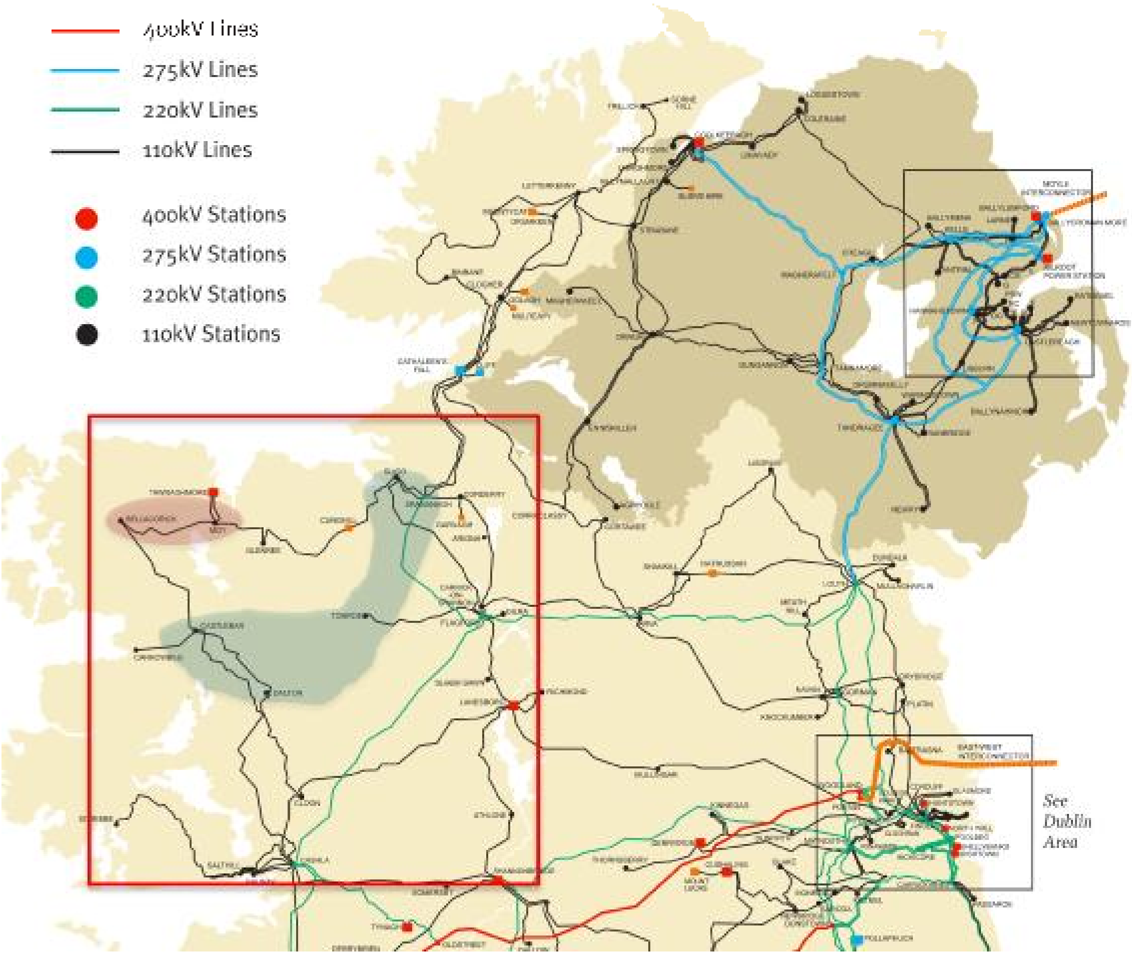


*Figure 3: Transmission System Map[4] and High Level Study Area in North Connacht*

The network issues which are caused by the planned connection of all generation in north Connacht area were identified in Step 1. It was assumed that the 301 MW of the Bellacorick subgroup generation will connect to the existing Bellacorick 110 kV substation. The total generated electricity (less the demand) in the north Connacht area has now to be moved to the south and east via the transmission system (depicted as a green zone in the red square in Figure 4). In situations with relative high wind, our studies have shown overloads for the loss of plant or equipment (known as an N-1 contingency) on the following circuits or station equipment:

- Glenree – Moy 110 kV;

[4] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-Transmission-System-Geographic-Map-Sept-2016.pdf

- Castlebar – Cloon 110 kV;
- Bellacorick – Castlebar 110 kV;
- Cunghill – Glenree 110 kV;
- Cunghill – Sligo 110 kV;
- Cashla – Dalton 110 kV;
- Bellacorick – Moy 110 kV; and
- on Dalton 110 kV busbar;

By transmission standards, each plant or equipment is manufactured to operate within a statutory voltage range and to carry power flows up to a certain level. In a situation of the loss of plant or equipment, the power flow is diverted. This could lead to a system voltage which is outside the statutory voltage range or to a power flow which exceeds the power carrying capability of plant or equipment. Both voltage violation and excess of power carrying capability are unacceptable. In north Connacht the loss of any circuit on the Moy – Glenree - Cunghill – Sligo or the Bellacorick – Castlebar route would result in the excess of manufactured capability of plan or equipment. These violations are in breach of EirGrid's Transmission System Security and Planning Standards[5] (TSSPS).

The need for reinforcement of the transmission system in north Connacht is driven by the Gate 3 generation requiring connection in the north Connacht area. Each option in the *Longlist of Technology Options* needs to be able to integrate the additional generation into the existing network along with the existing pre-Gate 3 wind generation, and should result in an increase of transfer capability between the red and green zones shown in Figure 4.

[5] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Transmission-System-Security-and-Planning-Standards-TSSPS-Final-May-2016-APPROVED.pdf

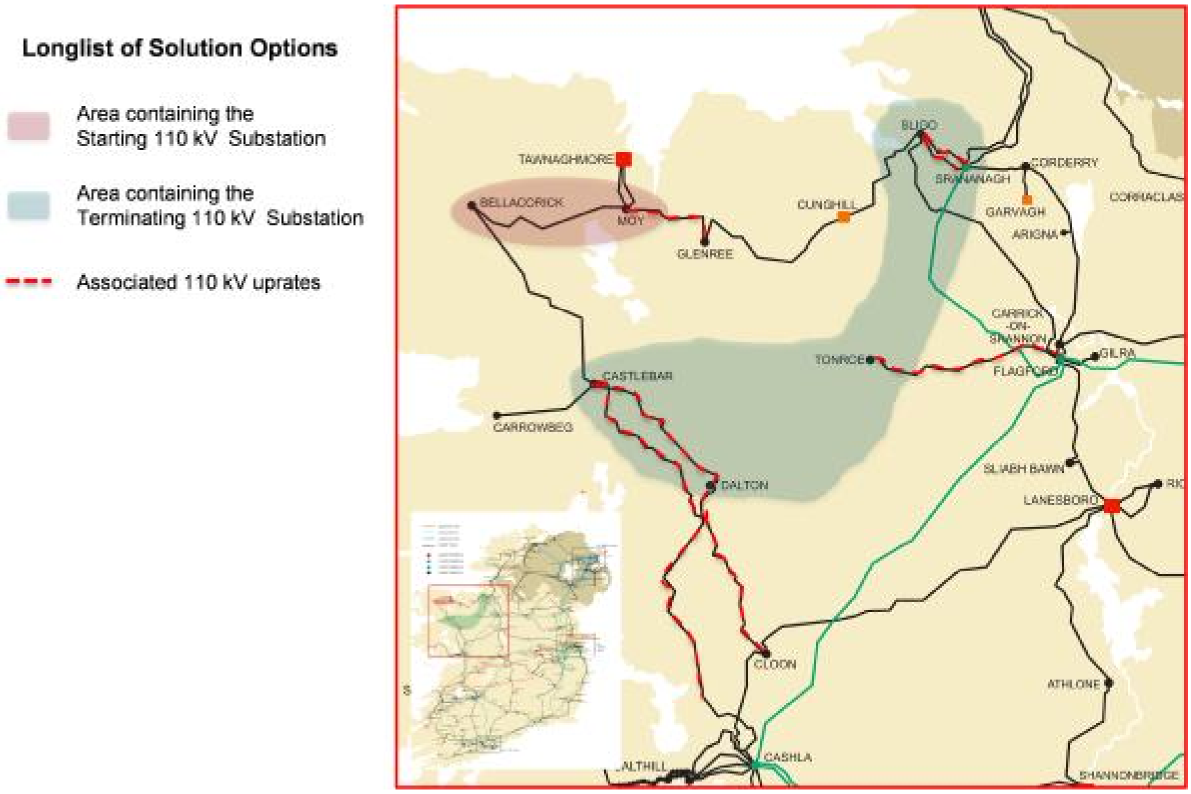


*Figure 4: Study Area: Starting and Terminating Substation of Technology Options*

The following subsection describes the development of the *Longlist of Technology Options*.

## 3.3 Longlist of Technology Options

For the initial technology overview, EirGrid's approved technology toolbox[6] has been used. This overview informs the development of the *Longlist of Technology Options*. These options could resolve the identified need. To determine the possible options, a number of aspects are considered.

### 3.3.1 Maintain Status Quo

The analysis of this option was carried out in the needs assessment studies in Step1. The analysis has showed that the existing 110 kV network in the study area is not capable of accommodating the levels of connected, contracted and planned generation capacity in north Connacht area. The Status Quo, as per today, is the reference case which has been used to quantify the benefit of each of the technology options.

[6] EirGrid's technology toolbox comprises approved technologies, e.g. types of overhead lines or underground cable, which could be used as a technology option to meet the need of grid development.

Under the European Union's renewable energy Directive 2009/28/EC, article 16(2), EirGrid has an obligation to ensure guaranteed or priority access for renewable generation. The 'do nothing' option does not facilitate the connection of Gate 3 renewable generation and so in contravention to the EU Directive. This option should not be considered any further.

### 3.3.2 Uprate Existing Infrastructure

This option only involves the uprate of existing transmission lines in the study area only. Technologies which allow the deliberate diversion of power flows in order to balance the flows on the transmission lines could be taken into consideration as a complement of the option, if required, but not as a technology option on its own.

The considered options which propose the uprate of existing infrastructure are

- Uprate Existing 110 kV Circuits; and
- Double Circuit Reconfiguration.

**Uprate existing 110 kV Circuits:**

This option includes the uprate of all circuits on the Cashla – Cloon/Dalton – Castlebar – Bellacorick – Moy – Glenree – Cunghill – Sligo 110 kV route whose ratings are below the rating of 430 $mm^2$ ACSR conductor OHL operating at 80°C with a summer/winter rating of 178/219 MVA respectively. Hence, the required uprates have to be implemented for four circuits namely:

- Cashla – Dalton 110 kV (c.39 km)
- Castlebar – Dalton 110 kV (c.28 km)
- Castlebar – Cloon 110 kV (c.58 km)
- Glenree – Moy 110 kV (c.14 km)

The total length of associated uprates amounts to 142 km.

**Double Circuit Reconfiguration:**

For this technology option, the Castlebar – Bellacorick – Moy – Glenree – Cunghill route would be converted from a single circuit to a double circuit route. The total length of the double circuit route is 125 km. It is assumed that the double circuit is realised in parallel using steel lattice towers capable of carrying a double 110 kV circuit of 430 $mm^2$ ACSR conductor OHL operating at 80°C with each circuit having a summer/winter rating of 178/219 MVA respectively. It should be noted that the existing single circuits of Cunghill – Sligo and

Cunghill – Glenree have recently been fully refurbished and uprated to single circuit 430s ACSR operating at 80 degrees and have a significant life span remaining. Bellacorick – Castlebar refurbishment and uprate is nearly complete and Bellacorick – Moy refurbishment and uprate has received planning permission with works due to start in 2019. All of this work would be made completely redundant if the circuits were replaced with a double circuit.

