The Grid Link Project

Report for the Independent Expert Panel

September 2015

EIRGRID

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1. EXECUTIVE SUMMARY

This report sets out an analysis of alternative options to meet the need of the Grid Link project in line with the Terms of Reference[1] as set by the Government-appointed Independent Expert Panel. The report considers both overhead and underground solutions in respect of environmental, technical and economic characteristics.

In our analysis we identified a solution, referred to as the 'regional option'. This option meets the need of the project, and minimises the development of new large scale infrastructure.

The 'regional option' uses a technology known as 'series compensation'. This would be the first time it is used on the Irish transmission grid. In this application it would be deployed as an advanced, smart-grid technology that would allow more power to flow through existing lines, and so does not require the significant new transmission circuits in the other options.

To complete this solution, an underwater cable across the Shannon estuary would need to be laid, in addition to a set of reinforcements elsewhere on the system. As this option would require no significant new overhead infrastructure, it would have a much reduced cost and reduced impact on the environment.

This report details the investigations for each option under the required technical, environmental and economic criteria. The analysis is based on the latest information available and work carried out to date. An equal analysis has been applied to the three options in accordance with the panel's terms of reference.

In March 2015, we published our draft grid development strategy "Your Grid Your Views Your Tomorrow" for consultation. We set out three strategic pillars for developing the grid; open engagement with communities, making the most of new technologies and a commitment to make the existing grid work harder before building new transmission infrastructure.

As a result of this new approach, this innovative 'regional option', has emerged as a potential solution to meet the needs of the Grid Link project.

The proposed 'regional option' was welcomed by many respondents to the draft strategy consultation.

While it is understood that a decision on the option to be brought forward is not within the remit of the panel, we believe that in the interests of transparency, our preference for the regional option should be noted.

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[1] http://www.dcenr.gov.ie/news-and-media/en-ie/Pages/PressRelease/Statement-by-the-Independent-Expert-Panel-considering-the-EirGrid-Grid-West-and-Grid-Link-projects.aspx

2. INTRODUCTION

In January 2014, the then Minister for Communications, Energy and Natural Resources Pat Rabbitte, announced the establishment of an Independent Expert Panel (IEP) to conduct an independent review of the overhead and underground options for the Grid West and Grid Link projects.

Under the Terms of Reference, as prescribed by the IEP, overhead and underground options should be assessed under technical, economic and environmental criteria. Other feasible alternatives should also be considered.

In March 2015, EirGrid published a draft strategy for the development of Ireland's electricity grid. This highlights that there remains a need for the Grid Link project. However, changing demand forecasts and a slower rate of growth than originally forecast at the commencement of the project, combined with upgrade works on existing lines and advances in technology, means that it is now possible to consider other technical options to meet the need of the Grid Link project.

As a result of the associated analysis, the Grid Link project now has three feasible technical options which meet the need. The three options set out in this report are as follows;

- 320 kV HVDC underground cable option (described in more detail at Section 6 of this report);
- 400 kV HVAC overhead line option (described in more detail at Section 7 of this report); and
- Regional option (described in more detail at Section 8 of this report).

2.1 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, 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 network generators and demand users, we must develop the electricity transmission network to ensure it is suitable for those connections.

2.2 PROJECT DEVELOPMENT TO DATE

Three key drivers underpin the need for further development of the electricity transmission network in the south and south east of Ireland, namely:

1. The integration of new generation
2. Ensuring that security of supply is maintained
3. The facilitation of possible future interconnections with either Great Britain or France

In 2010/2011 we examined the potential impact of the above on the technical performance of the transmission system. The network analysis, at that time, indicated that these drivers introduced generation patterns that gave rise to large regional electricity flows from the south of Ireland towards the east coast. This analysis identified the need for additional high capacity circuits between Cork, the south east region and the greater Dublin area. Possible options were identified and developed, and ultimately a 400 kV overhead line from Dunstown to Knockraha (via Great Island) was deemed to be the preferred option at that time.

Subsequently, a draft study area was developed in early 2012. Following a first round of public consultation, a final study area was confirmed and environmental and other constraints[2] within this study area were then identified and mapped. The outputs of this constraints gathering and mapping stage were the subject of a second round of public consultation in late 2012. The finalised constraints mapping was then analysed by a range of technical specialists. This was done in order to identify a number of feasible 1km corridors within the study area which could accommodate the proposed overhead line. This analysis also sought to avoid significant strategic constraints to the greatest extent possible. This analysis culminated in the publication of the Stage One Report in September 2013, followed by a third round of public consultation which attracted circa 39,000 public submissions. Towards the end of this consultation, in January 2014, the IEP was established.

In March 2015, EirGrid published a draft strategy for the development of Ireland's electricity grid.[3] This identified a third option to meet the present needs of the Grid Link project involving a suite of transmission network reinforcements. This, together with the underground option and overhead line option are included within this report.

3. SCOPE OF THIS REPORT

The aim of this report is to present the investigation in respect of the various technical, environmental and economic criteria for each of the three options based on the information available to date. It presents information for each of the options in a consistent fashion, in line with the IEP Terms of Reference. The three options are presented on an equal and comparable basis.

[2] A constraint in this context is something that limits where infrastructure such as a building or a pylon can be built. Examples of physical constraints include the presence of a large town, a wide river or steep slope. An example of a legal constraint is a heritage site

[3] *Your Grid, Your Views, Your Tomorrow*, published at www.eirgrid.com

Where possible, this report has been developed in line with the scope and format of a similar report on the Grid West project, which was submitted to the IEP in February 2015. The Grid West report covers a comprehensive analysis of underground and overhead options for the project, including assessment of potential environmental impacts, technical efficacy and cost factors. In April 2015, the IEP confirmed that the Grid West report has been completed in line with the panel's terms of reference. While the structure and scope of this report follows that of the Grid West IEP report it should be noted that the Grid West and Grid Link projects differ in several ways, such as their scale and project timelines. The Grid West project is at a more advanced stage, and is of a significantly smaller scale relative to the Grid Link project. This facilitated the identification and detailed analysis of an overhead line and an underground cable route for the Grid West project report.

For the purpose of this report and in order to facilitate technical, environmental and economic analysis of the Grid Link options, illustrative underground and overhead route options have been identified by our consultants RPS Group. These route options have not been confirmed or endorsed as “least constrained” or “preferred” by EirGrid.

The environmental appraisal undertaken for the purpose of this IEP report should not be considered as equivalent to the significantly more detailed environmental assessment required for the purposes of preparing a project-specific Environmental Impact Statement (EIS). Detailed route specific environmental assessments have not been undertaken to date.

Potential impacts are therefore based on environmental sensitivities identified as part of constraints studies. Where mitigation is referenced, it is not site specific. It is based on mitigation assumptions of avoidance, reduction and restoration. It also considers the application of standard best practice for infrastructure construction and operation.

In addition, while the environmental analysis incorporates the headline topics identified in the Grid West report, it does not specifically assess the topics of agriculture and equine. These have been acknowledged as key issues of public concern in respect of the Grid Link project, and are the subject of separate, specialised reports, published in May 2015[4].

The same level of environmental, technical, and economic analysis has been set out for each of the three options identified in this report. In terms of the economic analysis of the various options, the capital cost for each is estimated based on standard transmission development costs provided by ESB Networks, manufacturers' data and knowledge of similar developments. Life-cycle costs are calculated for each option. Details of associated assumptions and rationale are provided where relevant.

Each technical option is presented in a separate chapter of this report. While this approach facilitates comparability, it may also lend itself to some repetition, though every attempt has been made to minimise such instances where possible.

[4] ‘Responding to Agricultural Concerns’ and ‘Responding to Equine Concerns’ are available on request or at www.eirgrid.com

4. GRID LINK PROJECT NEED

4.1 BACKGROUND

In common with the majority of other European TSOs, we have historically developed the transmission network based on traditional demand and generation patterns. This ensures that a safe, secure, reliable, and efficient transmission infrastructure is in place where it is needed to move electricity from where it is generated to high demand centres e.g. cities and towns. This has to be done to ensure that at all times supply and demand is balanced. Moreover, in reference to our statutory obligation, the system must be economical.

The Grid Link project was originally developed in order to facilitate the following drivers:

1. The integration of new generation
2. Ensuring that security of supply is maintained
3. Meeting future need including possible interconnections with Great Britain or France

These drivers introduce generation patterns that give rise to large regional electricity flows from the south west towards the east coast of Ireland. In turn these electricity flows give rise to network problems which need to be addressed. These problems as originally identified, can be categorised as insufficient network capacity and insufficient voltage support. This need extended to the South, South East and South Midlands regions of Ireland. The loss of any of the 220 kV circuits in these regions would subsequently result in thermal overload primarily on the 110 kV network. It would also result in unacceptable low voltages and potential wide spread voltage collapse.

4.2 PROJECT REVIEW AND OUTCOME

Throughout the lifetime of individual projects, project need is regularly reviewed. A project can also be reviewed if an aspect or assumption which may influence the project changes. All reviews are carried out to ensure a continued robust justification for investment. The first review of the need for the Grid Link project was conducted in 2013 to coincide with the release of the lead consultant's Stage One report. This report was issued in September 2013.

This review confirmed that the original drivers for the project (as set out in section 2.2) remained. It was found that a very high percentage of the renewable generation applicants in the south west had signed their connection offers. It further confirmed EirGrid's statutory obligation of facilitating potential future interconnection and the requirement to ensure security of supply.

In addition, the review took account of changes to assumptions in demand forecasts, a slower rate of growth, and improvements to the existing grid.

The review also identified that the two original aspects of the need, i.e. insufficient network capacity and insufficient voltage support, were still present. However, the priority relative to each other had changed and the voltage support issue had become more urgent. It also identified further voltage support issues on the east coast, requiring additional reinforcement of this area.

Despite the identified change in need and change in priority between the issues, the analysis indicated that the Grid Link project was still required. On this basis the lead consultant's Stage One report was published for consultation in September 2013.

As the project progressed it was subjected to further review, ultimately forming part of our review of the Grid25[5] Strategy. During these investigations a third need came to light, which involved large phase angles. In addition, the requirement for looping the Grid Link development project into the Great Island station was seen to have lessened. Key factors contributing to this included changes in demand forecast and a slower rate of growth.

While it was identified that connecting into Great Island was not required for the overhead line option it was seen as strategically appropriate to continue to route the reinforcement towards the geographical area of the south east of the country. Doing so allows for potential future development in the south east such as a new industrial demand customer or a new interconnector.

The changes in demand forecasts, a slower rate of growth, and improvements to the existing grid have facilitated consideration of additional technical options to meet the need. Three alternative solutions were identified as technically feasible as part of the review. Two of these were based on original options presented in the lead consultant's Stage One report. The technically feasible options were communicated to the public in conjunction with the launch of the draft grid development strategy in March 2015.

4.3 THE INTEGRATION OF NEW GENERATION

As the national TSO, we are statutorily required[6] to offer terms and enter into agreements, where appropriate and in accordance with regulatory direction, to all those using and seeking to use the electricity transmission system. We must ensure that the grid can accommodate any new demand or generation seeking to connect. Hence, when offers to potential energy demand users and generators are accepted, we must develop the transmission grid to ensure it is suitable for those connections.

National and European energy and climate policy[7] means the nature of electricity generation is changing. Increased energy from renewable sources means that we must, in common with other European TSOs, develop the network in order to bring renewable energy sources onto the system. On-going innovation via our Delivering Secure Sustainable Systems programme[8] (DS3) places us at the forefront of operating these new forms of generation and their impact on the transmission system. This has facilitated our ability to operate the existing grid assets closer to their limits thereby maximising their potential. In tandem, given the requirement to integrate large amounts of renewable generation onto the system, there is an additional need for increased transmission infrastructure.

[5] In May 2014 EirGrid formally initiated a review of the Grid25 strategy
[6] Statutory Instrument No.445 of 2000 (as amended).
[7] Government White Paper, 12th March 2007, 2009/28/EC Renewables directive
[8] http://www.eirgrid.com/operations/ds3/

For electricity generators, the Commission for Energy Regulation (CER) has determined that applications to connect to the transmission and distribution systems are processed in groups called 'gates', in accordance with the Group Processing Approach[9].

The most recent group, Gate 3[10], comprises a significant amount of wind generation. Under Gate 3, circa 4000 MW of wind generation projects have been offered a contract to connect to the transmission network. Of this, circa 810 MW are located in the south west area of Ireland. Approximately 1300 MW of electricity generation technologies other than wind have also been offered a contract to connect under Gate 3.
In addition to the Gate 3 renewable generation existing contracted generation needs to be considered. This existing contracted generation consists of both conventional and renewable generation.

4.4 ENSURING SECURITY OF SUPPLY

Facilitation of new generation together with existing generation and/ or potential future interconnection in the south east introduces large regional electricity flows from the south towards the east coast of Ireland. These electricity flows cause three physical phenomena which affect security of supply and must be addressed, namely:

- Voltage collapse
- Large phase angles
- Thermal overload

The following provides the reader with a high level explanation of these factors.

4.4.1 Voltage collapse

On the existing transmission network, many of the 400 kV and 220 kV circuits are heavily loaded during certain operating conditions. It should, however, be noted that the circuits are not overloaded. This means that they are still operating within their power carrying capacity. These circuits are highlighted in Figure 4-4.

Any circuit transporting electricity will either produce or absorb reactive power depending on how much power

Figure 4-4: *Heavily loaded circuits (highlighted in orange)*

9 Commission for Energy Regulation, September 2004, Group Processing Approach for Renewable Generator Connection Applications, CER/04/317.
10 Commission for Energy Regulation, 16 December 2008, Criteria for Gate 3 Renewable Generator Offers & Related Matters, Direction to the System Operators, CER/08/260.

is transferred on the circuit. The point where the circuit goes from producing to absorbing reactive power is, in technical terms, referred to as the Surge Impedance Loading (SIL). The highlighted circuits are loaded far above their SIL point during certain operating conditions.

Heavily loaded overhead lines absorb reactive power. During operating conditions when many of the existing 400 kV and 220 kV circuits are heavily loaded, an unplanned loss of any of these circuits (N-1[11]) increases the loading on remaining circuits. This results in increased reactive power absorption on the remaining circuits.

Reactive power is needed in an alternating current (AC) system to enable the network to transfer power from generating sources to demand centres. Reactive power is used to maintain voltage within standards.

If an adequate level of reactive power is not available to the network, a voltage collapse and loss of supply may occur, which is not acceptable and needs to be addressed. Reactive power can be supplied by devices installed in electricity stations.

4.4.2 Large phase angles

Alternating electrical current or voltage is mathematically represented in waves (sinusoidal in shape). The difference in time between the peaks of the voltage and current waves is known as the phase angle and is expressed in degrees. The phase angle will vary at every point across the network due to the physical characteristics of the network that links these points together and the power transferred between those points.

With high power transfers across the network, an increased difference occurs between the phase angles at either end of circuits. When the network has circuits out of service, power will be diverted to remaining circuits and will thereby increase the power flowing through these. The result is increased difference between the phase angle at either end of the circuits.

Large phase angles can lead to instability, potentially leading to the loss of parts of the network. Also, with a large phase angle it may not be possible to restore circuits to operation.

Currently the Irish transmission system experiences phase angles which are less than 20° when re-closing/energising occurs. Once the renewable generation is integrated into the network and an economic generation dispatch is utilised the transmission system could experience phase angles far in excess of our Operating Security Standards (OSS), which are set at no more than 40°.

[11] (N-1) – a loss of one item of plant on the transmission network (e.g. a circuit or transformer).

4.4.3 Thermal overloads

A thermal overload can occur when the power flow on a circuit exceeds its power carrying capacity causing overheating of the circuit. Overheating will cause increased conductor sag and eventually mechanical damage to the conductor. Under a number of scenarios thermal overloads on some of the existing circuits in the system have been identified, namely:

- Scenario 1 - Single contingencies (N-1)

  Resulting in thermal overloads on six circuits, one of which is a 220 kV circuit and the rest are 110 kV circuits.

- Scenario 2 - Maintenance trip (N-1-1[12])

  Resulting in thermal overloads on three 110 kV existing circuits between Cullenagh and Waterford stations.

The technical solution must either resolve these issues inherently or be considered in conjunction with other future works.

4.5 MEETING FUTURE NEEDS

In accordance with our statutory obligation, the network must be developed in such a way that it facilitates future needs. For the South West and the South East regions of the transmission network, we have considered strategic, long term network requirements, in conjunction with the immediate need to connect contracted generation.

Some of the potential issues concerning the transmission system in the South West and South East regions are outlined below. The possible impact of these must be considered when assessing the future development of the transmission network. It should be noted that future needs are difficult to predict and therefore it is necessary to make certain assumptions, for example about future demand forecast.

National and European energy policies have also been considered in the development of the Grid Link project. The Irish Government set a target that 40% of electricity consumed be from renewable sources by 2020[13]. In addition, beyond Gate 3, we have received generation applications[14] for the South West and South East regions, of approximately 10,500 MW. These applications include a variety of generating technologies. These applications do not form the basis of the identified need set out above.

The level of demand in Ireland is expected to grow, according to our latest analysis[15]. This has been taken into account in the assessment of the future needs.

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[12] (N-1-1) – a loss of one item of plant on the transmission network equipment (e.g. a circuit or transformer) while another is out of service due to maintenance.

[13] Government White Paper, 12th March 2007, *Delivering a Sustainable Energy Future for Ireland.* The original target set in this paper was 33%. This was increased to 40% in the Carbon Budget of October 2008 and confirmed in the National Renewable Energy Action Plan, July 2010.

[14] http://www.eirgrid.com/customers/gridconnections/completedgenerationapplications/

[15] EirGrid, All-Island Ten Year Transmission Forecast Statement, 2013 and All-Island Generation Capacity Statement 2015-2024.

Part of our mandate is to explore opportunities for interconnection with other systems. We are currently in a pre-feasibility phase investigating the development of a new interconnector with France. This potential interconnector may terminate in a station adjacent to the southern coast, for example Knockraha 220 kV station or Great Island 220 kV station. We are also aware of other interconnector proposals being considered by third party developers. All of these issues must be considered in assessing the future development of the transmission network.

4.6 SUMMARY OF NEED

Facilitation of new generation together with existing generation and/ or potential future interconnection in the south east introduces large regional electricity flows from the south towards the east coast of Ireland. These electricity flows cause three physical phenomena which must be addressed by the Grid Link project:

- Voltage collapse
- Large phase angles
- Thermal overloads

The scale of the associated power transfers and need to maintain security of supply as well as future needs require significant transmission reinforcements to alleviate these issues. The options proposed must provide several hundred Megawatts (MW) of additional power transfer to the existing transmission network.

The available options for reinforcements provide further transfer capacity through either a new Extra High Voltage (EHV) circuit or enhancement of existing infrastructure where spare capacity may exist.

