Step 3 Emerging Best Performing Option Report

The Kildare-Meath Grid Upgrade

Capital Project 966

October 2020

EIRGRID

Revision Table:

Revision	Issue Date	Description
01	5 October 2020	Emerging Best Performing Option Report in Step 3

This page was intentionally left blank

1 Table of Contents

2 Introduction

The Kildare Meath Grid Upgrade (Capital Project 966) is a proposed reinforcement project of the electricity network between Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. The project is essential to enable the further integration of renewable energy in line with Government Policy ambitions. It will further be a key enabler in meeting the growing demand for electricity in the eastern part of the country. This report describes the outcome of various assessments with regard to identified options for the project. It presents the results that underpin the identified emerging best performing option.

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

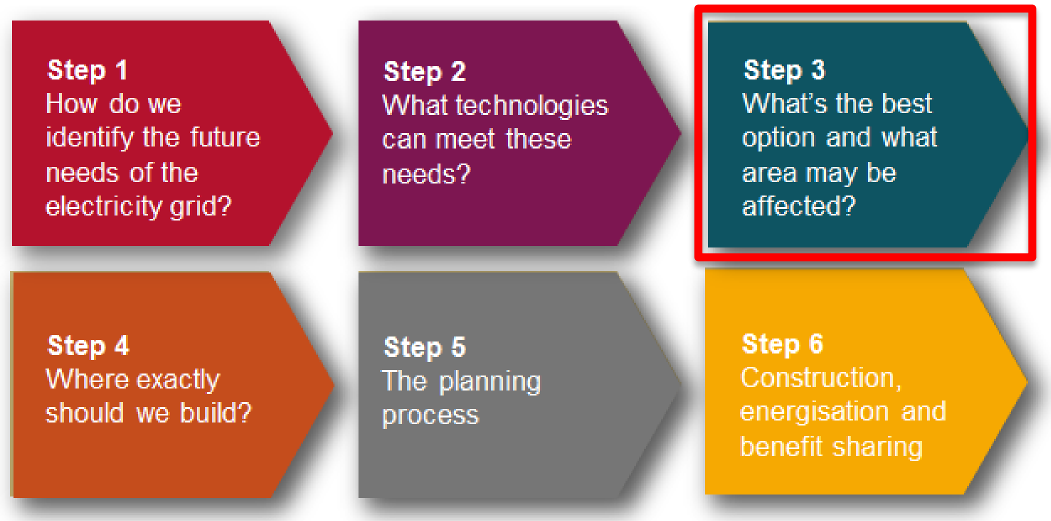


Figure 1 *High level description of Project Development Process*

In Step 2, this project was publicly referred to as Capital Project 966, given that the geographical area of the project had not been confirmed at that stage. The name "The Kildare-Meath Grid Upgrade" is now being used in all external engagement material for this project, due to all project options being located within these counties. The aim of the project title update is to provide a greater level of geographical association for stakeholders with where it will be located. Capital Project 966 will still be retained as the official technical project name and is therefore the term used in this report.

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

At the time of writing, Capital Project 966 (The Kildare - Meath Grid Upgrade) is in Step 3.

The activities and process followed in Step 3 are described in Section 4. The Kildare - Meath Grid Upgrade is nearing the end of Step 3. The remaining Step 3 process activities reference some terminology which will be used throughout this report. For clarity, these terminologies and expressions are introduced and listed below:

- Emerging Best Performing Option (EBPO)
  This is the option or options that emerge in Step 3 after the five criteria have been assessed. It will be announced at the start of the consultation period.
- Public consultation on EBPO
  A consultation period lasting 10 weeks will be held on the process followed and the EBPO. This provides for public participation and stakeholder engagement in the decision-making process. It allows for stakeholders and communities to be informed about the EBPO and any possible alternatives.
- Consideration of feedback
  The feedback received throughout the consultation period will be carefully considered and will inform selection of the Best Performing Option.
- Best Performing Option (BPO)
  This is the option which will be taken forward into Step 4 for further investigation and development into a proposal that will be the subject of consenting of the relevant consenting authority and further on toward detailed design, construction and energisation.

2.1 External professional assistance with the assessment

In Step 3 we assess the options against five criteria and these are described further in section 4. The assessments and investigations in relation to the environmental criterion and socio-economic criterion as well as some technical feasibility studies have been carried out by external parties. Where relevant, this is highlighted in this report and the referenced reports are named and a summary of the findings is presented.

Jacobs[2] assessed the environmental criterion and socio-economic criterion and also conducted certain technical feasibility studies. PSC[3] carried out the technical cable integration study. The detailed assessment reports can be found on our website[4].

[2] Jacobs Ireland Ltd
[3] PSC Ireland
[4] http://www.eirgridgroup.com/the-grid/projects/capital-project-966/the-project/

3 The Project

3.1 Confirmation of the Need

Capital Project 966 is a proposed electricity transmission development project that will help transfer electricity to the east of the country and distribute it within the network in Counties Meath, Kildare and Dublin. It involves a suite of transmission network reinforcements centred on strengthening the network between the existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath, with some dynamic reactive devices also required to support the voltage.

This project is in Step 3 of our six step approach and the reports from previous steps provide background to how we reached the conclusion that strengthening the electricity network between Dunstown and Woodland 400 kV stations and adding dynamic reactive devices is the most efficient way to avoid capacity and voltage problems in the electricity transmission grid in the future.

This section provides a summary of the need and the detailed report is available on our website[5] together with reports from previous steps.

In Step 3, we updated our assumptions to be in-line with Tomorrow's Energy Scenarios (TES) 2019[6] and carried out a set of studies to re-confirm the need. The need is based on two drivers, namely integration of generation and an increase in demand on the east coast. The review indicates that the previously identified drivers still remain and have further increased the need to strengthen the transmission network between Dunstown and Woodland stations, and that the need for the reinforcement is still robust.

The project is essential to enable the further integration of renewable energy in line with Government policy ambitions. It will further be a key enabler in meeting the growing demand for electricity in the east region, by improving the capacity of the network in this region. This forecasted growth within the region is due to increased economic activity and the planned connection of new large scale energy users.

A significant number of Ireland's electricity generators are located in the south and south west regions of the country. This is where many wind farms and some modern, conventional generators are located. This power needs to be transported to where it is

---

[5] http://www.eirgridgroup.com/the-grid/projects/capital-project-966/related-documents/

[6] Tomorrows Energy Scenarios (TES 2019) presents credible pathways for Ireland's clean energy transition with specific focus on what this means for the electricity transmission system over the next twenty years. The report is available on our website http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-TES-2019-Report.pdf

used. This need is also present when planned offshore wind generation facilities connect on the East coast. The Government's Climate Action Plan sets a target to connect 3.5 GW of offshore wind by 2030. This is more than three times the peak demand in the East Coast today. Once connected to the transmission system, this offshore power will have to be transported around the network to where it is used. The need associated with this offshore wind on the East coast is indicated in the TES System Needs Assessment.

When the transmission system is experiencing these generation and demand patterns, the system analysis indicates that the network experiences significant violations of the Transmission System Security and Planning Standards (TSSPS). The TSSPS is the standard the transmission network should adhere to so that a reliable and secure electricity system can be provided for all customers in Ireland.

The violations occur for the unplanned loss of any of the existing 400 kV circuits between Moneypoint 400 kV station in County Clare and Dunstown 400 kV in County Kildare and Woodland 400 kV station in County Meath in the East. The unplanned loss of one of number of 220 kV circuits running in parallel with these 400 kV circuits has the same effect.

3.2 Options considered

All options involve a suite of transmission network reinforcements centred on strengthening the network between the existing Dunstown 400 kV station in County Kildare and the Woodland 400 kV station in County Meath.

Four solution options were brought forward from Step 2[7] for more detailed analysis in Step 3. They represent three different technologies, namely:

- Overhead line (OHL);
- Underground cable (UGC); and
- A new technology which would involve an increase in the operating voltage of existing 220 kV circuits, called an up-voltage of existing 220 kV towers.

As described in the document 'Have Your Say' published on EirGrid's website, EirGrid has committed to bringing an equivalent cable option forward if an OHL option is the best performing option. In Step 2, there was uncertainty about the technical performance in relation to long high voltage UGC options. A 220 kV UCG was brought forward to Step 3, despite not performing as well technically as the other options in Step 2 because a long

[7] For details of Step 2 outcome and documents please refer to our website. http://www.eirgridgroup.com/the-grid/projects/capital-project-966/related-documents/

220 kV cable is known to create fewer technical issues compared to long 400 kV cables. Studies in Step 3 confirmed that all identified cable options were technically feasible for this reinforcement.

In Step 3, due to the nature of the UGC options and their ability to meet the technical criteria, a number of variations of UGC have been investigated to provide a broader view of their impact on all of the assessment criteria. The variations are presented as sub-options under Option 3.

With the additional UGC variations, the total number of options investigated in Step 3 is five:

1. Option 1: Up-voltage existing 220 kV OHL circuits
    - Using a new technology which would enable two existing 220 kV circuits connecting to Dunstown and Woodland stations to be modified, primarily by means of replacing existing 220 kV conductors (and associated tower structures if necessary) with 400 kV conductors to create a new Dunstown – Woodland 400 kV circuit.
    - The circuits selected to achieve this are the Gorman – Maynooth 220 kV circuit and the Dunstown – Maynooth 2 220 kV circuit.
2. Option 2: New 400 kV OHL circuit
3. Option 3: New UGC circuit;
    - Option 3A: 220 kV UGC;
    - Option 3B: 400 kV UGC: one circuit constructed along one route;
    - Option 3C: 400 kV UGC:
        i. Sub Option 3Ci: two circuits constructed along one route;
        ii. Sub Option 3Cii: two circuits constructed along two separate routes.

During Step 3, Option 3Ci was determined to be not feasible in the Cable Feasibility Report (Report Number 321084AE-REP-001). The reason was that the trench width, required to meet the standard capacity of a 400 kV circuit, far exceeded the width of the existing road network in the study area. It was therefore not considered further in this assessment. The remaining Option 3Cii will be called Option 3C in the report hereafter.

3.3 Project Study Area

The Project Study Area is defined as the area investigated for the possible installation of any of the options in Step 3. This study area is based on the study area identified in Step 2[8]

As part of this Step of the project (Step 3), the Project Study Area has been further refined by considering a wide variety of factors. These included technical requirements of the project, road network presence, settlements, presence of existing electrical utilities, physical constraints e.g. motorway, river or rail crossings and some environmental constraints. In particular, the Project Study Area has been confined to the west by peatlands and likely difficulties with construction and environmental protection in these areas, and to the east by the western edge of the conurbations surrounding Dublin.

The current Project Study Area is smaller than the Step 2 Study Area, but is still large enough for the examination of feasible options for the project. To ensure that a comprehensive and accurate environmental and social appraisal is carried out, a wider perspective is often needed for particular topics of relevancy (e.g. Natura 2000 Sites which may be located beyond the study area but are connected). The assessment of the project will cover all likely significant environmental impacts whether they occur inside the study areas or outside of it.

Figure 2 shows the Project Study Area for Capital Project 966. This study area is of sufficient size to accommodate Options 2, 3A, 3B and 3C. The study area for Option 1, the up-voltage of existing 220 kV circuits to 400 kV, is more refined, given that it focuses on specific existing OHL alignments. The Study Area for Option 1 is illustrated in Figure 3.

[8] The study area for Step 2 is shown in our project brochure from Spring 2019. http://www.eirgridgroup.com/site-files/library/EirGrid/Capital-Project-966-Brochure-Spring-2019.pdf

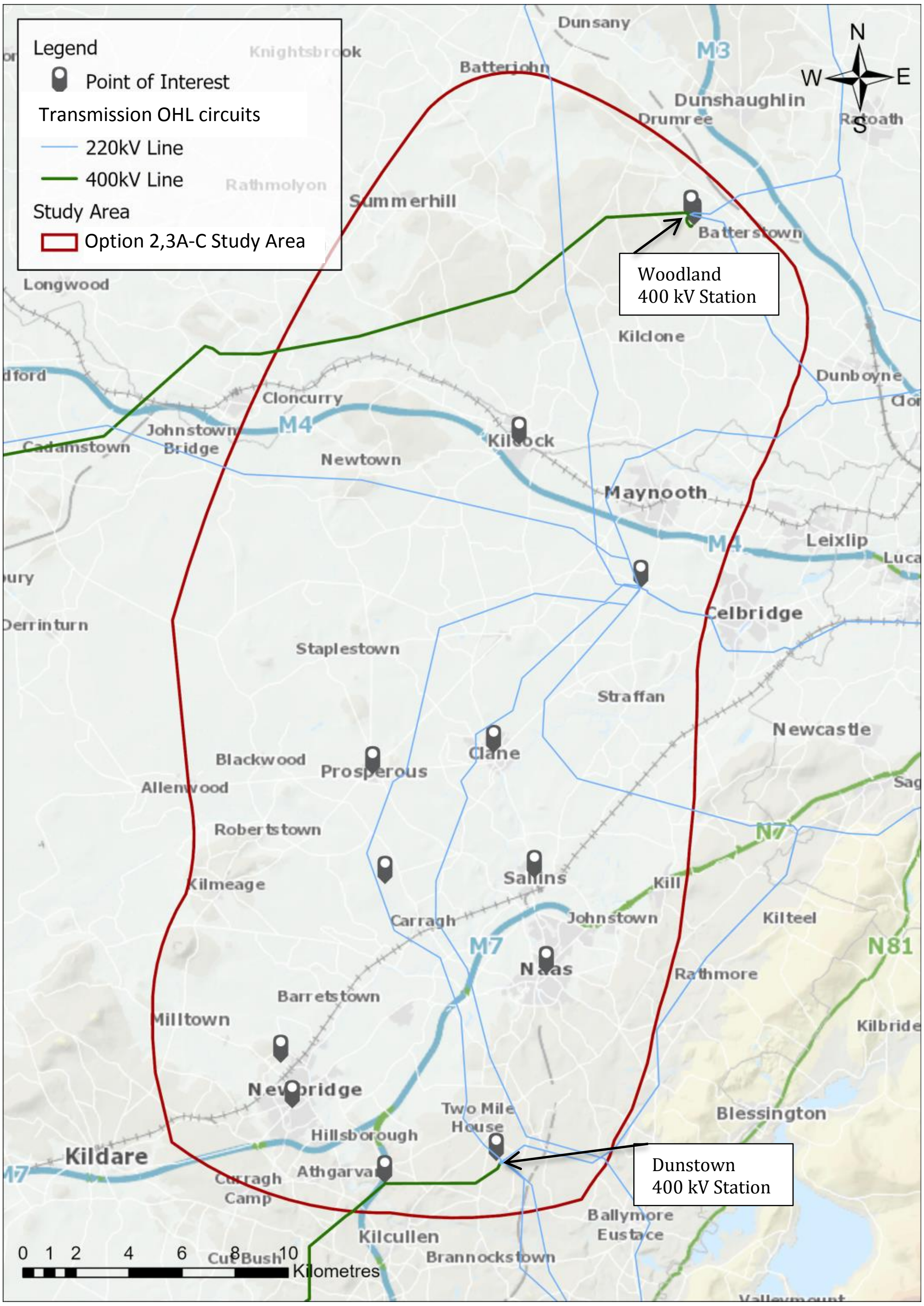


Figure 2 *Illustrative map showing the project study area in Step 3 for options 2, 3A, 3B and 3C.*

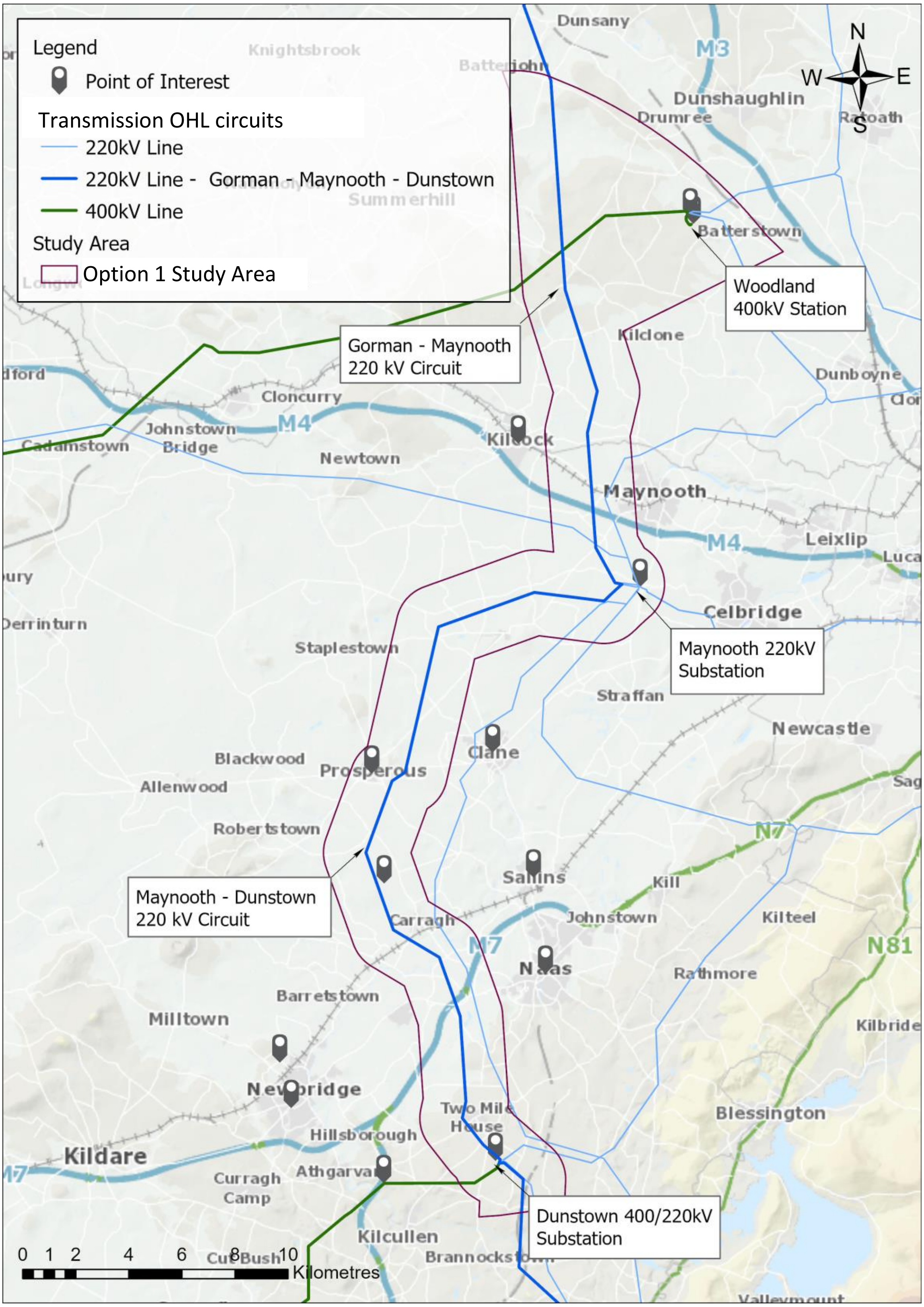


Figure 3 *Illustrative map showing the study area for Option 1 in Step 3.*

3.4 Stakeholder Engagement

3.4.1 Project complexity

In general, every grid development project is of a different scale and / or complexity, with no two projects being identical. To reflect the uniqueness of each project, the six-step Framework for Grid Development introduced three categories of projects, called Tiers. The Tier of a project indicates the considered required level of governance, external consultation and engagement, social impact assessment and analysis for a project.