In addition to the new double circuit reconfiguration, additional uprates of the wider existing 110 kV infrastructure would be required along the route of both routes connecting Sligo – Srananagh, Cashla – Cloon, Cashla – Dalton and Dalton – Castlebar. The total length of the uprates is 148 km. These circuits would each require a minimum rating equivalent to 430 $mm^2$ ACSR conductor OHL operating at 80°C with a summer/winter rating of 178/219 MVA respectively.

### 3.3.3 New 110 kV Point-to-Point Connection

The N-1 contingency analysis has shown that following connection of the remaining Gate 3 generation the loss of a line in north Connacht area due to either failure or maintenance could result in thermal overloads and voltage violations. Therefore, options incorporating a new 110 kV circuit connecting one of the 110 kV substations located in the red area identified in Figure 4 to one of the substations located in the green area are expected to resolve the network problems and will now be considered. This would create a second export pathway for the generation during N-1 contingencies of a line along the Castlebar – Bellacorick – Moy – Glenree – Cunghill – Sligo route. The options considered are at the voltage level of 110 kV on the basis of minimising likely costs and enabling integration with the existing 110 kV network.

The new circuit is required to connect to one of the following 110 kV substations in the high generation area (see red zone shown in Figure 4):

- Bellacorick; or
- Moy.

The new circuit should have as final terminating 110 kV substation one of the following 110 kV substations (see green zone shown in Figure 4):

- Srananagh;
- Sligo;
- Tonroe;
- Dalton; or

- Castlebar.

Stations further away could be considered but their greater distance will reduce any technical benefits, increasing the footprint in the environment they will potentially impact upon, while the associated deliverability impacts and the costs would be more substantial.

The *Longlist of Technology Options* under this heading contains new build and uprate of electricity infrastructure at 110 kV only. The circuit lengths assumed for modelling purposes for each of the new 110 kV circuits is shown in Table 1. Recognising that the realistic impact of traversing a landscape will require deviations from a straight line connection, this has assumed a straight line distance[7] from one substation to the other substation, plus 25% for routing around constraints.

*Table 1: Developed Longlist of Technology Options and Line of Sight Estimated Circuit Length (+ 25% of estimated contingency)*

| | | Starting Node in Red Zone | |
|---|---|---|---|
| | | **Bellacorick** | **Moy** |
| Destination in Green Zone | **Castlebar** | 45 km | 37 km |
| | **Dalton** | 76 km | 59 km |
| | **Tonroe** | 88 km | 58 km |
| | **Sligo** | 92 km | 61 km |
| | **Sranangh** | 97 km | 66 km |

It is also assumed that any of these point-to-point connections could be implemented as overhead, underground and hybrid technology option. The overhead line (OHL) would be modelled as the standard 430 mm$^2$ ACSR conductor OHL operating at 80°C with a summer/winter normal rating of 178/219 MVA respectively. The underground cable (UGC) option would be modelled as the standard 1,600mm$^2$ Al XLPE conductor with a summer/winter normal rating of 195/221 MVA respectively.

### 3.3.4 Extra-High-Voltage Tailed Connection

To address the need for the network reinforcement identified in Step 1, and to avoid the need for multiple lower voltage circuits, a single high capacity circuit could be considered. This circuit would act as a wind power collection node, transporting the generation directly to the 220 kV network at Flagford near Carrick-on-Shannon.

[7] No specific corridors or routes are considered at this time.

Technical studies confirmed that a fully underground solution is not feasible using HVAC[8], but is feasible using HVDC[9]. Consequently, a HVDC could be considered instead as an EHV underground technology.

For the OHL technology option, both the 400 kV and 220 kV HVAC OHL technology options are feasible. The 220 kV OHL technology option could be considered to allow the use of partial undergrounding along the route, within the technical limitations that this entails.

The installed capacity of each of the options is:

- 320 kV HVDC UGC option is rated for equivalent to 500 MVA;
- 400 kV HVAC OHL: Twin 600mm$^2$ Curlew ACSR operating at 80˚C with summer/winter rating of 1577/1944 MVA respectively;
- 220 kV HVAC OHL: 600mm$^2$ Curlew ACSR operating at 80 ˚C with a summer/winter rating of 434/534 MVA respectively.

These technology options were suitable for the need to integrate the large quantity of Gate 3 renewable generation (647 MW) that was originally expected. As per section 3.1 above, the level of renewable generation that is required to be accommodated has fallen. Because the revised need can now be met by a smaller-scale technology options, the EHV technology options are not considered further in this study. This is aligned with EirGrid’s statement in the Grid Development Strategy[10] that the existing grid infrastructure will be optimised to maximise the usage of the existing grid and to minimise new infrastructure. Furthermore, a solution of this scale would initially only be able to operate as a wind power collection node. This means that this technology option would not normally be connected to the local network for risk of the generation overloading that network. Therefore it would be difficult to utilise it and it would be limited in its ability to facilitate any increases in electricity demand in the area.

### 3.3.5 Developed Longlist of Technology Options

A new 110 kV circuit alone will in the most cases not facilitate all the anticipated renewable generation in the area. Therefore, further 110 kV line uprates could be required within the area to give each overall technology option. The subset of 110 kV line uprates associated with each new 110 kV circuit option is identified as part of this technical assessment.

[8] http://www.eirgridgroup.com/site-files/library/EirGrid/Cable-Studies-for-Grid-West-Partial-AC-UG-Solution-Main-Report.pdf
[9] http://www.eirgridgroup.com/site-files/library/EirGrid/Grid-West-HVDC-Technology-Review-Report-PSC.pdf
[10] http://www.eirgridgroup.com/the-grid/irelands-strategy/

Table 2 details the developed *Longlist of Technology Options* based upon the above considerations. The table also includes the scheme name, the voltage level, technology and if applicable the potential length of the required new circuit and associated uprates.

*Table 2: Longlist of Technology Options*

| Option | Scheme Name | Voltage [kV] | Technology | New Circuit[11] [km] | Uprates [km] |
|---|---|---|---|---|---|
| 1 | Status Quo | 110 | OHL | - | - |
| 2 | Uprate Existing 110 kV Circuits | 110 | OHL | - | 139 |
| 3 | Double Circuit Reconfiguration (Sligo - Castlebar) | 110 | OHL | 125 | 148 |
| 4 | Bellacorick - Castlebar No. 2 | 110 | OHL | 45 | 125 |
| 5 | Bellacorick - Dalton | 110 | OHL | 76 | 97 |
| 6 | Bellacorick - Tonroe | 110 | OHL | 88 | 32 |
| 7 | Bellacorick - Sligo | 110 | OHL | 92 | 81 |
| 8 | Bellacorick - Srananagh | 110 | OHL | 97 | 58 |
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 |
| 10 | Dalton - Moy | 110 | OHL | 59 | 97 |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 |
| 14 | Bellacorick - Castlebar No. 2 | 110 | UGC | 45 | 125 |
| 15 | Bellacorick - Dalton | 110 | UGC | 76 | 97 |
| 16 | Bellacorick - Tonroe | 110 | UGC | 88 | 32 |
| 17 | Bellacorick - Sligo | 110 | UGC | 92 | 23 |
| 18 | Bellacorick - Srananagh | 110 | UGC | 97 | - |
| 19 | Castlebar - Moy | 110 | UGC | 37 | 125 |
| 20 | Dalton - Moy | 110 | UGC | 59 | 97 |
| 21 | Moy - Tonroe | 110 | UGC | 58 | 32 |
| 22 | Moy - Sligo | 110 | UGC | 61 | 23 |
| 23 | Moy - Srananagh | 110 | UGC | 66 | - |

More significant Less significant

The length of the new required circuits is on average c.73 km. The upper bound of the required new build is represented by the double circuit reconfiguration on the route from Sligo to Castlebar 110 kV substation with a total required estimated new build of c.125 km. The option which requires the shortest estimated new build is the technology option from Castlebar to Moy 110 kV substation with a total estimated new build of 37 km.

[11] The circuit length includes a offset for routing around constraints of 25%.

Perhaps somewhat obviously, the technology options with Bellacorick as a starting 110 kV substation generally require a longer new build in comparison to their counterparts having Moy (located near Ballina to the east of Bellacorick 110 kV substation) as the starting 110 kV substation, given that all options connect with existing 110 kV substations to the east and south east. The circuits from Bellacorick 110 kV substation are therefore longer by approximately 20 to 50% depending on the final terminating 110 kV substation.

The UGC technology options from either Moy or Bellacorick 110 kV substation to Sligo or Srananagh do not require the uprate of Castlebar – Cloon 110 kV circuit of 58 km. The different makeup of the UGC results in different power flows which reduce the power flow on this particular export pathway.

#### *3.3.5.1 Overhead Line (OHL)*

Overhead line is the conventional technical option for high voltage power transmission. It is a well-established method of transmitting electrical energy over long distances and is used at all voltage levels[12] in Ireland and internationally. OHL structures can carry a single circuit or double circuit depending on system requirements; however, in the case of the North Connacht Project single and double circuit structures are being considered.

At 110 kV, the OHL conductor is supported by polesets such as that shown in Figure 5 (left) below. Figure 5 (right) shows a typical steel angle tower of the type used where an OHL needs to change direction or at a line termination point.

*Figure 5: 110 kV single circuit poleset with shield wire (left)*
*Typical 110 kV single circuit OHL steel angle tower with shield wire (right)*

[12] i.e. 10/20 kV to 400 kV

### 3.3.5.2 Underground Cable (UGC)

At 110 kV, it may be possible to construct the circuit using underground cable[13]. A 110 kV UGC circuit consists of three individual XLPE[14] cables. For 110 kV circuits the cables are typically installed in High-Density Polyethylene (HDPE) ducts within a trench measuring approximately 600 mm wide x 1250 mm deep. Where possible the ducts are usually installed in roadways or along road margins as shown in Figure 6.

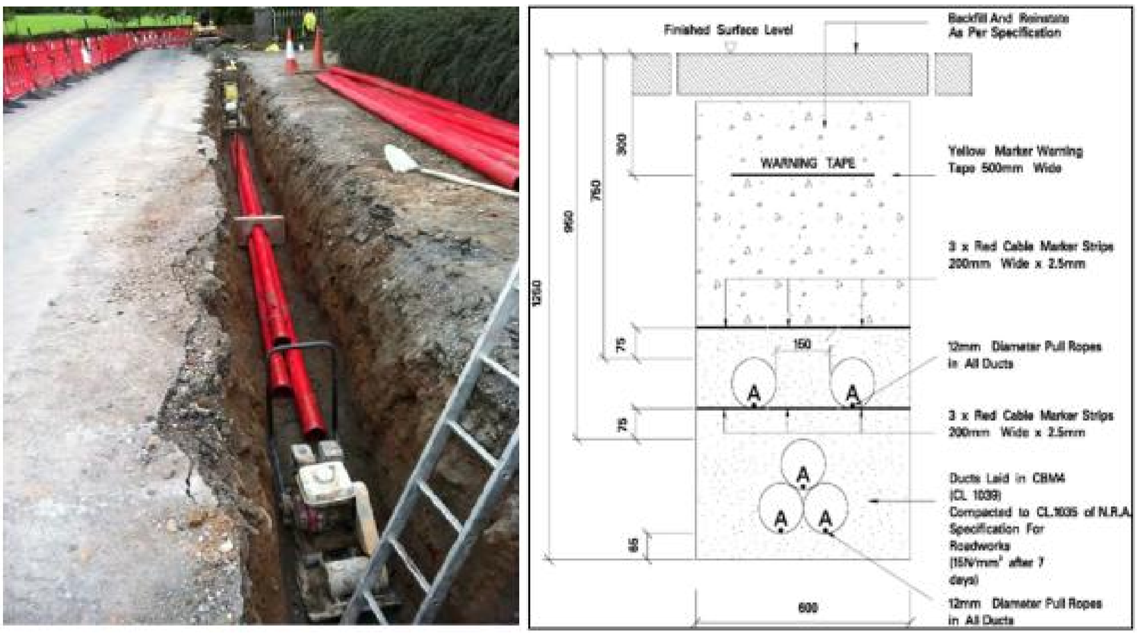


*Figure 6:* EirGrid Standard 110 kV cable trench

Underground cable solution may require filter banks or compensation devices at the starting and terminating 110 kV substation. The specification of these additional requirements for cables is not assessed in this Step 2 – Options report. This will be subject to a more detailed cable study in Step 3 of The Framework of Grid Development.