5. OPTIONS CONSIDERED

Three options have been identified that will meet the need for reinforcement of the electricity grid in the South and South East regions. These options are a High Voltage Direct Current (HVDC) underground cable (UGC) option, a High Voltage Alternating Current (HVAC) overhead line (OHL) option, and a regional option. In the following sections, each of these options will be assessed according to the three main criteria prescribed by the IEP - technical, economic and environmental. Each of the main criteria is broken down further and analysed under sub-headings. The options identified to meet the need are described in further detail below:

Option 1: High Voltage Direct Current (HVDC) underground cable option

A ±320 kV 750 MVA[16] Voltage Source Converter (VSC) Direct Current (DC) symmetrical monopole scheme incorporating an underground cable linking the existing transmission stations of Knockraha, Co. Cork and Dunstown, Co. Kildare. This is described in more detail in Section 6 of this report.

Option 2: High Voltage Alternating Current (HVAC) 400 kV overhead line option

A 400 kV overhead line, rated for 1580 MVA[17], linking the existing transmission substations at Knockraha, Co. Cork and Dunstown, Co. Kildare. This is described in more detail in Section 7 of this report.

Option 3: Regional option

A suite of transmission network reinforcements, described in more detail in Section 8 of this report. In essence, the option involves:

- series compensation devices installed in three station locations in existing or future planned 400 kV transmission stations;
- a new 400 kV underwater cable circuit linking the existing Moneypoint and Kilpaddoge transmission stations; and
- existing line uprates and station upgrades, namely Great Island – Kilkenny 110 kV line, Great Island – Wexford 110 kV line and Wexford 110 kV station upgrade.

5.1 SCALE USED TO ASSESS EACH CRITERIA

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

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

The scale is also quantified by text for example mid-level (**Dark Green**), low-moderate (**Green**) or low (**Cream**).

[16] The rating of HVDC circuits is generally quoted in MW. However, for the ease of comparison we have assumed unity power factor and displayed the rating in MVA to enable a better comparison with HVAC options.
[17] Based on lowest annual rating in summertime (at 25 degrees Celsius)

6. HVDC UNDERGROUND CABLE (UGC) OPTION

6.1 DESCRIPTION OF OPTION

To achieve a fully underground option from Knockraha, Co. Cork to Dunstown, Co. Kildare HVDC technology is required. While both onshore and offshore preliminary route options were identified, for the purpose of this report the onshore option is assessed on the basis that it is substantially shorter than its offshore equivalent. The offshore route option length is 330 km in length, including 110 km onshore, whereas the onshore route option is 242 km. The longer offshore route will have higher costs, poorer technical performance, and, given its location relative to the existing AC transmission network, the development potential is reduced.

The initial capacity required for the scheme is 750 MVA. The best solution is to use VSC HVDC technology configured as a symmetrical monopole, operated at ±320 kV and rated to a capacity of 750 MVA.

An illustration of the technical arrangement for this option is shown in Figure 6 -1.

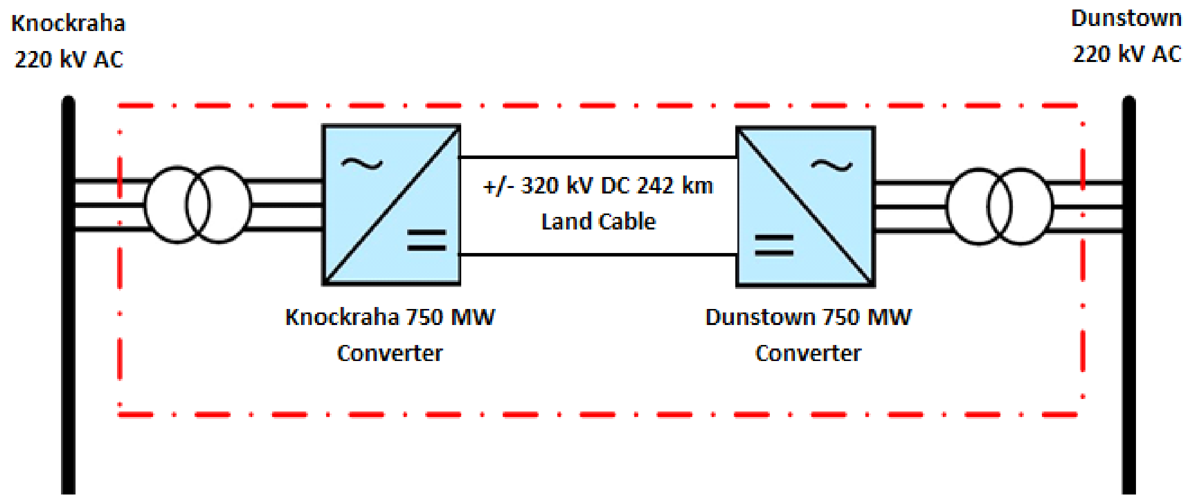

Figure 6-1 Technical arrangement for HVDC option

6.2 ENVIRONMENTAL ANALYSIS

6.2.1 Introduction

Environmental appraisal undertaken for this report should not be considered equivalent to the significantly more detailed environmental assessment required for a project-specific EIS.

Environmental constraints have been identified across a range of topics in line with the Terms of Reference of the IEP. For the purpose of this report, the environmental assessment for the underground option is based upon a potential underground route as identified by our consultants, RPS Group, and illustrated in Figure 6-2.

The analysis takes account of environmental studies prepared to date in respect of the Grid Link project. This analysis, for example, takes into account the Grid Link Stage One Report[18], and in particular the known possible environmental impacts arising from HVDC UGC technology. Therefore, while the analysis is at a high level, it does capture environmental sensitivities particular to the route corridor. The objective is to identify the potential for significant effects on a range of environmental topics. This is based on known impacts of transmission infrastructure development combined with local environmental sensitivities. The application of mitigation measures to reduce severity of impacts such as avoidance, reduction and/or restoration are assumed. Such mitigation is based on best practice for the construction and operation of transmission infrastructure.

This analysis also considers, where relevant, the findings of the Grid West Report for the Independent Expert Panel. It is also based on our experience in construction of transmission infrastructure of different technologies and in different landscape and habitat types.

Given the nature of this analysis, there are certain project-specific topics which to date have not been considered – these are air quality, climatic factors, traffic and noise. It is noted that these topics were considered for the Grid West IEP Report, given that it was predicated upon specific routes, rather than the illustrative options that form the basis of this report. For these topics it is considered reasonable to assume similar conclusions in the case of the Grid Link project. The conclusions of the Grid West IEP Report in respect of these topics are included in the summary of the environmental analysis - see Section 6.2.13 of this report. The following criteria are examined as part of the environmental analysis for the Grid Link HVDC UGC option.

- Biodiversity, Flora and Fauna
- Water
- Soils and Geology
- Landscape/visual
- Cultural Heritage

18 http://www.eirgridprojects.com/media/Stage%201%20Report.pdf

- Settlement/Communities
- Recreation and Tourism
- Material Assets (Land use)
- Air quality
- Climatic Factors
- Traffic and Noise

6.2.2 Underground Cable Route Option Description

The underground cable route option (Figure 6-2) is a length of 242 km running from Dunstown to Knockraha and primarily within the road network. From Dunstown to Durrow the route follows local and regional roads diverting around Athy. It then follows the alignment of the R639 (declassified N8) to Horse and Jockey where it diverts around Cashel via local and regional roads, re-joining the R639 south of Cashel. It follows the R639 to north of Mitchelstown and then follows on local and regional roads to Knockraha avoiding Mitchelstown, Fermoy, and the M8 motorway.

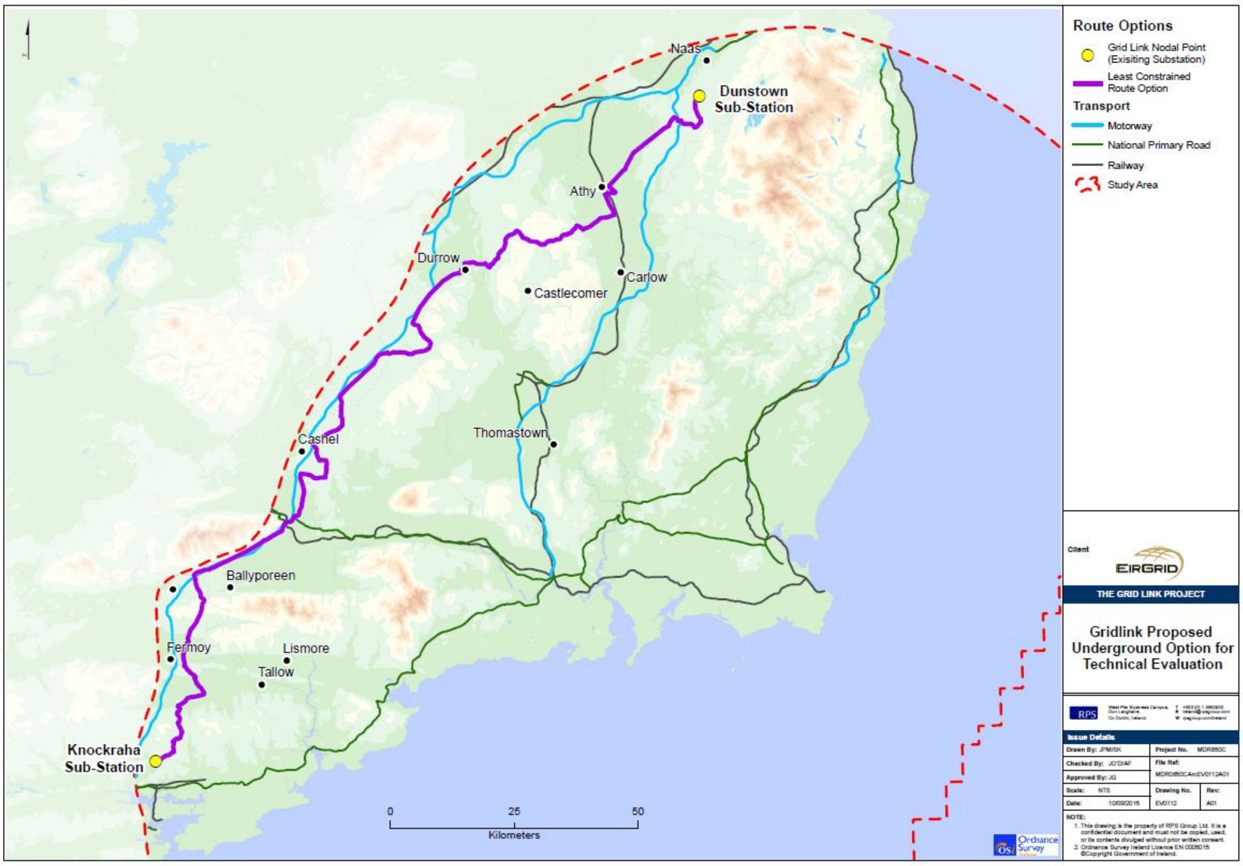

Figure 6-2 Grid Link underground option for technical evaluation

6.2.3 Biodiversity, Terrestrial Ecology

For the purpose of this assessment, terrestrial and aquatic ecology have been treated separately. Aquatic ecology is considered under Section 6.2.4 to avoid duplication of impacts.

For the most part, the UGC is installed under public roads, with cable joint pits installed every 800-1200m, and converter stations at each end on green or brown field sites. Potential impacts to ecological receptors from the UGC option will arise mainly from the construction phase, for example associated with cable crossings of rivers and habitat loss at converter stations.

The primary aspects considered include potential impacts on designated sites such as cSACs, and SPAs impacts on the terrestrial ecology and on high nature value habitats, birds and other fauna. Designated sites are avoided by route corridors where possible, with the exception of river cSACs (see section 6.2.4). While crossing one SPA, the overall impact of UGC on birds is considered low. There will be some localised habitat loss and the possible indirect effects on Lisbigney bog cSAC require more detailed assessment.

Overall the potential impact (negative) to terrestrial ecology without mitigation is considered to be of moderate (**Dark Green**) significance. Through the application of well-established standard mitigation measures, such as the avoidance of sensitive habitats, minimising construction impacts through the timing of works, restoration of habitats post construction, amongst other measures, it is reasonable to assume that this potential impact would be reduced.

6.2.4 Water and Aquatic Ecology

Key ecological receptors considered were rivers designated as cSAC, the number of crossings of cSAC rivers or their tributaries, salmonid watercourses, freshwater pearl mussel (FWPM) rivers and sensitive catchments.

There are nine crossings of cSAC designated rivers along the UGC route. The majority of these are within the River Suir and River Nore catchments, and within freshwater pearl mussel sensitive catchments. Approximately 5% of the potential underground route option traverses river catchments. No lakes are crossed by the UGC route

The only sections where the UGC route will be required to leave the road network are where horizontal directional drilling is needed under surface water features, such as rivers, streams and drains, and to avoid any major existing services or structures, such as bridges or railway tracks, along the route. The converter stations will be constructed off-road.

Potential impacts from these works may include increased sediment in surface water run-off. In particular, excavation works may result in elevated suspended solids entering receiving water courses. The effect of this impact could be the deterioration of water quality downstream of the construction works and indirect effects on downstream water dependant habitats and species.

There will be no direct impacts on water features during operation (although there may be a requirement for routine maintenance works). The potential for significant impacts on water quality and freshwater species and habitats cannot be ruled out and therefore this is considered a moderate-high impact (**Blue**). Through the application of well-established standard mitigation measures, such as the avoidance of sensitive aquatic habitats where feasible, best practice methods in pollution and siltation control, restoration of riverside habitats post construction amongst other measures, it is reasonable to assume that this potential impact would be reduced.

6.2.5 Soils and Geology, Hydrology and Hydrogeology

Key considerations to date have included an examination of soil and subsoil geology, bedrock geology, presence of geological heritage sites, county geological sites, karst features, contaminated lands, mines and quarries, source protection areas (for water) vulnerable aquifers, groundwater dependant ecosystems and areas of flooding risk.

Under this criterion, the potential impacts on soils, geology, hydrology and hydrogeology during construction were considered. Overall, based on the sensitivities along the UGC route and converter station locations, potential impacts are considered of medium significance. There is the potential for temporary impacts on soils during UGC operation as part of routine maintenance works. The impact is rated as potentially moderate (**Dark green**). Through the application of well-established standard mitigation measures such as the avoidance of sensitive areas for soils and hydrology and standard soil management it is reasonable to assume that this potential impact would be reduced.

6.2.6 Landscape/Visual

Key considerations to date have included an examination of international, national and county landscape designations, significant designed landscape features, landscape character and historic landscapes, scenic drives and routes, number of properties adjacent to the route and number of recreational facilities adjacent to the route.

The main permanent, visible structures associated with the proposed UGC route option for the Grid Link project will be the new converter stations in the vicinity of Knockraha, Co. Cork and in the vicinity of the existing Dunstown substation. The typical site footprint for each converter station will be in the order of approximately 180m by 120m, with building heights of up to 24m.

While landscape effects are concerned with the changes to the fabric and character of the landscape, visual effects result from changes to views.

Visual effects are anticipated to arise from plant and equipment along the UGC route and at the location of the converter stations during the construction phase. However, the most significant visual effects will be converter stations which will be permanent large structures in the landscape. The impact is rated as potentially low-moderate (**Green**). Screening and screen planting at the converter station sites will mitigate long-term visual effects, thereby further reducing the potential for impact at these sites.

6.2.7 Cultural Heritage

Key considerations to date have included an examination of candidate world heritage sites, national monuments, record of monuments & places (RMP) and sites and monuments record (SMR), national inventory of architectural heritage (NIAH), demesnes landscapes and historic gardens indicated on the Ordnance Survey Ireland (OSI) first edition mapping. All known cultural heritage sites were mapped in GIS along with high resolution aerial photography and OSI first edition mapping (Circa 1830).

By placing the proposed routes within existing roadways, the anticipated disturbance to recorded cultural heritage assets such as buildings or monuments has been minimised. However even in disturbed contexts such as roads there is a potential for archaeological remains to be revealed and this potential is increased when in close proximity to a site that may have extensive subsurface remains. Examples of such sites include ecclesiastical enclosures where burials may be identified, castle sites which have the potential to reveal additional structures and defensive features, churches and graveyards or historic towns (which can include evidence of historic streetscapes, property plots and boundaries, walled defences and early settlement activity).

The candidate UNESCO world heritage site of Dun Ailinne is located within the wider study area of Dunstown Co. Kildare. The UGC route will be located on a road adjacent to the RMP buffer zone of the site. There will be no direct physical impact on the monument itself or its setting within the existing cultural heritage landscape.

Assessments to date indicate that the UGC route does not pass through any recognised historic towns. The UGC routes passes near two national monuments. From the records, there are 33 RMP sites within the vicinity of the UGC.

The potential impact on cultural heritage is considered of moderate significance (**Dark Green**). Through the application of well-established standard mitigation measures, such as the avoidance of cultural heritage assets, limiting exposure of heritage assets through record or excavation, minimising construction impacts through the location of works areas and restoration post construction, it is reasonable to assume that this potential impact would be reduced.

6.2.8 Settlement/Communities

Key considerations include an examination of average population density and settlement clusters within the route corridor and converter/substation zones.
The UGC option will be relatively close to roadside houses along the extent of the route. The route generally aims to avoid towns and villages however, there are instances where this is not feasible.

The converter stations have the potential to impact on the immediate area in terms of visual impact as they are large structures and noise, particularly during the construction stage.

Overall, potential impacts on settlements and communities along the UGC route will largely be confined to the construction phase and be temporary in nature and the likely impact rated as low-moderate (**Green**). The application of well-established standard mitigation measures could be expected to ameliorate potential impacts further. The avoidance of significant impacts on settlement and communities through the sensitive location of any potential convertor station sites will be a primary focus.

6.2.9 Recreation and Tourism

Key considerations to date have included an examination of Fáilte Ireland attractions, facilities and accommodations within the route corridor and converter station locations, and within 1km of same. Consideration has also been given to a number of walking and cycling trails within or crossing the corridor.
Potential impacts on tourism are related to the impacts on landscape and visual features and on recreational facilities. Although there will be some impacts during construction, largely caused by traffic disruption, an underground cable option would have a low impact (**Cream**).

6.2.10 Air quality and climate

Construction of the UGC and converter stations has the potential to impact on local air quality. This potential impact is rated as moderate - low significance (**Green**). During the operational phase, there will be no emissions and therefore no impact on air quality.

The potential air quality impacts of the development to be considered are:

- Impacts of dust during the construction phase of the development; and
- Impacts of vehicle and plant emissions during the construction phases of the development.

Sulfur Hexafuoride (SF_6), which is a potential pollutant, is used as an insulating gas in substations and as an insulating and arc quenching medium in switchgear for high and medium voltage applications. These are all closed systems, which are extremely safe and unlikely to leak. SF_6 is non-flammable.

As with the majority of large civil engineering projects using plant and equipment, emissions to air are inevitable during the construction phase. However, this relatively short-term impact should be considered alongside the long-term benefit of the development. The Grid Link project will have net positive climatic impacts in facilitating the integration of renewable energy onto the grid, thereby reducing the national dependence on fossil fuels (**Cream**).

6.2.11 Material Assets

The construction phase is predicted to last approximately 3.5 years. The operational phase of a major power transmission project such as Grid Link could be expected to be 50 to 80 years, during which there will be routine maintenance and refurbishment of the infrastructure.

By concentrating the UGC along existing roads, the potential impacts on land use (such as agricultural land and activities) will be of moderate significance during the construction phase. Temporary soil disturbance during construction will have an impact where UGC crosses agricultural land. There will be temporary disturbance to access along public and private roads resulting in a possible moderate impact (**Green**).