Capital Project 966 is considered to be Tier 3 which is the most complex category. This assessment of the Tier is based on the most complex identified option, which in this case is a new linear project. New linear projects have the potential to traverse many different stakeholders, and as such, increase the number of stakeholders that need to be considered. As well as this, the potential impact on communities and the environment also requires significant investigations and consideration. For this reason, this project has been assigned a Tier 3 designation.

3.4.2 Stakeholder engagement activities

The aim of stakeholder engagement in Step 3 is to transparently communicate our findings so far in the project to key stakeholders and to ensure opportunities for public participation in the development of the project. In particular, this comprises receiving and taking on board feedback on the assessment and emerging conclusions, which will then inform EirGrid's decision-making prior to announcement of a Best Performing Option.

In order to ensure appropriate stakeholder feedback and inform our decision-making process during Step 3 on Capital Project 966, EirGrid has identified key strategic stakeholders in the study area. This engagement has enabled us to understand the spatial and economic planning that is underway at local and regional authority level, as well as the potential requirements for future investments by large energy users in the area. It has also allowed us to brief key stakeholders in the area, and to garner their views regarding the opportunities and challenges that exist for the project, as well as to receive feedback which will inform identification of the best performing option.

The stakeholder engagement for Capital Project 966 in Step 3 is divided into two phases: an information phase and a public consultation phase.

In the information phase, we have informed and engaged with relevant regional and national stakeholders such as Government Departments, Meath County Council, Kildare County Council, Elected Representatives, the IDA, the Eastern and Midlands Regional Assembly, Chambers of Commerce, Public Participation Networks and the Irish Farmers'

Association. This phase also included an information campaign in local newspapers and radio, video animation for social media awareness raising, the publication of investigative reports and technical assessments, an online interactive map and a webinar. This phase covered the period between 20 July and 5 October 2020.

At the end of the information phase, the Emerging Best Performing Option (EBPO) will be announced and a 10 week consultation period will commence. The feedback from this consultation will be collected and taken on board in the decision making process before the identification of the Best Performing Option (BPO) in early 2021.

4 Process followed and criteria

4.1 Description of process

This report details the outcomes of the assessments undertaken in Step 3. In Step 3, the options presented in Section 3.2 are investigated in more detail in order to identify an Emerging Best Performing Option (EBPO) to meet the identified need for the project. Each option is assessed against five criteria. A multi-criteria performance matrix is used to compare the options against each other.

As noted in Section 3, the EBPO will be announced at the start of the consultation period. The process provides for public participation and stakeholder engagement in the decision-making process; in addition to all the consultation and engagement that has occurred on the project to date[9], there occurs a specific period of consultation and engagement on the EBPO. Any feedback received during this consultation period will be carefully considered and will inform identification of the Best Performing Option (BPO) for the project.

In accordance with our six step approach, the BPO will be developed further in Step 4. It will then be the subject of a planning application in Step 5. In the event that the application is consented by the relevant consenting authority, the permitted development will be subject to detailed design, construction and energisation.

4.2 Criteria used for comparison of options

In Step 3, we consider a broad assessment of performance for each of the identified options. The broad assessment considers five different criteria that ensure that the full range of impacts and benefits of each option can be appropriately understood. .

These criteria are:

- Technical performance;
- Economic performance;
- Environmental aspects;
- Deliverability aspects; and
- Socio-economic aspects.

[9] A 10-week consultation period was held at the end of Step 2 (November 2018 to February 2019). This gathered feedback on the five technology options. No technology options were removed or added as a result of the consultation. Most of the responses declared a preference for either the underground option or the uprate option. More information can be found in our project brochure from Spring 2019. http://www.eirgridgroup.com/site-files/library/EirGrid/Capital-Project-966-Brochure-Spring-2019.pdf

Descriptions of the five criteria are provided below. The assessments undertaken for each option in Step 3 are for comparative purposes between the options and are not absolute assessments of the individual options.

4.2.1 Technical performance criteria

The technical performance criterion includes seven sub-criteria. Descriptions of these are provided below.

- Compliance with health and safety standards

  Regardless of the technical option chosen, it 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 and safety legislation, approved codes of practice and industry standards and all subsequent modifications or amendments in relation to same.

  The solution option should comply with relevant safety standards such as those from the European Committee for Electrotechnical Standardisation (CENELEC). Materials should comply with IEC or CENELEC standards.

- Compliance with EirGrid Security and Planning Standards

  The solution option should comply with the network reliability and security standards defined in the Transmission System Security and Planning Standards (TSSPS)[10] and the Operation Security Standards (OSS)[11]. All options investigated will meet the minimum technical requirements set out in the above standards. Options which extend or enhance technical performance margins beyond minimum acceptable levels are favoured over others.

  To be able to distinguish between the individual technical performance of each solution option, the options are assessed against three main technical criteria. A short description of these is given below. The technical criteria are based on the previous technical criteria used in the Step 2B report[12] and relate to the need identified. The criteria are thermal overload, voltage phase angle, and performance during maintenance conditions. It should be noted that in Step 2B, we also investigated short circuit performance and reactive support requirements.

---

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

[11] EirGrid, Operational Security Standards, 2011 (http://www.eirgridgroup.com/site-files/library/EirGrid/Operating-Security-Standards-December-2011.pdf)

[12] http://www.eirgridgroup.com/site-files/library/EirGrid/Step-2-Part-B-Options-Report-Capital-project-966.pdf

For the analysis in Step 3, we have not assessed the short circuit performance of the solution options as it was found in Step 2B that all of the options have very similar outcomes and the short circuit performance will not be the deciding factor between the options.

The reactive support requirements have been assessed under a different technical criterion, ‘Headroom’, and this criterion is described later in this section. In addition to the criteria set out above, the cable options have been assessed on the specific impact that cables will have on the network.

Thermal overload criteria

The options are assessed for compliance with the TSSPS. If thermal overload violations are identified, additional potential reinforcements will be added to the options until the enhanced option fully meets the TSSPS. For this technical criterion, we have assessed the options based on how many identified thermal overloads are remaining after the option has been added. This will provide an indication of how the options are performing in terms of adding thermal capacity.

Voltage phase angle

The options are assessed for compliance with the Operating Security Standards (OSS), which EirGrid is required to comply with in its licence. The OSS states that the maximum recommended voltage phase angle is 40˚.

We have recognised that a decrease in large voltage phase angles is beneficial to the operation of the electricity grid. The assessment of the options takes account of how much each option can reduce the angle difference between Woodland and Oldstreet stations when the Woodland – Oldstreet 400 kV circuit is opened. Improvements to angle differences are influenced by, among other things, the difference in impedance of the proposed new network reinforcements.

Performance during maintenance conditions

The options are assessed based on their requirement for additional reinforcements to keep the network within standards following a subsequent loss of plant and equipment whilst another is out for planned maintenance.

It should be noted that investments resulting from violations during planned maintenance are subject to an economic appraisal of the value in solving the identified problem compared to constraining generation. Before we would bring these forward as projects we will individually appraise whether each of these reinforcements could be economically justified.

To ensure value for money, we will defer a decision until much closer to the required commissioning date of the Best Performing Option. This will allow us to take account of new requirements for each reinforcement, which may include both local and regional needs which could have emerged in the meantime.

As such, for the purpose of this assessment in Step 3, we have only assessed the number of indicated violations of thermal capacity for each option and these possible additional reinforcements are not included in the full solution list of the options.

- Reliability performance

  The technologies and equipment associated with the different options have different performance and reliability characteristics. The reliability of transmission infrastructure is associated with two categories or type of outages, namely unplanned outages and planned outages. Each technology or type of equipment is associated with faults (unplanned outages) that routinely occur. These can be represented as average failure rates usually expressed as unplanned outages/100km/year.

  This criterion will also account for the mean time to repair. This is the time taken to return the equipment to service after a fault has occurred. The assessment has been based on transmission performance statistics[13] or industry standard reliability data.

  This sub-criterion will also assess the typical time the options would be unavailable for during planned outages. Planned outages are normally associated with annual routine maintenance and will be based on typical outage durations taken from maintenance policies. The reliability for each option will be based on a combination of the above type of outages. The reliability of the station equipment associated with the options is assumed to be the same for all options and is therefore not included in this analysis.

- Headroom

  This criterion assesses the ability of each option to accommodate increases in large scale demand growth in the Dublin and mid-east region, and replacement of thermal generation located in Dublin with increased renewable generation in the west and south of the country.

[13] Analysis of System Disturbances 2018, EirGrid, April 2019

Each option is compared relative to the others to determine the increase in demand, or renewable generation outside Dublin, that can be accommodated without further network reinforcements being required. The limit for each option can be found by increasing large scale demand in Dublin and renewable generation in the south and west until a voltage stability limit is reached.

The headroom for each option is the difference between the demand that can be accommodated by the network with that option included and the demand that can be accommodated by the network with no option included.

- Expansion or extendibility

  This considers the ease with which the option can be expanded, i.e. it may be possible to uprate an OHL to a higher capacity or a new voltage in the future. It will also consider the rating or capacity of the options.

- Repeatability

  This criterion examines whether this option can be readily repeated in the Irish network. One-off or bespoke solutions carry additional system integration, operational, and maintenance complexity. For example, an OHL option is very repeatable, but a fully or partially underground cable option is less repeatable as there may be harmonic filter and reactive compensation requirements that are bespoke for each option. The amount of cable that can be integrated in certain parts of the network may also be limited.

- Technical operational risk

  This criterion aims to capture the risk of operating different technologies on the network. It will consider if the option requires special procedures when energising or switching in the network. An example would be long cables which may require reactive compensation and special procedures when energised to prevent technical issues in the network.

4.2.2 Economic performance criteria

The economic appraisal we conduct as part of the Multi Criteria Assessment assesses the relative overall cost performance of the various options which meet the TSSPS and the impact on overall costs of production in meeting the demands on the system – it does not seek to replicate the economic trade-offs which have already been considered within the TSSPS itself.

The TSSPS, in driving new investment in transmission reinforcements, recognises that the economic cost to society of not preserving the security of supply standards defined by the TSSPS (N-1 etc.) is greater than the cost of maintaining such a standard. The TSSPS reflects the explicit and implicit economic trade-offs between enhanced security of supply and reduced risk of interruptions on the one hand and additional cost, including the full societal cost, of grid development on the other.

In this context then, the economic assessment described in Step 3 considers costs and benefits associated with each option.

A description of each of the cost criteria is given below.

- Pre-engineering cost

  The pre-engineering cost refers to the cost associated with the design and specification, route evaluation and management of the statutory planning application. The costs are capital in nature and are typically costs incurred by the Transmission System Operator (TSO) in the development of the reinforcement. The cost for the TSO to develop the option is based on experience of developing other current and previous projects.

- Implementation cost

  The project implementation costs are the costs associated with the procurement, installation and commissioning of the option. The capital cost estimates have been developed with input from the Transmission Asset Owner (TAO) and are based on desktop designs and costings for similar works. The capital cost estimates include all items to achieve a fully compliant solution with Transmission System Security and Planning Standards (TSSPS) and other investment policies, but exclude reinforcements driven by maintenance conditions as discussed in Section 4.2.1.

  Where capital costs were not available for a particular technology, the best, most recent estimates or quotes from manufacturers or assumed costs based on EirGrid or international experience have been used. The assumed cost for landowner payments, community fund and proximity payments are included under this cost category, as these costs are typically incurred during the implementation phase of the option.

- Life-cycle cost

  Life-cycle costs refer to the costs incurred over the useful life of the option and include the on-going cost of ensuring that it remains viable for the evaluation period. For the purposes of our assessments, decommissioning of assets is not considered. This criterion includes:

– Operation and maintenance cost

These costs are annualised and are based on estimated costs incurred to be able to maintain the option.

– Electrical losses

Losses are the electrical energy consumed by the transmission system as it transmits electricity. The more efficient a transmission reinforcement is, the lower the electrical losses it incurs.

The quantity of electrical losses is calculated for a standard year with each option included in turn and compared with the reference situation without the reinforcement. The losses calculation for a standard year includes assumptions in regards to other plant and equipment being unavailable due to faults or planned routine maintenance.

During the months between March and October, in any given year, the operation of the transmission system caters for approximately 20 circuits unavailable for various reasons per day. During the winter months, the transmission system has less than five circuits unavailable for various reasons per day.

The calculation has taken these aspects into account to a certain degree and assumed different 220 kV circuits, one at a time, unavailable for a week during the entire maintenance season simultaneously with different 110 kV circuits, one at a time, unavailable for a week during the entire year.

This assumption will provide a better understanding of the benefit in terms of losses that the proposed reinforcements will bring. A cost will be put against the losses incurred for each year during its lifetime following commissioning of the option. For this analysis, the average Day Ahead Market (DAM) price is used to represent the marginal cost of generation and is calculated to be €50.3 per MWh. The figure has been derived from the average Day Ahead Market (DAM) price for 2019, which was sourced from the Single Electricity Market Operator (SEMO) website[14].

– Replacement cost

The standard lifespan of a transmission asset is 50 years and this is the also the evaluation period for the economic assessment. Assets that have a

[14] https://www.semopx.com/news/market-summary-2019-repor-1/

shorter useful life would have to include the cost of replacement at the end of its useful life and thereafter factor in a residual value equivalent to the depreciated asset value at the end of the evaluation period.

In the economic assessments, it has been assumed that underground cable (UGC) options will have a useful lifespan of 40 years. The assumption is based on research of other utilities internationally. This indicates that there is recognition by some reputable utilities that the useful lives of OHL and UGC may not be the same. There isn't consensus about what the useful lifespan of UGCs could be and it may be dependent on differences in environmental conditions, duty cycle and operational use, installation choices etc. The cost of replacement is taken to be precisely the same as the project pre-engineering cost and project implementation cost.

A description of the benefit criteria is provided below.

- Socio-economic welfare:

  The benefits arising from transmission reinforcement project will usually be avoided costs. The value of some of these avoided costs is difficult to measure, especially in terms of beneficial contributions to society and the country's welfare and economy. Benefits in relation to the transmission system and its operations only have been taken into account in this assessment. In this case, the benefits refer to the difference in production cost savings between the system with the reinforcement option and the system without the reinforcement.

  The transmission system operational benefit can be measured by the amount of generation that is not constrained due the lack of transmission capability of the existing infrastructure. The benefit is therefore expressed as savings in generation costs due to the enhanced transmission capability. The constraints calculations are a result of annual market simulations. The simulations optimise the generation dispatch required to meet the electricity demand while taking into account the power carrying capability of the transmission system and contingencies.

  The calculation of the production cost savings for each option is based on the assumption that each MW produced by a generation unit that can't be exported due to a capacity constraint in the transmission network has to be procured elsewhere from another generation unit. The buying and selling of electricity is facilitated by the Single Electricity Market in order to meet the electricity demand in the All-Island electricity system.