110 kV cable circuits are usually installed as follows:

1. Total undergrounded circuit from location A to location B, or

2. Partially undergrounded, where relatively short sections of an otherwise OHL circuit are laid underground to avoid or overcome obstacles or visually sensitive areas. A partial undergrounding solution of an OHL is considered where it is technically feasible, environmentally acceptable and where such a solution can overcome or mitigate unavoidable local constraints.

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[13] Subject to confirmation of applicability via detailed design
[14] Cross linked polyethylene

Where a partial undergrounding of an OHL is required an OHL/UGC interface tower is used. An OHL/UGC interface tower allows a circuit to be diverted from OHL to UGC, and a typical interface tower is shown in Figure 7[15]. It consists of a steel tower with integrated cable sealing ends and lightning arresters which allow the OHL to be converted to UGC.

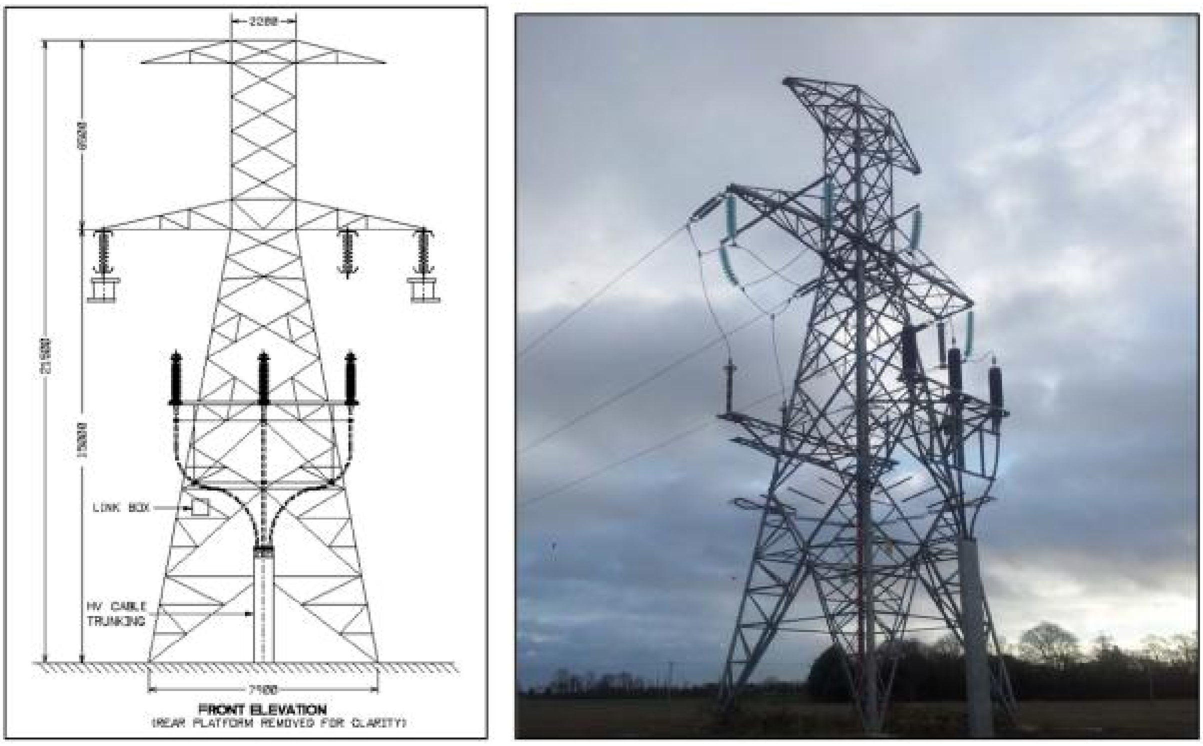


*Figure 7: 110 kV OHL/UGC Interface tower*

[15] Note: Example shown is without shieldwire

## 3.4 Evaluation of Longlist of Technology Options

The area in which the potential development of any longlisted technology option lies is shown in Figure 8. This area forms the initial and wider study area of the North Connacht Project. The boundary of the study area is determined by the potentially affected district electoral division (DED).

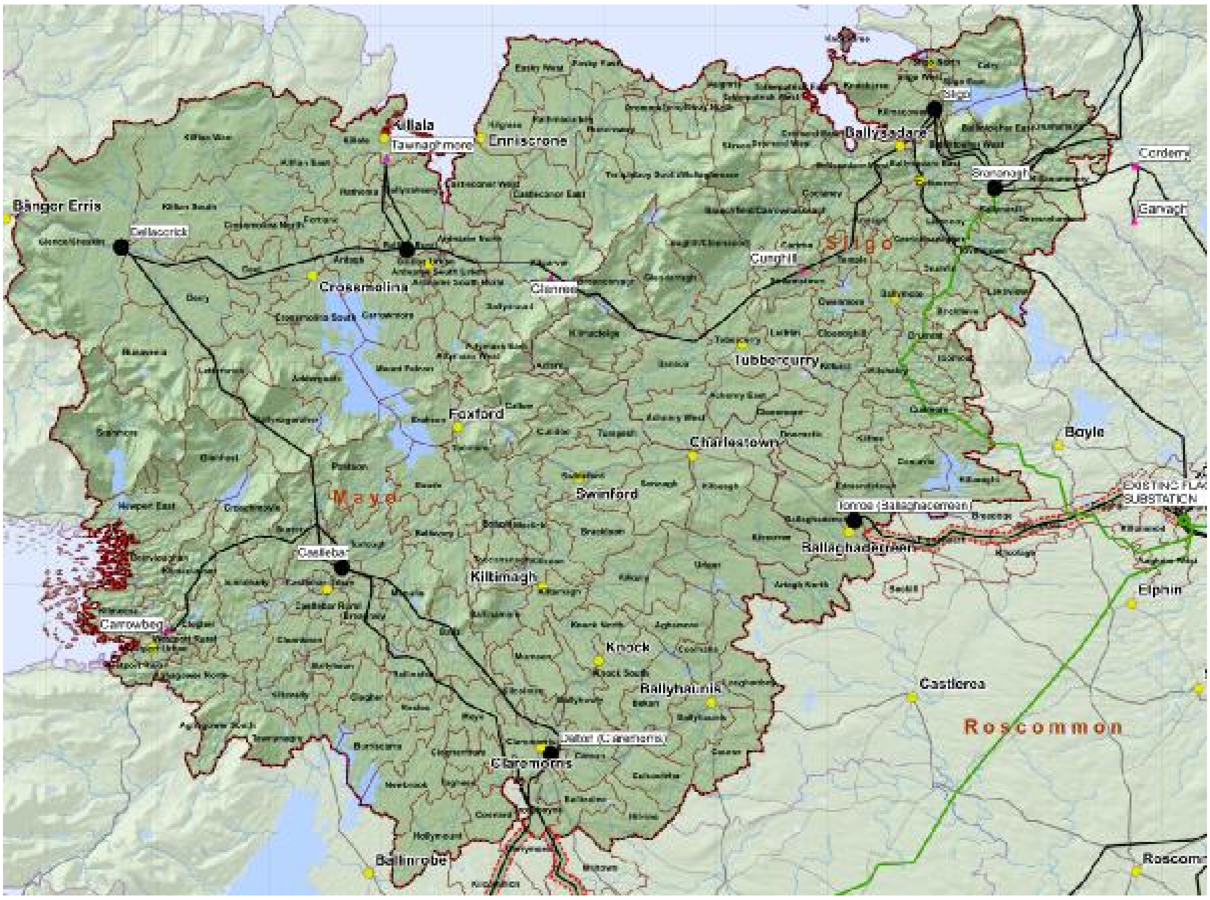


*Figure 8: Study Area for High Level Assessment of Longlist of Technology Options*

According to section 2.3, the *Longlist of Technology Options* is first assessed on two criteria, in order to reduce the number of potential options and refined the *Longlist of Technology Options*. These are (a) technical performance and (b) indicative capital costs.

### 3.4.1 Technical Performance

Each of the technology options with a new 110 kV circuit requires a new bay at the starting and terminating substations. A summary of potential new circuits is shown for the schemes in Table 3 below.

*Table 3: Summary of the Substations Included in each Node-to-Node Option*

| Option | Scheme Name | Voltage [kV] | UGC/ OHL | New Circuit [km] | Uprates [km] | Bellacorick | Castlebar | Moy | Dalton | Tonroe | Sligo | Cunghill | Glenree | Srananagh |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Status Quo | 110 | OHL | - | - | | | | | | | | | |
| 2 | Uprate Existing 110 kV Circuits | 110 | OHL | - | 139 | | | | | | | | | |
| 3 | Double Circuit Reconfiguration (Sligo - Castlebar) | 110 | OHL | 125 | 148 | ü | ü | ü | | | | ü | ü | |
| 4 | Bellacorick - Castlebar No. 2 | 110 | OHL | 45 | 125 | ü | ü | | | | | | | |
| 5 | Bellacorick - Dalton | 110 | OHL | 76 | 97 | ü | | | ü | | | | | |
| 6 | Bellacorick - Tonroe | 110 | OHL | 88 | 32 | ü | | | | ü | | | | |
| 7 | Bellacorick - Sligo | 110 | OHL | 92 | 81 | ü | | | | | ü | | | |
| 8 | Bellacorick - Srananagh | 110 | OHL | 97 | 58 | ü | | | | | | | | ü |
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | | ü | ü | | | | | | |
| 10 | Dalton - Moy | 110 | OHL | 59 | 97 | | | ü | ü | | | | | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | | | ü | | ü | | | | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | | | ü | | | ü | | | |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | | | ü | | | | | | ü |
| 14 | Bellacorick - Castlebar No. 2 | 110 | UGC | 45 | 125 | ü | ü | | | | | | | |
| 15 | Bellacorick - Dalton | 110 | UGC | 76 | 97 | ü | | | ü | | | | | |
| 16 | Bellacorick - Tonroe | 110 | UGC | 88 | 32 | ü | | | | ü | | | | |
| 17 | Bellacorick - Sligo | 110 | UGC | 92 | 23 | ü | | | | | ü | | | |
| 18 | Bellacorick - Srananagh | 110 | UGC | 97 | - | ü | | | | | | | | ü |
| 19 | Castlebar - Moy | 110 | UGC | 37 | 125 | | ü | ü | | | | | | |
| 20 | Dalton - Moy | 110 | UGC | 59 | 97 | | | ü | ü | | | | | |
| 21 | Moy - Tonroe | 110 | UGC | 58 | 32 | | | ü | | ü | | | | |
| 22 | Moy - Sligo | 110 | UGC | 61 | 23 | | | ü | | | ü | | | |
| 23 | Moy - Srananagh | 110 | UGC | 66 | - | | | ü | | | | | | ü |

The identified need in the Step 1 has shown that the Status Quo is not a feasible option due to excessive overloads. This option does not meet the identified need in the area. The option which only includes the uprate of the existing 110 kV infrastructure also does not meet the need of the area.