Potential impacts at the converter station locations may be of greater significance given the land take required.

A high level of temporary disturbance could be expected where access to private homes, commercial properties and community properties is affected by the construction phase. However when considered over the total operational phase, the impact will be imperceptible.

6.2.12 Traffic and Noise

The UGC option follows the existing public road network, and therefore passes close to existing sensitive receptors within the settlements linked by the road network. The displacement of traffic during the underground construction may result in temporary increases in road traffic noise at receptors resulting in moderate to high impacts during this phase (**Blue**). However, the application of mitigation measures post construction such as the resurfacing of roads following cable laying is likely to improve road conditions and could be seen as a beneficial effect overall.

Underground cables produce no audible noise. Operational noise sources relating to the underground option are restricted to fixed noise sources, and scheduled or emergency maintenance/repairs.
Fixed noise sources relevant to the UGC option will include converter station infrastructure. This could be considered a moderate impact (**Green**). Early detailed assessment and the specification of any required mitigation for incorporation in the design process should eliminate / minimise any potential noise impacts.

6.2.13 Summary of the Environmental Analysis of the HVDC UGC Route

Based on the information available, the possible likely significance of environmental impacts on each parameter is presented in Table 6-2 along a range from "more significant" to "less significant". The application of standard mitigation practices ranging along the scale of avoidance, reduction/design or remedy/restoration is considered in this table in terms of the ease of implementation of such measures. This follows the format presented in the Grid West report for the IEP. At this stage in the development of the HVDC UGC option, it is not possible to evaluate the effectiveness of proposed mitigation measures. The aim of any transmission infrastructure project developed by EirGrid will be to minimise the potential for residual effects wherever feasible. The likelihood of residual effects occurring post mitigation is shown for illustration but it should be noted that this does not equate to the *significance* of any potential residual effect.

	HVDC UGC		
	Significance of Impact/Effect	**Ease of mitigation**	**Likelihood of residual effect persisting (post mitigation)**
Biodiversity, Terrestrial flora and fauna;			
Aquatic Ecology /Water[1]			
Soil, Geology, Hydrology and Hydrogeology			
Landscape and Visual			
Cultural Heritage			
Settlements and Communities			
Recreation and Tourism			
Air Quality[1]			
Climatic Factors			
Material Assets			
Traffic and noise[1]			
Noise[2]			

Table 6-2 Summary of the Environmental Analysis of the HVDC Option

Notes:
1. During construction
2. During operation

NB: The identified Significance of Impact/Effect for Air Quality, Climatic Factors, Material Assets, Traffic and Noise is based on our experience in respect of other transmission infrastructure development, and on the findings of the Grid West Report to the IEP[19].

More significant **Difficult to Mitigate** **More Likely**	**Less significant** **Possible to Mitigate** **Less Likely**

6.3 TECHNICAL COMMENTARY ON HVDC UGC OPTION

6.3.1 Compliance with Health and Safety Standards

This section applies to all three options and will be referenced in the assessment of the other options.

It should be noted that most technical standards for high voltage equipment, whether for HVDC or HVAC equipment, are inherently based on safety requirements. Therefore, as a general rule, compliance with recognised technical standards will mean that the equipment is designed and manufactured so as to be safe.

The applicable standards originate from the European Committee for Electro-technical Standardization (or a similar internationally recognised standard). These standards take into account the integrity of installations and systems by operating conformity assessment systems to verify plant and systems perform to acceptable technical and safety standards.

All materials will be designed, manufactured, tested and installed according to relevant IEC or CENELEC standards. Where no IEC or CENELEC standards have been issued to cover a particular subject, another internationally recognised standard will be applied. The latest edition and amendments to standards and specifications will apply in all cases.

Regardless of the technical option chosen, the Grid Link project will be designed, constructed and maintained in accordance with applicable Irish and EU health and safety regulations and approved codes of practice. In undertaking a project, we are at all times aware of and comply with the applicable health & safety legislation, approved codes of practice and industry standards and all subsequent modifications or amendments in relation to same. To achieve this, we operate a formal legal compliance process as part of our health and safety management system.

All prospective technical options will comply with the Safety, Health and Welfare at Work (General Application) Regulations 2007, in particular Part 3: Electricity.

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[19] http://www.eirgridprojects.com/projects/gridwest/iep/

All designs will meet the requirements of our functional or operational specifications which incorporate CENELEC standards and contain specific national requirements e.g. environmental conditions, procedures and system network parameters. All equipment will be Grid Code compliant (EirGrid, 2014)

Designs will also be reviewed by appointed project supervisors for design stage (PSDP) as required by the Safety, Health & Welfare at Work (Construction) Regulations 2013.

Where any commissioning may involve connections to existing transmission infrastructure, then such commissioning is conducted in accordance with ESB Networks "Electrical Safety Rules 2006".

The principal document required at project completion / handover is the completed health & safety file, required under the Safety, Health & Welfare at Work (Construction) Regulations 2013 [S.I. No. 504 of 2006] and is required irrespective of the technical option adopted.
This option will be compliant with the relevant safety standards, and therefore is at the lowest point on the difficult/ risk scale. The impact is deemed low (**Cream**).

6.3.2 Compliance with Reliability and Security Standards

The reliability and security standards of the transmission network are defined in the following:

- The Transmission Planning Criteria (TPC)[20]; and
- The Operational Security Standards (OSS)[21].

The UGC HVDC option proposed will comply with both the TPC and OSS.

In the context of the industry accepted standard for the overall system availability of 99.99% and taking into account the inherent redundancy designed into the transmission network, the inclusion of a single UGC circuit has limited effect on the overall system availability. As a result, the UGC option is able to comply with the reliability and security standards for the network as a whole.

The option will be compliant with the relevant system reliability and security standards, and therefore rated at the lowest point on the difficult/ risk scale. The impact is deemed low (**Cream**).

6.3.3 Average Failure Rates, Repair Times and Availabilities

Unplanned outages

Our role includes the maintenance and development of a transmission system in Ireland that is safe, reliable, secure and economical and has due care for the environment. The reliability and security of the electrical supply are effectively determined by the availability of system, since, when the electrical grid is unavailable, users do not have a reliable or secure supply.

[20] EirGrid, Transmission Planning Criteria, 1998 (http://www.eirgrid.com/media/Transmission%20Planning%20Criteria.pdf)
[21] EirGrid, Operational Security Standards, 2011 (http://www.eirgrid.com/media/Operational%20Security%20Standards.pdf)

	220kV-500kV Cables
Reliability (Unplanned outages/100km/year)	0.277
Mean time to repair (days)	25 – 45 days[22]
Unavailability (days/100km/year)	7.0 – 12.5

Table 6-3 Average Failure Rates, Repair Times and Availabilities

The above table shows the statistics for reliability, the mean time to repair faults, and the unavailability for HV cables (based on international failure statistics of cables[23]). These statistics, given that they apply to XLPE cables, are taken to be applicable for HVDC cables.

Therefore, the assumed 242 km route, which consists of a symmetrical monopole HVDC circuit for this option makes the calculated overall unplanned unavailability to be 19 – 32.5 days rounded to the nearest half day.

Combination of the planned and unplanned outages

The publically accessible information on the overall availability of circuits using VSC technology is very limited. We are not aware of publically available information that differentiates between planned and unplanned outages.

Our planning includes policies in place for routine preventative maintenance for AC cables of 2-3 days per annum (dependant on the number of joint bays). Given that any cable requires many similar features in their installation, i.e. joints, earths, telecommunications it is reasonable to assume a similar value will be required for a HVDC UGC.

Common to all of the options is the need to perform planned maintenance for the associated substation switchgear and equipment. Each year an operational test is performed, and periodically a routine service is also undertaken. These maintenance outages equate to a total unavailability of 0.64%, or circa 2.5 days per annum.

The grid is designed to provide a specified level of redundancy. As such the failure of individual components or elements does not normally result in any loss of supply. The longer the time it takes to repair an individual component or element, the longer the system is in a state where there is no redundancy. This results in a greater the risk of a significant loss of supply.

The average failure rate and time to repair is deemed high. The availability for the proposed HVDC UGC circuit as a result of unplanned outages is approximately 95% at best and could be greater than a month per annum. This is well below the industry norm of 99.99%. As a result the availability of the circuit is considered to be at the mid-level on the difficult/risk scale (**Dark Green).**

[22] Dependant on whether method of cable installation is direct lay or in ducts respectively
[23] Cigre, TB379 Update of service experience of HV underground and submarine cable systems, 2009

6.3.4 Reliability of Supply

The primary driver for Grid Link is to resolve the security of supply issues arising as a result of large regional power flows across the country.

The HVDC UGC option for the Grid Link project is compliant with the Transmission Planning Criteria (TPC) and Operation Security Standards (OSS) and therefore meets the minimum acceptable reliability criteria.

However the TPC provides a balance between security of supply (reliability) and development cost and, as a result, only plans a resilient network for a justifiable range of events. Where opportunities exist to provide a higher security of supply at minimal or zero cost and impact on the environment then inherently these options become more preferable. This improves the quality of supply to customers and reduces financial costs to consumers or losses to the economy.

The relatively low availability associated with both the use of underground cable (UGC) and HVDC technology exposes the network to both additional constraint costs and security of supply issues.

In the context of the wider system, the use of a HVDC circuit reduces system strength, and due to the relatively high unavailability, increases the likelihood that a key circuit that supports both Dublin and Cork areas may be lost.

However, there is redundancy in the network that would enable the same level of power transfer to continue, for the single loss of the cable. Therefore the reduced availability of a cable circuit only affects the reliability of the network if a second failure occurs or during maintenance. Given the scale of the impact and the relatively low availability of the circuit, this would be considered to be between the lowest and mid-level on the difficult/ risk scale (**Dark Green**).

6.3.5 Implementation Timelines

The expected timeline, subject to and following statutory consenting, for implementation of the HVDC UGC option is 3.5 years. The long-lead items will be the converter stations, including the associated transformers, and possibly the HVDC cable itself. There are a limited number of manufacturers of HVDC cable and the manufacturing time will be dependent on the level of orders placed internationally. There are currently a large number of HVDC projects being implemented internationally, which is leading to extended cable delivery times

The implementation timeline for the UGC option is considered to be at the moderate / low level on the difficult/ risk scale. The impact is deemed (**Green**).

6.3.6 Future Reinforcement of Transmission Network

Grid infrastructure is expected to have a design life in excess of 50 years. It is therefore reasonable to expect that the grid will need to expand and adapt to accommodate an increasing and changing demand for electrical power.

The inflexibility in modification of HVDC equipment means that future expansion needs to be specified as part of the initial project. Subsequent changes to cater for unexpected demand increases or other changes in the transmission network may not be catered for without significant replacement and cost. This HVDC UGC option provides limited flexibility for the future reinforcement of the grid in the South East region.

If the capacity of the HVDC UGC option is required to increase beyond 750 MVA, a second parallel symmetrical monopole could provide a further 750 MVA. This would provide approximately the same capacity as a 400 kV HVAC overhead option and allow future capacity for power transfers across the transmission network from the south west towards the east and vice versa. A second symmetrical monopole would have an estimated capital cost of €798.0 million. The ability to add further connection points along the circuit is restricted by the technology and the rating of the circuit.

International standards for inter-operability for HVDC equipment is under development. There are concerted efforts in progress to define these standards, but these have not been published to date. Given that this option may ultimately involve two symmetrical monopoles, both terminating at the same points, there is a higher risk of interaction between the two schemes compared to if the schemes were terminated at separate locations. In a network where there are increasing network devices using HVDC equipment there is a significant risk of unintended responses from these devices.

In addition, the HVDC UGC option may require a line uprate during a subsequent loss of plant and equipment whilst another is out for maintenance. Under these conditions, we individually appraise whether each of these uprates could be financially justified. To ensure a prudent investment decision, we would defer a decision until much closer to the required commissioning date, to take account of all the needs identified, which may include both local and regional needs. Associated with this, a potential uprate of the Portlaoise – Newbridge 110 kV OHL is identified at an estimated capital cost of €13 million.

The performance of the HVDC underground option in terms of future reinforcements of the transmission network is considered to be above mid-level on the difficulty/risk scale (**Blue**).

6.3.7 Risk of Untried Technology

VSC HVDC technology is a relatively new technology, which is at an early point in its development cycle. This technology was used for the East West Interconnector (EWIC). The utilisation of a HVDC option using this specific application, within a small island system, is limited internationally. The industry is in a period of learning, and this is best evidenced by the number of delays and early operational problems that have been experienced with a number of recent HVDC projects.

The prospect of the HVDC scheme not performing as specified, given its size proportional to the network, presents a risk of a disturbance on the network that could potentially result in an interruption of supply to customers, impacting security of supply.

Another consideration is the ability of a technology to withstand short-term overloads. As a result of the need to produce a reasonably cost effective cable design insulation levels are typically reduced in a DC cable. However in DC operation the current does not fluctuate (as with AC operation). Therefore, the cable insulation is proportionally subjected to higher stress levels in comparison. As a result, the insulation is much closer to the point where permanent damage occurs and the cable is less able to withstand short term overloads. The properties of the cable mean that once the temperature inside the cable exceeds a particular point, there is a danger of the heat generated exceeding the capacity of the surrounding material to conduct the heat away. This causes the temperature to build up exponentially until the cable suffers failure. The power electronics used in the HVDC converter stations have a limited overload capability.

The short-term overload capability is utilised when an item of plant and equipment is lost and the power that was being transmitted through it is transferred to other parts of the network, until the network is reconfigured. The time taken to do this may vary from milliseconds to minutes. Without this short-term overload capability the need to further reinforce the network will be increased.

The impact of the different technical options on the operation of the existing electricity grid is of critical importance. Any interaction which may compromise the operation of the existing system would be unacceptable unless it can be mitigated.

The interaction of an HVDC UGC system with the existing HVAC grid system is complex. If the Grid Link project was to be implemented as a HVDC UGC some interactions are likely to require specific mitigation. The following is a list of some interactions which may require further investigation:

- Short Circuit Ratio (SCR);
- AC circuit overload;
- AC system voltage;
- DC faults affecting operation of AC system;
- AC faults interrupting DC power transfer;
- Distortion in AC voltages;
- Sub-synchronous interactions with generators; and
- Interactions between HVDC schemes, power electronic devices, and special protection schemes.

While the aforementioned interactions of the HVDC system with grid system operation can be reduced, the extent of these interactions and the complexities involved can be significant. Many of these interactions cannot be studied until the full details of the scheme being connected are known. In particular the full details of the equipment being used in new wind farms, the possible large scale demand increases from the IT sector and the proposals for further interconnection are some examples of issues which are not yet fully determined or known.

Application of HVDC technology would drive an on-going risk to effective network operation and planning. The controls and ancillary equipment for the HVDC is designed on a set of parameters which, over time, will change, most likely requiring retuning and modification. Identifying, scheduling and achieving these changes will become an increasing challenge as the network becomes ever more dynamic. There is a risk that resultant control mal-operation would compromise the security of supply of the transmission network. The highest documented loss of demand customers (approx. 326,000) in Ireland occurred following the mal-operation of the Moyle[24] HVDC Interconnector control system. This type of mal operation[25] could not have occurred on an AC system which naturally and automatically operates to balance itself.

Modern control theory and duplication reduces this risk but given its complexity and continuing nature it is still considered to be mid-level on the difficult/ risk scale (**Dark Green**).

6.3.8 Compliance with Good Utility Practice

Good utility practice is to develop a flexible, robust and cost-effective reinforcement solution accounting for environmental constraints.

Based on current knowledge, the HVDC UGC option is assessed as rating unfavourably in respect of compliance with good utility practice in the context of this project. While this option can be installed it does not provide a high level of flexibility and introduces inherent risk to the system. This is supported by the low percentage of HVDC circuits within the meshed system in Europe. The majority of HVDC circuits are underwater cables where an OHL is not a viable alternative.

TSOs have similar mandates to deliver a cost effective, efficient, flexible network. HVDC VSC symmetrical monopoles used in a meshed configuration given its high cost, low adaptability and relatively untried technological track history, only meets this mandate considering the options available in specialised circumstances. Although this option may be used in some circumstances and considered good utility practice, it is not the conventional selection of developing a meshed AC network. For the criteria compliance with good utility practice the HVDC UGC option is therefore considered to be the mid-level on the difficult/ risk scale (**Dark Green**).

[24] HVDC Interconnection between Northern Ireland and Scotland

[25] A power flow reversal, which drew power from a stressed area of the network.

6.3.9 Summary of the Technical Analysis of the HVDC Underground Option

The table below summarises the technical assessment of the HVDC UGC Option.

	HVDC UGC
Compliance with all relevant safety standards	
Compliance with system reliability and security standards	
The average failure rates during normal operation, average repair times and availabilities of the main elements of each option	
The expected impact on reliability of supply of unavailability of the development	
Implementation timelines	
The extent to which future reinforcement of, and/or connection to, the transmission network is facilitated	
Risk of untried technology	
Compliance with good utility practice	

More Difficult
More Risk

Less Difficult
less Risk

Table 6-4 Summary of the Technical Commentary of the HVDC Underground Option

6.4 ECONOMIC ANALYSIS

The economic appraisal of the reinforcement option was completed in compliance with the requirements of the IEP Terms of Reference and the results are summarised below.

6.4.1 Approach

The economic assessment measures the impact of the reinforcement project on the Irish economy, rather than on the company responsible for making the capital investment. The approach represents the case of the Transmission Asset Owner (TAO) financing the investment with the benefits accruing to society.

The costs, together with a regulated return, are then recovered from consumers through the tariff structure and would correspond to an increase in the Transmission Use of System (TUoS) tariff component of a consumer's electricity bill. The regulated return is the real, pre-tax Weighted Average Cost of Capital (WACC) of 5.2%[26] approved by the Commission for Energy Regulation (CER). Similarly, any benefits resulting from a reduction of production costs or greater system efficiency would translate into a reduction in the cost of energy, also represented on the consumer's electricity bill.

The approach is consistent with that endorsed by the Office of Gas and Electricity Markets (Ofgem) in the United Kingdom for cost benefit analysis and referred to as the Spackman Approach[27]. Using this approach, all the costs (including the costs of financing the assets together with the actual cost of the assets) and benefits are considered annually over the useful life of the new asset.

6.4.2 Time Value of Money

The Discounted Cash Flow (DCF) analysis method is used to evaluate the economic merits of a reinforcement option. It uses the concept of the time value of money in which all future cash flows are estimated and discounted using an approved Net Discount Rate (NDR) to calculate their equivalent present values. The method facilitates the consistent representation of all the values that are associated with each of the alternative reinforcements.

The NDR is taken to be the real societal discount rate, which is interpreted to be the Test Discount Rate specified by the Department of Finance for use in cost benefit analysis and cost effectiveness analysis for public sector projects, i.e. 5.0%[28] in real terms (i.e. excluding projected inflation).

All financial values are represented in the current year's Euro and are expressed in real terms (i.e. excluding projected inflation).

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[26] Commission for Energy Regulation, Mid-Term Review of WACC Applying to the Electricity TSO and TAO and ESB Networks Ltd for 2014 to 2015, CER/14/026, 31 January 2014.