On a very high level, the market is operated on the basis that the most efficient (cheapest) generation unit should be generating at any given time to reduce the electricity price. When the most efficient units are constrained due to a capacity constraint in the transmission network, a more expensive generation unit will be used to supply the electricity required. This will incur a higher cost in the operation of the system and market.

Transmission reinforcements will address network constraints and as such will help to reduce cost incurred. The project benefit can be expressed as expected annual savings of generation costs in the All-Island system depending on the respective option. For the estimate of annual savings in generation costs the hourly marginal generation costs are used from the simulations carried out.

- Cost to the Single Electricity Market

  This criterion will take account of the impact of the cost to the electricity market for the periods where the reinforcement option is not available. The technologies and equipment associated with the different options have different performance and reliability characteristics. The reliability of transmission infrastructure is associated with two categories or type of outages, namely unplanned outages and planned outages. The reliability performance criterion was described in Section 4.2.1 and will be used in combination with the calculated production cost benefits described in Section 4.2.2 to represent the cost to the Single Electricity Market for each option.

The robustness of each option's economic performance is also considered as part of the economic assessment. The robustness test considers two different aspects, namely:

- Least worst regrets

  To assess the robustness of each option's economic performance, 'Least Worst Regret' (LWR) analysis is carried out. This will indicate if some options perform better or worse under different future energy scenarios.

- Sensitivity analysis

  In addition, the options' sensitivity to changes in the reference parameters (implementation cost, WACC and Benefits) are assessed and taken into account.

4.2.3 Deliverability

In Step 3, the deliverability performance criterion includes a number of sub-criteria. A short description of these is provided below.

- Implementation timelines

  This criterion assesses the length of time required for each option to progress through each phase (including pre-consenting, consenting, pre-engineering (detailed design) and implementation (construction) up to project energisation). This will include timelines starting from Step 4, where the process will identify the exact location of the development. It assumes planning consent times or other permissions required, with the assumption of no unreasonable delays and/or potential judicial review.

- Project plan flexibility

  This criterion assesses the flexibility of the project plan to include for issues arising during pre-planning conceptual design, post-planning design, consenting and construction.

- Risk of untried technology

  This criterion assesses any aspects (positive or negative) and risks each technology option may have including if the technology has been used in the past internationally or on the Irish transmission network.

- Dependence on other projects (outages)

  This criterion assesses dependence on completion of other projects and outage length required to implement the option. It also considers general inter-dependence with other projects, including in terms of multi-project programme sequencing.

- Supply chain constraints, permits, wayleaves

  This criterion assesses any constraints (e.g. small number of suppliers in Ireland or internationally) that would affect the procurement of materials or services (e.g. cable laying vessels waiting list lead time) to complete the project.

  This criterion also assesses the complexity and challenge in respect of various permissions and consents required, including the potential risk to achieving statutory consent(s) without reasonable delay (having regard to environmental and other impacts), the potential level of public interest, and the potential for Oral Hearings, considered potential for Judicial Review.

This criterion also addresses the complexity and challenge of obtaining community and landowner "social licence" to construct an option, including securing access to land for pre-application survey, and obtaining post-consent wayleaves/easements.

4.2.4 Environmental

This criterion is assessed to identify and describe the types of environmental constraints that are most likely to be affected by the construction and operation of the identified solution options. It is based on a review of publicly available datasets, information gathered from County Development Plans (CDP) and Local Area Plans and mapping from state agencies such as the National Parks and Wildlife Service (NPWS).

The online resources were referenced between September 2019 and December 2019 to inform this assessment. This assessment was carried out by Jacobs and a summary of its findings are presented in this report. Jacobs' detailed report (321084AE-REP-003 – CP 966 Environmental Constraints report is available on our website – see Section 2.1 for the link.

The environmental constraints have been organised into the following topics to aid understanding and presentation of the assessment findings:

- Biodiversity: Assessment of the potential impacts on protected sites for nature conservation, habitats and protected species;
- Soils and Water Impacts: Potential impact on soils (geology, Irish geological heritage sites, etc.) and water (water quality of surface waters and groundwater);
- Planning Policy and Land Use: Impact on land use (forestry, farmland, bogs/peats, horticulture);
- Landscape and Visual: Assessment of landscape constraints and designations and the potential impact on visual amenity; and
- Cultural Heritage (Archaeological and Architectural Heritage): The potential for impacts on the cultural heritage resources.

These topics have been selected as they are the most likely to represent the key considerations, constraints, risks and opportunities for the project.

Only environmental constraints are described in this criterion; the socio-economic constraints are described under the socio-economic criterion. It is acknowledged that there is potential for environmental issues to result in socioeconomic effects; this is particularly the case for potential effects on amenities of local communities which could be adversely affected by noise, air quality, views and traffic. Notwithstanding this interrelationship, this criterion does not consider amenity effects; these are presented in the socio-economic criteria.

4.2.5 Socio-Economic

This criterion is assessed to identify and describe the social issues and their potential impacts within the study area(s) that are most likely to be affected by the construction and operation of the identified solution options. This assessment was carried out by Jacobs and a summary of its findings are presented in this report. Jacobs' detailed report (321084AE-REP-003 – CP 966 Strategic SIA Scoping Report) is available on our website – see Section 2.1 for the link.

The assessment is based on a number of data sources, such as County Development Plans for Kildare and Meath County Councils, Census 2016 Data, Central Statistical Office (CSO.ie), National datasets from Prime 2 (Ordnance Survey Ireland's central database of spatial information) and some of the other findings from the investigation carried out by Jacobs as part of its assessment. It is also based on public consultation.

The social issues considered have been organised under particular topics to aid understanding and presentation of the assessment findings. These topics have been selected as they are the most likely to represent the key considerations, constraints, risks and opportunities for the project. Other criteria such as Land Use and Cultural Heritage are assessed under the environmental criterion.

- Amenity: Here 'amenity' is the term used to describe the overall pleasantness or attractiveness of surroundings. This includes effects on local communities, community facilities, local businesses and recreation and tourism assets. This builds on the work in the 321084AE-REP-003 – CP 966 Environmental Constraints report compiled by Jacobs.
- Health: To determine potential effects on humans, this considers amenity effects as well as considering WHO health thresholds; EMF is considered as set out in EirGrid's Guidelines[15];
- Local Economy: Effects on the regional and local economy;
- Traffic & transport: This considers potential effects on traffic and transport in the study area, during the construction phases of the different solutions. Of concern to communities is the potential for severance, isolation and significant delays

[15] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-The-Electricity-Grid-and-Your-Health.pdf

during the construction phase. Also considered in this topic are potential effects on the crossings of major roads, railways and navigable waterways if relevant;

- Utilities: Consideration of third-party assets, including telecommunications and aviation.

4.3 Scale used to assess each criteria

The effect on each criterion parameter is qualitatively determined using expert judgement and experience. This is presented by means of colour coding, along a range from “more significant”/”more difficult”/“more risk” to “less significant”/”less difficult”/“less risk”.

The following scale is used to illustrate the performance of each criterion. :

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

In the text, this colour-coded scale is qualified by text comprising:-

- Low (Cream);
- Low-Moderate (Green);
- Moderate (Mid-level) (Dark Green);
- Moderate-High (Blue);
- High (Dark Blue).

5 Option Evaluation Summary

In Step 3, the short-listed options, described in Section 3.2, are further analysed and assessed. Each short-listed option has been assessed against the five criteria and sub-criteria, which are outlined in Section 4 of this report.

The summary of this multi-criteria assessment is presented in this section and reveals the Emerging Best Performing Option (EBPO). Further detail on each option is provided in Section 6 for the existing circuit up-voltage option, Section 7 for the new 400 kV OHL option, and Section 8 for the new UGC options.

A period of public consultation will focus on the EBPO and the analysis that underpins it and the possible alternatives. All feedback received will be carefully considered before the Best Performing Option (BPO) or options are identified and taken forward to Step 4 for further investigations.

As described in Section 4, the following scale is used to illustrate the performance of each criterion. The lighter the colour the better the option performs. It should be noted that the assessments undertaken for each option in Step 3 are for comparison against each other and are not absolute assessments of the individual options.

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

5.1 Basis of evaluation of multi-criteria assessment

In line with EirGrid's roles and responsibilities, we have an obligation to develop a safe, secure, reliable, economical, and efficient electricity transmission system while having due regard for the environment of Ireland. In our decision making, these fundamentals are captured in the five criteria considered. In addition, our decision making process also provides for public participation and stakeholder engagement and deliverability aspects.

All of the five criteria are important when considering the options in the assessment and establishing the EBPO. The options were assessed on an equal basis with no weighting applied for any of the criteria. We have also taken on board experience from other projects where applicable.

5.2 Emerging Best Performing Option based on the multi-criteria assessment

Table 1 provides a summary of the performance of each option against the five evaluation criteria and the resulting overall combined performance. The detail of the performance of each option for each criterion is contained in sections 6, 7, and 8 of this report.

Based on the multi-criteria assessment, Option 1, the up-voltage option, is the emerging best performing option. Option 3B, which is the emerging best performing alternative, does not perform as well as Option1 for three of the five criteria.

	Option 1 Up-voltage	Option 2 400 kV OHL	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Technical Performance					
Economic Performance					
Deliverability					
Environmental					
Socio-economic					
Combined Performance					

Table 1 *Overall comparison of options using five criteria in Step 3*

Option 2, the 400 kV OHL option, performs well from a technical and economic performance perspective, but is considered to have high risk or significant impact (**Dark Blue**) from a deliverability and socio-economic perspective making this option not preferable.

Option 3A performs poorly from a technical perspective in comparison to the other options and in addition it has a relatively high level of risk associated with the deliverability and socio-economic aspects making this option not preferable.

Option 3C does not perform well overall based on the multi-criteria assessment. For three out of the five criteria assessed, this option is considered to have a high risk or significant impact (**Dark Blue**) and is therefore not preferable.

5.3 Summary of technical performance of options

All options investigated will meet the minimum technical requirements. Options which extend or enhance technical performance margins beyond minimum acceptable levels are favoured over others. Figure 4 shows the technical performance of the various options in relation to the different sub-criteria. This figure is also displayed in Appendix 2.

Summary of technical performance all options					
	Option 1 Up-voltage option	Option 2 400 kV OHL option	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Health and Safety Standard compliance					
Security & Planning Standard compliance					
Reliability performance					
Headroom					
Expansion or Extendibility					
Repeatability					
Technical Operational risk					
Combined Technical Performance					

Figure 4 *Overall technical performance of the options.*

The two OHL options, Option 1 and Option 2, have a similar technical performance with both performing very well.

Option 1 would be using two existing circuits to achieve the new reinforcement. Option 1 would need a bespoke design for large parts of the reinforcement as an existing route is used, resulting in a reduced performance in the repeatability criterion.

Option 2 is based on our standard 400 kV OHL design and will provide an additional new circuit when compared to Option 1 which would give more operational flexibility.

Option 3A is the worst performing option under the technical criterion. Connecting the Woodland and Dunstown stations using a 220 kV voltage level will not support the network as effectively as the other options in transferring the electricity to where it is needed. This option would not provide enough headroom for future growth. This option would require an additional reinforcement compared to the other options, the uprate of the existing Cashla – Tynagh 220 kV OHL.

The cable options 3B and 3C have some advantages in their technical performance in the criterion ‘Headroom’ and ‘Compliance with planning and security standards’. However, they also have some challenges and difficulties, which vary depending on the cable option; these are in relation to reliability, extendibility, repeatability and technical operational risk.

5.4 Summary of economic performance of options

The economic performance of each option is a combination of the economic result and a robustness test. All options have costs and savings which are considered in the economic result. A robustness test to check the options’ performance for different credible future energy scenarios was also carried out including sensitivity to changes in some reference parameters. Figure 5 shows a summary of the economic assessment inputs and resulting economic performance of the various options. This figure is also displayed in Appendix 3.

Summary of Economic performance all options 2020 values						
	units	Option 1 Up-voltage	Option 2 400 kV OHL	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Pre-Engineering Costs	[€M]	9.4	11.2	8.4	8.4	8.9
Project Implementation Costs	[€M]	239	168	372	356	679
Project Life-Cycle Costs (Losses)	[€M] pa	1.2	-0.529	-1.28	-1.28	-1.76
Project Life-Cycle Costs (O & M) Presented in period of years (1-20), (20-40), (40-50)	[€k] pa	0.84 0.458 0.14	0.42 0.524 0.86	0.96 0.259 0.96	0.129 0.252 0.129	0.244 0.491 0.244
Project Life-Cycle Costs (Decommissioning & Replacement)	[€M]	N/A	N/A	380.3	364.3	687.6
Cost to SEM based on unavailability of reinforcement (TES Scenario used)	[€M] pa	Range -3 to 13	Range 1 to 20	Range 0 to 16	Range 1 to 20	Range 1 to 21
Combined Economic Performance						

Figure 5 *Summary of economic inputs and performance for all options*

Option 2 has the best economic performance followed by Option 1 and Option 3B which perform equally in this criterion. Option 3C has the worst economic performance overall.

5.5 Summary of deliverability aspects of the options

All options would be challenging to deliver, but for different reasons. Figure 6 shows the deliverability performance of the various options in relation to the different sub-criteria. This figure is also displayed in Appendix 4.

Option 1, Option 3A and Option 3B perform the same overall under the deliverability criterion, but there are differences that are worth pointing out.

Option 1 would have a relatively long delivery timeline and risks associated with it as this is a new technology. This option would require existing OHLs to be taken out of service for extended periods of time while the option is constructed and the other options do not have this as an impact. Option 1 may require in-line modification of the existing tower locations for construction reasons.

Option 2, comprising a new 400 kV OHL, has in this aspect the longest implementation timeline based on similar projects undertaken by EirGrid. It is also anticipated that it would be very challenging to achieve societal acceptance for such a development.

Option 3A and 3B are UGC options, and have the best implementation timelines when compared to all options under consideration. They would preferably be accommodated in the public road network and would require a 4 metre wide cable trench and an additional working strip, thereby requiring an overall cable alignment width (permanent and temporary). Road closures and potentially significant implications for traffic movements for both local access and commuter traffic would be a factor for all the UGC options during construction.

Option 3C, which will require two separate routes or roads, introduces a significant risk to the deliverability of the reinforcement in three of the sub-criteria and as such this option does not perform very well in the deliverability criteria.

Summary of Deliverability performance of all options					
	Option 1 Up-voltage option	Option 2 400 kV OHL option	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Implementation timelines					
Project plan flexibility					
Risk of untried technology					
Dependence on other projects					
Supply chain constraints, permits, wayleaves etc					
Combined Deliverability Technical Performance					

Figure 6 *Overall deliverability performance of the options.*

5.6 Summary of Environmental aspects of the options

Figure 7 shows the environmental performance of the various options in relation to the different sub-criteria. This figure is also displayed in Appendix 5.

Summary of Environmental performance of all options					
	Option 1 Up-voltage option	Option 2 400 kV OHL option	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Biodiversity					
Soils and water					
Planning policy and land use					
Landscape and views					
Cultural heritage					
Combined Environmental Performance					

Figure 7 *Summary of the Environmental performance of the options.*

Option 1 has the best overall performance in relation to environmental aspects and impacts. This option uses existing corridors and maximises use of existing infrastructure thereby minimising the need to build new infrastructure in an area. The impacts for Option 1 are mainly related to the construction phase. Once operational, the up-voltage option would not be significantly different from the current baseline.

Option 2, Option 3A and Option 3B are all deemed to have a moderate overall impact on the environmental considerations, but there are differences in the individual sub-criteria.

Option 3C has the worst performance under this criterion as it uses two routes.

5.7 Summary of Socio-Economic aspects of the options

The assessment in this criterion has not considered the feedback from the consultation and stakeholder engagement, as this process has not yet been concluded. All feedback received will be carefully considered before the Best Performing Option (BPO) or options are identified and taken forward to Step 4 for further investigations.

To account for social acceptance in identifying the Emerging Best Performing Option for stakeholder engagement, and taking account of previous experience with 400 kV OHL technology on other projects, EirGrid has deviated from the draft outcome of Jacobs' assessment. The combined socio-economic performance for this criterion for Option 2 was considered to have a high significance impact to reflect this aspect. It should be noted that this anticipated outcome could be amended depending on the feedback from the consultation period in Step 3.

Figure 8 shows the socio-economic performance of the various options in relation to the different sub-criteria. This figure is also displayed in Appendix 6.

Summary of Socio-Economic performance of all options					
	Option 1 Up-voltage option	Option 2 400 kV OHL option	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Amenity and Health					
Economy					
Traffic and Transport					
Utilities					
Combined Socio-Economic Performance					

Figure 8 *Summary of the Socio-economic performance of the options.*

Option 1 has the overall best performance in relation to socio-economic aspects and impacts and Option 2 and Option 3C have the worst performance under this criterion.

6 Up-voltage existing 220 kV OHL circuits to 400 kV OHL circuit

This section describes the assessment of the up-voltage option against the five criteria and their sub-criteria as described in Section 4.2. Each criterion is described in separate sections and a summary of the overall performance of the option is provided in Section 6.7.