The double circuit configuration would be mounted on one tower and is associated with the double power carrying capability of a single circuit. Assuming that a potential trip or maintenance event would affect both circuits, the risk of security of supply would therefore be still present for certain trip-maintenance events. At this early point in the grid development process, the analysis of the existing 110 kV substations to facilitate one or two additional line bays for the double circuit configuration has not been done along the route. Hence, the risk exists that some 110 kV substations do not have enough space for additional bays and would require further busbar or substation uprates.

In the case of a second new Bellacorick – Castlebar 110 kV circuit in parallel, it is crucial that the line impedance of the new circuit is similar to the existing one in order to achieve balanced power flows[16]. Hence, the Bellacorick – Castlebar UGC technology option performs poorly.

The technology options with either Dalton or Castlebar as the final terminating 110 kV substation would not enhance the potential of demand growth in north Connacht. For further demand growth, the uprate of Moy – Glenree is required because this circuit is the limiting factor during a trip-maintenance event of Dalton – Cashla and Castlebar – Cloon. The uprate of Moy – Glenree would require an additional outage season in north Connacht. The required uprate, in addition to the already required uprates of c.125 km, and the risk in deliverability of these technology options, result in a poorer performance for these options.

All technology options will enhance the security of supply of either Bellacorick or Moy 110 kV substations. The new circuit in place converts either substation into a fully meshed 110 kV substation. This enhances the security of supply in the adjacent area significantly. Because Moy 110 kV substation load is approximately five times greater than the Bellacorick 110 kV substation load, the security of supply aspect is weighted greater for the technology option with Moy as starting 110 kV substation.

All UGC technology options require, to a certain extent, compensation equipment in order to prevent voltage range violations. The reactive power demand[17], which has to be compensated, tends to increase in proportion with the circuit length. Increasing compensation requirements would therefore result in a weaker performance. In addition, the reliability of UGC is affected by certain factors such as cable insulation, joint integrity and integrity of covering ground (e.g. unintentional excavation or piercing). Because UGC is buried, it does not have a direct access, meaning that failures are more difficult to detect which prolongs repair times. Consequently, the average failure rates and repair times are higher than for OHL. Hence, UGC performance on reliability is poor relative to OHL. Both compensation and reliability are related to the length of the circuit which would give shorter

[16] Asymmetrical power flows on two parallel circuits could result in certain situations in an overload of one circuit while the other circuit would still have capacity available.
[17] A detailed assessment of the required compensation will be carried out in a cable study at Step 3. The high level assessment would not be appropriate to quantify the compensation requirements.

UGC technology options a slightly better technical performance than longer UGC technology options.

The technology options with Bellacorick as starting 110 kV substation show overloads on the Bellacorick – Castlebar circuit during events of loss of the Cunghill – Sligo 110 kV circuit. During these events the wind generation along the route Cunghill – Glenree – Moy – Bellacorick accumulates on the outgoing Bellacorick – Castlebar 110 kV circuit which exceeds at high wind power output the power carrying capability of the existing circuit. In order to prevent these overloads, the wind generation in the area has to be constrained by more than 20% during summer peak.

The OHL technology options with Tonroe as final terminating 110 kV substation show overloads in summer peak of up to 10% on the Castlebar – Cloon circuit during the event of loss of Cashla – Dalton circuit. In situation with higher wind or lower electricity demand, the overloads could exceed the power carrying capability of Castlebar – Cloon circuit. In future, this technology option may require the uprate of Castlebar – Cloon in order to facilitate higher wind generation in north Connacht area. The UGC technology options have in general different circuit impedance to OHL which result in different balance of power load flows in a meshed network. Therefore, the UGC technology options with Tonroe as final terminating 110 kV substation perform better in this regard than its respective OHL technology option due to more balance power flows.

Taking the analysis above into account, each technology option has had a scoring applied. This is shown in Table 4 below.

*Table 4: Technical Performance of Longlist of Technology Options*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Technical |
|---|---|---|---|---|---|---|
| 1 | Status Quo | 110 | OHL | - | - | Options 1 and 2 do not meet the need |
| 2 | Uprate Existing 110 kV Circuits | 110 | OHL | - | 139 | |
| 3 | Double Circuit Reconfiguration (Sligo - Castlebar) | 110 | OHL | 125 | 148 | |
| 4 | Bellacorick - Castlebar No. 2 | 110 | OHL | 45 | 125 | |
| 5 | Bellacorick - Dalton | 110 | OHL | 76 | 97 | |
| 6 | Bellacorick - Tonroe | 110 | OHL | 88 | 32 | |
| 7 | Bellacorick - Sligo | 110 | OHL | 92 | 81 | |
| 8 | Bellacorick - Srananagh | 110 | OHL | 97 | 58 | |
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | |
| 10 | Dalton - Moy | 110 | OHL | 59 | 97 | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | |
| 14 | Bellacorick - Castlebar No. 2 | 110 | UGC | 45 | 125 | |
| 15 | Bellacorick - Dalton | 110 | UGC | 76 | 97 | |
| 16 | Bellacorick - Tonroe | 110 | UGC | 88 | 32 | |
| 17 | Bellacorick - Sligo | 110 | UGC | 92 | 23 | |
| 18 | Bellacorick - Srananagh | 110 | UGC | 97 | - | |
| 19 | Castlebar - Moy | 110 | UGC | 37 | 125 | |
| 20 | Dalton - Moy | 110 | UGC | 59 | 97 | |
| 21 | Moy - Tonroe | 110 | UGC | 58 | 32 | |
| 22 | Moy - Sligo | 110 | UGC | 61 | 23 | |
| 23 | Moy - Srananagh | 110 | UGC | 66 | - | |

More significant/risk — Less significant/risk

### 3.4.2 Indicative Capital Costs

The indicative capital costs for each technology options are based on the length of the new circuit and the expected associated uprates which would be required. The indicative capital costs for each option are shown in Table 5.

*Table 5: Indicative Capital Costs of Longlist of Technology Options*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Indicative capital costs of new and uprated infrastructure [€ Mio.] |
|---|---|---|---|---|---|---|
| 1 | Status Quo | 110 | OHL | - | - | 0 |
| 2 | Uprate Existing 110 kV Circuits | 110 | OHL | - | 139 | 45 |
| 3 | Double Circuit Reconfiguration (Sligo - Castlebar) | 110 | OHL | 125 | 148 | 146 |
| 4 | Bellacorick - Castlebar No. 2 | 110 | OHL | 45 | 125 | 56 |
| 5 | Bellacorick - Dalton | 110 | OHL | 76 | 97 | 57 |
| 6 | Bellacorick - Tonroe | 110 | OHL | 88 | 32 | 42 |
| 7 | Bellacorick - Sligo | 110 | OHL | 92 | 81 | 52 |
| 8 | Bellacorick - Srananagh | 110 | OHL | 97 | 58 | 47 |
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | 54 |
| 10 | Dalton - Moy | 110 | OHL | 59 | 97 | 52 |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | 34 |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | 43 |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | 38 |
| 14 | Bellacorick - Castlebar No. 2 | 110 | UGC | 45 | 125 | 75 |
| 15 | Bellacorick - Dalton | 110 | UGC | 76 | 97 | 89 |
| 16 | Bellacorick - Tonroe | 110 | UGC | 88 | 32 | 80 |
| 17 | Bellacorick - Sligo | 110 | UGC | 92 | 23 | 75 |
| 18 | Bellacorick - Srananagh | 110 | UGC | 97 | - | 71 |
| 19 | Castlebar - Moy | 110 | UGC | 37 | 125 | 69 |
| 20 | Dalton - Moy | 110 | UGC | 59 | 97 | 77 |
| 21 | Moy - Tonroe | 110 | UGC | 58 | 32 | 58 |
| 22 | Moy - Sligo | 110 | UGC | 61 | 23 | 53 |
| 23 | Moy - Srananagh | 110 | UGC | 66 | - | 49 |

More risk/costly Less risk/costly

Even though the first two options do not meet the need, we have calculated the estimated costs of these for comparison purposes.

The uprate of the existing 110 kV infrastructure is limited to the pathways Moy – Glenree, Castlebar – Dalton, Dalton – Cashla and Castlebar – Cloon. The remaining lines on the route Castlebar – Bellacorick – Moy – Glenree – Cunghilll – Sligo meet already the transmission capacity of the 430mm$^2$ Bison ACSR operating at 80 ˚C in summer/winter of 178/219 MVA.

The double circuit configuration would be installed on steel lattice towers with two 430mm$^2$ Bison ACSR circuits operating at 80 ˚C in summer/winter of 178/219 MVA. The new build of a double circuit configuration would be along the route Castlebar – Bellacorick – Moy – Glenree – Cunghilll – Sligo. Further uprates are required for the pathways south from Castlebar via Dalton and Cloon to Cashla and east from Sligo to Srananagh to match the capacity of the new double circuit configuration. Due to the high costs for the double circuit route and the associated uprates, the economic performance is expected to be very poor.

Circuits with either Dalton or Castlebar as the final terminating 110 kV substation require uprates of the pathways south. The uprates ensure that the power carrying capability on the export pathways match the total capacity of lines coming from both Bellacorick and Moy 110 kV substations.

Technology options with Tonroe as a final terminating 110 kV substation require a new build of Tonroe 110 kV substation. A further line uprate is required between Flagford and Tonroe 110 kV substation to match the power carrying capability of the new circuit.

For the technology options with Sligo as a final terminating 110 kV substation, these would be associated with the line uprate of the two circuits going to Srananagh 110 kV substation.

Due to the location of Bellacorick 110 kV substation in the north-west of Connacht, the technology options with Bellacorick 110 kV substation as a starting 110 kV substation are associated with longer length of new circuits. In comparison with the technology options which have Moy as a starting 110 kV substation, the Bellacorick technology options are longer by a factor in a range of c.20 to 50% depending on the technology option. Hence, the technology options connecting into Bellacorick 110 kV substation have a poorer economic performance than their counterparts which have Moy as a starting 110 kV substation.

The UGC technology options to Sligo and Srananagh perform for both Moy or Bellacorick as starting 110 kV substation better than the respective OHL technology options. The UGC options result in different power flow in the north Connacht area because of a different makeup of cables. Therefore, these options could be managed without the uprate of Castlebar – Cloon of 58 km. Therefore, the capital cost for the associated uprates are lower in comparison to the respective OHL technology options.

### 3.4.3 Decision-Making

In the previous section, a high level assessment was performed for the *Longlist of Technology Options* against the technical and economic criteria. Table 6 shows the summary of the high level combined assessment.