[27] Ofgem, *RIIO-T1: Consultation on our assessment of National Grid Electricity Transmission's proposed National Development Policy for the Electricity Transmission Price Control*, 3 May 2013; and Joint Regulators Group, *Discounting for CBAs Involving Private Investment, but Public Benefit*, 4 October 2011.

[28] Department of Finance: http://www.per.gov.ie/project-discount-inflation-rates/

6.4.3 Duration of Evaluation and Terminal Values

The start date of the economic assessment is taken as the current year and all future values are referred (or discounted) to that year. The duration of the evaluation is taken as the regulatory authority-approved useful life for Transmission assets, i.e. 50 years[29] for each of the options post their completion and year of commissioning.

6.4.4 Input Costs

Each reinforcement incurs incremental costs (e.g. project implementation costs, incremental maintenance costs) and has an impact on the overall transmission system efficiency (e.g. transmission system losses and system reliability costs).

HVDC reinforcements are typically delivered through the appointment of an Engineer, Procure and Construct (EPC) contractor. As a result of the proprietary nature of the technology involved in delivering a HVDC reinforcement, the EPC contractor is usually the owner and manufacturer of the equipment, referred to as an Original Equipment Manufacturer (OEM).

All cost estimate inputs associated with the HVDC scheme are sourced from the best available information at EirGrid's disposal from either transmission standard development cost provided by ESB Networks or bespoke projects reports. The costs considered in this assessment are consistent with the Terms of Reference and are described in the sections below.

6.4.4.1 Project Pre-Engineering Costs:

The pre-engineering costs refer to the costs associated with the design and specification, route evaluation and management of the statutory planning application. The costs are capital in nature and are estimated to be €16.5 million. This amount includes a contingency provision of €0.3 million to account for the risk that the amount may vary.

The phasing of the costs is as follows:

	2015	*2016*	*2017*	*2018*	*2019*	*2020*
Pre-Engineering Costs	67%	12%	12%	9%	0%	0%

Table 6-5 Phasing of Pre-Engineering Costs

The present value of the project pre-engineering costs was calculated using the estimated value of €16.5 million, phased according to the table above. The capital amounts are discounted at the Test Discount Rate, resulting in a present value of €16.1 million (this is inclusive of a contingency of €0.3 million).

[29] Decision on TSO and TAO transmission revenue for 2011 to 2015, CER/10/206, 19th November 2010: "...the CER stated its intention to continue using average assets lives of 50 years for the TAO's network assets".

6.4.4.2 Project Implementation Costs

The project implementation costs are the costs associated with the procurement, installation and commissioning of the reinforcement and therefore includes all the transmission equipment that form part of the reinforcement's scope.

The estimated capital cost is categorised into its general components and is summarised in the table below:

Cost Category	*Project Implementation Cost (€ M)*
Overhead Line	0.0
Stations[30]	162.5
Underground Cable	507.2
Series Compensation	0.0
Other	
Flexibility Payments, Proximity and other allowances	1.8
Non-EPC Costs	39.0
SUB-TOTAL	**710.5**
Contingency	71.0
TOTAL	**781.5**

Table 6-6 Summary of Project Implementation Costs for the HVDC Option

Station costs include the cost of the HVDC converters and the HVAC transmission station modifications required to connect the HVDC system into the transmission system.

In the table above, the category "Other" is comprised of provisions for flexibility payments, proximity allowance, and community fund amounting to €1.8 million and the engineering costs that are not covered by an EPC contractor (i.e. "Non-EPC" costs) amounting to €39.0 million. The "Non-EPC" costs would typically refer to front-end project development, licenses, permits, external advisors and consultants, grid connection studies, finance, insurance, test energy and O&M facilities, not already accounted for in the pre-engineering costs. There may also be some engineering, design and construction costs that are excluded from the EPC contract for the project. These costs can occur where the risk profile makes it difficult or impossible for the EPC contractor to accurately price the work or where the work needs to be performed on the assets of the project owner or another party. The total value for "Other" amounts to €40.8 million.

[30] The "stations" category refers to all HVDC converter stations and HVAC associated equipment in substations required by the option

A contingency provision of 10% is included to address the likelihood that costs may increase. The contingency amount is therefore €71.0 million and the total project implementation, inclusive of contingency provision is then €781.5 million.

The phasing of the costs is as follows:

	2018	*2019*	*2020*	*2021*	*2022*	*2023*
Project Implementation Costs	0%	33%	33%	21%	13%	0%

Table 6-7 Phasing of Project Implementation Costs

The present value of the project implementation costs was calculated using the estimated value of €781.5 million, phased according to the table above. The capital amounts are discounted at the Test Discount Rate, resulting in a present value of €612.4 million.

6.4.4.3 Project Life-Cycle Costs

Life-cycle costs refer to the costs incurred over the useful life of the reinforcement. They include the on-going cost of ensuring that the reinforcement remains viable for the evaluation period.

The useful life of the HVDC system, based on the CER permitted depreciation of transmission assets, is 50 years. The useful life is the same as the evaluation period and as a result, no replacement costs are considered for the option.

In accordance with the Terms of Reference, the life-cycle costs include:

- Cost of losses:

  Electrical losses in the transmission network, refer to the electrical energy consumed by the transmission system as it transmits electricity. New transmission infrastructure (such as new circuits) or a change in the physical characteristics of a circuit that allow greater power transfer, will inherently lower electrical losses incurred on the transmission system. As all three reinforcements options lower the electrical losses on the transmission system, the cost of losses will be treated as a benefit/saving to the option for each year following commissioning for the lifetime of the option.

  The three options identified for the Grid link project all reduce network losses as they are designed to permit greater large scale power transfer across the entire network.

  High level network analysis indicates that the proposed options will incur only a marginal difference in reduced losses to the transmission system. Given the significant difference in project implementation costs between the three options the reduction in losses identified will have a negligible impact on the outcome of the economic appraisal of the options. The calculation method used, and accuracy of the system losses, is consistent for each option.

  For completeness each option has a monetary value of the reduction in annual average system losses included in the calculations. This value is treated as a benefit to the option for each year following commissioning for the lifetime of the HVDC scheme in the economic appraisal.
  The reduction in system losses are calculated based on a merit order dispatch with 35% wind dispatch (all-island) which represents an average of a year. The losses are calculated at their highest, based on the Winter Peak demand scenario, which is believed to represent a conservative approach.

  The cost of electrical losses is typically determined using the cost of producing increasing power production with available capacity in the next most economical power station, referred to as the marginal cost of generation. For this analysis, the average System Marginal Price (SMP) is used to represent the marginal cost of generation and is calculated to be €60.66/MWh. The figure has been derived from the average system marginal price for Ireland between 2007 and 2013, which was sourced from information published on the Single Electricity Market Operator (SEMO) website[31].

  The average annual system losses and the corresponding savings in system losses associated with the HVDC scheme is summarised in the table below.

[31] SEMO System Marginal Price (EP2) from 11 December 2007 to 18 February 2013: http://www.sem-o.com/Publications/General/SMP2007-2014.zip.

	System losses with HVDC option included (GWh/yr)	Annual Savings in system losses relative to a system without reinforcement (€ M/a)
HVDC Option	1,721	4.6

Table 6-8 Summary of the annual system losses with HVDC scheme included and savings

The estimated annual saving in system losses with the HVDC option is €4.6 million per annum. Assuming the annual savings of losses is constant for the duration of the evaluation, and then discounting those annual savings at the Test Discount Rate, results in a present value of €59.0 million.

- Operating and maintenance cost:
  Specialist repair teams are required for this option and these costs are included in the operating cost estimates.

  Bespoke project reports regarding the HVDC option have estimated an annual cost of €5.0 million for the operating and maintenance costs for the HVDC scheme. The option also includes some HVAC equipment to connect the scheme to the existing network. The estimated annual cost for the operating and maintenance of this equipment this is relatively small compared with the overall HVDC scheme. The total estimated annual cost for the operating and maintenance of this option is €5.0 million. This figure includes a provision for risk which is assumed to be 10%, which represents €0.5 million per annum.

  For HVDC schemes, mid-life refurbishment typically consists of a control and protection systems refurbishment at the mid-life of the HVDC transmission scheme (15 – 20 years). This is often driven by issues such as technical obsolescence and the availability of spare parts, in which case the actual timing of the refurbishment will be dependent on the life cycle of the control and protection system used.

  The control system refurbishment plan for the HVDC UGC option, estimated by EirGrid's consultants, is split into three stages, namely:

  - Stage 1 - 7-15 years, estimated at €4 million and assumed to occur in year 12;
  - Stage 2 - 15-25 years, estimated at €5 million and assumed to occur in year 22; and
  - Stage 3 - 20-40 years, estimated at €7 million and assumed to occur in year 31.

  The costs, for the purpose of the high level evaluation are treated as being part of normal operation and maintenance. They are included as part of the maintenance cost in the year that they arise.

  Discounting the annual operating expenses, which are assumed to be constant in real terms for the duration of the evaluation, results in a present value of €68.9 million including a contingency provision of 10%.

- Decommissioning and Replacement cost:
  The useful life is the same as the evaluation period and as a result, no replacement costs are considered for the option.

  Due to the economic appraisal being referenced to the end of the asset life of the regional option there is a residual value of €7.3 million for this option.

6.4.4.4 Cost of Unreliability:

The main integrated transmission system is a network that has parallel paths to other parts of the network. To be compliant with the planning standards it is designed to withstand planned or unplanned outages of any single piece of plant or equipment. This means unreliability for unplanned outages in normal operation for the main network will have a negligible cost.

Planned maintenance outages of plant and equipment are required periodically, for example, annually, and usually for short durations. The network must remain compliant with planning standards during such maintenance outages. Additional system upgrades may be required to ensure compliance under this scenario. Alternatively, as the cost of generation at these times is generally low, generator output may be constrained to obviate the need for upgrades. The value of constrained generation must be determined and compared to the expected cost of the upgrade. The most cost effective solution is brought forward.

The HVDC option resolves the need identified, however during maintenance periods one additional circuit uprate is required to comply with planning standards unless generation is constrained.

Constraint calculations for this uprate are based on broad assumptions. This is due to uncertainty surrounding future emerging drivers, the construction programmes of the numerous generators and associated connections already planned. Nevertheless, the same assumptions have been used and the results allow direct comparison of the options.

The constraint calculations accounted for each maintenance outage of plant and equipment that could require a circuit uprate. For each maintenance outage, the level of constraint that is required on generation in the south west has been calculated. This has been factored with the average loading of the system and wind speed to provide the average constraint over the maintenance period. This average hourly constraint level has then been calculated using the average SMP of €60.66/MWh.

The result of the analysis is to favour constraining generation annually. The total power flow constraint cost to avoid an uprate and permit the planned maintenance outages has been calculated as €0.4 million per annum. The constraint cost per annum amounts are discounted at the Test Discount Rate, resulting in a present value €5.5 million.
It should be reiterated that the development of a circuit uprate would be re-evaluated when there is greater certainty of the needs in future years.

6.4.5 Estimate of Cost Uncertainty:

In the absence of a detailed route or site being selected it is not possible to develop specific contingency allowances. For the purposes of the evaluation, typical desktop contingency allowances are provided for in accordance with standard engineering practices. These provisions are the result of standard assumptions being made regarding complexity and site specific conditions.

Capital cost estimates include a contingency. The contingency allowance for the reinforcement project costs are assumed to be 5% of the remaining projected spend of the pre-engineering cost and 10% for the project implementation costs. Similarly, a contingency allowance of 10% is provided for in the average maintenance costs that have been calculated and represented above.

Other cost elements (i.e. losses, reliability) are based on historical data and, as such, no specific contingency has been provided for.

6.4.6 Present Value Summary of Costs:

The abovementioned costs for the reinforcement are summarised in present value terms in the table below. Estimate of cost uncertainty (contingency) is subtracted from the itemised values and presented separately in table below.

	Present Value (€ M)
Pre-Engineering Costs	15.8
Project Implementation Costs	556.7
Project Life-Cycle Costs	
Cost of Losses	-59.0*
Operating and maintenance Costs	62.6
Decommissioning & Replacement	-0.5**
Cost to SEM from Development Unavailability (Reliability)	
Cost of Unplanned Outages	0.0
Cost of Planned Outages	5.5
Estimate of Cost Uncertainty	
Pre-Engineering Costs	0.3
Project Implementation Costs	55.7
Operating and maintenance Costs	6.3
Decommissioning & Replacement	0.0
TOTAL	**643.4**

*This figure represents a benefit rather than a loss.

**This figure represents the residual value of the option

Table 6-9 Summary of Present Value of Costs Associated with the Reinforcement

The total present value of this option amounts to €643.4 million. Given the rated capacity of the HVDC, this would equate to the cost per MVA of capacity is €0.9 million/MVA.

The variation of estimated completion dates of each option impacts on the overall present value. If the HVDC option is assumed to be commissioned end of 2024 (the same date assumed for the 400kV AC OHL option) then the present value would be €585.6 million.

7. 400 KV HVAC OVERHEAD LINE (OHL) OPTION

7.1 DESCRIPTION OF OPTION

The proposed technology for an OHL option is HVAC technology. The option comprises a 400 kV overhead line linking the existing transmission substations of Knockraha, Co. Cork to Dunstown, Co. Kildare. The 400 kV HVAC OHL option is designed with a rated capacity of approximately 1580 MVA[32] and covers a distance of circa 220 km.

As part of our assessment we investigated the feasibility of HVAC UGC. The task was to complete a review of the maximum amount of HVAC UGC that could be utilised as part of an OHL option for Grid Link and still meet the project need. These investigations concluded that less than 10 km of 400 kV HVAC UGC is feasible for an OHL option for Grid Link.

7.2 ENVIRONMENTAL ANALYSIS

7.2.1 Introduction

The environmental appraisal undertaken for the purpose of this IEP report should not be considered as equivalent to the significantly more detailed environmental assessment undertaken for the purposes of preparing a project-specific EIS. Environmental constraints have been identified across a range of topics in line with the Terms of Reference as set out by the IEP. For the purpose of this report, the environmental assessment is based upon a potential overhead line option as identified by our consultants, RPS Group. This option was subject to an evaluation by RPS Group of the options as presented in the Grid Link Stage One Report and is illustrated below in Figure 7-1.

While the environmental analysis can be considered high level, it does capture the environmental sensitivities particular to the route corridor. The objective of this analysis is to identify the potential for significant effects on a range of environmental topics. This is based on known impacts of transmission infrastructure development combined with local environmental sensitivities. The application of mitigation measures to reduce severity of impacts such as avoidance, reduction and/or restoration are assumed. Such mitigation is based on best practice for the construction and operation of transmission infrastructure.

The analysis also considers, where relevant, the findings of the Grid West Report for the IEP. It is also based on our experience in development of transmission infrastructure of different technologies and in different landscape and habitat types.

Given the nature of this analysis, there are certain project-specific topics which have not been considered in this report – these are air quality, climatic factors, traffic and noise. It is noted that these topics were considered for the Grid West IEP Report, given that it was predicated upon specific routes,

[32] Based on the lowest annual rating in summertime (at 25 degrees)

rather than the illustrative options that form the basis of this report. For these topics it is considered reasonable to assume similar conclusions in the case of the Grid Link project. The conclusions of the Grid West IEP report in respect of these topics are included in the summary of the environmental analysis - see Section 7.2.13 of this report. The following criteria are examined as part of the environmental analysis for the Grid Link HV OHL option:

- Biodiversity, Flora and Fauna
- Water
- Soils and Geology
- Landscape/visual
- Cultural Heritage
- Settlement/Communities
- Recreation and Tourism
- Material Assets (Land use)
- Air quality
- Climatic Factors
- Traffic and Noise

7.2.2 Overhead Line Route Option Description

The overhead line corridor option (Figure 7-1) is an approximate length of 220 km. From Dunstown the route heads south passing Knockaulin Hillfort parallel to the M9. It then crosses over the Barrow River northwest of Maganey crossing the N80 national road east of Kilashin and west of Carlow town. It then parallels the M9 towards its junction with the N10 east of Kilkenny. Crossing the M9 and the river Nore between Kells and Stoneyford. It then passes west of Knocktopher and Ballyhale and the east of Glenmore. This corridor was identified as DSN9 within the Grid Link Stage One Report.

Heading west the route then heads towards Kilmacow and north of Waterford City crossing the N24 national road and river Suir south of Mooncoin, north of Kilmacthomas and west of Lemybrien. It then crosses the N72 national road northwest of Dungarvan. It extends south of Villertown crossing the rivers Goish and Blackwater. The route then passes partially through Clonmult and then onto Knockraha. This corridor was identified as KRA8 within the Grid Link Stage One Report.

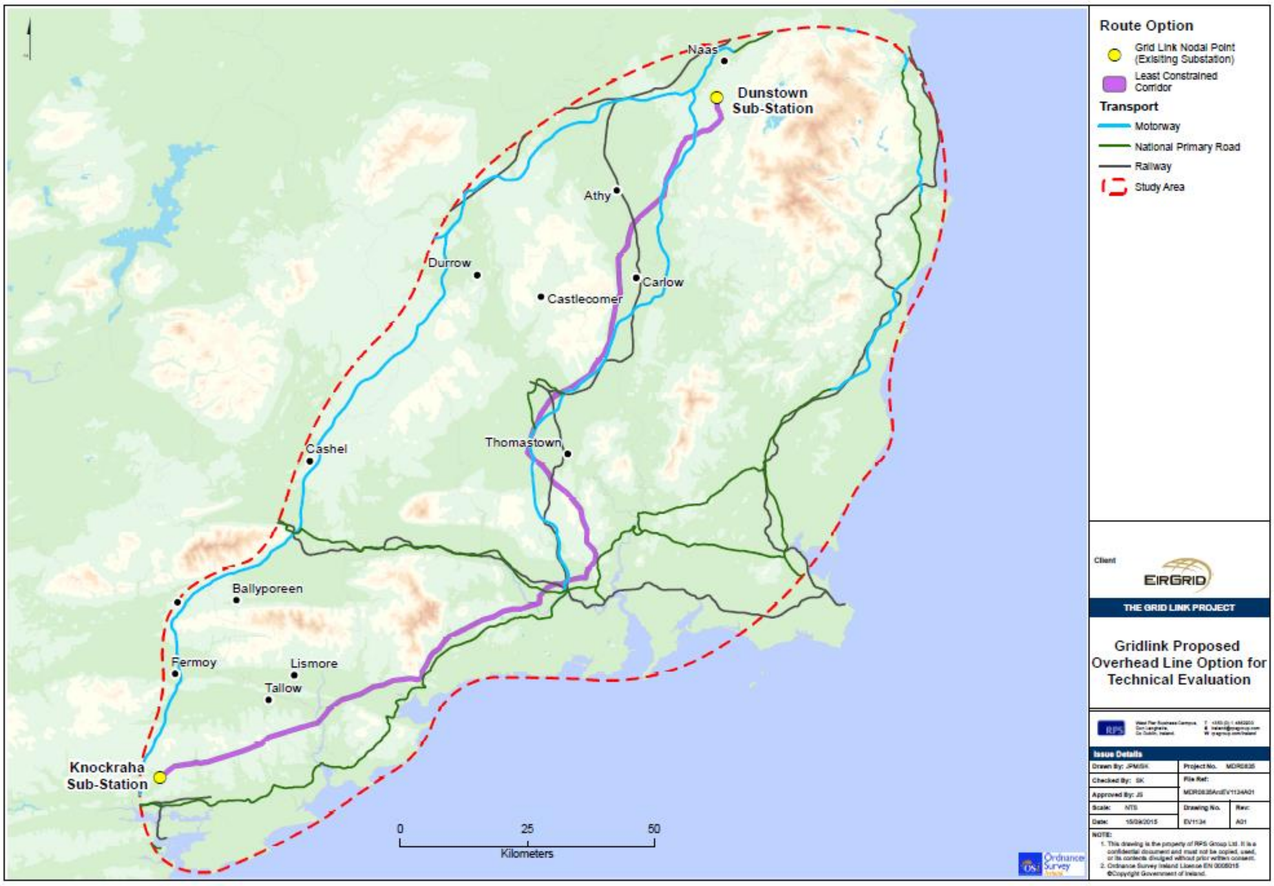

Figure 7-1 Grid Link overhead line option for technical evaluation

7.2.3 Biodiversity: Terrestrial Ecology

For the purpose of this assessment, terrestrial and aquatic ecology have been separated, aquatic ecology is considered under Section 7.2.4 to avoid duplication of impacts.