The assessments for the environmental and socio-economic criteria have been carried out by Jacobs, and a summary of its findings are presented in this report. Jacobs' detailed reports of these assessments can be found on our website and the links can be found in Section 2.1.

6.1 Description of option

This option would involve a suite of transmission network reinforcements centred on strengthening the network between the existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. In the below text reference is made to Gorman 220 kV station and Belcamp 220 kV station. A Map in Appendix 1 shows the location of these stations.

This option consists of:

- Up-voltage part of the Gorman – Maynooth 220 kV circuit and all of the Dunstown – Maynooth 2 220 kV circuit. This would involve using a new technology which would enable the existing 220 kV towers to be modified or replaced, and the 220 kV conductors and insulation hardware to be replaced with 400 kV equipment to create a new Dunstown – Woodland 400 kV circuit.
    - The existing Gorman - Maynooth 220 kV overhead line circuit (shown in blue in Figure 9 would be modified to incorporate a "turn in" to Woodland 400 kV station. This would create two new circuits into Woodland station, namely a Gorman – Woodland 220 kV circuit and a circuit connecting Maynooth and Woodland (that would be used for the up-voltaging element of the option).
    - The newly created circuit connecting Maynooth and Woodland would be linked together with the existing Dunstown – Maynooth 2 220 kV circuit (shown in green in Figure 9) in the vicinity of Maynooth station. The circuits would then be modified to enable operation at 400 kV.

- Two dynamic reactive support devices, located preferably in the vicinity of Belcamp 220 kV station in north county Dublin and Dunstown 400 kV station in County Kildare. The devices will be connected at 220 kV, and rated at approximately ±250 Mvar.
- This option would require work in the Woodland and Dunstown 400 kV stations to facilitate the connection. Bays would have to be constructed on the 400 kV busbars in both stations. Both these stations would require extensions to the 220 kV busbars. In Dunstown, the extension would be required to accommodate the connection of the dynamic reactive support device and in Woodland the extension would be required to accommodate the connection of the 220 kV circuit coming from Gorman station. Gorman 220 kV station is located in Causestown, Co Meath.

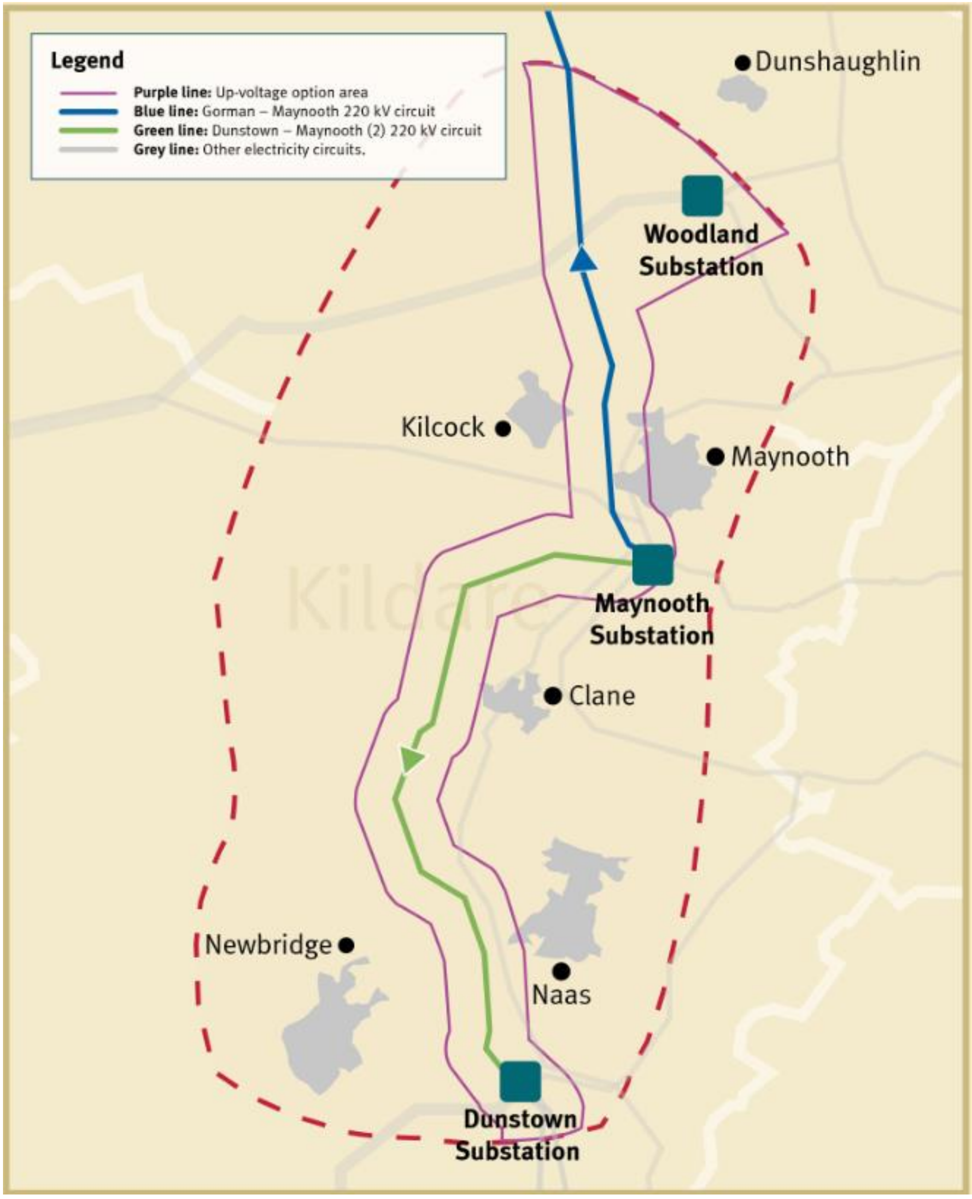


Figure 9 *Illustrative map showing the option to up-voltage existing 220 kV circuits to 400 kV OHL. The lines chosen for the up-voltage are the Gorman – Maynooth 220 kV (shown in Blue) and the Maynooth – Woodland 220 kV (shown in Green).*

The various alternatives to create the turn-in of the Gorman - Maynooth 220 kV overhead line circuit into Woodland 400 kV station and their impact on the five criteria was investigated by Jacobs and is presented in its reports (321084AE-REP-002 – CP 966 Environmental Constraints report and 321084AE-REP-003 – CP 966 Strategic SIA scoping report). This report can be found on our website – see Section 2.1 for the link.

There are three alternatives on how to achieve the turn-in:

1. Two single circuits using OHL between new towers positioned on the line of, or adjacent to, existing OHL alignment and into new 220kV and 400kV bays at Woodland station
2. Two single circuits using UGC between new towers and cable sealing end compounds positioned on the line of, or adjacent to, existing OHL alignment into new 220kV and 400kV bays at Woodland station
3. One double circuit OHL between new a tower positioned on the line of, or adjacent to, existing OHL alignment either north or south of the existing crossing point and into new 220 kV and 400 kV bays at Woodland station.

These three alternatives will have their own challenges and impacts on the five criteria. The decision on which of these is the best alternative will be taken in Step 4 and engagement and consultation with the local community will feed in to this decision. These alternatives and impacts will be further considered and investigated if the up-voltage option is brought forward into Step 4.

6.2 Technical Performance

6.2.1 Compliance with health and safety standards

The text included in this section applies to all options and will be referenced in the assessment of the other options rather than repeating the text.

Most technical standards for high voltage 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 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 Capital Project 966 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.

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

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 compliant with the most recent version of the Grid Code at the time of design.

The Up-voltage option will be compliant with the relevant safety standards, and is considered to have a low (**Cream**) risk of not complying with health and safety standards.

6.2.2 Compliance with Security and Planning Standards

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

- The Transmission System Security and Planning Standards (TSSPS)[16]; and
- The Operational Security Standards (OSS)[17].

These standards will ensure that the system is planned and operated in a manner which adheres to system security and integrity, and reliability of supply criteria.

The Up-voltage option proposed will comply with the relevant system reliability and security standards listed above. Although the option will meet the minimum technical requirements, certain aspects may differentiate the option’s technical performance compared to other options. A high level summary of the technical aspects considered and investigated is presented below.

The need analysis for 2030 indicated that, without mitigation, single contingencies (the unexpected loss of a single circuit or piece of equipment), such as the loss of any of the 400 kV circuits, the loss of any of several major 220 kV circuits or the loss of any of

[16] EirGrid, Transmission System Security and Planning Standard, 2016 (http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Transmission-System-Security-and-Planning-Standards-TSSPS-Final-May-2016.pdf
[17] EirGrid, Operational Security Standards, 2011 (http://www.eirgridgroup.com/site-files/library/EirGrid/Operating-Security-Standards-December-2011.pdf)

several generators or interconnectors leads to major, widespread, voltage issues and voltage collapse in the counties of Dublin, Kildare, and Meath in particular, and sometimes extends towards the South East, Midlands and North East.

The analysis indicates widespread low voltage and voltage collapse issues across a large part of the country for certain single contingencies. When the up-voltage option is added to the system model, the analysis indicates an improvement in these issues by reducing the extent of the indicated voltage collapses in Winter Peak from 47 to 12 instances. These improvements were similarly indicated for the Summer Peak cases. Despite the improvement in security of supply, the up-voltage option requires two additional dynamic reactive support devices to comply with the TSSPS.

The need analysis indicated capacity problems related to thermal overload and highly loaded circuits. When the up-voltage option is added, the overall loading of the circuits under an intact network is reduced. However, this solution results in increased congestion on some circuits in the Dublin area because two existing 220 kV circuits have been replaced with one, higher capacity 400 kV circuit.

In terms of voltage phase angle, this option performs well as it reduces the difference in voltage phase angle to 19˚ between the Oldstreet and Woodland stations post the single contingency on the Oldstreet – Woodland 400 kV circuit. This is a reduction of 12˚ compared to that observed in the needs analysis.

An assessment was undertaken into keeping the transmission network within standards following a loss of plant and equipment while another is out for planned maintenance. Maintenance is carried out annually during March to October. For planned outages, some re-dispatch of generation is allowed, but this should be kept to a minimum to ensure the most cost effective generation is dispatched.

The assessment shows that the capacity ratings of 33 circuits were exceeded for multiple maintenance and contingency trip combinations (N-1-1). The highest circuit capacity loading observed was 156.9%. This is a reduction compared to the issues indicated in the needs assessment, which highlighted 42 circuits had exceeded their thermal rating with a worst case loading of 177.5%. This will have a positive effect on the amount of generation that will have to be re-dispatched to overcome circuits exceeding their capacity limits during maintenance.

When all aspects are considered, the up-voltage option is considered to have a low to moderate compliance when assessed against the above standards and hence has been given a low to moderate impact (**Green**) in the assessment.

6.2.3 Reliability performance

This criterion has been assessed using three inputs, namely unplanned outages, planned outages and the time it takes to repair the circuit. The collective impact of these provides an indication of the annual availability of the asset. The reliability and outages of the station equipment associated with the circuit are assumed to be the same for all options and are therefore not included in this analysis.

The statistics for reliability are based on EirGrid's and international failure statistics, the mean time to repair and the availability in days per 100 km per year for OHL and UGC. It has been assumed that the new up-voltaged circuit will be approximately 50 km in length.

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 of 400 kV, 275 kV and 220 kV OHLs (approximately 2326 km) in the All Island transmission system.

Unplanned Outages:

Almost all OHL faults are of short duration as a result of transient faults such as lightning strikes. If an auto-reclose function is provided for the protection of the line, it will restore the circuit shortly after the fault, generally in 0.5 – 3 seconds. 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. Transmission system statistics indicate that 91.5 % of unplanned overhead line outages lasted less than one day[18].

Taking the fault statistics of the above combined network length of OHL for the period 2004 to 2018, gives a projected fault rate of 0.38 unplanned outages/100km/year.

Given typical repair times this would equate to the circuit being out of service due to a permanent fault for less than 9 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 are set out in the table below and adjusted to reflect the length of the proposed option.

[18] EirGrid, Analysis of Disturbance and Faults 2018, System Performance, April 2019

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[19].

Combination of the planned and unplanned outages:

Due to the length of the Up-voltage OHL circuit (approximately 50km), the total unplanned outage time per year is circa 9 hours, which combined with the planned outage rate of 2.5 days can be taken as 3 days per annum (rounded to nearest half day).

Parameter	Average statistics for 400 kV & 220 kV OHL combined
Reliability (Unplanned outages/50km/year)	0.19
Mean time to repair (days)	Circa 2 days
Unplanned Outages (combined) Unavailability due to disturbance (days/50km/year)	0.38 days (c.9 hours)
Planned Outages	2.5 days
Total Annual Unavailability (days/50km/year)	3 days

Table 2 *Average failure statistics for a 50 km 400 kV OHL*

The availability rate for the up-voltage option is high at 99.2% over any given year and this up-voltage option is deemed to have a low risk of not meeting the reliability criterion (**Cream**).

[19] http://www.eirgridgroup.com/site-files/library/EirGrid/Guide-to-Transmission-Equipment-Maintenance-March-2018.pdf

6.2.4 Headroom

The up-voltage option accommodates a similar amount of large-scale demand in the Dublin and Mid-East region compared to Option 2, the new 400 kV OHL option.

The assessment indicates that the up-voltage option creates headroom (increases the amount of additional large-scale demand that could be accommodated) of approximately 70 - 110 MW compared to no reinforcement, depending on which scenario is analysed. As indicated in Section 6.2.2, the option requires two dynamic reactive support devices to be in compliance with planning and security standards of the transmission network. With two dynamic reactive support devices added the total headroom created by this option is approximately 370 – 470 MW depending on which scenario is analysed.

The up-voltage option performs in the mid-range in the headroom criteria compared to the other options and is deemed to have a moderate (**Dark Green**) performance in terms of headroom.

6.2.5 Expansion or extendibility

The up-voltage option is based on Overhead Line (OHL) technology and has a thermal capacity[20] equivalent to the existing 400 kV circuits. The option provides a platform for future demand or generation development within the east of the country.

The up-voltage option will use existing circuit corridors, which pass near many areas where it is expected that demand will increase significantly. In the event that another connection along the circuit would be required, this could be achieved by constructing another station which could be connected into this line. This is a very common way to expand the transmission network and is normally technically feasible and achievable. As such, this option has the potential to provide a base for further expansion of the transmission network and the option offers a low to moderate (**Green**) difficulty to accommodate potential for future expansion.

6.2.6 Repeatability

This option uses Overhead Line (OHL) technology, which is already in use in the Irish transmission system with more than 4,500 km of circuit length. This option will also use a new technology which will mean that existing OHL towers along a route can be modified to accommodate a higher voltage level. To be able to accommodate this new technology,

[20] Thermal capacity of existing 400 kV OHL is a winter rating of 2963 A and summer rating of 2506A based on conductor 2 x 600 mm2 ACSR CURLEW at 80°C,

bespoke design of the OHL in question will have to be carried out to ensure that the circuit will meet design criteria.

The up-voltage technology is repeatable, but will require bespoke design if it were to be used on another circuit in the future. In principle, there are no limits in regards to repeatability of the up-voltage technology on the Irish transmission system, but consideration has been given to the bespoke design that has to be completed for future applications. This option is considered to have a moderate to low risk of not meeting the repeatability criteria (**Green**).

6.2.7 Technical operational risk

This option uses Overhead Line (OHL) technology, which is widely used internationally and in Ireland. This option will also use a new technology which will modify or replace the OHL towers along an existing route to be able to accommodate a higher voltage level.

This up-voltage technology has been used internationally and it is not anticipated that this technology would introduce any technical operational risk once it is in use on the Irish transmission system. This new technology has not been used on the Irish transmission network previously and could initially introduce some operational uncertainty. Any uncertainty would be mitigated by tests and trials prior to implementation to gain experience with the new OHL design. This option is considered lowest on the difficult/ risk scale (**Cream**) in terms of operational risk.

6.2.8 Conclusion of technical performance

When all technical aspects are considered, the up-voltage option has a moderate to low (**Green)** overall technical performance.

Summary of technical performance of Up-voltage option	
Health and Safety Standard compliance	
Security & Planning Standard compliance	
Reliability performance	
Headroom	
Expansion or Extendibility	
Repeatability	
Technical Operational risk	
Combined Technical Performance	

Table 3 *Summary of technical performance for up-voltage option*

6.3 Economic Assessment

The economic performance of the options is represented using our colour scale with the individual performance of an option assessed relative to the performance of the other solution options.

6.3.1 Input cost for the economic appraisal

6.3.1.1 Pre-engineering cost

The pre-engineering costs are estimated to be €9.4 million. In the economic appraisal, a contingency provision of 5% has been applied to this amount.

The phasing of the pre-engineering costs is as follows:

	2021	2022	2023	2024	2025
Phasing of Pre-Engineering Spend	24%	30%	22%	14%	10%

Table 4 *Phasing of Pre-engineering spend for Option 1*

6.3.1.2 Implementation cost

The capital investment required to deliver the up-voltage option is estimated to be €239 million. For the purpose of this cost assessment, this cost included an assumption that the turn-in would be using UGC as this is the worst case scenario from a cost perspective. A provision for Transmission System Operator (TSO) related implementation cost and landowner payments, proximity allowance and local community fund has been included in this cost. In the economic appraisal, a contingency provision of 10% has been applied to this amount. The estimated implementation cost is categorised into its general components and is summarised in Table 5.