*Table 6: Technical and Economic Performance of Longlist of Technology Options*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Technical | Indicative Capital Cost |
|---|---|---|---|---|---|---|---|
| 1 | Status Quo | 110 | OHL | - | - | Options 1 and 2 do not meet the need | |
| 2 | Uprate Existing 110 kV Circuits | 110 | OHL | - | 139 | | |
| 3 | Double Circuit Reconfiguration (Sligo - Castlebar) | 110 | OHL | 125 | 148 | | |
| 4 | Bellacorick - Castlebar No. 2 | 110 | OHL | 45 | 125 | | |
| 5 | Bellacorick - Dalton | 110 | OHL | 76 | 97 | | |
| 6 | Bellacorick - Tonroe | 110 | OHL | 88 | 32 | | |
| 7 | Bellacorick - Sligo | 110 | OHL | 92 | 81 | | |
| 8 | Bellacorick - Srananagh | 110 | OHL | 97 | 58 | | |
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | | |
| 10 | Dalton - Moy | 110 | OHL | 59 | 97 | | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | | |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | | |
| 14 | Bellacorick - Castlebar No. 2 | 110 | UGC | 45 | 125 | | |
| 15 | Bellacorick - Dalton | 110 | UGC | 76 | 97 | | |
| 16 | Bellacorick - Tonroe | 110 | UGC | 88 | 32 | | |
| 17 | Bellacorick - Sligo | 110 | UGC | 92 | 23 | | |
| 18 | Bellacorick - Srananagh | 110 | UGC | 97 | - | | |
| 19 | Castlebar - Moy | 110 | UGC | 37 | 125 | | |
| 20 | Dalton - Moy | 110 | UGC | 59 | 97 | | |
| 21 | Moy - Tonroe | 110 | UGC | 58 | 32 | | |
| 22 | Moy - Sligo | 110 | UGC | 61 | 23 | | |
| 23 | Moy - Srananagh | 110 | UGC | 66 | - | | |

More significant/difficult/risk/costly — Less significant/difficult/risk/costly

Four of five assessed OHL technology options with Moy as starting 110 kV substation perform the best in terms of technical and economic criteria. These four options show in the high level appraisal the best performance and provide a good technical performance for a reasonable economic effort.

For UGC technology options, the length of the circuit affects the technical and economic performance significantly due to the compensation requirements and associated civil work costs per km. The high level assessment shows that the best performing UGC technology option is Moy – Srananagh.

While this analysis only is based on technical and economic criteria, it should be noted that any option connecting to Bellacorick would also be highly constrained by environmental factors. An overhead line or underground cable would likely involve some degree of impact on the Bellacorick Bog Complex SAC and the River Moy SAC and could pose challenges passing the test of Appropriate Assessment- impacts on site integrity. Potential significant landscape and visual impacts would also be associated with any OHL development in the Bellacorick area.

As such, the *Refined List of Technology Options* comprise both UGC and OHL technology options; a total of four OHL and two UGC options will be brought forward for further multi-criteria evaluation in a level of detail appropriate to Step 2.

In summary, the *Refined List of Technology Options* includes the following development schemes:

- Castlebar – Moy 110 kV OHL
- Moy – Tonroe 110 kV OHL
- Moy – Sligo 110 kV OHL
- Moy – Srananagh 110 kV OHL
- Moy – Tonroe 110 kV UGC
- Moy – Srananagh 110 kV UGC

These technology options each have varying levels of 110 kV uprates as per Table 7.

## 3.5 Evaluation of Refined List of Technology Options

According to section 2.4, the *Refined List of Technology Options* is now assessed on five criteria, in order to reduce the number of potential options to the *Shortlist of Technology Options*. These criteria are (a) technical performance, (b) indicative capital costs, (c) environmental performance, (d) socio-economic performance and (e) deliverability.

To assist EirGrid in this analysis, TOBIN consultants were engaged to prepare a feasibility study[18]. This study was intended to determine the feasibility, or otherwise, of options primarily by way of identifying technical, environmental, and social issues. It does not provide any evaluation as to the comparative merit of those options. The initial study area introduced in section 3.4 has now been refined. The study area of the *Refined List of Technology Options* is shown in Figure 9.


*Figure 9: Study Area for High Level Assessment of Refined List of Technology Options*

[18] North Connacht 110 kV Feasibility Study - 2017

### 3.5.1 Technical Performance

The studies have shown that each technology option in the *Refined List of Technology Options* requires further upgrading works (commonly termed 'uprates') in other more remote parts of the network in order to be a technical viable technology option.

Table 7 lists for each technology option the required length of new circuit (+ 25% of estimated contingency) and the associated uprates of existing 110 kV circuits in km.

*Table 7: New Build and Associated Uprates Required by Technology Options*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Castlebar - Dalton 110 kV | Cashla - Dalton 110 kV (partial) | Castlebar - Cloon 110 kV | Glenree - Moy 110 kV | Flagford - Tonroe 110 kV | Sligo - Sranangh 110 kV #1 | Sligo - Sranangh 110 kV #2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Uprated line length [km]** | | | | | **28** | **39** | **58** | **14** | **32** | **11** | **12** |
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | ü | ü | ü | | | | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | | | | | ü | | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | | | ü | | | ü | ü |
| 13 | Moy - Sranangh | 110 | OHL | 66 | 58 | | | ü | | | | |
| 21 | Moy – Tonroe | 110 | UGC | 58 | 32 | | | | | ü | | |
| 23 | Moy - Sranangh | 110 | UGC | 66 | 0 | | | | | | | |

In order to assess the technical performance of each of the technology options, two different study cases were performed with either high or low electricity demand. The study cases were modelled for the year 2023 and are namely:

- Summer Peak with wind generation at 80%;in north Connacht dispatched; and
- Summer Valley with wind generation at 70% in north Connacht dispatched.

It is rare that the output of a particular wind farm is at 100% due to the geographical spread of the turbines. It is even rarer that all the wind farms in a region are operating at 100% at the same time for similar reasons, even during situations of high wind. Therefore the dispatch levels listed above are deemed to be credible.

Table 8 summarises the results of the more detailed assessment and the associated performance. These criteria tested against are required as part to ensure the legal planning standards of the network have been met, as below:

- **System Voltage Ranges:** Standards require the system voltage to stay within certain limits used to operate the system and rating of equipment. These include not only the actual voltage level but also the shift or change in voltage that will occur for the loss of an item of plant and equipment. In more extreme circumstances this shift will be so severe that the network will be unable to cope with this shift and the wider network voltage will collapse. These are commonly termed '**voltage violations'**;
- **Equipment Power Carrying Capability:** All equipment operating at transmission voltages has a capability to be able to safely pass through power. These capability limits can be defined by the manufacturer for a prefixed period. For example equipment may be capable of passing more power for a short duration (seconds to hours) than for a continuous period. If power flows greater than the capability flow through overhead power lines for example, the line will heat up, stretch and sag closer towards the ground. The thermal excess of equipment power carrying capability is commonly termed **'overloads'**;
- **Phase Angle**: Power can typically flow in a number of different ways through the transmission network to supply demand. These power flows are determined by the length and makeup of equipment in the various pathways in the transmission network. Power flows will meet different resistive forces which determine how much power will flow in one pathway or another. As the size of the power flow increases, and/or when the different resistive forces for each pathway are significantly different, the re-closure of one pathway can create a sudden change in power flow in the transmission network. This sudden change places stress on plant and equipment that can result in their failure. The stress level that will occur on re-closure is defined by the magnitude of the phase angle. Consequently, the operational standards[19] define a **maximum level of stress** which must not be breached; and
- **Load Growth Potential:** All reinforcement options should be assessed on their ability to address the use of electricity by existing demand customers and new demand customers for the foreseeable future.

The 110 kV substations which are considered as starting and terminating 110 kV substations of the respective technology options were assessed in the feasibility study. Identified issues

[19] Operating Security Standards - December 2011

in regard to operation and maintenance are also considered in this assessment for the starting and terminating 110 kV substation and the new circuit.

*Table 8: Technical Performance of the Refined List of Technology Options*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Technical |
|---|---|---|---|---|---|---|
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | |
| 13 | Moy - Sranangh | 110 | OHL | 66 | 58 | |
| 21 | Moy – Tonroe | 110 | UGC | 58 | 32 | |
| 23 | Moy - Sranangh | 110 | UGC | 66 | 0 | |

More significant//risk Less significant//risk

### 3.5.1.1 *System Voltage Ranges*

The voltage levels for the OHL technology options are within the normal operating voltage range. The voltage for the UGC technology options tend to be higher in comparison to the OHL technology options. Adequate compensation will resolve this issue. The required compensation will be analysed in a detailed cable study in Step 3. Hence, the UGC technology options perform slightly poorer.

### 3.5.1.2 *Equipment Power Carrying Capability (Overloads)*

All technology options show overloads during the event of contingency with a wind dispatch of 70% in summer valley and 80% in summer peak. The technology options OHL Moy – Tonroe, OHL Moy – Sligo, OHL Moy – Srananagh and UGC Moy – Srananagh show maximum overloads (5-10%) at the upper bound of the short term emergency rating. Less electricity demand or a higher wind generation could result into an excess flows higher than the overload capability which would require further constraints in the area.

The OHL Castlebar – Moy and UGC Moy – Tonroe perform slightly better in this regard but show also overloads of 1-5%.

However, these overloads are all within the 10% emergency rating.

#### 3.5.1.3 Phase Angle

The studies revealed that certain contingencies in north Connacht could result in phase angles of greater than 40 degrees (maximum level of stress) on re-closing. This is in breach of EirGrid's Operating Security Standards - December 2011. Depending on the technology option the circuit with the greatest phase angle after tripping is either:

- Cunghill – Sligo 110 kV; or
- Bellacorick – Castlebar 110 kV

In order to reduce the level of stress, the generation or demand level has to be adjusted in the area to prevent the sudden change of significant power flows on the transmission system. Remedial action post-contingency and pre re-closing were considered to alleviate the level of stress in order to be technically viable.

The maximum level of stress was exceeded for the following technology options:

- Castlebar – Moy 110 kV – OHL;
- Moy – Sligo 110 kV – OHL; and
- Moy – Srananagh 110 kV – OHL.

Due to the high generation capacity connected to Bellacorick, constraints were applied on these generators post-contingency and pre re-closing. The remedial action result in a reduction in phase angle on pre re-closing in a range of 5 to 11 degrees.

The OHL Moy – Tonroe technology options did not require remedial action but the level of stress would be considered to be at the upper bound of the admissible stress.

In this regard, both UGC technology options perform better than their respective OHL technology options. Due to the different makeup of equipment the level of stress is lower.

#### 3.5.1.4 Load Growth Potential

The demand potential was assessed in a load growth analyses at Moy and Bellacorick 110 kV substation for the contingency events of N-1[20] and N-1-1[21]. All the technology options

[20] The N-1 tests include disturbances in which the loss of a plant or equipment occurs.

make Moy 110 kV a new meshed node which is beneficial in terms of security of supply. The additional circuit and the associated connection into a meshed node ensures supply to that particular 110 kV substation in any N-1-1 contingency event.

The technology option Castlebar – Moy is only allowing for an additional load of c.10 MW in Summer Peak in times without any generation on (worst case). In this case the power carrying capability of Moy – Glenree is limiting the load growth potential during the N-1-1 of Cashla – Dalton 110 kV and Castlebar – Cloon. The uprate of the Moy – Glenree circuit, which limits the power flows, would increase the power carrying capability during events of contingencies from 115 MVA to 195 MVA. The additional capability would allow for more load growth potential in the area.

All remaining Technology Options along with their uprates have a load growth potential of c.60 MW during Summer Peak in times without any generation on in the area. The limiting factor is the voltage range and reactive power support in the area. Assuming no generation in the area, the system services provided by generators are not available which consequently lead to voltage violations. Additional reactive power support would in these situations allow for an additional 10-20 MW load growth potential.