The primary aspects considered included potential impacts on designated sites such as cSACs, and SPAs, impacts on terrestrial ecology and on high nature value habitats, birds and other fauna. Designated sites were avoided where possible however, a number of river cSACs (see section 7.2.4) are crossed at multiple locations. The route has the potential to impact on SPA sites and non-designated areas of significance for birds. The possible impact on birds is high.

Overall the impact (negative) to terrestrial ecology is considered potentially high (**Blue**). Through the application of well-established standard mitigation measures for OHL, such as the avoidance of sensitive ecological sites and habitats through routing, minimising construction impacts through the timing of works, installation of bird flight deflectors and restoration of habitats post construction, it is reasonable to assume that this potential impact would be reduced.

7.2.4 Water and Aquatic Ecology

Key ecological receptors considered were rivers designated as cSACs, the number of crossings of cSAC rivers or their tributaries, salmonid watercourses, freshwater pearl mussel (FWPM) rivers and FWPM sensitive catchments.

While an OHL will not impact directly on watercourses, the construction activities associated with tower construction, access requirements for example, have the potential to cause indirect impacts to sensitive watercourses in particular. Potential impacts from construction activities may include increased sediment in surface water run-off and pollution from construction related plant or concrete. The effect of these impacts could result in the deterioration of water quality downstream of the construction works and an indirect effect on downstream water dependant habitats and species.

There will be no direct impact on water features during operation, however, there may be a requirement for routine maintenance works over the lifetime of the OHL

The potential for significant impacts on water quality and freshwater species and habitats cannot be ruled out therefore this is considered a potential moderate to high impact (**Blue**). Through the application of well-established standard mitigation measures, such as the avoidance of sensitive aquatic habitats where feasible, best practice methods in pollution and siltation control and restoration of habitats post construction, it is reasonable to assume that this potential impact would be reduced.

7.2.5 Soils and Geology, Hydrology and Hydrogeology

Key considerations include an examination of soil and subsoil geology, bedrock geology, presence of geological heritage sites, county geological sites, karst features, contaminated lands, mine and quarries, source protection areas (for water) vulnerable aquifers, groundwater dependant ecosystems, areas of flooding risk. Under these criteria the potential impacts on soils, geology, hydrology and hydrogeology during construction were considered.

Overall based on the sensitivities along the OHL, potential impacts are considered low-moderate (**Green**). Through the application of well-established standard mitigation measures such as the avoidance of sensitive geology and hydrology features and the application of standard soil management, it is reasonable to assume that this potential impact would be further reduced.

7.2.6 Landscape/Visual

Key considerations include an examination of international, national and county landscape designations, significant designed landscape features, landscape character and historic landscapes, scenic drives and routes, number of properties adjacent to the route, number of recreational facilities adjacent to the route.

While landscape effects are concerned with the changes to the fabric and character of the landscape, visual effects result from changes to views. The presence of a 400 kV OHL and associated substations in the landscape will likely constitute a significant effect at various locations throughout the route, depending on local sensitivities.

The overall landscape and visual impact is likely to be potentially high (**Blue**). The application of well-established standard mitigation measures could be expected to ameliorate potential impacts further. Sensitive routing of the OHL and the use of screening and screen planting at the substations may assist in mitigating visual effects, however, it is noted that mitigation is difficult to achieve at the landscape level.

7.2.7 Cultural Heritage

Key considerations include an examination of candidate world heritage sites, national monuments, record of monuments & places (RMP) and sites and monuments record (SMR), national inventory of architectural heritage (NIAH), demesnes landscapes and historic gardens indicated on the Ordnance Survey Ireland (OSI) first edition mapping. All known cultural heritage sites were mapped in GIS along with high resolution aerial photography and OSI first edition mapping (Circa 1830).

The candidate UNESCO world heritage site of Dun Ailinne is located within the wider study area of Dunstown Co. Kildare but outside the route corridor and no national monuments are located within the OHL route corridor.

The majority of potential construction effects will be direct, physical impacts on known and previously unrecorded archaeological, architectural or cultural heritage sites, structures, monuments or features. Care has been taken during the corridor identification stages to avoid such impacts as far as is practicably possible, taking into account all the other constraints.

Whilst avoiding direct impact on known sites, the avoidance of impact upon the setting of cultural heritage sites will not be feasible in all instances.

The overall impact on cultural heritage is considered potentially high (**Blue**). Through the application of well-established standard mitigation measures, such as the avoidance of cultural heritage assets, limiting exposure of heritage assets through record or excavation, minimising construction impacts through the location of works areas and restoration post construction, it is reasonable to assume that this potential impact would be reduced. However it is noted that mitigation to avoid significant effects on 'setting' are more difficult to achieve.

7.2.8 Settlement/Communities

Key considerations include an examination of average population density and settlements clusters within the route corridor and substation zones.

The most significant negative impact from the OHL option is the visual impact from structures and new or extended/altered substations. This arises along the entire length of the line, but the extent of the impact depends on the number of houses in the surrounding area; the greater the number of houses, the greater the impact. As a general rule, populated areas are avoided.

Overall the impact on settlement and communities is likely to be potentially high (**Blue**). Sensitive routing of the OHL and the use of screening and screen planting at the substations may assist in mitigating visual effects, however, mitigation to avoid all significant effects is difficult to achieve at this scale.

7.2.9 Recreation and Tourism

Key considerations include an examination of Fáilte Ireland top visitor attractions within the route corridor/ station locations, and within 1km of same; Fáilte Ireland attractions, facilities and accommodations within the route corridor/ station locations and within 1km of same; number of walking and cycling trails within or crossing the corridor.

Any impacts on recreation and tourism will arise primarily due to the landscape and visual impacts of the OHL and also may occur as disruption during construction of the OHL and work at the stations. Although there will be some traffic disruption during construction, this is not expected to be significant for the OHL options. While there will be a high visual impact, the impacts on recreational facilities are expected to be low.

The overall potential for impact on tourism is therefore ranked as low-moderate (**Green**). Sensitive routing of the OHL and the use of screening and screen planting at the substations may assist in mitigating visual effects, however, mitigation to avoid all significant effects is difficult to achieve at this scale.

7.2.10 Air quality and Climate

The potential air quality impacts of the development include impacts of dust during the construction phase of the development; and impacts from vehicle and plant emissions during the construction phases of the development.

The OHL will consist of multiple small scale construction sites, each in operation for a short length of time during the construction of individual towers. While there will be a large number of such sites, they will be spread out along the length of the OHL development, and construction will be scheduled in such a way as to reduce the duration and intensity of construction activities and vehicle movements on the road network.

Sulfur Hexafuoride (SF_6), which is a potential pollutant, is used as an insulating gas in substations and as an insulating and arc quenching medium in switchgear for high and medium voltage applications. These are all closed systems, which are extremely safe and unlikely to leak. SF_6 is non-flammable.

The construction of the OHL and work at sub stations has the potential to impact on local air quality. This impact is considered potentially moderate - low (**Green**). During the operational phase, there will be no emissions and therefore no impact on air quality.

As with the majority of large civil engineering projects using plant and equipment, emissions to air are inevitable during the construction phase. However, this relatively short-term impact should be considered alongside the long-term benefit of the development. The Grid Link project will have net positive impacts in facilitating the integration of renewable energy onto the grid, thereby reducing the national dependence on fossil fuels (**Cream**).

7.2.11 Material Assets

The construction phase is predicted to last approximately 4.25 years. The operational phase of a major power transmission project such as Grid Link could be expected to be 50 to 80 years, during which there will be routine maintenance and refurbishment of the infrastructure.

During the construction period there may be temporary disturbance to livestock and farm operations due to construction activity at each tower location (approx.1 month). At the substation sites, construction activity will occur over a longer period (e.g. 18 months) with the consequent potential for disturbance near the boundary of these sites. Clearing of trees/forestry and other vegetation may occur at various points along the route option. There will be permanent impacts on land use during the operational life of an OHL option.

Given the generally high quality of agricultural land and land use patterns in the study area under consideration for the OHL, the overall impact on land use is considered potentially high (**Blue**). Sensitive routing of the OHL and careful tower spotting may assist in mitigating significant effects on land use.

7.2.12 Traffic and Noise

Installation of an overhead line includes the construction of towers located at discrete intervals. Access and temporary works will be required to accommodate the construction of the towers in a range of land use types. An increase in traffic would be experienced in the local area due to construction vehicles accessing the site. Additionally, rolling closures of local roads will be required to facilitate access for larger vehicles; however overall traffic impact is expected to be relatively low as construction is largely off road.

Impacts from construction noise would be limited to effects on receptors in close vicinity to construction sites. Construction related impacts would be localised and short term. Once constructed, the overhead lines can produce audible noise from the corona effect and also Aeolian noise. Noise resulting from corona discharge will be most noticeable when conductors are wet, i.e. in foggy or wet weather conditions.

Substation noise has the potential to be audible without mitigation measures. Early detailed assessment and the specification of any required mitigation for incorporation in the design process should eliminate / minimise any potential noise impacts. Maintenance and repair over a short period may have an effect on sensitive nearby receptors.

Overall the potential impact of noise is considered of moderate to low significance (**Green**).

7.2.13 Summary of the Environmental Analysis of the OHL Route

Based on the information available, the effect of environmental impact on each parameter is presented in Table 7.1 along a range from “more significant” to “less significant”. The application of standard mitigation practices ranging along the scale of avoidance, reduction/design or remedy/restoration is considered in this table in terms of the ease of implementation such measures. This follows the format presented in the Grid West report for the IEP.

At this stage in the development of the 400 kV OHL option, it is not possible evaluate the effectiveness of proposed mitigation measures. The aim of any transmission infrastructure project developed by EirGrid will be to minimise the potential for residual effects where ever feasible. The likelihood of residual effects occurring post mitigation is shown in for illustrative purposes. However, it should be noted that this does not equate to the significance of any potential residual effect.

	400 kV OHL		
	Significance of Impact/Effect	**Ease of mitigation**	**Likelihood of residual effect persisting (post mitigation)**
Biodiversity, Terrestrial flora and fauna;			
Aquatic Ecology /Water[1]			
Soil, Geology, Hydrology and Hydrogeology			
Landscape and Visual			
Cultural Heritage			
Settlements and Communities			
Recreation and Tourism			
Air Quality[1]			
Climatic Factors			
Material Assets			
Traffic and Noise[1]			
Noise[2]			

Notes:
1. During construction
2. During operation

Table 7-1 Summary of Environmental Analysis for the 400 kV OHL option

More significant
Difficult to Mitigate
More Likely

Less significant
Possible to Mitigate
Less Likely

7.3 TECHNICAL COMMENTARY ON THE 400 KV HVAC OHL OPTION

7.3.1 Compliance with Health and Safety Standards

Please refer to section 6.3.1. The assessment for the OHL option is deemed low impact (**Cream**).

7.3.2 Compliance with Reliability and Security Standards

The reliability and security standards of the transmission network are defined in the following:

- The Transmission Planning Criteria (TPC)[33];
- The Operational Security Standards (OSS)[34];

The 400 kV OHL option proposed will comply with both the TPC and OSS. This option will be compliant with relevant reliability and security standards, and therefore rates at the lowest level on the difficult/ risk scale (**Cream**).

7.3.3 Average Failure Rates, Repair Times and Availabilities

Unplanned outages:

Almost all OHL faults are of short duration as a result of transient faults such as lightning strikes, where the auto reclose function provided for the protection of the line restores the circuit shortly (0.5 – 3 seconds) after the fault. Even if the line suffers physical damage, faults can be rapidly located and identified by visual inspection from the ground or air, and repairs effected in a matter of hours.

There are 439 km of existing 400 kV OHLs in Ireland. This length of 400 kV OHL is too small a sample for determining meaningful performance statistics.

Meaningful statistics can, however, be obtained by considering the fault statistics of the combined quantity (approximately 2245 km) of 400 kV, 275 kV and 220 kV OHLs under our control. Taking the fault statistics of this existing 2245 km of OHL for the period 2004 to 2012, gives a projected fault rate for a circa 100 km long 400 kV OHL of one permanent fault (that is a fault that requires repairs before the OHL can be returned to service) every 28 years.

Given typical repair times this would equate to the circuit being out of service due to a permanent fault for less than 2 hours per annum. The average failure rates during normal operation, average repair times and availabilities of the main elements of a typical 400 kV OHL is set out in the table below.

[33] EirGrid, Transmission Planning Criteria, 1998 (http://www.eirgrid.com/media/Transmission%20Planning%20Criteria.pdf)
[34] EirGrid, Operational Security Standards, 2011 (http://www.eirgrid.com/media/Operational%20Security%20Standards.pdf)

Parameter	400kV HVAC OHL
Reliability (Unplanned outages/100km/year)	0.035
Mean time to repair (days)	Circa 2days
Unavailability (days/100km/year)	0.073 days (c.2 hours)

Table 7-2 Average Failure Statistics for a 400 kV HVAC OHL

Transient faults are not considered, as any interruptions to supply that they may cause would be of such short duration that their effect is considered to be negligible, despite being an inconvenience for electricity users.

Planned outages:

Planned outages are normally associated with routine maintenance. For a 400 kV OHL much of the required routine maintenance can be completed without an outage of the circuit, therefore the planned outage rates and the typical outage durations taken from our maintenance policies result in an annual planned outage rate of 0.65% for the 400 kV option, or circa 2.5 days per annum.

Combination of the planned and unplanned outages:

Due to length of the Grid Link OHL circuit the total unplanned outage time is circa 4 hours, which combined with the planned outage rates can be taken as 2.5 days per annum (rounded to nearest half day).

Given the availability rates for this circuit are marginally below the 99.99% (four nines generally accepted by industry for power networks as a system) at 99.95% typically expected for unplanned outages this circuit option is aligned with those expected for the network, this option scores at the lowest level on the difficult/ risk scale (**Cream**).

7.3.4 Reliability of Supply

The primary driver for Grid Link is to resolve the security of supply issues arising as a result of large regional power flows across the country.

The 400 kV OHL option of the Grid Link project is compliant with the TPC and therefore meets the minimum acceptable reliability criteria.

The TPC provides a balance between security of supply (reliability) and development cost and, as a result, plans a resilient network for a justifiable range of events. Where opportunities exist to provide a higher security of supply at minimal or zero cost and impact on the environment, these options become preferable. This improves the quality of supply to customers and reduces financial costs to consumers or losses to the economy.

The high reliability of this option maximises security of supply and has a negligible economic or consumer cost due to unavailability. High availability reduces exposure to both additional constraint costs and security of supply issues and on its own would be considered at the lowest level on the difficult/risk scale.

As part of the wider system the OHL is consistent with the rest of the network and does not impose any additional reliability risk on the system. The reliability of supply for the 400 kV OHL option is at the lowest level on the difficult/ risk scale (**Cream**).

7.3.5 Implementation Timelines

The timeline provided is based on the assumption that required planning permissions are granted. The expected timeline for implementation of the 400 kV OHL option is 4.25 years. The significant risk factor to this timeline is access to private land.

The implementation timelines rating for the 400 kV option is assessed to be difficult on the difficult/ risk scale (**Dark Green**).

7.3.6 Future Reinforcement of Transmission Network

This option presents a flexible solution for the South East region. It provides a new corridor through which transmission power transfers across the system can take place.

As a 400 kV development, the reinforcement provides a very strong platform for future demand or generation development within the South region of the country. In the event that another connection along the circuit is required this can be achieved for a cost of tens of millions of Euros, depending on the required connection size.

While it was identified that connecting into Great Island was not required for the OHL option, it was seen as strategically appropriate to continue to route the reinforcement towards the geographical area of the south east of the country. Doing so allows for possible future development in the south east such as a new industrial demand customer or a new interconnector.

The 400 kV OHL option for Grid Link has a design capacity of 1580 MVA[35]. The option offers a high potential for future expansion, with its inherent capacity, proven flexibility in adapting to the changing load profiles, and relatively simple implementation of new extensions and modifications.

Overall the 400 kV OHL option is rated at the lowest level on the difficult/risk scale for future reinforcement of the transmission network (**Cream**).

[35] Based on the lowest annual rating in summertime (at 25 degrees)

7.3.7 Risk of Untried Technology

The 400 kV OHL technology proposed for the Grid Link project is tried and tested in Ireland. This option uses no new technology and therefore is considered lowest on the difficult/ risk scale (**Cream**).

7.3.8 Compliance with Good Utility Practice

This option uses standard network design and technology for system reinforcement in Ireland. In Europe, similar projects have been developed using the same approach, accounting for the changing network. HVAC OHL, used in a meshed configuration), meets this mandate and is the standard building block of international networks. Therefore this option is considered the best utility practice, placed at the lowest level on the difficult/ risk scale (**Cream**).

7.3.9 Summary of the Technical Analysis of the HVAC OHL

The table below summarises the technical assessment of the HVAC OHL Option.

	400 HVAC OHL
Compliance with all relevant safety standards	
Compliance with system reliability and security standards	
The average failure rates during normal operation, average repair times and availabilities of the main elements of each option	
The expected impact on reliability of supply of unavailability of the development	
Implementation timelines	
The extent to which future reinforcement of, and/or connection to, the transmission network is facilitated	
Risk of untried technology	
Compliance with good utility practice	

More Difficult
More Risk

Less Difficult
Less Risk

Table 7-3 Summary of the Technical Commentary of the HVAC OHL

7.4 ECONOMIC ANALYSIS FOR THE 400 KV OHL OPTION

An economic appraisal of the 400 kV HVAC OHL option, consistent with the requirements of the IEP Terms of Reference, was completed and the results are summarised below.

7.4.1 Approach and Methodology

The approach and methodology used in conducting the economic assessment is already discussed in detail in Sections 6.4.1 to 6.4.3 above.