Categorised implementation cost Option 1 – Up-voltage	
Cost category	**Implementation cost (€m)**
Overhead line	71.1
Underground cable	56.8
Stations	20.7
STATCOMs	66.0
Other (TSO related implementation cost, flexibility & proximity payments and other allowances)	24.4
SUB-TOTAL	239
Contingency (10%)	23.9
TOTAL	263

Table 5 *Categorised implementation cost for Option 1*

The phasing of the implementation costs is as follows:

Phasing of Implementation Spend – Option 1				
2025	**2026**	**2027**	**2028**	**2029**
2%	14%	18%	32%	24%

Table 6 *Phasing of Implementation cost for Option 1*

6.3.1.3 Life-cycle cost

This sub-criterion consists of three separate inputs incurred over the useful life of the option, namely operation and maintenance cost, electrical losses and replacement cost.

The equipment associated with the up-voltage option is expected to be maintained in accordance with the well-established existing practices. The operation and maintenance cost varies over the assets' life time and as such three periods of approximate costs are assumed. Table 7 displays rounded figures to the nearest thousand. No replacement cost is assumed as the equipment has a life expectancy of 50 years which is line with the period for the economic assessment.

Life-cycle cost for Option 1 – Up-voltage		
Annual Operation and maintenance cost (€k)	0-20 year period	€84k
	21-40 year period	€458k
	41-50 year period	€14k
Annual Electrical losses cost (€k)	€1.2*	
Replacement cost	N/A	

Table 7 *Life-cycle cost for Option 1*

*This option will not add any new circuits. It will use two existing circuits to create the solution. This will effectively remove two 220 kV circuits instead of adding additional circuits to the network, which will increase the losses in the system.

6.3.1.4 Cost to Single Electricity Market

As described in Section 4.2.2, the cost to the single electricity market will represent the cost for the periods when the reinforcement is unavailable. The unavailability is based on the reliability performance of the option. This is a cost to the single electricity market and is calculated as a combination of the benefit in production cost saving (project benefit) and reliability performance of the option. The reliability performance of the option is taken from Section 6.2.3. The production cost savings assessment used the TES 2019 scenarios and as such a range of annual production cost savings are used in the assessments as the different scenarios have different demand and generation patterns.

Cost to Single Electricity Market for Option 1 – Up-voltage	
Annual Production cost saving (Benefit) (€m/annum)	Range €-3m to €13m
Annual unavailability of option during which benefits cannot be attributed	Unavailable for 3 days, available 99.18%
Annual Cost (saving) to SEM	Range €-2.97m to €12.89m

Table 8 *Cost to single electricity market for Option 1*

6.3.2 Economic performance for Up-voltage option

When all of the above costs and savings are considered, the Up-voltage option (Option 1) has a good economic result compared to the other options and hence is considered to have a low to moderate (**Green**) impact on the economic result. To be able to differentiate between competing options in a measured way and to check the options' performance in different credible future energy scenarios, a robustness and sensitivity test was carried out. The objective is to identify the option that is impacted the least from an economic perspective for a range of credible future energy scenarios. This robustness test indicates a stable performance compared to the other options independent from which future energy scenario is used in the assessment.

After considering both the economic result and the robustness test, the up-voltage option is considered to provide a relatively good economic performance in comparison with the other options and hence has been given a low to moderate impact (**Green**) in the assessment.

Summary of economic performance of Up-voltage option	
Economic result	
Robustness	
Combined Economic Performance	

Table 9 *Summary of economic performance for up-voltage option*

6.4 Deliverability

6.4.1 Implementation timelines

The expected timeline for implementation of the up-voltage option is a period of 9 years in total. This is subject to and following statutory consenting for the structures and associated access routes. This time frame can be divided into two phases.

The first phase is based on 4.75 years for the mechanical, electrical and insulation coordination studies required for the new up-voltaging design, environmental assessment and the planning process.

The second phase is 4.25 years and includes detailed circuit design, procurement of materials and all construction works. This assumption includes time for securing landowner consents and a materials order period. This assumption incorporates time required for the outages associated with the works.

The design works, material procurement and construction period for the works required in the existing stations will be incorporated into the above timeline for the overhead line works. There are several elements required in the stations to accommodate the up-voltage option.

The timeline for new 400 kV bays at Dunstown and Woodland 400 kV stations is estimated at 1.5 years. Woodland and Dunstown stations will require extensions to the 220 kV busbars to accommodate the dynamic reactive support device in Dunstown and the 220 kV circuit coming from Gorman station. The timeline for these works are anticipated as 2.5 years. The installation of the dynamic reactive support devices at Belcamp (into spare bay) and Dunstown is anticipated to take three years and will be incorporated into the overall programme.

The up-voltage option has the second worst implementation timeline compared to the other options. The impact of the implementation timelines on the project is assessed to be high to moderate (**Blue**) for the Up-voltage option.

6.4.2 Project plan flexibility

As this option is based around infrastructure which is already in place, the route corridors have little flexibility to be modified. The constraint identified is the current angle mast locations, which would be unlikely to change along the whole route.

The route would be designed to a level that would incorporate the foundation enhancements, tower strengthening and access routes to the existing structures as well as any new structures that would be required along the route.

Once the best performing route option has considered all the constraints, an emerging preferred route would be the basis for the planning submission.

There is very little flexibility on the route once the planning consent is in place. Some of the tower locations may have the potential for minor modifications, but this could be subject to a modification to the planning consent. Access routes to the tower locations would also form part of the planning consent and changes to these would also require modification to the planning consent.

The up-voltage option is assessed to have a high to moderate (**Blue**) impact with regard to project plan flexibility.

6.4.3 Risk to untried technology

The up-voltage technology proposed is new to the Irish transmission system. The technology solution would have to be designed specifically for this project. It would involve upgrading the existing 220 kV towers to operate at 400 kV by modifying or replacing the structures on existing (or upgraded) foundations and replacing the conductor.

This technology is the subject of a separate trial project currently underway. The trial is being implemented on the Donard 220 kV Test Line in Co Wicklow. The scope includes the installation of the 400 kV upgraded towers, stringing of required conductors and other associated work to test this technology. This trial provides the opportunity to get more familiar with the technology and highlight any complications that may have to be resolved prior to use in the Irish transmission system.

While implemented elsewhere in the world, this technology has currently not been implemented on the Irish transmission system. Although this technology is safe to use, it is considered to have a greater risk to the project as unknown technical issues may have to be resolved and therefore this sub-criteria is deemed to have a high to moderate (**Blue**) significance on the project.

6.4.4 Dependence on other projects (outages)

This option has a number of elements which will require planned outages. The construction works will be dependent on the availability of outages to complete the enabling works ahead of the transfer of the existing Gorman to Maynooth line to create a new line from Gorman to Woodland. These outages will be competing with other network projects and may not be granted in successive outage windows.

The works to enhance the foundations and string sections of the existing 220 kV lines will have to be completed while the circuits are out of service.

The required work in both Woodland and Dunstown stations will need proximity and commissioning outages. In Woodland, the work involves the construction of an extension to the 220 kV busbar to create a point of connection for the 220 kV circuit coming from Gorman. In Dunstown, the work involves the construction of an extension to the 220 kV busbar, which is required to connect the dynamic reactive support device.

Other on-going projects in both these stations may cause conflicting outages depending on the projects' individual programmes and this will have to be taken into consideration and could have impacts on granting necessary outages.

Relative to the other options the up-voltage option is considered to have high to moderate (**Blue**) dependence on other projects.

6.4.5 Supply chain constraints, permits, wayleaves

For the purposes of this analysis, while angle towers (where the OHL changes direction) would be of a similar 400 kV design as existing angle towers, intermediate towers would comprise a new and bespoke design that does not currently exist on the Irish Transmission system. In addition, there may be a limited number of suppliers with the ability to supply the composite insulators in the manner envisaged for the intermediate towers.

Overall, while standard timelines for procurement and design may not apply given the bespoke nature of much of the option, it is envisaged that there would be no significant supply chain constraints, given this primarily relates to the design of steel structures.

Permitting is likely to be challenging irrespective of final scope, nature and design. Based on established precedent, the up-voltage option comprises work to an existing circuit and is likely to require planning permission.

However, given the proposed voltage of the overall circuit, and the fact that the up-voltage option includes portions of new circuit, An Bord Pleanála (ABP) could deem the up-voltage option to comprise Strategic Infrastructure Development (SID). In either consenting scenario, it is envisaged that there could be considerable public interest in the planning application and, combined with the relative complexity of the option, this could result in the holding of an Oral Hearing in respect of any such proposed development.

Given the nature of the proposed development as ultimately comprising a 400 kV OHL circuit (albeit using smaller towers sited more frequently than a standard 400 kV circuit, there is the potential for any planning application to be subject to Environmental Impact Assessment (EIA).

Notwithstanding all the above, the 400 kV OHL circuit would be assumed to follow the alignment of the existing long-established 220 kV circuits – although it is noted that there will be locations for the tie-ins between the existing circuits, and between the circuit and Woodland station, where new OHL or UGC would be required. The decision on which of the three alternatives would be used for the turn-in would be taken in Step 4 and engagement and consultation with the local community will feed in to this decision. Therefore, the existing 220 kV OHLs form part of the baseline receiving environment for the purposes of environmental assessment of the proposed up-voltage circuit.

This would not be the case if the up-voltage option would result in towers, apparatus and other equipment at materially different locations to that which exists at present, as there are likely to be resultant new or altered impact in relation to topics such as visual impact, and impact on land use activities.

It is assumed new wayleaves would be required to be issued having regard to the altered voltage of the OHL. This process would occur in engagement with landowners who have an established relationship with the asset owner (ESB Networks).

This wayleave process would become significantly more complicated if the design of the up-voltage option would stray from the existing alignment of the OHL circuit. In addition, it may be challenging if new 400 kV OHL is used to tie-in the existing 220 kV circuits, and the tie-in to Woodland Station. The final decision to use OHL or UGC for the tie-in to Woodand will be made in Step 4 if this option is progressed.

Having regard to all the above, the option is considered to have a moderate risk (**Dark Green)** with regard to Supply Chain Constraints, Permits and Wayleaves.

6.4.6 Conclusion of deliverability performance

There are five aspects considered when the overall deliverability performance is assessed. For the up-voltage option, most of these aspects indicate a moderate to high significance. This means that overall this option is considered relatively challenging to deliver, with some risks and unknown technical issues that will have to be solved during the subsequent stages of project development.

The implementation timeline for any network reinforcement is important to be able to ensure that the transmission network will be in compliance with security standards and that all consumers have a secure electricity supply.

On the other hand, this option is assumed to use existing OHL alignments, and indeed uses conductors and structures that are very similar in terms of nature and scale as that existing along those OHL alignments. It does not thereby introduce wholly new overhead line electricity infrastructure into the receiving environment, and this is considered beneficial for the purposes of consenting and social acceptance.

When all of these deliverability aspects are considered, the up-voltage option is deemed to have high to moderate impact (**Blue)** from a deliverability point of view.

Summary of deliverability performance of Up-voltage option	
Implementation timelines	
Project plan flexibility	
Risk of untried technology	
Dependence on other projects	
Supply chain constraints, permits, wayleaves etc.	
Combined Deliverability Performance	

Table 10 *Summary of deliverability performance for up-voltage option*

6.5 Environmental Assessment

This assessment was carried out by Jacobs and a summary of its findings are presented in this report. The detailed Jacobs report (321084AE-REP-002 – CP 966 Environmental Constraints report) is available on our website[21].

6.5.1 Biodiversity

The greatest potential for effects on biodiversity is expected to be during construction as a result of the modification of the OHL. There would be few significant impacts during operation, as a similar footprint is assumed for the new OHL as the existing. EirGrid's Evidence-Based Studies on birds[22] concluded that collisions with power lines were considered to be rare events. Whilst the conductors and towers would be slightly higher, this is not expected to pose a significant collision risk to birds. For the up-voltage of the 220 kV, effects on biodiversity are considered to be moderate (**Dark Green**).

[21] http://www.eirgridgroup.com/the-grid/projects/capital-project-966/the-project/
[22] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Evidence-Based-Environmental-Study-5-Birds.pdf

6.5.2 Soils and water

There would be no significant effects from this technology during the operational phase; the effects would only occur during construction. These would be fairly limited as the proposed solution would be to replace the existing 220 kV OHL with towers in the same locations as those currently, thereby minimising excavations of soils and potential impacts on soils and water. For the up-voltage of the 220 kV OHL, effects on soils and water are considered to be low to moderate (**Green**).

6.5.3 Planning Policy and Land Use

It is likely that this technology would accord with regional and local planning policies. From a land use perspective, there would be no significant effects from this technology during the operational phase; the effects would only occur during construction as a result of temporary land take. However, this would not be significant. For the up-voltage of the 220 kV OHL, effects on planning policy and land use are likely to be low (**Cream**).

6.5.4 Landscape and Views

It is likely that the up-voltage of the 220 kV OHL would have some limited effects on landscape and views during operation as a result of the slightly increased height of the towers. There may be some effects during construction, but these are unlikely to be significant. For the up-voltage of the 220 kV OHL, the risk to landscape and views are considered to be low to moderate (**Green**).

6.5.5 Cultural Heritage

It is likely that this technology would have limited effects on heritage assets during operation. There may be some effects during construction, but these are unlikely to be significant if the new towers are installed within a similar footprint as the existing towers. For the up-voltage of the 220 kV OHL, effects on heritage assets are likely to be low (**Cream**).

6.5.6 Summary of Environmental assessment of the Up-voltage option

Having considered the potential environmental impacts for the up-voltage option, it is concluded that this option would have low to moderate environmental impact (**Green**) when all the above aspects were considered. The impacts are mainly related to the construction phase. This option uses existing corridors and maximises existing infrastructure as opposed to introducing the need to build new infrastructure in an area.

Once operational, the up-voltage option would not be significantly different from the current baseline. The technology used will replace existing towers in existing corridors with towers of similar size and scale.

Summary of environmental assessment of Up-voltage option	
Biodiversity	
Soils and water	
Planning policy and land use	
Landscape and views	
Cultural heritage	
Combined Environmental Performance	

Table 11 *Summary of Environmental assessment of the up-voltage option*

6.6 Socio-economic Assessment

This assessment was carried out by Jacobs and a summary of its findings are presented in this report. It should be noted that this is a draft report and it will be finalised after the consultation period has been completed for the project in Step 3. This is normal procedure as this criterion will have to incorporate stakeholder engagement and any feedback resulting from this engagement. The detailed draft Jacobs report (321084AE-REP-003 – CP 966 Strategic SIA Scoping Report) is available on our website[23].

6.6.1 Amenity and Health

The greatest potential impact is during construction. Once installed, the new OHL would look very similar in size and form to the existing OHL. There could be increased anxiety regarding the OHL in operation as a result of the increased voltage and EMF, potentially leading to some stress related health effects, although these would not likely be greater than low to moderate risk. The risk during construction is based on the worst-case scenario of the existing OHL having to be fully dismantled and all foundations removed. For the up-voltage of the 220 kV towers, effects on amenity and health are considered to be a moderate risk (**Dark Green**).

[23] http://www.eirgridgroup.com/the-grid/projects/capital-project-966/the-project/

6.6.2 Local Economy

There is some potential for adverse and beneficial effects during construction as a result of possible traffic and access disruption but also additional employment locally. For the up-voltage option, the effects on the local economy are considered to be a low to neutral effect (**Cream**).

6.6.3 Traffic & Transport

There is some potential for adverse effects during construction as a result of possible traffic and access disruption. For the up-voltage of the 220 kV OHL, effects on Traffic and Transport are considered to be a high to moderate risk (**Blue**).

6.6.4 Utilities

It is unlikely that there would be additional third-party utilities to consider for the Up-voltage works as it will utilise the existing locations of towers and foundations. For the up-voltage option, the effects on utilities are considered to be low (**Cream**).

6.6.5 Summary of Socio-economic assessment of up-voltage option

Having considered the above described socio-economic aspects for the proposed up-voltage option, it is considered that it will have a moderate (**Dark Green**) socio-economic impact. This evaluation could be amended depending on the feedback from the stakeholder engagement in Step 3.

Summary of Socio-economic assessment of Up-voltage option	
Amenity and Health	
Local Economy	
Traffic and Transport	
Utilities	
Combined Socio-economic Performance	

Table 12 *Summary of Socio-economic performance for up-voltage option*

6.7 Summary of the assessment for the Up-voltage option

This option would involve using a new technology which would enable the existing 220 kV towers to be modified or replaced, and the 220 kV conductors and insulation hardware to be replaced with 400 kV equipment to create a new Dunstown – Woodland 400 kV circuit. This option performs well under the technical and economic criteria.

As the option seeks to maximise existing infrastructure with minimum new build, the impact on the environmental and socio-economic aspects are less compared with the other options which use new infrastructure. The Deliverability of the option is considered to be challenging. Having considered all of the five criteria, the outcome of the multi criteria assessment indicates that the up-voltage option has a moderate (**Dark Green**) overall performance.