#### *3.5.1.5 Maintenance and Operations*

**Stations**

Moy will also have an upgraded busbar by the time new bay is required, but the bay will need to be installed in a back to back formation due to space availability and to provide a balanced busbar layout in terms of electrical power flows. Because Moy is the starting 110 kV substation, this is applicable to all six technology options in the *Refined List of Technology Options*.

From an operations and maintenance perspective Tonroe would be the most desirable technology option, as any new busbar will be built to EirGrid's latest standards and policies.

Sligo and Srananagh require a standard line bay installation in an existing 110 kV substation, so it is not envisaged that the bays will be subject to any specific restrictions or procedures.

[21] The trip-maintenance N-1-1 tests include disturbances in which the trip outage of a transmission or power infeed element occurs while another element is on an outage, where there is sufficient period between the first and second outage to allow for adjustment back to normal operation.

Castlebar station is already quite congested, and any new bay would be required to be connected with a back to back connection, and may lead to Designated Work Area (DWA) outages on the bay and adjacent bays when maintenance is required.

**New Circuits**

The technology option Castlebar – Moy has three export pathways which are namely:

- Cashla – Dalton 110 kV circuit
- Castlebar – Cloon 110 kV circuit
- Cunghill – Sligo 110 kV circuit.

If any of these circuits is out for maintenance, the remaining export pathways are reduced to two. A further outage of plant or equipment would leave north Connacht with one remaining export pathway. This increases the complexity for outage planning and the associated maintenance. During these periods of maintenance it is likely that constraints would have to be applied on wind generation to prevent the system from overloads. All the other technology options create an additional export pathway to the above mentioned ones. This additional pathway reduces the complexity in regard to maintenance and operations. Hence, Castlebar – Moy option has the lowest performance in comparison to the other options.

Due to the inaccessibility of UGC, the UGC technology options are associated with high maintenance effort and repair times than OHL technology options. Hence, the UGC technology options perform poorer than their respective OHL technology options. The UGC options receive a downgrade in this regard.

### 3.5.2 Indicative Capital Costs

The estimated indicative capital costs associated with each technology option are calculated. Table 9 shows the performance. These estimated costs include a contingency of 10%. Note only project indicative capital costs estimates for the circuit elements and associated uprated are included here. Pre-engineering cost will be considered at Step 3 of The Framework of Grid Development but is expected they will be largely the same for all technology options.

*Table 9: Estimated Capital Costs for Refined List of Technology Options including 10% Contingency*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Indicative Capital Costs [Mio. €] | | Total |
|---|---|---|---|---|---|---|---|---|
| | | | | | | New Circuit | Associated Uprates | |
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | 14 | 45 | 59 |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | 21 | 16 | 37 |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | 22 | 26 | 48 |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | 24 | 18 | 42 |
| 21 | Moy – Tonroe | 110 | UGC | 58 | 32 | 48 | 16 | 64 |
| 23 | Moy - Srananagh | 110 | UGC | 66 | 0 | 54 | 0 | 54 |

More risk/costly Less risk/costly

The new build elements of the OHL technology options range from €14m to €24m. In contrast, the build of the UGC technology options range from €48m to €54m.

The technology option with Castlebar as final terminating 110 kV substation is associated with the uprate of the three 110 kV circuits of Cashla – Dalton, Castlebar – Dalton and Castlebar – Cloon and the uprate of Dalton 110 kV substations busbar. These uprates add up to a total length of c.125 km. This equates into an indicative capital cost of c.€45m for uprates only. The estimate of indicative costs for the new circuits of c.37 km totals to c.€14m. The economic performance is poor due to the high capital cost.

Currently the Flagford – Tonroe 110 kV line has a rating of 98 MVA and functions as the supply for the electricity demand customers connected to Tonroe (Ballaghaderreen) only. As there is only one circuit into the 110 kV substation at Tonroe there is only limited equipment with no busbar available. Hence, in addition to the uprate of the Flagford – Tonroe circuit the Tonroe 110 kV substation has to be redeveloped. The estimate of indicative capital costs for the line uprate and the new 110 kV substation are c.€16m for the technology option with Tonroe as terminating 110 kV substation.

The OHL technology options with Sligo or Srananagh as terminating 110 kV substation require the uprate of Castlebar – Cloon of c.58km. The associated capital costs are estimated to c.€18m. The respective UGC technology options do not require this uprate due to different power flows.

Technology options with the terminating 110 kV substation in Sligo require the uprate of the two lines connecting Sligo into Srananagh 110 kV substation. The total length of these uprates is c.23 km with a total estimated capital costs of c.€8m.

The technology options with the lowest associated indicative capital costs for new build and uprates are either the OHL technology option Moy – Tonroe or Moy – Srananagh. The estimates of indicative capital costs are in a range of c.€37m to c. €42m.

### 3.5.3 Environmental

This high level assessment of environmental performance is based on a desktop appraisal of environmental constraints including, ecology, water, cultural heritage and landscape. The appraisal considers both the identified new circuit options, and the identified uprates to existing circuits associated with each option in the *Refined List of Technology Options*.

Existing data sets related to these environmental variables have been examined as well as previously compiled constraints studies carried out in this area. Key issues considered in this high level assessment include potential interactions with European Sites designated Special Areas of Conservation (SAC) or Special Protection Areas (SPA), where satisfying the test of Appropriate Assessment under the Habitats Directive could prove challenging.

Other environmental topics such as cultural heritage, noise, traffic (for example, the need for localised road closures and/or diversions) etc. are generally more location-specific and are difficult to subject to a high-level appraisal. In this regard, it is considered that there is no large-scale or wide-ranging issue in respect of these other environmental topics that would distinguish one option from another.

The wider study area is influenced by the natural landscape features of this region. There are notable overlaps between the ecological, landscape and cultural heritage importance of many features in this area of north Connacht. The River Moy and its tributaries influence a significant catchment area. Lough Conn and Lough Cullin, south of Ballina are of high landscape and amenity value and designated sites for nature conservation. Towards Sligo, the Ox Mountains, and Lough Hoe Bog SAC are of ecological and landscape significance as are the coastal landscape and habitats that provide for bird species (SPAs such as Killala Bay / Moy Estuary SPA and Ballysadare Bay SPA); these are also areas of significant visual beauty, amenity and interest.

There are also significant peat deposits in this region with sites designated SAC and Natural Heritage Areas (NHA) for bog complexes. There are numerous sites designated SPA for migrating and overwintering bird species including whooper swan. The future routing of any circuit will need to factor potential collisions for at risk species.

The assessment of the technology options is shown in Table 10 below and described further in the following paragraphs.

*Table 10: High Level Assessment of Environmental Performance*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Environmental |
|---|---|---|---|---|---|---|
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | |
| 21 | Moy – Tonroe | 110 | UGC | 58 | 32 | |
| 23 | Moy - Srananagh | 110 | UGC | 66 | 0 | |

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

#### *3.5.3.1 Castlebar – Moy (OHL)*

The area between Castlebar and Moy is influenced by the large waterbodies Lough Conn/Lough Cullin and the River Moy. These features are European Sites and of high amenity and define the landscape of the area.

The Castlebar – Moy OHL technology option would require crossings of the River Moy SAC and a crossing of the Moy valley NHA. While not insurmountable, Conn and Lough Cullin (SPA) is a significant environmental constraint in this area, and options around this large water body will need to address ecological, landscape amenity and cultural heritage considerations.

A route to the West of Lough Conn and Lough Cullin is also highly constrained by ecological and landscape features. The River Moy SAC extends to this area and the Bellacorick Bog complex is a significant constraint further west. Towards the south of this area, the Westport River catchment is a highly sensitive freshwater system, further constrained by Natural Heritage Areas (NHA) of Croaghmoyle Mountain NHA and Cunnagher More Bog NHA.

The extent of associated uprates for this option is the highest among the six brought forward. While the uprates occur to existing infrastructure, the potential environmental impacts, particularly in relation to European Sites (SAC, SPA) and NHA sites need to be considered.

#### *3.5.3.2 Moy – Tonroe (UGC & OHL)*

It is likely any route would be south of Ballina, requiring crossings of the River Moy SAC and a crossing of the Moy Valley NHA. The routing of an overhead line east of Ballina would be challenging due to the upland influence of the Ox Mountains, Lough Hoe Bog SAC and Lough Nabrickkeagh Bog SAC. The catchment of the River Moy SAC dominates the ecological and water environment between Foxford and Tonroe. Landscape and Cultural Heritage factors are also of significance.

While overhead line options will need to factor landscape and bird collision risks in particular, underground cable options will also need to consider potential impacts on water dependant features including peatlands and crossings of the River Moy SAC in particular. The excavations required for cable installation could destabilise peat deposits and any implications for water quality and peat habitat degradation will require careful consideration.

This option has a low requirement for associated uprates.

#### *3.5.3.3 Moy – Sligo (OHL), Moy – Srananagh (UGC & OHL)*

Taking an eastern / north eastern option from Moy to Sligo or Srananagh, all of these options require crossing of the River Moy SAC (close to Ballina) and crossing of the Unshin River SAC south of Sligo.

An overhead line option in each case would run parallel to the coastline to the north and may constitute a collision risk for birds travelling from the coast (SPAs such as Killala Bay/ Moy Estuary SPA and Ballysadare Bay SPA) to inland waterbodies such as Lough Gara SPA and the River Moy SAC.

In addition, this area is also highly constrained in terms of landscape designations and cultural heritage assets, including those associated with the Carrowmore Passage Tomb Cemetery. Again, while not insurmountable, this adds an additional layer of environmental complexity to these options.

The routing of an overhead line east of Ballina would be challenging due to the upland influence of the Ox Mountains, Lough Hoe Bog SAC and Lough Nabrickkeagh Bog SAC.

An underground cable route located within the road network would reduce the need for land take from protected habitats and eliminate any collision risk associated with overhead lines in all cases. This option for all cases is therefore considered less ecologically constrained. It should be noted however that there is a risk of contamination of water courses during construction, and crossing of SPAs and SACs within the road network may in some cases require working in very close proximity to protected habitats or species. The risk of habitat loss, destruction or disturbance of species is not offset by opting for an underground cable.

In addition to the potential environmental issues of any new circuit option, the Moy – Sligo option has the second highest length of associated uprates in the *Refined List of Technology Options*, which is also factored into this appraisal.

### 3.5.4 Socio-Economic

Social impacts are generally seen as changes to one or more of the following:

- People's way of life – how they live, work, interact etc.
- Their culture – shared beliefs, customs, values, language etc.
- Their community – cohesion, stability, character, facilities etc.
- Their political systems – participation in decision-making, level of democratisation, resources available for this etc.
- Their environment – quality of water, air, food etc.; level of emissions they are exposed to; adequacy of sanitation; physical safety etc.
- Their health and wellbeing – physical, mental, spiritual etc.
- Their personal and property rights – economics, disadvantage etc.
- Their fears and aspirations – perceptions of safety; fears for the future of the community; aspirations for their future and the future of their children.

Step 2 of the Methodology addresses "*Early Baselining and Screening for SIA*". Given that the technology options are based on straight line circuits between existing substations, plus 25% for routing around constraints, as well as the identified associated uprates of existing circuits, there is generally not a significant level of detail to facilitate anything more than a high-level appraisal. The summary is shown in Table 11 below.