As stated previously, the economic assessment measures the impact of the reinforcement project on the Irish economy, rather than on the company responsible for making the capital investment. It makes use of the Discounted Cash Flow (DCF) analysis method to present costs in a consistent manner.

All financial values are represented in the current year's Euro; and are expressed in real terms (i.e. excluding projected inflation). The start date of the economic assessment is taken as the current calendar year and all future values are referred (or discounted) to the current year. The duration of the evaluation is taken as the regulatory authority-approved useful life of the new asset being considered, i.e. 50 years.

7.4.2 Input Costs

Each reinforcement incurs incremental costs (e.g. inception capital costs, incremental maintenance costs); and has an impact on the overall transmission system efficiency (e.g. transmission system losses and system reliability costs).

All cost estimate inputs associated with the HVAC 400 kV OHL option are sourced from the best available information at EirGrid's disposal and from transmission standard development cost provided by ESB Networks. The costs considered in this assessment are consistent with the Terms of Reference and are described in the sections below.

7.4.2.1 Project Pre-Engineering Costs

The pre-engineering costs refer to the costs associated with design and specification; route evaluation; and managing the statutory planning application.

The costs are capital in nature are estimated to be €31.2 million. This amount includes a contingency provision of €1 million to account for the risk that the amount may vary.

The phasing of the costs is as follows:

	2015	2016	2017	2018	2019	2020
Pre-Engineering Costs	35%	26%	26%	10%	3%	0%

Table 7-4 Phasing of Pre-Engineering Costs

The present value of the project pre-engineering costs was calculated using the estimated value of €31.2 million, phased according to the table above. The capital amounts are discounted at the Test Discount Rate, resulting in a present value of €29.7 million (this is inclusive of a contingency of €1 million).

7.4.2.2 Project Implementation Costs

The project implementation costs refer to the costs associated with the procurement, installation and commissioning of the reinforcement and includes all the transmission equipment that form part of the reinforcement's scope.

The capital investment required to deliver the reinforcement is estimated to be €357.0 million, using standard development costs provided by ESB Networks. This cost estimate contains a contingency provision of 10% that has been applied to all the cost components and amounts to €32.5 million.

The estimated capital cost is categorised by its general components of OHL, UGC and stations costs. Also considered is a provision for flexibility payments, proximity allowance and local community fund (referred to as "Other"). The costs, by category, are summarised in the table below:

Cost Category	*Project Implementation Cost (€ M)*
Overhead Line	248.0
Substations	35.1
Underground Cable	1.8
Series Compensation	0.0
Other	
Flexibility Payments, Proximity and other allowances	39.6
Non-EPC Costs	0.0
SUB-TOTAL	**324.5**
Contingency	32.5
TOTAL	**357.0**

Table 7-5 Summary of Project Implementation Costs for the 400 kV OHL Option

The phasing of the costs is as follows:

	2019	2020	2021	2022	2023	2024
Project Implementation Costs	0%	25%	25%	25%	15%	10%

Table 7-6 Phasing of Project Implementation Costs

The present value of the project implementation costs was calculated using the estimated value of €357.0 million, phased according to the table above. The capital amounts are discounted at the Test Discount Rate, resulting in a present value of €260.1 million.

7.4.2.3 Project Life-Cycle Costs

Life-cycle costs refer to the costs incurred over the useful life of the reinforcement. They include the on-going cost of ensuring that the reinforcement remains viable for the evaluation period.

Project life cycle costs, consistent with those referred to in the Terms of Reference, are taken to be:

- The cost of electrical losses;
- Operation and maintenance costs;
- Decommissioning costs; and
- The costs of retaining any necessary specialist repair teams.

The equipment associated with the 400 kV HVAC OHL option is expected to be maintained in accordance with the well-established maintenance practices that already prevail. No replacement or upgrading would be necessary over its useful life. As a result, no cost for decommissioning has been included. No necessary specialist repair teams are required for this option.

Losses and operation and maintenance costs are considered in turn below.

- Cost of losses:

  Electrical losses in the transmission network, refer to the electrical energy consumed by the transmission system as it transmits electricity. New transmission infrastructure (such as new circuits) or a change in the physical characteristics of a circuit that allow greater power transfer, will inherently lower electrical losses incurred on the transmission system.

  The three options identified for the Grid link project all reduce network losses as they are designed to permit greater large scale power transfer across the entire network.

  High level network analysis indicates that the proposed options will incur only a marginal difference in reduced losses to the transmission system. Given the significant difference in project implementation costs between the three options the reduction in losses identified will have a negligible impact on the outcome of the economic appraisal of the options. The calculation method used, and accuracy of the system losses, is consistent for each option.

For completeness each option has a monetary value of the reduction in annual average system losses included in the calculations. This value is treated as a benefit to the option for each year following commissioning for the lifetime of the 400 kV HVAC OHL option in the economic appraisal.

The reduction in system losses are calculated based on a merit order dispatch with 35% wind dispatch (all-island) which is representative of an average year. The losses are calculated at their highest, based on the Winter Peak demand scenario, which is believed to represent a conservative approach.

The cost of electrical losses is typically determined using the cost of increasing power production with available capacity in the next most economical power station, referred to as the marginal cost of generation. For this analysis, the average System Marginal Price (SMP) is used to represent the marginal cost of generation and is calculated to be €60.66/MWh. The figure has been derived from the average system marginal price for Ireland between 2007 and 2013, which was sourced from information published on the Single Electricity Market Operator (SEMO) website[36].

The average annual system losses and the corresponding savings in system losses associated with the 400 kV HVAC OHL scheme is summarised in the table below.

	System losses with 400 kV HVAC OHL option included (GWh/yr)	Annual Savings in system losses relative to a system without reinforcement (€ M/a)
400 kV HVAC OHL Option	1,687	6.6

Table 7-7 Summary of the annual system losses with 400 kV HVAC OHL option included and savings

The estimated annual saving in system losses with the 400 kV HVAC OHL option is €6.6 million per annum. Assuming the annual savings of losses is constant for the duration of the evaluation, and then discounting those annual savings at the Test Discount Rate, results in a present value of €76.6 million.

- Operating and maintenance cost:

The incremental maintenance costs are those costs incurred to ensure that the appropriate level of utility is maintained over the useful life of the new reinforcement.

[36] SEMO System Marginal Price (EP2) from 11 December 2007 to 18 February 2013: http://www.sem-o.com/Publications/General/SMP2007-2014.zip.

The approach taken is to represent the maintenance costs as an annualised costs provision that is based on standard rates per equipment type which is taken from information provided by ESB Networks[37]. The maintenance costs provided are assumed to include a contingency provision of 10%.

The annual maintenance costs, inclusive of contingency provision, are summarised in the table below.

Age of Asset	Station Maintenance Cost (€ M/a)	OHL Maintenance Cost (€ M/a)	UGC Maintenance Cost (€ M/a)	Annual Cost of Maintenance (€ M/a)
< 20 years	0.061	0.182	0.018	0.245
20-40 years	0.061	0.202	0.018	0.264
>40years	0.061	0.228	0.018	0.288

Table 7-8 Summary of the Annual Cost of Maintenance

The present value of the cost of maintenance, including contingency provision, associated with this option is €2.9 million.

- Decommissioning and Replacement cost:
  The useful life is the same as the evaluation period and as a result, no replacement costs are considered for the option.

  Due to the economic appraisal being referenced to the end of the asset life of the regional option there is a residual value of €11.4 million for this option.

7.4.2.4 Cost of Unreliability

The main integrated transmission system is a network that has parallel paths to other parts of the network. To be compliant with the planning standards it is designed to withstand planned or unplanned outages of any single piece of plant or equipment. This means unreliability for unplanned outages in normal operation for the main network will have a negligible cost.

Planned maintenance outages of plant and equipment are required periodically, for example, annually, and usually for short durations. The network must remain compliant with planning standards during such maintenance outages. Additional system upgrades may be required to ensure compliance under this scenario. Alternatively, as the cost of generation at these times is generally low, generator output may be constrained to obviate the need for upgrades. The value of constrained generation must be determined and compared to the expected cost of the upgrade. The most cost effective solution is brought forward.

[37] ESB Networks, Transmission Maintenance Unit Costs (Confidential), Rev. 2, 8 December 2014

The 400 kV HVAC overhead line option resolves the needs and complies with planning standards. It resolves not only the need to be compliant for the loss of an item of plant and equipment in normal operation but also during maintenance periods. Consequently the cost of unreliability during unplanned and planned outages is negligible.

7.4.3 Estimate of Cost Uncertainty

In the absence of a detailed route or site being selected it is not possible to develop specific contingency allowances. For the purposes of the evaluation typical desktop contingency allowances are provided for in accordance with standard engineering practices. These provisions are the result of standard assumptions being made regarding complexity and site specific conditions.

Capital cost estimates, including pre engineering costs, include a contingency. The contingency allowance for the project development costs are assumed to be 5% of the remaining projected spend and 10% for the project implementation costs.

Similarly, a contingency allowance of 10% is provided for in the average maintenance costs that have been calculated and represented above. Other cost elements (i.e. losses, reliability) are based on historical data and, as such, no specific contingency has been provided for.

7.4.4 *Present Value Summary of Costs*

The abovementioned costs for the reinforcement are summarised in the table below. Estimate of cost uncertainty (contingency) is subtracted from the itemised values and presented separately in table below.

	Present Value (€ M)
Pre-Engineering Costs	28.7
Project Implementation Costs	236.5
Project Life-Cycle Costs	
Cost of Losses	-76.6*
Operating and maintenance Costs	2.6
Decommissioning & Replacement	-0.7**
Cost to SEM from Development Unavailability (Reliability)	
Cost of Unplanned Outages	0.0
Cost of Planned Outages	0.0
Estimate of cost uncertainty	
Pre-Engineering Costs	1.0
Project Implementation Costs	23.6
Operating and maintenance Costs	0.3
Decommissioning & Replacement	0.0
TOTAL	**215.4**

***** This figure represents a benefit rather than a loss.

**This figure represents the residual value of the option

Table 7-9 Summary of Present Value of Costs Associated with the Reinforcement

The total present value amount of the 400 kV HVAC OHL option is to €215.4 million. Given the rated capacity of the HVDC, this would equate to the cost per MVA of capacity is €0.1 million/MVA.

The variation of estimated completion dates of each option impacts on the overall present value. The 400kV AC OHL option has the latest commissioning date of 2024. Therefore it has been used as the reference case for the HVDC and Regional options, and unlike these option is unchanged.

8. REGIONAL OPTION

8.1 DESCRIPTION OF OPTION

The regional option is a suite of transmission network reinforcements centred on the reinforcement of the existing 400 kV circuits. These consist of:

- Series compensation devices installed in three locations on the existing 400 kV overhead lines, namely:
    - Oldstreet 400 kV station;
    - Moneypoint 400 kV station and;
    - Dunstown 400 kV station.

- An underwater 400 kV cable between Moneypoint and Kilpaddoge station under the Shannon Estuary; and

- Uprating of the Great Island - Kilkenny and Great Island – Wexford 110 kV overhead lines as well as uprating of the Wexford 110 kV station busbar.

Series compensation is used to change the characteristics of overhead lines to increase their usage. Traditionally their use has been in relatively large transmission networks around the world with long overhead lines. Their application represents an innovation in the context of the Irish transmission system. The devices may be located in substations at either end of the power line or located at points along the line. For this application it is envisaged that the series compensation devices will be installed at the end of the power lines within the confines of existing or future planned 400 kV substations (refer to Figure 8-1).

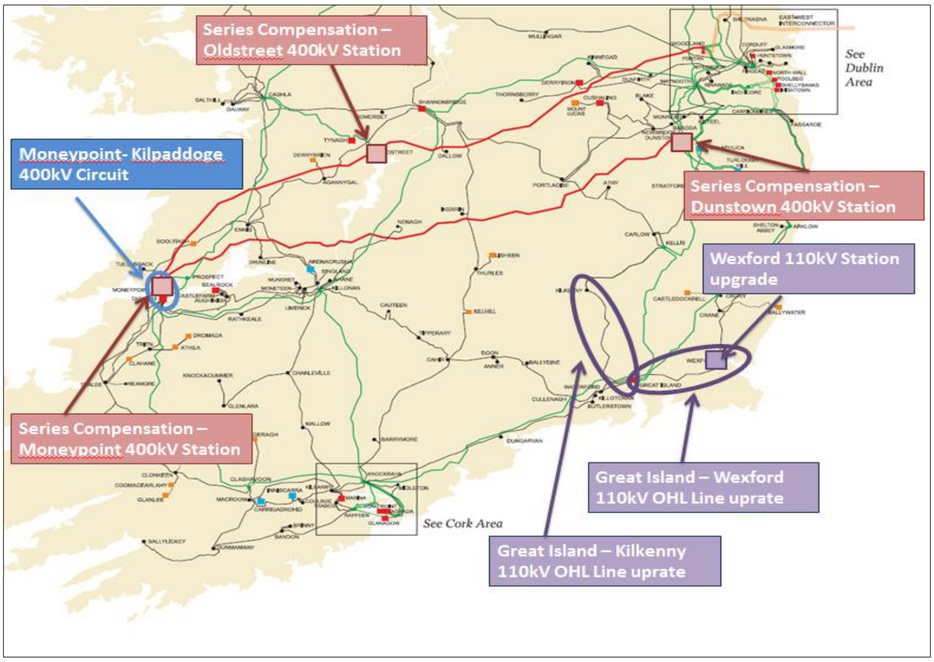

Figure 8-1 Regional Option components

8.2 ENVIRONMENTAL ANALYSIS

8.2.1 Introduction

A review of the likely environmental issues for the regional option components has been carried out. This review aims to cover the environmental topics addressed for the HVDC UGC option and 400 kV OHL options in so far as are feasible and practical.

With the exception of the underwater cable element, this option uses existing transmission infrastructure assets and thus implicitly reduces the potential environmental impacts that could be expected when compared with the development of a new circuit (whether UGC or OHL).

The objective of this section is to identify the potential for significant effects on a range of environmental topics in terms of the proposed regional solution. This is based on known impacts of transmission infrastructure development, including line uprating and refurbishment, combined with local environmental sensitivities. The application of mitigation measures to reduce severity of impacts such as avoidance, reduction and/or restoration are assumed. Such mitigation is based on best practice for the construction and operation of transmission infrastructure. The following criteria are examined as part of the environmental analysis for the Regional Option:

- Biodiversity, Flora and Fauna
- Water
- Soils and Geology
- Landscape/visual
- Cultural Heritage
- Settlement/Communities
- Recreation and Tourism
- Material Assets (land use)
- Air quality
- Climatic Factors
- Traffic and Noise

8.2.2 Biodiversity, Terrestrial Flora and Fauna

For the purpose of this assessment, terrestrial and aquatic ecology have been separated, aquatic ecology is considered under Section 8.2.3 to avoid duplication of impacts.

The primary aspects considered include potential impacts on designated sites such as cSACs, and SPAs impacts on the terrestrial ecology and on high nature value habitats, birds and other fauna.

The installation of series compensation technology in substations does not present a risk of any likely significant impacts to terrestrial flora and fauna. The uprating of existing lines requires the consideration of possible impacts on sites designated for nature conservation. All of the lines identified for uprate either cross cSAC/SPA sites or are adjacent to designated sites (including pNHA/ NHA sites). Potential impacts are largely restricted to disturbance of protected fauna or sensitive habitats arising from access requirements along the existing transmission lines and any ground works, where foundation works are required. There will be no increased risk (of collision) posed to bird species by this option.

There may be some limited disturbance of habitats and fauna during the underwater cable installation but this would be temporary in nature (see section 8.2.3).

Overall the potential impact (negative) to terrestrial ecology is considered low-moderate (**Green**). Through the application of well-established standard mitigation measures, such as the avoidance of sensitive habitats, minimising construction impacts through the timing of works and restoration of habitats post construction, it is reasonable to assume that this potential impact would be reduced.

8.2.3 Water and Aquatic Ecology

Key ecological receptors considered are rivers and estuaries designated as cSACs, the number of crossings of cSAC rivers or their tributaries, salmonid watercourses, freshwater pearl mussel (FWPM) rivers and sensitive catchments.

Indirect impacts to sensitive watercourses in particular will require consideration during any line uprates which require foundation works within sensitive river catchments. The underwater cable crossing of the Shannon estuary will require consideration with regard to the Habitats and Birds Directives.

Potential impacts from construction related activities may include increased sediment in surface water run-off and pollution from construction related plant or concrete. The potential effect of these impacts could result in the deterioration of water quality downstream of the construction works (were required) and an indirect effect on downstream water dependant habitats and species. Due to the potential impacts to surface water at locations close to rivers and streams, this impact is rated as potentially low-moderate (**Green**). Through the application of well-established standard mitigation measures, such as the avoidance of sensitive aquatic habitats where feasible, best practice methods in pollution and siltation control and restoration of riverside habitats post construction, it is reasonable to assume that this potential impact would be reduced.

8.2.4 Soils and Geology, Hydrology and Hydrogeology

The potential impact on these receptors is based on an understanding of the anticipated likely impacts, and with consideration of site specific sensitivities. Any potential impacts on soils, geology, hydrology and hydrogeology will likely be confined to the installation of cable (underwater and terrestrial sections) and to any localised excavations required for foundation reinforcements as part of line uprates.

Under this criterion the potential impacts on soils, geology, hydrology and hydrogeology during construction were considered. Overall based on the known sensitivities of the areas and the limited excavations required, potential impacts are considered low-moderate (**Green**). Through the application of well-established standard mitigation measures such as the avoidance of sensitive areas for soils and hydrology and standard soil management, it is reasonable to assume that this potential impact would be reduced.

8.2.5 Landscape/Visual

The utilisation of existing transmission infrastructure including overhead lines and substations means that for the line uprates and substation works associated with this option, there will be no significant change in the visual appearance of the infrastructure.

The added height of the series compensation technology within the existing substations will not significantly alter how the stations appear in the landscape or in terms of visual appearance. The installation of underwater cable and terrestrial sections of underground cable will not result in any significant landscape effects. The only visual or landscape effects that are likely to occur will be during the construction phase but these will be temporary and should not be significant from a landscape or visual perspective. The overall impact is considered low (**Cream**).

8.2.6 Cultural Heritage

The installation of series compensation technology at substations means that no impacts are expected to cultural heritage assets. The uprating of existing lines will need to take into account the presence of any known cultural heritage assets in the vicinity of any, works areas and access areas. This will prevent direct impacts or indirect impacts to any upstanding monuments, for example. Impacts on setting are not significant in this instance.

The overall potential significance of impacts on cultural heritage is considered to be low-moderate (**Green**). Through the application of well-established standard mitigation measures, such as the avoidance of known cultural heritage assets and minimising potential construction impacts through the location of works areas, it is reasonable to assume that any potential impacts would be reduced even further.

8.2.7 Settlement/Communities

The utilisation of existing transmission infrastructure including overhead lines and substations means that for the line uprates and substation works associated with this option, there will be no significant change in the visual appearance of the infrastructure. The location of the proposed underwater cable is such that settlements will not be impacted as only very localised areas will be required for construction activities. There may be some temporary disruption to boating or fishing activities during the underwater cable laying period. There may be some temporary disruption associated with the line uprate activities in terms of access to structures and construction activity however, the overall potential significance of impacts on settlement/ communities is considered to be low (**Cream**).