	Option 1 Up-voltage 220 kV to 400 kV
Technical Performance	
Economic Performance	
Deliverability	
Environmental	
Socio-economic	
Combined Performance	

Table 13 *Overall assessment outcome for the Up-voltage option*

7 New 400 kV OHL

This section describes the assessment of a new 400 kV OHL option against the five criteria, and their sub-criteria as described in Section 4.2. Each criterion is described in separate sections and a summary of the overall performance of the option is provided in Section 7.7.

The assessments for the environmental and socio-economic criteria have been carried out by Jacobs, and a summary of its findings are presented in this report. Jacobs' detailed reports of these assessments can be found on our website and the links can be found in Section 2.1.

7.1 Description of option

This option involves a suite of transmission network reinforcements centred on strengthening the network between the existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. These consist of:

- Construction of a new 400 kV overhead line linking Dunstown 400 kV station to Woodland 400 kV station. For the purpose of this investigation, we have assumed the length of the overhead line to be approximately 50 km;
- Two dynamic reactive support devices, located preferably in the vicinity of Belcamp 220 kV station in north County Dublin and Dunstown 400 kV station in County Kildare. Appendix 1 provides clarification on the location of Belcamp station. The devices would be connected at 220 kV and rated at approximately ±250 Mvar each;
- This option would require work in the Woodland and Dunstown 400 kV stations to facilitate the connection. Bays would have to be constructed on the 400 kV busbars in both stations. The Dunstown station would require an extension to the 220 kV busbar to accommodate the dynamic reactive support device in Dunstown.

Figure 10 *Illustrative map showing the study area where the new 400 kV OHL option could be located.*

7.2 Technical Performance

7.2.1 Compliance with health and safety standards

Please refer to Section 6.2.1 for a detailed description. The new 400 kV OHL option will be compliant with the relevant safety standards, and is considered to have a low (**Cream**) risk of not complying with health and safety standards.

7.2.2 Compliance with Security and Planning Standards

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

- The Transmission System Security and Planning Standards (TSSPS)[24]; and
- The Operational Security Standards (OSS)[25].

These standards will ensure that the system is planned and operated in a manner which adheres to system security and integrity, and reliability of supply criteria.

The 400 kV OHL option proposed will comply with the relevant system reliability and security standards referenced above. Although the option will meet the minimum technical requirements, certain aspects may differentiate the option's technical performance compared to other options. A high level summary of the technical aspects considered and investigated is presented below.

The need analysis indicated that, without mitigation, single contingencies (the unexpected loss of a circuit or piece of equipment), such as the loss of any of the 400 kV circuits, the loss of any of several major 220 kV circuits or the loss of any of several generators or interconnectors leads to major voltage issues and voltage collapse in the counties of Dublin, Kildare, and Meath in particular, and sometimes extends towards the South East, Midlands and North East. The analysis indicates widespread low voltage and voltage collapse issues across a large part of the country for certain single contingencies.

When the 400 kV OHL option is added to the system model, the analysis indicates an improvement in these issues by reducing the extent of the indicated voltage collapses in Winter Peak from 47 to 9. These improvements were similarly indicated for the Summer Peak cases. Despite the improvement in security of supply provided by the 400 kV OHL circuit, the option also requires two additional dynamic reactive support devices to comply with the TSSPS.

The need analysis indicated capacity problems related to thermal overload and highly loaded circuits. When the 400 kV OHL option is added, the overall loading of the circuits under an intact network is reduced. However, this solution results in increased congestion on some circuits in the Dublin area.

In terms of voltage phase angle, this option performs well as it reduces the difference in voltage phase angle to 18˚ between the Oldstreet and Woodland stations post the single

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

[25] EirGrid, Operational Security Standards, 2011 (http://www.eirgridgroup.com/site-files/library/EirGrid/Operating-Security-Standards-December-2011.pdf)

contingency on the Oldstreet – Woodland 400 kV circuit. This is a reduction of 13˚ compared to the needs analysis.

An assessment was undertaken into keeping the transmission network within standards following a loss of plant and equipment while another is out for planned maintenance. Maintenance is carried out annually during March to October. For planned outages, some re-dispatch of generation is allowed, but this should be kept to a minimum to ensure the most cost effective generation is dispatched.

The assessment shows that the capacity ratings of 33 circuits were exceeded for multiple maintenance and contingency trip combinations (N-1-1). The highest circuit capacity loading observed was 157.1%. This is a reduction compared to the issues indicated in the needs assessment, which highlighted 42 circuits had exceeded their thermal rating with a worst case loading of 177.5%.

When all aspects are considered, the 400 kV OHL option is considered to have good compliance when assessed against the above standards and hence has been given a low impact (**Cream**) in the assessment.

7.2.3 Reliability performance

This criterion has been assessed using three inputs namely unplanned outages, planned outages and the time it takes to repair the circuit. The collective impact of these provides an indication of the annual availability of the asset. The reliability and outages of the station equipment associated with the circuit is assumed to be same for all options and is therefore not included in this analysis.

The statistics for reliability are based on EirGrid's and international failure statistics, the mean time to repair and the availability in days per 100 km per year for OHL and UGC. It has been assumed that the new OHL circuit will be approximately 50 km in length for the purpose of this assessment.

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 of 400 kV, 275 kV and 220 kV OHLs (approximately 2326 km) in the All-Island transmission system.

Unplanned Outages:

Almost all OHL faults are of short duration as a result of transient faults such as lightning strikes. If an auto-reclose function is provided for the protection of the line, it will restore the circuit shortly after the fault, generally in 0.5 – 3 seconds. 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. Transmission system statistics indicate that 91.5 % of overhead line outages lasted less than one day[26].

Taking the fault statistics of the above combined network length of OHL for the period 2004 to 2018, gives a projected fault rate of 0.38 unplanned outages/100km/year.

Given typical repair times, this would equate to the circuit being out of service due to a permanent fault for less than 9 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 are set out in Table 14 and adjusted to reflect the length of the proposed option.

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. The planned outage rates and the typical outage durations taken from our maintenance policies[27] result in an annual planned outage rate of 0.65% for the 400 kV option, or circa 2.5 days per annum[28].

Combination of the planned and unplanned outages:

Due to the length of the new OHL circuit (approximately 50km), the total unplanned outage time per year is circa 9 hours, which combined with the planned outage rate of 2.5 days sums to a total of 3 days per annum (rounded to nearest half day).

[26] EirGrid, Analysis of Disturbance and Faults 2018, System Performance, April 2019
[27] EirGrid, Routine Maintenance Activities Overhead Transmission Lines, April 2018
[28] EirGrid, Transmission Engineering Maintenance Statistics

Parameter	Average statistics for 400 kV & 220 kV OHL combined
Reliability (Unplanned outages/50km/year)	0.19
Mean time to repair (days)	Circa 2 days
Unplanned Outages (combined) Unavailability due to disturbance (days/50km/year)	0.38 days (c.9 hours)
Planned Outages	2.5 days
Total Annual Unavailability (days/50km/year)	3 days

Table 14 *Average failure statistics for a 50 km 400 kV OHL*

The availability rate for this OHL option is high at 99.2% over any given year and this OHL option is deemed to have a low risk of introducing additional reliability issues in the system (**Cream**).

7.2.4 Headroom

The new 400 kV OHL option accommodates a similar amount of large-scale demand in the Dublin and Mid-East region compared to option 1, the Up-voltage option.

The assessment indicates that the 400 kV OHL option creates headroom (increases the amount of additional large-scale demand that could be accommodated) of approximately 100 - 190 MW compared to no reinforcement, depending on which scenario is analysed. As indicated in Section 7.2.2, the option requires two dynamic reactive support devices to be in compliance with planning and security standards of the transmission network. With two dynamic reactive support devices added, the total headroom created by this option is approximately 400 - 500 MW depending on which scenario is analysed.

The 400 kV OHL option performs well in the headroom criteria compared to the other options and is deemed to have a moderate (**Dark Green**) performance in terms of headroom.

7.2.5 Expansion or extendibility

The 400 kV OHL option is based on Overhead Line (OHL) technology and has a thermal capacity[29] equivalent to the existing 400 kV circuits. The option provides a platform for future demand or generation development within the east of the country.

In the event that another connection along the circuit would be required, this could be achieved by constructing another station which could be connected into this line. This is a very common way to expand the transmission network and is normally technically feasible and achievable, depending on the required connection size. As such, this option has the potential to provide a base for any further expansion of the transmission network and the option offers a low to moderate (**Green**) difficulty to accommodate potential future expansion.

7.2.6 Repeatability

Overhead Line (OHL) technology is already in use on the Irish transmission system with more than 4,500 km of circuit length. This criterion is assessed on a technical basis and there are few technical issues with OHL technology that would introduce additional system integration, operational, and maintenance complexity that would affect the repeatability of OHL circuits on the Irish transmission system. There may of course be other challenges with OHL technology, but they are assessed under other criteria. This option is considered to have a low risk of not meeting the repeatability criteria (**Cream**).

7.2.7 Technical operational risk

The new 400 kV overhead line option is based on Overhead Line (OHL) technology. This technology is tried and tested internationally and in Ireland and it is considered to have a low operational risk. This option is therefore considered lowest on the difficult/ risk scale (**Cream**) in terms of operational risk.

[29] Thermal capacity of existing 400 kV OHL is a winter rating of 2963 A and summer rating of 2506A based on conductor 2 x 600 mm2 ACSR CURLEW at 80°C,

7.2.8 Conclusion of technical performance

This option is considered to perform very well when all of the technical sub-criteria are considered and hence has been given a low impact (**Cream**) in the assessment.

Summary of technical performance of 400 kV OHL option	
Health and Safety Standard compliance	
Security & Planning Standard compliance	
Reliability performance	
Headroom	
Expansion or Extendibility	
Repeatability	
Technical Operational risk	
Combined Technical Performance	

Table 15 *Summary of technical performance for 400 kV OHL option*

7.3 Economic Performance

The economic performance of the options is represented using our colour scale with the individual performance of an option assessed relative to the performance of the other solution options.

7.3.1 Input cost to the economic appraisal

7.3.1.1 Pre-engineering cost

The pre-engineering costs are estimated to be €11.2 million. In the economic appraisal, a contingency provision of 5% has been applied to this amount.

The phasing of the pre-engineering costs is as follows:

	2021	2022	2023	2024	2025	2026
Phasing of Pre-Engineering Spend	36%	24%	17%	10%	10%	3%

Table 16 *Phasing of pre-engineering spend for Option 2 – New 400 kV OHL*

7.3.1.2 Implementation cost

The capital investment required to deliver the new 400 kV OHL option is estimated to be €168 million. A provision for Transmission System Operator (TSO) related implementation cost and landowner payments, proximity allowance and local community fund has been included in this cost. In the economic appraisal, a contingency provision of 10% has been applied to this amount. The estimated implementation cost is categorised into its general components and is summarised in Table 17.

Categorised implementation cost Option 2 – 400 kV OHL	
Cost category	**Implementation cost (€m)**
Overhead line	64.2
Underground cable	N/A
Stations	10.4
STATCOMs	66.0
Other (flexibility & proximity payments and other allowances)	27.5
SUB-TOTAL	168
Contingency (10%)	16.8
TOTAL	185

Table 17 *Categorised implementation cost for Option 2*

The phasing of the implementation costs is as follows:

Phasing of implementation spend – 400 kV OHL option										
2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
4%	5%	20%	21%	13%	10%	10%	6%	5%	5%	1%

Table 18 *Phasing of implementation cost spend for Option 2*

7.3.1.3 Life-cycle cost

This sub-criterion consists of three separate inputs incurred over the useful life of the option, namely operation and maintenance cost, electrical losses and replacement cost.

The equipment associated with the new OHL option is expected to be maintained in accordance with the well-established existing practices. The operation and maintenance cost varies over the assets' life time and as such three periods of approximate costs are assumed. Table 19 displays rounded figures to the nearest thousand. No replacement cost is assumed as the equipment has a life expectancy of 50 years which is line with the period for the economic assessment.

Life-cycle cost for up-voltage option		
Annual Operation and maintenance cost (€k)	0-20 year period	€420k
	21-40 year period	€524k
	41-50 year period	€86k
Annual Electrical losses cost (€k)	-€529k*	
Replacement cost	N/A	

Table 19 *Life-cycle cost for Option 2*

*This option will reduce the losses and as such is a saving.

7.3.1.1 Cost to Single Electricity Market

As described in Section 4.2.2, Economic performance criteria, the cost to the Single Electricity Market represents the cost for the periods when the reinforcement is unavailable. The unavailability is based on the reliability performance of the option. This is a cost to the single electricity market and is calculated as a combination of the benefit in production cost saving (project benefit) and reliability performance of the option.

The reliability performance of the option is taken from Section 7.2.3 Reliability. The production cost savings assessment used the TES 2019 scenarios and as such a range of annual production cost savings are used in the assessments as the different scenarios have different demand and generation patterns. Table 20 show the input for this criterion.

Cost to Single Electricity Market for 400 kV OHL option	
Annual Production cost saving (Benefit) (€m/annum)	Range €1m to €20m
Annual unavailability of option during which benefits cannot be attributed	Unavailable for 3 days, available 99.18%
Annual Cost (saving) to SEM	Range €0.99m to €19.84m

Table 20 *Cost to single electricity market for Option 2*

7.3.1 Economic performance for Option 2 – New 400 kV OHL

When all of the above costs and savings are considered, the economic result of the new 400 kV OHL (Option 2) indicates a very good result compared to the other options and hence is considered to have a low (**Cream**) impact on the economic result. To be able to differentiate between competing options in a measured way and to check the options' performance in different credible future energy scenarios, a robustness and sensitivity test was carried out. The objective is to identify the option that is impacted the least in its economic result for a range of credible future energy scenarios. This robustness test indicates a stable performance compared to the other options independent from which future energy scenario is used in the assessment.

After considering both the economic result and the robustness test, the new 400 kV OHL (Option 2) is considered to provide a very good economic performance in comparison with the other options and hence has been given a low impact (**Cream**) in the assessment.

Summary of economic performance of the new 400 kV option	
Economic result	
Robustness	
Combined Economic Performance	

Table 21 *Summary of economic performance for new 400 kV option*

7.4 Deliverability

7.4.1 Implementation timelines

The expected timeline for implementation of the 400 kV overhead is a period of 15 years in total. This time frame can be divided into two phases.

The first phase is based on 4.25 years for the outline design, environmental assessment and the planning process, and would be subject to the outcome of the consenting process.

The second phase is 10.75 years and includes detailed design, procurement of materials and construction works. This assumption includes time for the design to be confirmed, all landowner consents to be obtained by EirGrid including the use of compulsory acquisition powers if necessary, and materials procurement in the first 5.75 years of this period.

This includes a period of one (1) year to allow for a modification of the approved planning permission, which in EirGrid's experience of grid development is a normal process, as the permitted development is subject to detailed design and the accommodation where possible of landowner preferences for tower siting. The time to construct the OHL (five (5) years) includes construction access, foundation works, tower erection and stringing which would include sections that require transmission outages.

The design works, material procurement and construction period for the works required in the existing stations has been incorporated into the above timeline for the OHL works. The timeline for new 400 kV bays at Dunstown and Woodland 400 kV stations is estimated at 1.5 years. Dunstown station would require an extension to the 220 kV busbar to accommodate the additional bay needed to accommodate the dynamic reactive support device and this work is anticipated to take 2.5 years. The installation of the dynamic reactive support devices at Belcamp (into spare bay) and Dunstown is anticipated to take three (3) years.

The implementation timeline for the 400 kV OHL option is the longest compared to the other options. The impact of the implementation timelines is assessed to be high (**Dark Blue**) for the 400 kV OHL option.

7.4.2 Project plan flexibility

Route corridors for the OHL would be developed in Step 4 of our grid development process and would factor in constraints in the study area. Within the corridors, there would be a reasonable level of flexibility to identify the OHL routes. Once the route options have considered all the constraints, an emerging preferred OHL route would be the basis for the planning submission.

The preferred route would be designed within the identified corridor and the design would consider the access routes for construction, stringing locations and tree cutting requirements. The design would be completed to a level that we would consider the foundation requirements and would identify all the requirements for the line construction.

There would be very little flexibility on the route once the planning consent is in place. Some of the tower locations may have the potential for minor modifications, which could require a modification to the planning consent. Access routes to the tower locations would also form part of the planning consent and changes to these would also require modification to the planning consent.

The 400 kV OHL option is assessed to have a moderate (**Dark Green**) impact on the project plan flexibility compared to the other options.

7.4.3 Risk to untried technology

OHL technology is tried and tested in Ireland and internationally. This technology is considered international best practice and is a proven technical solution for transmission of high-voltage electricity. It is the technology around which the transmission network in Ireland has been developed to date. Nevertheless, it has been some time since new 400 kV infrastructure was built in Ireland and therefore it is not without some technological risk. Overall, this option is considered to have a moderate (**Dark Green**) risk in relation to this sub-criterion when compared to the other options.

7.4.4 Dependence on other projects (outages)

This option has a number of elements which would require planned outages. There are a number of existing 220 kV and 110 kV overhead lines which would need to be crossed between Dunstown and Woodland stations. These would require a transmission outage to allow the line stringing to take place.