*Table 11: High Level Assessment of Socio-Economic Performance*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Socio-Economic |
|---|---|---|---|---|---|---|
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | |
| 21 | Moy – Tonroe | 110 | UGC | 58 | 32 | |
| 23 | Moy - Srananagh | 110 | UGC | 66 | 0 | |

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

The nodes themselves are located in proximity to larger settlements – Ballina (Moy), Castlebar, Ballaghaderreen (Tonroe), and Sligo (both Sligo and Srananagh). Other larger settlement, community and employment nodes in the area include Foxford, Swinford, Charlestown, Knock Airport, Tobercurry, Collooney, Ballysadare and Sligo. This is by no means intended as an exhaustive list. Nor is it intended to exclude other settlements and nodes that may ultimately occur in proximity to a new circuit, whether OHL or UGC.

Tourism in this area is of significant importance, generally based upon the existing landscape and natural features of the area. This includes Lough Conn south-west of Ballina, the Nephin uplands west of Lough Conn, and the uplands and coastal area between Ballina and Ballysadare/Sligo. It also includes settlement nodes and associated tourism resources of Sligo and environs, Ballina, Foxford and Swinford, including tourism accommodation and activities such as the woollen mills in Foxford, and angling on the Moy River and Lough Conn.

Aside from rural agricultural activities, primarily rough grazing and turbary, in the generally rural Social Area of Influence (SAOI), the larger employment nodes include Ballina, Sligo and environs, Knock Airport and the Charlestown area, and Ballaghaderreen.

In general, it can be considered that a new circuit OHL solution will have a greater potential for social impact than a UGC, due to the perception of impact or change, whether or not this is the case in fact. The uprating of existing OHL does not have the same level of impact;

however, from a social impact perspective, the perception of change may have a resulting social impact. All OHL options (including associated uprates) therefore have potential at this stage for some level of impact; while some options are longer, and therefore might be considered to potentially have a greater extent of social impact, they generally travel through areas with less settlements.

All OHL options have nothing more than a medium level of significance / difficulty / risk in this Step, as most potential impacts will be able to be mitigated through appropriate siting, as well as stakeholder, public and landowner engagement in the various Steps of The Framework. It might be reasonable to assume that greater potential for social impact occurs in the vicinity of settlements, and as such, those options from Moy (Ballina) to Castlebar, Tonroe, and Sligo are considered to have a slightly higher level of significance relative to Srananagh.

UGC generally has no social impact (as defined above) at this high-level. In further Steps of The Framework, this issue needs further consideration, particularly in terms of routing through or in the vicinity of settlements, employment nodes and along any significant tourism routes.

### 3.5.5 Deliverability

The 110 kV substations which are considered as starting and terminating 110 kV substations of the respective technology options were assessed in a feasibility study[22]. Table 12 shows the summary of the analysis for the relevant substations, as concluded in a previous feasibility study. The basis for these conclusions is summarised below.

*Table 12: Summary of the Substations Analysis*

| Station | | Project Duration | Circuit outages to facilitate the new bay in station | Constructability of new line bays and associated works | Constructability of filter and compensation devices |
|---|---|---|---|---|---|
| 1 | Castlebar | | | | |
| 2 | Moy | | | | |
| 3 | Sligo | | | | |
| 4 | Srananagh | | | | |
| 5 | Tonroe | | | | |

[22] North Connacht 110 kV Feasibility Study - 2017

| More significant/difficult/risk | Less significant/difficult/risk |
|---|---|

In terms of project duration, the construction of a new Tonroe 110kV substation requires extensive amount of construction works. However, the construction of a new Tonroe 110 kV substation could be carried outside of the existing area where there is live equipment. Therefore it can be constructed in parallel to the circuit new build.

In terms of circuit outages, Tonroe offers the option with the least amount of outages due to the fact that a new busbar could be constructed on the existing site within a separate compound. It may be possible to divert the incoming Flagford 110 kV line to a mobile bay to enable the construction of the new busbar to be completed in a fenced off section of the site. This would allow the substation to remain energised during the installation works. However one outage is required anyway. EirGrid has indicated that obtaining the necessary outage may prove extremely difficult which makes the Tonroe option a less favourable option.

In terms of constructability of new line bay and associated works, Moy and Castlebar are the most challenging options. Due to the limited space within the substations, the bay may need to be installed in a "Back to Back" arrangement which may require DWA outages for maintenance on the energized equipment located in close proximity to the new bay. Moy performs slightly better than Castlebar as the substation is less congested, and space may be gained by realigning the substation fence line.

In terms of constructability of filter and compensation devices, Moy and Sligo have adequate space in their respective control rooms (the Moy control room is to be extended as part of the busbar uprate works). However, the lands required for extension of substations are owned by third parties. In Castlebar, Srananagh and Tonroe, the main obstacle to constructability is the extension of the substation boundary.

Based on the substation assessment a high level risk assessment in terms of deliverability was performed. Furthermore, the length of new circuit and uprates were also taken into account in this assessment. Table 13 shows the results of this high level assessment.

*Table 13: High Level Assessment of Deliverability*

| Option | Scheme Name | Voltage [kV] | UGC/OHL | New Circuit [km] | Uprates [km] | Deliverability |
|---|---|---|---|---|---|---|
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | |
| 21 | Moy – Tonroe | 110 | UGC | 58 | 32 | |
| 23 | Moy - Srananagh | 110 | UGC | 66 | 0 | |

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

The Castlebar – Moy OHL technology option has the shortest new build (37 km) and is associated with the longest uprates of 125 km. The new circuit can be build offline without impacting on the existing network. The associated uprates will need to be completed over several outages seasons. In addition there is a high risk in Castlebar 110 kV substation in regard to constructability of a new line bays and associated works and the future risk related to operations and maintenance. Therefore, this option would be the least favourable technology option.

Moy – Tonroe OHL requires a new 110 kV substation in Tonroe (Ballaghaderreen), a new build of approximately 58 km and uprates of 32 km. The new 110 kV substation requires additional time for construction and transfer over of circuits. However, the deliverability is expected to be better than technology options terminating in Castlebar or Sligo 110 kV substation because of less required uprates and better station performance.

The Moy – Tonroe UGC technology option is expected to perform slightly poorer than its OHL counterpart assuming that the civil works associated with the UGC technology options take longer to implement than the OHL.

The technology options Moy – Sligo and Moy – Srananagh perform similar in regard to the terminating 110 kV substation. The new build of a 110 kV substation is associated with a more extensive project duration and The Moy – Srananagh Technology Options requires the longest new build and a similar amount of uprates. But Moy – Sligo OHL technology option is associated with longer uprates and would therefore be associated with higher risk in terms of deliverability than the Moy – Srananagh OHL technology option.

The Moy – Srananagh UGC technology option is associated with less uprates and would perform better than its OHL technology option due to less works in this regard. However, the peatland between Moy and Srananagh 110 kV station would be associated with significant impact on associated civil works. Hence, the total performance of this UGC option is poorer than its respective OHL option.

### 3.5.6 Decision-Making

Using a multi-criteria performance matrix the *Refined List of Technology Options* is reduced to the *Shortlist of Technology Options* to be taken into Step 3 of The Framework process. The performance matrix assesses the relative performance of options across criteria prescribed in the sections 3.4.1 to 3.4.5. A standard set of five (5) criteria, namely: technical, economic, socio-economic, environmental and deliverability criteria are used. Table 13 shows the relative performances of each option in the *Shortlist of Technology Options*.

*Table 14: Performance Assessment of Refined List of Technology Option*

| **Option** | **Scheme Name** | **Voltage [kV]** | **UGC/OHL** | **New Circuit [km]** | **Uprates [km]** | **Technical** | **Economic** | **Environmental** | **Socio-Economic** | **Deliverability** |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Castlebar - Moy | 110 | OHL | 37 | 125 | | | | | |
| 11 | Moy - Tonroe | 110 | OHL | 58 | 32 | | | | | |
| 12 | Moy - Sligo | 110 | OHL | 61 | 81 | | | | | |
| 13 | Moy - Srananagh | 110 | OHL | 66 | 58 | | | | | |
| 21 | Moy – Tonroe | 110 | UGC | 58 | 32 | | | | | |
| 23 | Moy - Srananagh | 110 | UGC | 66 | 0 | | | | | |

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

The technology option **Castlebar – Moy OHL** shows a low technical performance and higher associated capital costs relative to other options. The potential for environmental impact associated with this circuit is expected to be relatively high, while the socio-economic impact is influenced by its potential proximity to a number of larger settlements in the north

Connacht region. In terms of deliverability, this Technology Options is associated with a relatively high risk due to the length of required uprates. Hence, this OHL technology option would be the least favourable option in the *Shortlist of Technology Options*.

The technology option **Moy – Sligo OHL** shows in the high level assessment significant challenges with regard to the environment relative to other technology options. As with **Castlebar – Moy OHL**, the potential socio-economic impact is influenced by its potential proximity to a number of larger settlements in the north Connacht region, in particular Ballina and Sligo and environs. However, the technical and economic performance relative to other technology options, does not outweigh the relatively poorer performance against environmental, socio-economic and deliverability criteria. Therefore, this technology option does not perform as well as other options in this multi-criteria analysis.

The technology option **Moy – Tonroe OHL** has the best technical performance relative to the other identified technology options. Due to the shortest total length of new build and associated uprates this option has also the best economic performance relative to other options. The environmental appraisal shows higher potential risks than the **Moy – Tonroe UGC** option but lower potential risks than the OHL technology options terminating in either Sligo or Srananagh 110 kV substation; however, in contrast, the relative socio-economic performance of the **Moy – Tonroe OHL** is moderate relative to the UGC options and Moy – Srananagh OHL option. In terms of deliverability, the **Moy – Tonroe OHL** performs better due to less expected civil works in comparison to the **Moy – Tonroe UGC** option. However relative to other OHL options, the **Moy – Tonroe OHL** option performs the most favourably option in the multi-criteria analysis.

The technology option **Moy – Srananagh OHL** performs well in the multi-criteria analysis, relative to other technology options. In comparison with the **Moy – Tonroe OHL** option, it has slightly higher estimated capital costs and therefore relatively a poorer economic performance. Higher capital costs associated with the **Moy – Srananagh UGC** reduce the economic performance further in comparison to the **Moy – Srananagh OHL**. Socio-economic performance of the **Moy – Srananagh OHL** is better relative to the other OHL options but not as good as the performance of the UGC options. In regard to deliverability, the performance of the **Moy – Srananagh OHL** is better than the **Moy – Srananagh UGC.** This OHL option is considered to be one of the preferable OHL options in this regard.

Overall, on the basis of the multi-criteria analysis above, the OHL technology options which, in relative terms, perform the best are the **Moy – Tonroe OHL** and the **Moy – Srananagh OHL.**

Overall, the UGC technology options **Moy – Tonroe UGC** and **Moy – Srananagh UGC** both perform generally similarly. In relative terms, the **Moy – Tonroe UGC** technology option has a slightly poorer economic and deliverability performance.

Due to the overall average rating of both UGC technology options, both will be taken into the Step 3 of The Framework process.

Having regard to the multi-criteria analysis above, and the expert judgement that underpins this analysis as set out in this Step 2 - Options Report, the *Shortlist of Technology Options* that will be taken into Step 3 of EirGrid's Framework for Project Development comprise the following and have been re-labelled as option 1 to 4:

1. Moy – Tonroe new 110 kV – OHL plus 32 km uprates;
2. Moy – Srananagh new 110 kV – OHL plus 58 km uprates;
3. Moy – Tonroe new 110 kV – UGC plus 32 km uprates; and
4. Moy – Srananagh new 110 kV – UGC plus 0 km uprates;

Figure 10 shows the starting and terminating 110 kV substations of the respective technology options. Further it also highlights the associated uprates in the south and east of the study area which are namely:

- Castlebar – Cloon 110 kV circuit (58 km); and
- Flagford – Tonroe 110 kV circuit (32 km).