8.2.8 Recreation and Tourism

The utilisation of existing transmission infrastructure including overhead lines and substations means that for the line uprates and substation works associated with this option, there will be no significant change in the visual appearance of the infrastructure which may affect a tourism experience.

Although there will be some traffic disruption during construction, this is not expected to be significant. There may be some temporary disruption to boating or fishing activities during the underwater cable laying period. The overall potential significance of impacts on recreation and tourism is considered to be low (**Cream**).

8.2.9 Air quality and Climate

The utilisation of construction plant and construction works at existing infrastructure will result in potential impacts on the local air quality through vehicle emissions and dust. However, in terms of the line uprate component and works in the substations, these impacts would be expected to be significantly less than for any new build project (**Green**). This relatively short-term impact should be considered alongside the long-term benefit of the development.

This option will have net positive impacts for climate in facilitating the integration of renewable energy onto the grid, thereby reducing the national dependence on fossil fuels (**Cream**).

8.2.10 Material Assets

The utilisation of existing transmission infrastructure including overhead lines and substations means that for the line uprates and substation works associated with this option, there will be no significant change in the current land use or on other material assets.

There may be some temporary disruption associated with the line uprate activities in terms of access to structures and construction activity depending on the level of work required at existing infrastructure. There may be some temporary disruption to boating and or fishing activities during the subsea cable period.

The overall potential significance of impacts on material assets is considered to be a low -moderate temporary impact (**Green**). With the application of standard mitigation practices, this impact could be reduced further.

8.2.11 Traffic and Noise

An increase in traffic would be experienced in the local area of proposed line uprates, works at substations and landfall areas for a subsea cable. This could result in some localised temporary impacts on local traffic.

Impacts from construction noise would be limited to effects on receptors in close vicinity to construction sites. Construction related impacts would be localised and short term. There should be no increase in noise from the current baseline associated with the substation works and line uprates. Overall the potential impact of noise and traffic is considered of moderate to low significance (**Green**).

8.2.12 Summary of the Environmental Analysis of the Regional Option

Based on the information available, the possible likely significance of environmental impact on each parameter is presented along a range from “more significant” to “less significant”. The application of standard mitigation practices ranging along the scale of avoidance, reduction/design or remedy/restoration is considered in this table in terms of the ease of implementation such measures. This follows the format presented in the Grid West report for the IEP. At this stage in the development of the regional option, it is not possible evaluate the overall effectiveness of proposed mitigation measures. The aim of any transmission infrastructure project developed by EirGrid will be to minimise the potential for residual effects where ever feasible. The likelihood of residual effects occurring post mitigation is shown in Table 8.1 for illustration but it should be noted that this does not equate to the significance of any potential residual effect.

	Regional Option		
	Significance of Impact/Effect	Ease of Mitigation	Likelihood of residual effect persisting (post mitigation)
Biodiversity, Terrestrial flora and fauna;			
Aquatic Ecology /Water [1]			
Soil, Geology, Hydrology and Hydrogeology			
Landscape and Visual			
Cultural Heritage			
Settlements and Communities			
Recreation and Tourism			
Air Quality[1]			
Climatic Factors			
Material Assets			
Traffic and Noise [1]			
Noise[2]			

Notes:

1 During construction
2 During operation

Table 8-1 Summary of Environmental Analysis for the Regional Option

More significant
Difficult to Mitigate
More Likely

Less significant/
Possible to Mitigate
Less Likely

8.3 TECHNICAL ANALYSIS

8.3.1 Compliance with Health and Safety Standards

Please refer to section 6.3.1. The assessment for the regional option is deemed low impact (**Cream**).

8.3.2 Compliance with Reliability and Security Standards

The reliability and security standards of the transmission network are defined in the following:

- The Transmission Planning Criteria (TPC)[38];
- The Operational Security Standards (OSS)[39]; and

This proposed option, which involves a suite of transmission network reinforcements, will comply with both the TPC and OSS for all the elements involved. All equipment and elements part of this option will be compliant with the relevant security and reliability standards and will therefore be rated at the lowest point on the difficulty/ risk scale (**Cream**).

8.3.3 Average Failure Rates, Repair Times and Availability

Unplanned outages:

Failure Rates, Repair Times and Generic Availability Figures	220-500 kV Cables
Reliability(Unplanned outages/100km/year)	0.277
Mean time to repair (days)	25 – 45 days[40]
Unavailability (days/100km/year)	c.7 – 12 days/annum

Grid Link Option Specific Availability Rates	400 kV UGC
option section lengths	5 km (UGC)
Unavailability (days/220 kV OPTION/year)	c.8 – 15 hours/annum

Table 8-2 Average Failure Rates, Repair Times and Availability

The regional option has many constituent parts with series compensation, a new underwater cable and potential associated line uprates. Almost all OHL faults are of short duration as a result of transient faults such as lightning strikes, where the auto reclose function provided for the protection of the line restores the circuit shortly (0.5 – 3 seconds) after the fault. Even if the line suffers physical damage, faults can be rapidly located and identified by visual inspection from the ground or air, and repairs effected in a matter of hours.

[38] EirGrid, Transmission Planning Criteria, 1998 (http://www.eirgrid.com/media/Transmission%20Planning%20Criteria.pdf)
[39] EirGrid, Operational Security Standards, 2011 (http://www.eirgrid.com/media/Operational%20Security%20Standards.pdf)
[40] Dependant on method of cable installation: direct lay or in ducts respectively.

Therefore as the line uprating works will not add any additional length and will renew some of the existing assets on these lines it is expected that they will have a negligible impact on availability of these circuits.

Similarly the installation of series compensation devices, which may be physically bypassed in most circumstances automatically, are also expected to have negligible impact on availability of the circuits on which they are installed.

However faults on underground cables are considered to be permanent and will not be re-energised until an investigation has been undertaken. Consequently when a cable fault occurs, fault localisation can result in prolonged circuit outages. As such, cable circuits have a lower availability than OHLs because of the prolonged outage times in the event of a fault. Given the short length of the underwater section of the Shannon cable crossing circuit it is reasonable to install a spare cable to make restoration following a fault more expedient.

Consequently the unplanned outages for the cable element of the regional option will vary from typically from circa 8 – 15 hours per annum.

Planned outages:

Planned outages are normally associated with routine maintenance. The typical routine maintenance outage duration for HVAC 400 kV cables taken from our maintenance policies is 2-3 days per annum (dependant on the number of joint bays and cable sections). Common to all of the options is the need to perform planned maintenance for the associated substation switchgear and equipment. Each year an operational test is performed, and periodically an ordinary service. These maintenance outages equate to a total unavailability of 0.64%, or c.2.5 days per annum.

Whilst operational tests, ordinary services and condition assessment on bays can be carried out simultaneously with OHL maintenance, cable maintenance must be carried out separately. This is why Station and OHL maintenance cannot be carried out concurrently with UGC maintenance.

Therefore the planned outages for the Shannon cable crossing for the regional option would equate to a total of circa 4.5 days per annum on average, but much of this work would be scheduled to be completed simultaneously where possible.

The planned outages for the series compensation would be expected to be completed as part of the existing switchgear and line maintenance. Similarly for the lines post uprating these are considered to require the same level of planned outages and hence availability post their uprating. Therefore no additional planned outages are considered for these items.

Combination of the planned and unplanned outages:

The combination of the planned and unplanned outages gives a total of circa 4.5 - 5 days per annum.

The regional option has many constituent parts with series compensation, a new underwater cable and potential associated line uprates.
The line uprating works and series compensation are assumed to have a negligible impact on the availability of the existing lines.

However, the underwater cable will impact availability. Therefore, the availability rate for unplanned outages will be below the overall network reliability rate, i.e. not lower than 99.99% (four nines generally accepted by industry for power networks as a system), for the entire regional option, at approximately 99.9%. This marginal reduction in availability has limited network effect and is at the lowest level on the difficult / risk scale (**Cream**).

8.3.4 Reliability of Supply

The regional solution is compliant with the transmission planning criteria and therefore meets the minimum acceptable reliability criteria.

However, the transmission planning criteria provide a balance between security of supply (reliability) and development cost and, as a result, only require us to plan a resilient network for a justifiable range of events. Where opportunities exist to provide a higher security of supply at minimal or zero cost and impact on the environment, these options are preferable. The overall reliability of the circuit changes depends on the changing mix of technology (i.e. ratio of UGC to OHL) used and their individual reliability rates.

High availability reduces exposure to both additional constraint costs and security of supply issues and on its own is considered to be at the lowest level on the difficult/ risk scale. Low availability exposes the network to additional constraint costs and security of supply issues.

The regional option maximises the use of the existing transmission network and the option includes a minimal amount of underwater cable across the Shannon estuary. The use of mostly OHL is consistent with the rest of the network and does not impede future network development options and is the lowest level on the difficult/ risk scale (**Cream**).

8.3.5 Implementation Timelines

The expected timeline for implementation of the regional option is 3 years. This is based on our previous experience of similar developments. The timeline is dependent on the ability to schedule outages for long periods of time.

The rating for the regional option in terms of implementation timelines is assessed to be the lowest level on the difficult/risk scale taking into account the risk of timely completion of the large number of individual elements and the alignment of those completions (**Cream**).

8.3.6 Future Reinforcement of the Transmission System

With the current demand forecast, this option meets the immediate need to resolve the security of supply issue arising as a result of large regional power flows across the country. However, the regional option will not provide significant additional capacity on the network but rather maximise the potential of the existing grid. The regional option does not develop new transmission network in the south east of the country. Depending on future needs, development of the network in the south east may be required in order to provide reinforcement, for example to accommodate future interconnection. Currently, we have no connection applications for connecting any interconnector in the south east of Ireland.

In addition, the regional option may require line uprates to allow the network to be within standards during a subsequent loss of plant and equipment whilst another is out for maintenance. This option has the potential to incur a wind curtailment under certain maintenance conditions. We will individually appraise whether each of these uprates could be financially justified. To ensure value for money, we will defer a decision until much closer to the required commissioning date. This will allow us to take account of all requirements from each uprate, which may include both local and regional needs. The total cost estimate for line uprates which may be required with the regional option in place amounts to circa €100 million. Given the estimated capital cost for each individual project it is expected that many of these uprates would not be justified. The potential uprates are presented in table 8-3.

Potential line uprates associated with the regional option during a subsequent loss of plant whilst another is out for maintenance
Portlaoise – Newbridge 110 kV OHL
Agannygal – Shannonbridge 110 kV OHL
Arva – Carrick on Shannon 110 kV OHL
Lanesboro – Mullingar 110 kV OHL
Flagford – Louth 220 kV OHL
Killonan - Shannonbridge 220 kV OHL
Maynooth - Shannonbridge 220 kV OHL
Oldstreet - Tynagh 220 kV OHL

Table 8-3 Potential line uprates

Overall the Regional option would be between mid-level and lowest level on the difficult / risk scale for future reinforcement of the transmission network (**Dark Green**).

8.3.7 Risk of Untried Technology

The series compensation element of the regional option is widely in use in transmission systems across the world and is now seen as a tried and tested technology. The mitigations to technical issues that arise with the technology are well known, numerous, generally tried, and tested.

The use of underwater 400 kV AC cable across a large river estuary (the Shannon) is an untried technology on the Irish system and relatively new worldwide. However, the inclusion of a spare phase cable mitigates reliability problems with the other three phase cables required to make up this crossing.

The proposed 400 kV AC (XLPE type) onshore cable is also a relatively new technology which has not been used in Ireland and has seen limited use internationally.

It has previously been identified that there can be technical issues with the use of 400 kV cables in Ireland as it has low system strength. The principle determining factor of the acceptability of 400 kV cable is its length. The underwater elements of this project require the use of a cable. The length of the onshore elements also makes an overhead option impractical.

The system strength of both terminating stations is considered high for Ireland. High system strength inherently reduces the scale of the technical issues. The total cable length combined with the local system strength means that a 400 kV cable circuit is considered acceptable.

Uprating of existing 110 kV and 220 kV circuits is commonly carried out in Ireland.

Therefore, in aggregate, the regional option is on the lowest level on difficult/ risk scale (**Cream**).

8.3.8 Compliance with Good Utility Practice

Good utility practice is to develop a flexible, robust and cost-effective option with due regard to environmental constraints. The maximisation of existing assets, when this meets the envisaged long term needs, is considered good utility practice. Therefore the overall approach of the regional option is consistent with good utility practice.

The use of series compensation to change the characteristics of overhead lines to increase their usage is also in line with good utility practice and is commonly used throughout the world. The use of this technology on lines the length of those proposed, and in a system the size of Ireland's is considered new internationally. A new application of a known technology is also considered good utility practice.

Utilisation of Extra High Voltage HV AC cables is limited internationally (compared to overhead technology). It is generally restricted to applications where an overhead alternative is not technically and/or environmentally possible. In this context the use of 400 kV cables to cross the Shannon is in line with good utility practice.

As such, with regard to good utility practice, it is rated at the lowest point on the difficult/risk scale (**Cream**).

8.3.9 Summary of the Technical Analysis of the Regional Option

The table below summarises the technical assessment of the regional option.

	Regional option
Compliance with all relevant safety standards	
Compliance with system reliability and security standards	
The average failure rates during normal operation, average repair times and availabilities of the main elements of each option	
The expected impact on reliability of supply of unavailability of the development	
Implementation timelines	
The extent to which future reinforcement of, and/or connection to, the transmission network is facilitated	
Risk of untried technology	
Compliance with good utility practice	

More Difficult
More Risk

Less Difficult
Less Risk

Table 8-4 Summary of the technical commentary of the regional option

8.4 ECONOMIC ANALYSIS FOR THE REGIONAL OPTION

An economic appraisal of the regional option, consistent with the requirements of the IEP Terms of Reference, was completed and the results are summarised below.

8.4.1 Approach and Methodology

The approach and methodology used in conducting the economic assessment is already discussed in detail in Sections 6.4.1 to 6.4.3 above.

As stated previously, the economic assessment measures the impact of the reinforcement project on the Irish economy, rather than on the company responsible for making the capital investment. It makes use of the Discounted Cash Flow (DCF) analysis method to present costs in a consistent manner.

All financial values are represented in the current year's Euro; and are expressed in real terms (i.e. excluding projected inflation). The start date of the economic assessment is taken as the current calendar year and all future values are referred (or discounted) to the current year. The duration of the evaluation is taken as the regulatory authority-approved useful life of the new asset being considered, i.e. 50 years.

8.4.2 Input Costs

Each reinforcement incurs incremental costs (e.g. inception capital costs, incremental maintenance costs); and has an impact on the overall transmission system efficiency (e.g. transmission system losses and system reliability costs).

The costs considered in this assessment, consistent with the Terms of Reference, are as follows:

8.4.2.1 Project Pre-Engineering Costs

The pre-engineering costs refer to the costs associated with design and specification; route evaluation; and managing the statutory planning application.

The costs are capital in nature are estimated to be €14.2 million. This amount includes a contingency provision of €0.1 million to account for the risk that the amount may vary.

The phasing of the costs is as follows:

	2015	***2016***	***2017***	***2018***	***2019***	***2020***
Pre-Engineering Costs	77%	18%	5%	0%	0%	0%

Table 8-5 Phasing of Pre-Engineering Costs

The present value of the project pre-engineering costs was calculated using the estimated value of €14.2 million, phased according to the table above. The capital amounts are discounted at the Test Discount Rate, resulting in a present value of €14.1 million (this is inclusive of a contingency of €0.1 million).

8.4.2.2 Project Implementation Costs

The project implementation costs refer to the costs associated with the procurement, installation and commissioning of the reinforcement and includes all the transmission equipment that form part of the reinforcement's scope.

All cost estimate inputs associated with the Regional option are sourced from the best available information at EirGrid's disposal from either transmission standard development cost provided by ESB Networks or bespoke projects reports. The capital investment required to deliver the reinforcement is estimated to be €184.1 million. This cost estimate contains a contingency provision of 10% that has been applied to all the cost components and amounts to €16.7 million.

The estimated capital cost is categorised by its general components of OHL, UGC and station costs. Also considered is a provision for flexibility payments, proximity allowance and local community fund (referred to as "Other"). The costs, by category, are summarised in the table below:

Cost Category	*Project Implementation Cost (€ M)*
Overhead Line	22.7
Substations	21.0
Underground Cable	54.4
Series Compensation	69.3
Other	
Flexibility Payments, Proximity and other allowances	0.0
Non-EPC Costs	0.0
SUB-TOTAL	**167.4**
Contingency	16.7
TOTAL	**184.1**

Table 8-6 Summary of Project Implementation Costs for the Regional Option

The phasing of the costs is as follows:

	2017	*2018*	*2019*	*2020*	*2021*	*2022*
Project Implementation Costs	0%	25%	50%	25%	0%	0%

Table 8-7 Phasing of Project Implementation Costs

The present value of the project implementation costs was calculated using the estimated value of €184.1 million, phased according to the table above. The capital amounts are discounted at the Test Discount Rate, resulting in a present value of €152.5 million.

8.4.2.3 Project Life-Cycle Costs

Life-cycle costs refer to the costs incurred over the useful life of the reinforcement. They include the on-going cost of ensuring that the reinforcement remains viable for the evaluation period.

Project life cycle costs, consistent with those referred to in the Terms of Reference, are taken to be:

- The cost of electrical losses;
- Operation and maintenance costs;
- Decommissioning costs; and
- The costs of retaining any necessary specialist repair teams.

The equipment associated with the regional option is expected to be maintained in accordance with the well-established maintenance practices that already prevail. No replacement or upgrading would be necessary over its useful life. As a result, no cost for decommissioning has been included. No necessary specialist repair teams are required for this option.

Losses and operation and maintenance costs are considered in turn below.

- Cost of losses:

  Electrical losses in the transmission network, refer to the electrical energy consumed by the transmission system as it transmits electricity. New transmission infrastructure (such as new circuits) or a change in the physical characteristics of a circuit that allow greater power transfer, will inherently lower electrical losses incurred on the transmission system.

  The three options identified for the Grid link project all reduce network losses as they are designed to permit greater large scale power transfer across the entire network.

  High level network analysis indicates that the proposed options will incur only a marginal difference in reduced losses to the transmission system. Given the significant difference in project implementation costs between the three options, the reduction in losses identified will have a negligible impact on the outcome of the economic appraisal of the options. The calculation method used, and accuracy of the system losses, is consistent for each option.

  For completeness each option has a monetary value of the reduction in annual average system losses included in the calculations. This value is treated as a benefit to the option for each year following commissioning for the lifetime of the regional option in the economic appraisal.

The reduction in system losses are calculated based on a merit order dispatch with 35% wind dispatch (all-island) which is representative of an average year. The losses are calculated at their highest, based on the Winter Peak demand scenario, which is believed to represent a conservative approach.

The cost of electrical losses is typically determined using the cost of increasing power production with available capacity in the next most economical power station, referred to as the marginal cost of generation. For this analysis, the average System Marginal Price (SMP) is used to represent the marginal cost of generation and is calculated to be €60.66/MWh. The figure has been derived from the average system marginal price for Ireland between 2007 and 2013, which was sourced from information published on the Single Electricity Market Operator (SEMO) website[41].