The required work in both Woodland and Dunstown stations would need proximity and commissioning outages. In Woodland, the work is in relation to the construction of the 400kV bay. In Dunstown, the work involves the construction of an extension to the 220 kV busbar, which would be required to connect the dynamic reactive support device. The works required to connect the dynamic reactive support device at Belcamp station would also require commissioning outages.

Other on-going projects in both these stations may cause conflicting outages depending on the projects' individual programmes and this would have to be taken into consideration and could have impacts on granting necessary outages.

The impact on the dependence on other projects for the 400 kV overhead line option is considered to be at a low to moderate (**Green**) level.

7.4.5 Supply chain constraints, permits, wayleaves

For the purposes of this analysis, it is assumed that 400 kV structures, apparatus and equipment would be equivalent, if not similar in terms of nature and extent of materials, to that being planned and procured for the North South Interconnector (NSIC) development. There are no significant supply chain constraints envisaged, with standard procurement and design timelines and scopes involved.

Permitting is likely to be very challenging, with the provision of new 400 kV OHL infrastructure in what can be described as a peri-urban commuter belt of the Greater Dublin Area, irrespective of final design and location. The Woodland station is also the terminus of the existing Moneypoint – Woodland 400 kV OHL circuit, and the permitted North-South Interconnector (NSIC) 400 kV OHL.

Based on established precedent, the infrastructure development comprising the provision of a new 400 kV OHL circuit is likely to be the subject of an application directly to An Bord Pleanála (ABP) as Strategic Infrastructure Development (SID). Given the nature of the proposed development as comprising a new 400 kV OHL circuit, the planning application would be subject to Environmental Impact Assessment (EIA). These factors make it almost inevitable that ABP would hold a full Oral Hearing in respect of a new 400 kV OHL development.

A new 400 kV OHL circuit would need to be located on a new alignment. This would result in potentially significant environmental and social impacts on receiving environments and communities, including biodiversity, land use activities, and visual impacts. Social impacts may include community concerns regarding the provision of new large-scale OHL within an area.

Significant engagement with landowners and communities would be required in the delivery of the new circuit, for such purposes as surveying, siting and construction. These parties may be new to accommodating electricity infrastructure on their landholdings and within their communities.

New wayleaves would be required to facilitate construction of the new circuit. Based on recent precedent in terms of the provision of new 400 kV transmission infrastructure, there is the potential for significant landowner, community and public concerns with this option, with the likely consequence of project delays or difficulties in gaining access to land.

Having regard to all the above aspects, the 400 kV OHL option is deemed to have a significant (**Dark Blue)** impact and risk in terms of Supply Chain Constraints, Permits and Wayleaves.

7.4.6 Conclusion of deliverability performance

There are five aspects considered when the overall deliverability performance is assessed. For the new 400 kV OHL option, two of the aspects indicate a significant risk to the deliverability of the reinforcement. The two areas that have a significant risk identified are implementation timelines and required permits and wayleaves.

This is a new 400 kV OHL development and based on experience on other similar OHL projects, permitting would be expected to be very challenging due to societal acceptance of such a development. This means that overall the option could very likely experience delays in its development compared to the other options.

The implementation timeline for any network reinforcement is important to be able to ensure that the transmission network will be in compliance with security standards and that all consumers have a secure electricity supply. The time it takes to develop and construct reinforcements is also important in terms of accommodating new generation and demand that would like to connect to the system.

This option has the longest implementation timeline compared to the other options and this, in combination with the perceived risk of delays due to societal acceptance, means this option does not perform well from a deliverability point of view and this has been taken into account in the overall assessment of this option.

When all of these deliverability aspects are considered the 400 kV OHL option is deemed to have a very high and significant impact (**Dark Blue)** from a deliverability point of view. Table 22, presents the conclusion of each sub-criterion and the overall assessment.

Summary of deliverability performance of new 400 kV OHL option	
Implementation timelines	
Project plan flexibility	
Risk of untried technology	
Dependence on other projects	
Supply chain constraints, permits, wayleaves etc.	
Combined Deliverability Performance	

Table 22 *Summary of deliverability performance for 400 kV OHL option*

7.5 Environmental Assessment

This assessment was carried out by Jacobs and a summary of its findings is presented in this report. The detailed Jacobs report (321084AE-REP-002 – CP 966 Environmental Constraints report) is available on our website.

7.5.1 Biodiversity

During construction, permanent habitat loss would be one of the significant impacts. Additional temporary loss of habitats, including biodiversity-rich hedgerows and ditches may occur to accommodate temporary works. During operation there would be pruning requirements for mature trees and there is a potential collision risk to whooper swans and other bird species from the new OHL. For the new OHL, effects on biodiversity are considered to be low to moderate (**Green**).

7.5.2 Soils and water

There would be no significant effects from this technology during the operational phase; significant effects would only occur during construction. The potential level of impact significance during construction would be likely to be limited as the proposed solution would avoid designated water bodies and excavations would be limited to the tower foundations; access tracks from local roads would require minimal soil strip in site preparation. The significant karst feature to the north of Woodland station would not be affected as any new connection would come from the south. For the new OHL option, effects on soils and water are considered to be low to moderate (**Green**).

7.5.3 Planning Policy and Land Use

As a worst case, it is possible that this technology would not fully accord with county planning policies as new structures are proposed and the route is not yet defined, however it is assumed that protected areas would not be crossed, main settlements avoided and the more sensitive landscape also avoided where possible.

From a land use perspective, there may be a small number of significant effects on particular parcels of land during the operational phase. For the new OHL option, effects on planning policy and land use are considered to be moderate (**Dark Green**).

7.5.4 Landscape and Views

As set out above, there is potential for effects on landscapes and views across the Study Area, and the new OHL could be in the order of 50km in length depending on the exact route. However, with the more sensitive landscapes, viewpoints and main settlements largely avoided, this effect would be moderate to high. This would be an effect during the operation of the OHL, effects on landscape and views would be limited and not likely to be significant during construction. For the new OHL option, effects on landscape and views are considered to be moderate to high (**Blue)**.

7.5.5 Cultural Heritage

There is a combined effect of the potential for harm to unknown archaeological assets during construction and to the setting of built heritage assets during operation. Of these two potential effects, however, it is during operation that the more significant effects are likely to arise. For the new OHL option, effects on heritage assets are considered to be moderate risk (**Dark Green**).

7.5.6 Summary of Environmental assessment of a new 400 kV OHL

Having considered the potential environmental impacts for the new OHL option it is concluded that this option will have moderate environmental impact (**Dark Green**) with a mixed impact during both the construction and operational phase. Table 23, presents the conclusion of each sub-criterion and the overall assessment.

Summary of environmental assessment of a new 400 kV OHL option	
Biodiversity	
Soils and water	
Planning policy and land use	
Landscape and views	
Cultural heritage	
Combined Environmental Performance	

Table 23 *Summary of Environmental assessment of a new 400 kV OHL option*

7.6 Socio-economic Assessment

This assessment was carried out by Jacobs and a summary of its findings is presented in this report. It should be noted that this is a draft report and it will not be finalised until after the consultation period has been completed for the project in Step 3. This is normal procedure as this criterion will have to incorporate stakeholder engagement and any feedback resulting from this engagement. The detailed draft Jacobs report (321084AE-REP-003 – CP 966 Strategic SIA Scoping Report) is available on our website – see Section 2.1 for the link.

7.6.1 Amenity and Health

There would be a moderate to high risk impact during construction. However, this solution proposes a new OHL in an area which is heavily constrained by communities and it is likely that it would be routed within 200m of some properties and community facilities. During operation, therefore, there could be an amenity effect from the combined effects of noise and visual impact from the new OHL as well as increased anxiety relating to EMFs, potentially leading to some stress related health effects. For the new OHL, effects on amenity and health are considered to be high to moderate risk (**Blue**).

7.6.2 Local Economy

The effects on the local economy could be quite mixed; both adverse and beneficial effects are possible. With careful routing to avoid significant industrial, tourism and equine sites, it is not considered that there would be significant adverse effects. On the basis that this is not always possible, a low to moderate (**Green**) impact on the local economy has been identified. Beneficial effects, whilst welcome, are not likely to be significant in the local economy.

7.6.3 Traffic & Transport

There is some potential for adverse effects during construction as a result of possible traffic and access disruption and temporary effects on the conditions of local roads. For the new OHL option, effects on traffic and transport are considered to be moderate to high risk (**Blue**).

7.6.4 Utilities

There is some potential for disruption; this would necessarily occur during construction as other utilities may need to be removed or diverted to accommodate the new 400 kV OHL. For the new OHL option, effects on utilities are considered to be low (**Cream**).

7.6.5 Summary of Socio-economic assessment of a new 400 kV OHL option

It should be noted that the above sub-criteria have not considered social acceptance or any feedback from the stakeholder engagement as the announcement of the EBPO happens at the start of the consultation period. To account for this aspect, and mindful of previous experience with 400 kV OHL line technology in projects, EirGrid has deviated from the draft outcome of Jacobs' assessment for the overall performance assessment for this criterion. Jacobs' draft overall outcome, without the feedback from the stakeholder engagement, was given a moderate (Dark Green) impact in regards to this criterion.

Having considered the different aspects in this criterion, and to reflect an anticipated outcome from the stakeholder engagement in regards to this option, it is considered that a new 400 kV OHL option would have a high (**Dark Blue**) socio-economic impact. This evaluation could be amended depending on the feedback from the stakeholder engagement in Step 3. Table 24, presents the conclusion of each sub-criterion and the overall assessment.

Summary of Socio-economic assessment of a new 400 kV OHL option	
Amenity and Health	
Local Economy	
Traffic and Transport	
Utilities	
Combined Socio-economic Performance	

Table 24 *Summary of Socio-economic performance for a new 400 kV OHL option*

7.7 Summary of the assessment for the 400 kV OHL option

This option would involve constructing a new 400 kV OHL. This option is the best performing option in the technical and economic criteria compared to the other options. The environmental criterion is considered to be of moderate impact when compared to the other options.

Based on other projects of a similar nature, some aspects under the deliverability and the socio-economic criteria are anticipated to be very challenging and would bring high risks to the completion of the project.

Having considered all of the five criteria, the outcome of the multi-criteria assessment indicates that the new 400 kV OHL option (Option 2) does not perform very well and it has been given a high impact (**Dark Blue**) on its overall performance i.e. the worst performance in terms of the colour scale used.

	Option 2 400 kV OHL
Technical Performance	
Economic Performance	
Deliverability	
Environmental	
Socio-economic	
Combined Performance	

Table 25 *Overall assessment outcome for the 400 kV OHL option*

8 New Underground Cable options

This section describes the assessment of the new underground cable options against the five criteria and their sub-criteria as described in Section 4.2. Each criterion is described in separate sections below and a summary of the overall performance of the option is provided in Section 8.7.

The assessments for the environmental and socio-economic criteria have been carried out by Jacobs, and a summary of its findings is presented in this report. Jacobs' detailed reports of these assessments can be found on our website and the links can be found in Section 2.1.

Due to the nature of UGC options, additional investigations were carried out to better inform the assessment from a feasibility and technical point of view. There are certain aspects that we need to understand before an UGC option can be deemed feasible. For instance, the power carrying capacity (rating) of the cable is dependent on how it is laid in the ground.

These investigations included how wide the cable trench would have to be to meet the required power carrying capacity (rating) and a high level feasibility study to determine if indicative feasible routes (which achieve required capacity ratings) can be found in the road network in the study area and what type of obstacles the cables may have to cross. Jacobs carried out this assessment and its detailed report (321084AE-REP-001 Rev C – Cable route feasibility report) can be found on our website – see Section 2.1 for the link.

Also, other technical behaviours of UGCs had to be examined to avoid the cables causing damage to other electrical equipment once installed. These investigations included cable integration studies and indicative reactive compensation requirements, harmonic filter requirements, and temporary overvoltage assessments (TOV).

PSC carried out these assessments and its detailed report (Final report for Capital Project 966 Cable Integration Studies – JI7867-03-02 (Rev2)) can be found on our website – see Section 2.1 for the link.

Further investigations will have to be carried out in relation to these issues if any of the underground cable options are brought forward to Step 4 to reflect the actual route and parameters of the cable option.

8.1 Description of underground options

There were originally two underground cable options taken forward to Step 3. During the investigations in Step 3, another underground option was added to take account of the UGC and their ability to provide power carrying capacity (rating) depending on, among other things, the width of the cable trench and voltage level. Ideally, we would like all options to provide an equal power rating capacity, but we also know that as this may trigger UGC options which have other technical limitation and challenges in deliverability. As a result, the three UGC options have different technical abilities and deliverability aspects.

Option 3A, a new Dunstown – Woodland 220 kV UGC, was investigated as 220 kV cables generally have fewer technical issues than 400 kV cables in terms of reactive compensation requirements, harmonic filter requirements, and temporary overvoltage assessments (TOV). This option provides the lowest thermal capacity of all options, but was brought forward to Step 3 in case it was found that 400 kV UGC could not be accommodated on the network.

Option 3B, a new Dunstown – Woodland 400 kV UGC (one circuit constructed along one route), was developed to maximise the power carrying capacity (rating) using only one 400 kV circuit. From other projects, we know that this will not provide an equal power carrying capacity (rating) to standard 400 kV OHLs, but it may provide other benefits when the assessment criteria are examined in more detail. As a result, this option has a lesser power carrying capacity (rating) than our standard 400 kV OHLs.

Option 3C, a new Dunstown – Woodland 400 kV UGC (two circuits constructed along two separate routes), would provide an equivalent power carrying capacity (rating) to our standard 400 kV OHLs but presents other challenges when assessed against the other criteria.

All UGC options involve a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath.

A dynamic reactive support device, located preferably in the vicinity of Belcamp 220 kV station in north county Dublin is also required for each UGC option. Appendix 1 provides detail of the location. The device would be connected at 220 kV, and rated at approximately ±250 Mvar and is common to all of the underground cable options.

The underground cable options are:

- Option 3A: New Dunstown – Woodland 220 kV UGC

In addition to the new cable circuit, the following are required:

- Uprating of the Oldsteet – Tynagh 220 kV overhead line
- Woodland and Dunstown station would require extensions to the 220 kV busbars to facilitate the connection.
- Shunt reactors (50 Mvar) at each end of the cable
- Possible filters (to be determined at design phase to take account of more accurate data)

* Option 3B: New Dunstown – Woodland 400 kV UGC (one circuit constructed along one route)

  In addition to the new cable circuit, the following are required:

  - Bays would have to be constructed on the 400 kV busbars in both Woodland and Dunstown stations
  - Shunt reactors (145 Mvar) at each end of the cable
  - Possible filters (to be determined at design phase to take account of more accurate data)

* Option 3C: New Dunstown – Woodland 400 kV UGC (two circuits constructed along two separate routes)

  In addition to the new cable circuits, the following are required:

  - Bays would have to be constructed on the 400 kV busbars in both Woodland 400 kV station and Dunstown 400kV station.
  - Shunt reactors (435 Mvar) at each end of the circuit, before the two cables enter into the 400 kV bay
  - Possible filters (to be determined at design phase to take account of more accurate data)

Figure 11 *Illustrative map showing the study area where the UGC options could be located.*

8.2 Technical Performance

8.2.1 Compliance with health and safety standards

Please refer to Section 6.2.1 for a detailed description. All underground cable (UGC) options perform the same for this criterion. All of the UGC options would comply with health and safety standards and hence have been given a low (**Cream**) impact in the assessment.

8.2.2 Compliance with Security and Planning Standards

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

- The Transmission System Security and Planning Standards (TSSPS)[30]; and
- The Operational Security Standards (OSS)[31].

These standards will ensure that the system is planned and operated in a manner which adheres to system security and integrity, and reliability of supply criteria.

The UGC options proposed would comply with the relevant system reliability and security standards above. Although the options would meet the minimum technical requirements, certain aspects may differentiate each option's technical performance compared to other options. A high level summary of the technical aspects considered and investigated is presented below.

The need analysis indicated that, without mitigation, single contingencies (the unexpected loss of a circuit or piece of equipment), such as the loss of any of the 400 kV circuits, the loss of any of several major 220 kV circuits or the loss of any of several generators or interconnectors leads to major voltage issues and voltage collapse in the counties of Dublin, Kildare, and Meath in particular, and sometimes extending towards the South East, Midlands and North East. The analysis indicates widespread low voltage and voltage collapse issues across a large part of the country for certain individual contingencies.

When the UGC cable options are added to the system model, the analysis indicates an improvement in these issues by reducing the extent of the indicated voltage collapses in Winter Peak from 47 to 2 for Option 3A and to 1 for Options 3B and 3C. These improvements were similarly indicated for the Summer Peak cases. Despite the improvement in security of supply, the UGC options required one additional dynamic reactive support device to comply with the TSSPS.