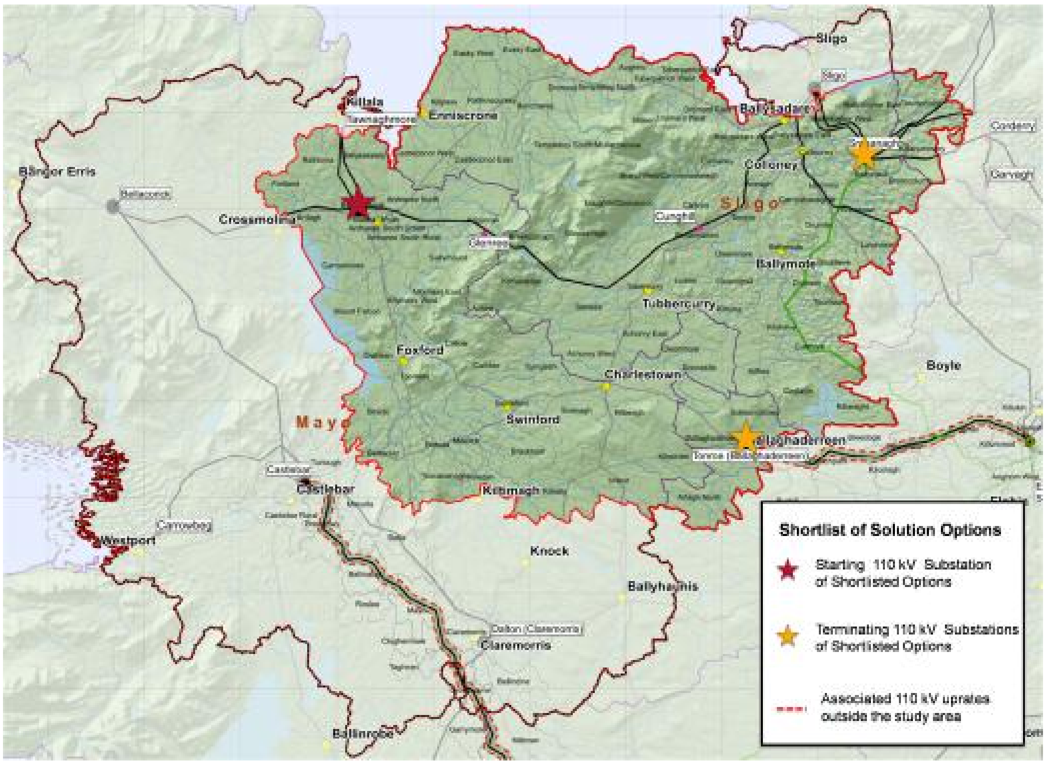


*Figure 10: Starting and Terminating 110 kV Substation of Shortlist of Technology Options*

It should be noted that these technology options do not require to be exclusively OHL or UGC, but rather could ultimately be implemented as hybrid (OHL and UGC). This is a decision that is unlikely to be taken until the latter Steps of The Framework, and in particular Steps 4 and 5, when the final nature, extent, location, and likely technical, economic social and environmental impact is known.

## 3.6 Project Complexity

The analysis has shown that each option in the *Shortlist of Technology Options* of the North Connacht Project requires a new circuit. The new build could be implemented as a OHL, UGC or a hybrid of both OHL and UGC. Any option involves the acquisition of land and its transformation into a transmission corridor which eventually facilitate the new circuit.

The implementation of North Connacht Project affects many customers and stakeholders and may affect the natural, human and built environment along its potential corridor. Therefore, the project has been classified as Tier 3 having regard to EirGrid's Framework for Grid Development.

## 3.7 Stakeholder Engagement

In September 2017, EirGrid announced plans to replace the Grid West electricity transmission project with a smaller-scale development[23].

Landowners, communities and stakeholders along the former Grid West corridor for whom EirGrid had postal contact details, and local and national media were informed about the changes in the need for transmission system development the north Connacht area. For further stakeholder engagement with people from the area, the Castlebar Regional Office was opened, in September 2017, to the public to inform in more detail about the changes in need.

The Western Development Commission[24] (WDC) and the Mayo County Council[25] raised concern in regard to the demand growth development potential in the north Connacht area. They had concerns that demand growth would be potentially limited by the smaller-scale development.

The smaller-scale options actually enhance the security of supply in the north Connacht region because the new circuit will strengthen the existing 110 kV infrastructure, especially in the area adjacent to Moy 110 kV substation. Some of the developed options will allow for a substantial demand growth of c.60 MW in north Connacht region in summer peak in 2023 (see section 3.5.1.4). This basically corresponds to a demand growth of at least two to three times of the expected demand of Moy 110 kV substation which totals c.22 MW in summer peak in 2023[26].

Grid West, in its initial form as a wind generation collection node would have been operated as a tail. This solution option would not have been connected into the existing 110 kV network in north Connacht. Consequently, the loss of Grid West due to failure of plant or equipment leads to the total loss of supply of the connection node. This high risk associated with a tailed operation would not be acceptable for certain commercial customers. Therefore, the demand growth potential would have been available only for customers that would accept the associated risk level of interruption of supply.

In Step 3 of The Framework, the demand growth potential will be analysed in more detail as part of the multi criteria analysis. These concerns have been taken into consideration in the

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23 http://www.eirgridgroup.com/the-grid/projects/grid-west/whats-happening-now/
24 http://www.wdc.ie/
25 http://www.mayococo.ie/en/
26 http://www.eirgridgroup.com/site-files/library/EirGrid/All-Island-Ten-Year-Transmission-Forecast-Statement-2016.pdf

assessment of the *Refined List of Technology Options* regarding load growth potential in section 3.5.1.4.

# 4 Conclusion

In the Step 1 for the North Connacht Project, the need for this project was identified. In order to meet this need, the *Longlist of Technology Options* was created in Step 2 – Options Report which could potentially meet the identified need. The *Longlist of Technology Options* included 23 technology options which comprised 110 kV line uprates only and 110 kV new build of circuits. For the new build both underground cable (UGC) and overhead line (OHL) were analysed. This evaluation was based on “straight-line” point-to-point options (with some provision made for anticipated divergence from a straight line) and standard capital costs (with some contingency). The *Longlist of Technology Options* was subject to initial high-level technical and economic appraisal, facilitating the creation of the *Refined List of Technology Options* of four OHL and two UGC technology options which do meet the identified need for the project. A more detailed, but still high level, assessment against technical, economic, environmental, socio-economic and deliverability criteria was carried out on the *Refined List of Technology Options* of six Technology Options. The result of this multi criteria assessment is the *Shortlist of Technology Options* of four options which will be taken into the Step 3 of The Framework for Grid Development.

All the technology options have Moy 110 kV substation (Ballina) as the starting point and either Tonroe (Ballaghaderreen) or Srananagh as the terminating 110 kV substation. The two point to point connections could be built as OHL or UGC[27]. The four technology options are as follows:

1. Moy – Tonroe new 110 kV – OHL plus 32 km uprates;
2. Moy – Srananagh new 110 kV – OHL plus 58 km uprates;
3. Moy – Tonroe new 110 kV – UGC plus 32 km uprates; and
4. Moy – Srananagh new 110 kV – UGC plus 0 km uprates;

Given the potential technologies that may be used for any of these options, the results indicate a range of estimated indicative capital costs of c.€35m to c.€65m. These costs will be refined further in Step 3 when a full economic assessment will be carried out.

In accordance with The Framework, the complexity of the project was defined as Tier 3.

The project enters Step 3 of The Framework, which will subject these four shortlisted options to greater technical, economic, environmental, socio-economic and other analysis, and on a

[27] The hybrid of overhead line and underground cable as technology option was not analysed yet and could represent a viable technology option.

spatial and geographical basis. This process will help to determine the best performing technology option, and the geographical area in which it is likely to be situated.

# Appendix A: List of Figures

# Appendix B: List of Tables

# Appendix C: Generation Capacity

## C.1 Detailed Overview of Step 2 Process

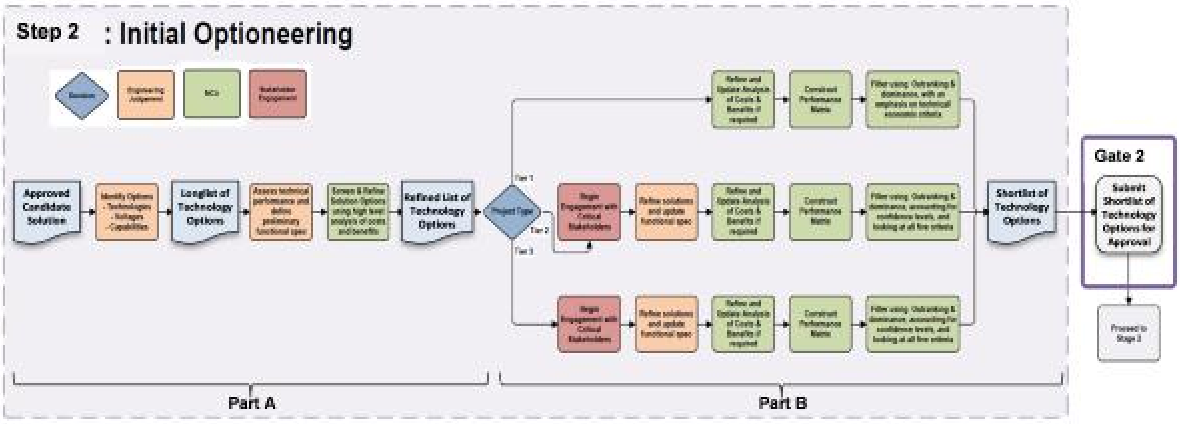


*Figure 11: Overview of Step 2 of Developing the Shortlist of Technology Options*

## C.2 Generation in North Connacht

| | Connected/Contracted Capacity [MW] | | | | | | |
|---|---|---|---|---|---|---|---|
| Station | Pre-Gate | Gate 1 | Gate 2 | Gate 3 (Wind) | Misc (FAQ) | Misc (non FAQ) | Total |
| Bellacorick | 6 | 0 | 0 | 301 | 10 | 0 | 317 |
| Moy | 0 | 6 | 0 | 0 | 0 | 1 | 7 |
| Tawnaghmore | 0 | 0 | 0 | 30 | 153 | 0 | 183 |
| Glenree | 0 | 0 | 62 | 15 | 0 | 0 | 77 |
| Cunghill | 24 | 0 | 11 | 0 | 0 | 0 | 35 |
| Dalton | 0 | 0 | 3 | 41 | 0 | 1 | 45 |
| Carrowbeg | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cloon | 0 | 0 | 4 | 0 | 0 | 4 | 8 |
| Tonroe | 6 | 0 | 4 | 0 | 0 | 8 | 18 |
| Sligo | 3 | 0 | 0 | 14 | 0 | 0 | 17 |
| Castlebar | 23 | 0 | 22 | 0 | 0 | 0 | 45 |
| Total | 62 | 6 | 106 | 401 | 163 | 14 | 752 |

*Table 15: Generation Capacity Assigned to Areas Adjacent to substations in north Connacht in 2017*