The average annual system losses and the corresponding savings in system losses associated with the regional option is summarised in the table below.

	System losses with regional option included (GWh/yr)	Annual Savings in system losses relative to a system without reinforcement (€ M/a)
Regional Option	1,742	3.3

Table 8-8 Summary of the annual system losses with Regional option included and savings

The estimated annual saving in system losses with the regional option is €3.3 million per annum. Assuming the annual savings of losses is constant for the duration of the evaluation, and then discounting those annual savings at the Test Discount Rate, results in a present value of €47.1 million.

- Operating and maintenance cost:

  The incremental maintenance costs are those costs incurred to ensure that the appropriate level of utility is maintained over the useful life of the new reinforcement.

  The approach taken is to represent the maintenance costs as an annualised costs provision that is based on standard rates per equipment type which is taken from information provided by ESB Networks[42]. The maintenance costs provided are assumed to include a contingency provision of 10%.

  The annual maintenance costs, inclusive of contingency provision, are summarised in the table below.

[41] SEMO System Marginal Price (EP2) from 11 December 2007 to 18 February 2013: http://www.sem-o.com/Publications/General/SMP2007-2014.zip.
[42] ESB Networks, Transmission Maintenance Unit Costs (Confidential), Rev. 2, 8 December 2014

Age of Asset	Station Maintenance Cost (€ M/a)	OHL Maintenance Cost (€ M/a)	UGC Maintenance Cost (€ M/a)	Annual Cost of Maintenance (€ M/a)
< 20 years	0.061	0.0	0.014	0.076
20-40 years	0.061	0.0	0.014	0.076
>40 years	0.061	0.0	0.014	0.076

Table 8-9 Summary of the Annual Cost of Maintenance

The present value of the cost of maintenance, including contingency provision, associated with this option is €1.1 million.

- Decommissioning and Replacement cost:
  The useful life is the same as the evaluation period and as a result, no replacement costs are considered for the option.

  Due to the economic appraisal being referenced to the end of the asset life of the regional option there is no residual value for this option.

8.4.2.4 Cost of Unreliability

The main integrated transmission system is a network that has parallel paths to other parts of the network. To be compliant with the planning standards it is designed to withstand planned or unplanned outages of any single piece of plant or equipment. This means unreliability for unplanned outages in normal operation for the main network will have a negligible cost.

Planned maintenance outages of plant and equipment are required periodically, for example, annually, and usually for short durations. The network must remain compliant with planning standards during such maintenance outages. Additional system upgrades may be required to ensure compliance under this scenario. Alternatively, as the cost of generation at these times is generally low, generator output may be constrained to obviate the need for upgrades. The value of constrained generation must be determined and compared to the expected cost of the upgrade. The most cost effective solution is brought forward.

The regional option is a suite of transmission reinfrocemnt. All of the elements combined resolves the needs and complies with planning standards. However, during maintenance periods eight additional circuit uprates are required to comply with planning standards unless generation is constrained.

Constraint calculations for these uprates are based on broad assumptions. This is due to uncertainty surrounding future emerging drivers, the construction programmes of the numerous generators and associated connections already planned. Nevertheless, the same assumptions have been used and the results allow direct comparison of the options.

The constraint calculations accounted for each maintenance outage of plant and equipment that could require a circuit uprate. For each maintenance outage, the level of constraint that is required on generation in the south west has been calculated. This has been factored with the average loading of the system and wind speed to provide the average constraint over the maintenance period. This average hourly constraint level has then been calculated using the average SMP of €60.66/MWh.

The result of the analysis is to favour constraining generation annually. The total power flow constraint cost to avoid all associated uprates and permit the planned maintenance outages has been calculated as €2.5 million per annum. The constraint cost per annum amounts are discounted at the Test Discount Rate, resulting in a present value €36.2 million

It should be reiterated that the development of any circuit uprate would be re-evaluated when there is greater certainty of the needs in future years.

8.4.3 Estimate of Cost Uncertainty

In the absence of a detailed route or site being selected it is not possible to develop specific contingency allowances. For the purposes of the evaluation typical desktop contingency allowances are provided for in accordance with standard engineering practices. These provisions are the result of standard assumptions being made regarding complexity and site specific conditions.

Capital cost estimates, including pre engineering costs, include a contingency. The contingency allowance for the project development costs are assumed to be 5% of the remaining projected spend and 10% for the project implementation costs.

Similarly, a contingency allowance of 10% is provided for in the average maintenance costs that have been calculated and represented above. Other cost elements (i.e. losses, reliability) are based on historical data. As such, no specific contingency has been provided for.

8.4.4 Present Value Summary of Costs

The abovementioned costs for the reinforcement are summarised in the table below. Estimate of cost uncertainty (contingency) is subtracted from the itemised values and presented separately in table below.

	Present Value (€ M)
Pre-Engineering Costs	14.0
Project Implementation Costs	138.6
Project Life-Cycle Costs	
Cost of Losses	-47.1*
Operating and maintenance Costs	1.0
Decommissioning & Replacement	0.0
Cost to SEM from Development Unavailability (Reliability)	
Cost of Unplanned Outages	0.0
Cost of Planned Outages	36.2
Contingency Cost Provisions	
Pre-Engineering Costs	0.1
Project Implementation Costs	13.9
Operating and maintenance Costs	0.1
Decommissioning & Replacement	0.0
TOTAL	**156.8**

***** This figure represents a benefit rather than a loss.

Table 8-10 Summary of Present Value of Costs Associated with the Reinforcement

The total present value amount of the regional option is €156.8 million. When considering the capacity created by the regional solution as a package its elements cannot be considered separately. With the additional cable across the river Shannon the capacity is increased by 750 MW. The rated capacity of the 400 kV lines is not increased with series compensation, but the capability of the network to transfer power through the 400 kV lines is increased by approximately 750 MW. Therefore in combination the increase in capacity can be considered to be 750 MW, equating to a cost per MVA of capacity of €0.2 million/MVA.

The variation of estimated completion dates of each option impacts on the overall present value. If the regional option is assumed to be commissioned end of 2024 (the same date assumed for the 400kV AC OHL option) then the present value would be €130.9 million.

9. SUMMARY

This report comprises a comprehensive technical, environmental and economic analysis of underground and overhead technology options, as well as a regional solution for the Grid Link project.

While based on illustrative underground and overhead routes, as well as a more spatially defined regional option, we are satisfied that these criteria provide a representative and appropriate basis for the analysis set out in this report. A comprehensive and equal examination has been completed for each option, in the context of the information available in respect of the Grid Link project at this time.

Summary tables of the technical analysis, capital costs and environmental appraisal for all three options are shown below:

Technical	HVDC UGC	400 kV OHL	Regional
Compliance with all relevant safety standards			
Compliance with system reliability and security standards			
The average failure rates during normal operation, average repair times and availabilities of the main elements of each option			
The expected impact on reliability of supply of unavailability of the development			
Implementation timelines			
The extent to which future reinforcement of, and/or connection to, the transmission network is facilitated			
Risk of untried technology			
Compliance with good utility practice			

Table 9-1 Summary tables of technical analysis

More Difficult
More Risk

Less Difficult
Less Risk

Summary of Cost Assessment

ITEM	HVDC UGC OPTION Present Value (€ M)	400 kV HVAC OHL OPTION Present Value (€ M)	Regional Option Present Value (€ M)
Capacity of option in MVA	**750**	**1580**	**750***
Pre-Engineering Costs	15.8	28.7	14.0
Project Implementation Costs	556.7	236.5	138.6
Project Life-Cycle Costs			
Cost of Losses	-59.0**	-76.6**	-47.1**
Operating and maintenance Costs	62.6	2.6	1.0
Decommissioning & Replacement	-0.5***	-0.7***	0.0
Cost to SEM from Development Unavailability (Reliability)			
Cost of Unplanned Outages	0.0	0.0	0.0
Cost of Planned Outages	5.5	0.0	36.2
Contingency Cost Provisions			
Pre-Engineering Costs	0.3	1.0	0.1
Project Implementation Costs	55.7	23.6	13.9
O&M	6.3	0.3	0.1
Decommissioning & Replacement	0.0	0.0	0.0
TOTAL	**643.4**	**215.4**	**156.8**
Cost per MVA of Capacity	**0.9**	**0.1**	**0.2**

* Additional power transfer level provided by option

** This figure represents a benefit rather than a loss

*** This figure represents the residual value of the option

Table 9-2 Summary tables of cost assessment

Summary of High Level Environmental Assessment

	HVDC UGC Option			HVAC 400 kV OHL Option			Regional Option		
	Significance of Impact/Effect	Ease of Mitigation	Likelihood of residual effect (post mitigation)	Significance of Impact/Effect	Ease of Mitigation	Likelihood of residual effect (post mitigation)	Significance of Impact/Effect	Ease of Mitigation	Likelihood of residual effect (post mitigation)
Biodiversity, Terrestrial flora and fauna;									
Aquatic Ecology /Water[1]									
Soil, Geology, Hydrology and Hydrogeology									
Landscape and Visual									
Cultural Heritage									
Settlements and Communities									
Recreation and Tourism									
Air Quality[1]									
Climatic Factors									
Material Assets									
Traffic and noise[1]									
Noise[2]									

Table 9-3 Summary tables of environmental assessment

10. EIRGRID CONCLUSION

This report sets out an analysis of alternative options to meet the need of the Grid Link project in line with the Terms of Reference[43] as set by the Government-appointed Independent Expert Panel.

In our analysis we identified a solution, referred to as the “regional option”. This option, which meets the need of the project, minimises the development of new large scale infrastructure and impact on the environment at a reasonable cost.

As required, this report allowed for the comparison of the underground, overhead and regional options.

The report details the investigations for each option in respect of the required technical, environmental and economic criteria. The analysis is based on the latest information available and work carried out to date.

While it is understood that a decision on the option to be brought forward is not within the remit of the panel, we believe that in the interests of transparency, our preference for the ‘regional option’ should be noted.

[43] http://www.dcenr.gov.ie/news-and-media/en-ie/Pages/PressRelease/Statement-by-the-Independent-Expert-Panel-considering-the-EirGrid-Grid-West-and-Grid-Link-projects.aspx

11. GLOSSARY OF TERMS

AC electricity – a type of power used to deliver electrical power to businesses and residences and where the electric charge reverses direction at regular intervals.

An Bord Pleanála – Ireland's independent national planning authority.

Assets – All substations and electricity transmission lines that form the transmission network. ESB owns the transmission network, and EirGrid operates it.

Biodiversity – this refers to the variety of plant and animal life on earth. It includes all species of plants, animals and micro-organisms on land and in water.

Capacitance – the capability of a system, circuit, or device for storing an electric charge.

Capacity – the maximum power capability of a system or a piece of equipment.

CENELEC – European Committee for Electrotechnical Standardisation.

CER - (The Commission for Energy Regulation) **–** the regulator for the electricity and natural gas and water sectors in Ireland.

Circuit – an electricity line or cable that links two electrical points.

Conductor – An object or material that can transfer electricity, for example, found in underground cables or overhead power lines.

Conductor Sag (OHL) – It is the distance between the highest and lowest point on a hanging conductor. This distance increases as the conductor heats up.

Constraint (1) **–** something that limits where infrastructure such as a building or a pylon can be built. Examples of physical constraints include the presence of a large town, a wide river or steep slope. An example of a legal constraint is a heritage site.

Constraint (2) **–** the limit on the amount of electricity that can be transmitted (sent) from a generation station due to the limited capacity of the local network.

Conventional generation – The generation of electricity using fossil fuels, such as natural gas, coal or peat.

Converter station – a special type of station that converts direct current to alternating current or the reverse. Direct current is used in undersea or underground cables or long stretches of overhead lines that connect electricity between two points. Converting direct current into alternating current means the electricity can be used in the local electricity networks. The Woodland converter station in Meath carries out this function for the East West Interconnector.

cSAC (Candidate Special Areas of Conservation) – are sites that have been submitted to the European Commission, but no yet formally adopted as Special Areas of Conservation - see SAC for definition.

DC electricity – direct current (DC) is used for sending electricity long distances, frequently underground or beneath the sea and often between countries. In direct current, the flow of electric charge goes in one direction only.

Demand – the electrical power that is drawn from the network by energy-users.

Demand forecasts – the amount of electricity that is predicted to be drawn from the network by energy users. The forecast is updated every year.

Distribution Asset Owner – the company that owns the electricity distribution network. In Ireland, this is ESB. In Northern Ireland, this is Northern Ireland Electricity (NIE).

EIS – Environmental Impact Statement.

Electric and magnetic fields (EMFs) – these are invisible areas of energy which occur naturally – the earth itself has natural electric and magnetic fields. EMFs can also be created artificially – an example would be electricity power lines. EMFs can create electrical currents in nearby materials that can conduct electricity.

Emissions – in relation to the atmosphere, emissions are gases or particles released into the air that can contribute to global warming or poor air quality. For example, cars release dangerous gases such as carbon monoxide into our air.

Energy import and export – Ireland imports and exports energy on to the transmission system using two interconnectors that link it to the UK; the East West and Moyle Interconnectors.

Energy security – this is the uninterrupted availability of energy sources at an affordable price.

EWIC – the East West interconnector, which links the Irish and UK transmission systems. It is owned and operated by EirGrid. It is used both to import and export electricity.

Fossil fuel – fuels such as coal, gas, peat and oil that are formed in the ground over a long time from dead plants and animals, and are used up once they are burned for energy.

Frequency – the number of complete cycles per second in AC direction. The standard unit of frequency is the hertz, abbreviated Hz. If a current completes one cycle per second, then the frequency is 1 Hz. The standard frequency in Ireland is 50 Hz.

Generation Adequacy – a measure of the capability of electricity supply to meet the demand on the system.

Generator – a machine that converts energy into electricity.

Grid – a network or 'energy motorway' made up of high-voltage overhead lines and underground cables, as well as transmission stations. The network links energy users with energy creators. It is designed to ensure that power can flow freely to where it is needed.

Grid infrastructure – the physical structures which make up the transmission grid. These include the cables and lines used to transmit electricity, the pylons which hold the lines, and the substations used to convert the electrical current and raise or lower the voltage of that current.

Heat mapping – a visual representation of information using colours to represent different values. Heatmaps are used to identify constraints such as roads or special areas of conservation, when planning a new transmission line.

HTLS conductors – high Temperature, Low-Sag conductors were first introduced to the Irish transmission system in 2011. They carry substantially more electricity than the conductors normally used in Ireland.

IEC – International Electrotechnical Commission – International, Standards and Conformity Assessment for all electrical, electronic and related technologies.

Indigenous renewable energy – energy from a resource that is in plentiful supply such as the sun or wind, which can be sourced or availed of on a local, regional or national level.

Infrastructure – refers to the structures and facilities of a region or country, such as buildings, roads, bridges and the electrical grid.

Interconnector – a high voltage transmission line connecting the national electricity networks of two countries.

Karst – a type of landscape occurring in an area composed of soluble rock – that is, rock that can be easily eroded by water, such as limestone. The rock has been gradually dissolved by flowing water, such as a stream or river. This gives rise to underground drainage systems, sinkholes and caves. Example: The Burren in Co Clare.

Kilovolt (kV) – operating voltage of electricity transmission equipment. One kilovolt is equal to one thousand volts. The highest voltage on the Irish transmission system is 400 kV.

Megawatt (MW) – a unit measurement for the amount of power produced by a generator or transported on the transmission grid.

(N-1) – a loss of one item on the transmission network equipment (e.g. a circuit or transformer).

(N-1-1) – a loss of one item on the transmission network equipment (e.g. a circuit or transformer) while another is out of service due to maintenance.

NHA, Natural Heritage Area – This is the basic designation for wildlife in Ireland. It is an area considered important for the habitats present or which holds species of plants and animals whose habitat needs protection. **Proposed NHAs (pNHAs),** were published on a non-statutory basis in 1995, but have not since been statutorily proposed or designated. These sites are of significance for wildlife and habitats.

Non-synchronous generation – the speed and frequency of this energy (typically associated with wind energy) needs to be corrected to match the speed and frequency of the transmission network.

Outage – an outage is when part of the network is switched off. This can be either planned (i.e. when work needs to be done on a circuit) or unplanned (i.e. a system fault caused by a storm)

Reactive Power – the portion of electricity that is used to control voltage on the transmission system.

Renewable energy – energy from a non-exhaustible resource such as the sun or wind.

Reinforcement – increasing the capacity of the existing electricity transmission network. We do this by building new lines or cables, or by uprating existing ones.

SAC (Special Areas of Conservation) – these are sites that are strictly protected under the EC Habitats Directive. The habitat types and species identified at these sites are protected. Example: Killarney National Park is an example of such a site and Killarney Fern is an example of protected species.

Series Compensation – Series Compensation is a technology that would allow us to safely and securely put more power on an existing transmission line. It is used to optimise the power flows on the system. In effect, series compensation allows us to get the most out of the existing transmission grid.

Short Circuit Ratio – indicates the strength of the transmission system at a particular location. A high short circuit level indicates a more stable system.

Surge Impedance Loading (SIL) – the point at which an overhead line goes from producing to absorbing reactive power.

Smart Grid – a type of emerging technology that monitors and manages the transport of electricity to meet the different electricity demands of consumers.

SPA (Special Protection Areas) – these are sites that are strictly protected under the EC Birds Directive, as they are home to rare or vulnerable birds.

Stakeholder – a person, interest group or organisation that has an interest or concern in something.

Substation – a site that has electrical equipment which is part of the national electricity network. The voltage of the electricity can be raised or lowered here according to the needs of the energy user.

Sustainable energy – energy from non-exhaustible resources such as the sun, waves, and wind. It can be used in a way that meets the energy needs of people today without reducing the ability of future generations to meet their own energy needs.

Switchgear – a term for all of the devices associated with the control, protection and isolation of electrical equipment. Switchgear is regularly used to turn off electrical power when working on equipment.

Switching Station – a particular type of substation where the flow of electricity can be directed from different sources **or** to different customers.

Synchronous generation – in an AC power system, this is the process of matching the speed and frequency of a generator to a running network. An AC generator can only deliver power to the grid when it is running at the same speed and frequency as the network.

Transmission Grid – a network or energy motorway made up of high voltage overhead lines and underground cables, as well as transmission stations (stations used to transmit (send) radio frequency signals for wireless communication, broadcasting, microwave link, mobile telephone or other purposes). The network links energy users with energy creators. It is designed to ensure that power can flow freely to where it is needed.

Transmission Line – a high-voltage power line running at three voltages: 400 kV, 220 kV, or 110 kV. This power line transmits (sends) electricity across long distances.

Transmission Network – an electricity network made up of power lines, cables and substations. It links energy users with energy creators.

Uprate – this is work carried out to improve or increase the capacity of an electric circuit.

Voltage – this is a measure of ‘electric potential’, which is similar to ‘pressure’ in a water system. Just like water needs pressure to force it through a hose, electrical current needs a force to make it flow. This force is called the voltage and is usually supplied by a battery or a generator.

VSC – voltgae source converter

Wind power – energy harnessed from the wind at wind farms and converted to power.

XLPE – Cross-Linked Polyethelene – Insulation material used for high voltage cables.