The need analysis indicated capacity problems related to thermal overload and highly loaded circuits. When the UGC options are added, the overall loading of the circuits under an intact network is reduced. However, these solutions result in increased congestion on some circuits in the Dublin area under certain operating conditions. In addition, when Option 3A is added to the system model, the analysis showed an overload on the Oldstreet – Tynagh 220 kV circuit and so it is required to be uprated for

[30] EirGrid, Transmission System Security and Planning Standard, 2016 (http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Transmission-System-Security-and-Planning-Standards-TSSPS-Final-May-2016.pdf
[31] EirGrid, Operational Security Standards, 2011 (http://www.eirgridgroup.com/site-files/library/EirGrid/Operating-Security-Standards-December-2011.pdf)

this option to be compliant with the TSSPS. Connecting the required Woodland and Dunstown stations using a 220 kV voltage level will not support the network as effectively as the other options in transferring the electricity to where it is needed. The uprate of Oldstreet – Tynagh 220 kV circuit is not required for Options 3B and 3C.

In terms of voltage phase angle, Option 3A performs the least well of all options as it reduces the difference in voltage phase angle to 28˚ between the Oldstreet and Woodland stations post the single contingency on the Oldstreet – Woodland 400 kV circuit. This is a reduction of only 3˚ compared to that observed in the needs analysis.

In terms of voltage phase angle, options 3B and 3C perform well, as they reduce the difference in voltage phase angle to 17˚ and 16˚ between the Oldstreet and Woodland stations post the single contingency on the Oldstreet – Woodland 400 kV circuit, respectively. This is a reduction of 14˚ and 15˚, respectively, compared to that observed in the needs analysis.

An assessment was undertaken into keeping the transmission network within standards following a loss of plant and equipment while another is out for planned maintenance. Maintenance is carried out annually during March to October. For planned outages, some re-dispatch of generation is allowed, but this should be kept to a minimum to ensure the most cost effective generation is dispatched.

The assessment shows that the capacity ratings of 33 circuits were exceeded for multiple maintenance and contingency trip combinations (N-1-1) for Option 3B and Option 3C. The highest circuit capacity loading observed was 157.8%. The amount of circuits observed is a reduction compared to the issues indicated in the needs assessment, which highlighted 42 circuits had exceeded their thermal rating with a worst case loading of 177.5%. This will have a positive effect on the amount of generation that will have to be re-dispatched to overcome circuits exceeding their capacity limits during maintenance.

The assessment for Option 3A shows the same circuits, as above, exceeding the capacity ratings for multiple maintenance and contingency trip combinations (N-1-1). The circuit capacity loadings observed with Option 3A included are slightly higher compared with Option 3B and Option 3C and, as such, Option 3A performs slightly worse during planned maintenance.

Underground cables by their nature introduce a number of additional technical aspects which have to be considered compared to overhead line solutions. UGCs are effectively a large capacitance and will store electrical energy. This will impact the grid in various ways which we will have to be able to manage to guarantee a safe and secure grid. The cables would have to be compensated with shunt reactors (inductive) to avoid large increases in voltage during both normal operation and during switching of the cable.

The amount of compensation is dependent on the length of the cable and the voltage level to which it is connected. For Option 3A (220 kV UGC), one reactor of approximated 50 Mvar at either end of the cable is required. For Option 3B (400 kV UGC 1 route), one reactor of approximately 145 Mvar at each end of the cable is required. For Option 3C (400 kV UGC 2 separate routes) the size of the reactor(s) needs to be approximately 435 Mvar at each end of the circuit (before the two cables enter into the the 400 kV bay).

The cables may also require harmonic filters to mitigate against harmonic resonances which can occur. These resonances occur because the transmission network is made up mostly of overhead lines making it overall inductive while underground cables are capacitive. The combination of the inductive and capacitive elements can create resonances in the system which, if not mitigated, can damage transmission network and customer equipment.

The three cable options would have different filter requirements. The level (size and location) of filters required is dependent on available harmonic limit 'headroom' at the time of connection of the cable. Analysis indicates that in the worst case scenario, harmonic filters may be required involving the installation of 5, 7, or 8 harmonic filters in the Dublin region for options 3A, 3B, or 3C, respectively.

No filters are associated at this stage of the development as these would have to be designed closer to the time of connection to achieve the best tuning. The technical analysis also covered Temporary Over-Voltage (TOV) which may be associated with underground cables. No unacceptable TOV issues were identified for any of the underground cable options[32].

When all aspects are considered for this criterion, Option 3A is considered to have a high (**Dark Blue**) impact on compliance with security and planning standards as it will not support the network as effectively as the other options in transferring the electricity to where it is needed. Options 3B and 3C are considered to have a low (**Cream**) impact on compliance with security and planning standards as these options perform well.

8.2.3 Reliability performance

This criterion is assessed using three inputs namely unplanned outages, planned outages and the time it takes to repair the circuit. The collective impact of these provides

[32] The cable integration studies (carried out by PSC) assumed a cable length of 60 km. This was based on existing OHL lengths between the stations plus a margin to cover that the cable will have to follow roads. This was the best available assumption at the time, as no feasibilities had been carried out at the initiation of these studies.

an indication of the annual availability of the asset. The reliability and outages of the station equipment associated with the circuit are assumed to be the same for all options and are therefore not included in this analysis.

The statistics for reliability are based on EirGrid's and international failure statistics, the mean time to repair and the availability in days per 100 km per year for UGC. It is assumed that the options with one conductor per phase (Option 3A and 3B) would be approximately 50 km in length and the option with two conductors per phase (Option 3C) would be 100 km in length as it has double the amount of cable.

Unplanned Outages*:*

As mentioned in Section 7.2.3, almost all faults on OHLs are of short duration as a result of transient faults. If an auto-reclose function is provided for the protection of the OHL, it will restore the circuit shortly after the fault. Auto-reclose is not available for faults on UGC and as such faults are considered to be long-lasting and will not be re-energised until an investigation has been undertaken. Consequently when a cable fault occurs, finding a fault location and resolving it 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.

There is only 1 km of existing 400 kV UGC in Ireland. This length of 400 kV UGC is too small a sample for determining meaningful performance statistics.

As previously detailed in Section 6.2.3, meaningful statistics can, however, be obtained by considering the fault statistics of the combined quantity (approximately 144 km) of 400 kV and 220 kV UGC under our control along with international failure statistics for cables[33]. Taking the fault statistics of this existing 144 km of UGC for the period 2004 to 2018, gives a projected fault rate of 0.27 Unplanned outages/100km/year.

Parameter	Average statistics for 400 kV & 220 kV UGC combined
Reliability (Unplanned outages/100km/year)	0.27
Mean time to repair (days)	25 – 45 Days[34]
Unavailability due to disturbance (days/100km/year)	7 – 12 days

Table 26 *Average failure statistics for a 100 km 400 kV or 220 kV UGC*

[33] Cigre, TB379 Update of service experience of HV underground and submarine cable systems, 2009
[34] Dependant on installation method and number of joint bays

Table 26 shows the statistics for reliability, the mean time to repair faults, and the unavailability for 220 kV and 400kV cables (based on international failure statistics for cables[35]). These statistics, given that they apply to XLPE[36] cables, are taken to be applicable for this option.

Planned outages:

Planned outages are normally associated with routine maintenance. The typical routine maintenance outage duration for 400 kV cables taken from our maintenance policies is 2-3 days per annum (dependent on the number of joint bays and cable sections). Each year an operational test is performed, and periodically an ordinary service. These maintenance outages equate to a total unavailability of 0.84%, or c.2.5 days per annum.

Combination of the planned and unplanned outages:

The combination of the planned and unplanned outages for the three UGC options and the total annual unavailability are set out in the table below and adjusted to reflect the length of each proposed option.

Summary of reliability performance of UGC options			
	Option 3A 220 kV UGC (50 km)	**Option 3B 400 kV UGC (50 km)**	**Option 3C 400 kV UGC (2 routes, 100 km)**
Reliability (Unplanned outages/circuit length(km)/year)	0.135	0.135	0.27
Mean time to repair (days)	25 – 45 days[37]	25 – 45 days	25 – 45 days
Unplanned outages (Combined) Unavailability due to disturbances (days/circuit length(km)/year)	3.5 – 6 days/annum	3.5 – 6 days/annum	7 – 12 days/annum
Planned Outages	2.5 days	2.5 days	2.5 days
Total Annual Unavailability	6 – 8.5 days/annum	6 – 8.5 days/annum	9.5 – 14.5 days/annum
Difficulty/risk scale			

Table 27 *Reliability comparison of all cable options*

[35] Cigre, TB379 Update of service experience of HV underground and submarine cable systems, 2009
[36] XLPE cable means cross linked polyethylene
[37] Dependant on method of cable installation: direct lay or in ducts respectively.

The average failure rate and time to repair for the UGC options are deemed to be high when compared to the two OHL options. The availability of Options 3A and 3B as a result of outages is in the range of 97-98% at best and unavailability could potentially be greater than a month per annum. Based on this assessment, the reliability criterion for Options 3A and 3B is considered to be at a moderate performance (**Dark Green)**.

As Option 3C effectively doubles the length of the circuit, the inherent risk of failure is increased. The average failure rate and repair time is again deemed high. The availability of this option is in the range of 96-97% at best and unavailability could potentially be greater than a month per annum. Based on this assessment, the reliability criterion for option 3C is considered to be at a high risk of unavailability performance **(Blue)**.

8.2.4 Headroom

8.2.4.1 Option 3A

Compared to the other options, Option 3A, the 220 kV UGC option, accommodates the least amount of increase in large-scale demand in the Dublin and Mid-East region.

The assessment indicates that Option 3A creates headroom (increases the amount of additional large-scale demand that could be accommodated) of approximately 80 - 110 MW compared to no reinforcement, depending on which scenario is analysed. As indicated in Section 8.2.2, the option requires one dynamic reactive support device to be in compliance with the planning and security standards of the transmission network. With one dynamic reactive support device added the total headroom created by this option is approximately 270 – 300 MW depending on which scenario is analysed.

Option 3A, the 220 kV UGC option, performs worst in the headroom criteria compared to the other options and hence has been given a high to moderate (**Blue**) impact in the assessment

8.2.4.2 Option 3B

Of the cable options, Option 3B, the 400 kV UGC option (one circuit constructed along one route), accommodates the second largest increase in large-scale demand in the Dublin and Mid-East region.

The assessment indicates that Option 3B creates headroom (increases the amount of additional large-scale demand that could be accommodated) of approximately 320 - 420 MW compared to no reinforcement, depending on which scenario is analysed. As indicated in Section 8.2.2, this option requires one dynamic reactive support device to be in compliance with the planning and security standards of the transmission network. With one dynamic reactive support device added the total headroom created by this option along with the dynamic reactive support device is approximately 560 – 600 MW depending on which scenario is analysed.

Option 3B, the 400 kV UGC option, performs relatively well in the headroom criteria compared to the other options and hence has been given a low to moderate (**Green**) impact in the assessment.

8.2.4.3 Option 3C

Of all the cable options, Option 3C, the 400 kV UGC option (two circuits constructed along two separate routes), accommodates the largest increase in large-scale demand in the Dublin and Mid-East region when thermal generation is minimised.

The assessment indicates that Option 3C creates headroom (increases the amount of additional large-scale demand that could be accommodated) of approximately 590 - 660 MW compared to no reinforcement, depending on which scenario is analysed. As indicated in Section 8.2.2, the option requires one dynamic reactive support device to be in compliance with the planning and security standards for the transmission network. With one dynamic reactive support device added, the total headroom created by this option along with the dynamic reactive support device is approximately 760 – 830 MW depending on which scenario is analysed.

Option 3C, the 400 kV UGC option, performs very well in the headroom criteria compared to the other options and hence has been given a low impact (**Cream**) in the assessment.

8.2.5 Expansion or extendibility

All three underground cable options will provide a future new circuit and as such there are opportunities for further expansion of the transmission network using these cable options as a platform in the future. In the event that another connection along the cable route would be required, these cable options may make the opportunity for expansion and extendibility more challenging and difficult compared to if an OHL technology was used.

There are a number of aspects which make this more challenging. The cables used for the options are relatively long. Each cable option would have bespoke reactors at each end of the of the cable to limit the impact during energisation of the cables and also during normal operation as the reactors will make sure that the voltage does not deviate outside planning standards.

If the length of the cable is changed then these reactors would have to be resized and new reactors purchased. In the event that the cable is associated with harmonic filters, then additional studies would have to be undertaken to ensure that the filters are properly tuned for any new cable length and size. This could mean that some purchased equipment would become redundant in the future, if the cable option chosen is altered. There may also be difficulties in accommodating additional cables in the road network (cables would preferably be accommodated in roads to have an easier access to the asset for maintenance and repair) and this may further limit the cable options' extendibility.

In addition, each of the cable options would provide different thermal capacities and this would in turn have an effect on the future expandability of the transmission network. A lower capacity associated with a proposed reinforcement may result in additional reinforcements of the network being required earlier than some of the options that have a higher capacity.

The 220 kV UGC option (Option 3A) would be designed with a thermal capacity (rating) equivalent to a 220 kV High Temperature Low Sag (HTLS) conductor[38]. This is less than the capacity provided by any of the other options under consideration.

The aim for the 400 kV UGC option (Option 3B) would be to achieve an equivalent rating to the existing 400 kV circuits. However, cable rating calculations indicate that this would not be achievable and a lesser rating would have to be accepted for this option. The rating that potentially can be achieved is a winter rating of 2377A and summer rating of 2289A. This is less than the capacity of a 400 kV OHL circuit.

The 400 kV UGC option (option 3C) would be designed with a thermal capacity[39] (rating) equivalent to the existing 400 kV circuits.

It should be noted that further possible rating limitations may apply to the cable circuits as it may be difficult to achieve the required thermal rating due to obstacles that would have to be crossed on a potential route. Crossing of obstacles such as rivers, train tracks, bridges and motorways etc. may require that the cable(s) be buried deeper and this would have an impact on the thermal rating of the cable.

After considering all aspects in this criterion, all cable options provide a worse base for any further expansion of the transmission network compared to OHL technology.

[38] Thermal rating of a 220 kV HTLS conductor, 586 GZTACSR Traonach 210° conductor, with a winter rating of 2377A and summer rating of 2289A

[39] Thermal capacity of existing 400 kV OHL is a winter rating of 2963 A and summer rating of 2506A based on conductor 2 x 600 mm2 ACSR CURLEW at 80°C,

Although there are some differences in each UGC option's ability to accommodate future expansion, especially in terms of capacity, this is not significant enough to provide a difference in their performance for this criterion. The implications of the opportunity for expansion and extendibility is more challenging and difficult compared to OHL technology and all of the UGC options will have a high (**Dark Blue**) impact in terms of difficulty to accommodate potential for future expansion.

8.2.6 Repeatability

All three cable options perform the same for this sub-criterion. Underground Cable (UGC) technology for 220 kV and 400 kV voltages is already in use in the Irish transmission system, but on a smaller scale compared to OHL. Every time an UGC option is proposed as a solution, each cable option will have to be studied on its own merits. Bespoke network design would have to be considered for each option that would take account of necessary harmonic distortion introduced by any cable or if voltage limiting equipment is required to accommodate the cable options into the transmission network.

In terms of repeatability, it is therefore considered that there may be limitations in the network in regards to accommodating cables. The impacts of the above points are usually greater the higher the operating voltage of the cable used. As such, it is considered that the UGC options have high to moderate risk of not meeting the repeatability criteria (**Blue**).

8.2.7 Technical operational risk

The cable options use a technology that is tried and tested internationally and in Ireland. However, the nature of this technology means that when cables are used over long lengths they required a bespoke design to be able to be accommodated technically into the network.

The higher voltage level and the considerable length will influence the technical operational risk in regards to cable options. In addition, depending on the network, these cable options will require filter banks to filter out harmonics that they may introduce. Special energising and switching procedures will be required to manage any of the UGC options in an operational environment.

All these aspects and additional equipment required to accommodate these options will increase the technical operational risk. The cable options 3A and 3B are considered to have a high to moderate (**Blue**) impact in relation to technical operational risk and option

3C is considered to have a high (**Dark Blue**) impact in relation to technical operational risk as it consists of two parallel UGCs and will increase the operational risk further.

8.2.8 Conclusion of technical performance

When all technical aspects are considered for the three UGC options, the following sets out the overall technical performance:

Option 3A is the worst performing option from a technical perspective compared with the other options and hence has been given a high (**Dark Blue**) impact in the assessment. Connecting the required Woodland and Dunstown stations using a 220 kV voltage level will not support the network as effectively as the other options in transferring the electricity to where it is needed. This option will not provide enough headroom for future growth. This option also requires an additional reinforcement compared to the other options.

Option 3B has some advantages in its technical performance in the criterion ‘Headroom’ and ‘Compliance with planning and security standards’. However, this option also has some challenges and difficulties in relation to reliability, extendibility, repeatability and technical operational risk and hence has been given a moderate (**Dark Green**) impact in the assessment.

Option 3C has some advantages in its technical performance in the criterion ‘Headroom’ and ‘Compliance with planning and security standards’. However, this option also has some challenges and difficulties in relation to reliability, extendibility, repeatability and technical operational risk and hence has been given a high to moderate (**Blue**) impact in the assessment. This option has a more significant impact than Option 3B due to the additional cable length. Table 28 show the individual technical sub-criterion and overall technical performance of the UGC options.

Summary of technical performance of UGC options			
	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Health and Safety Standard compliance			
Security & Planning Standard compliance			
Reliability performance			
Headroom			
Expansion or Extendibility			
Repeatability			
Technical Operational risk			
Combined Technical Performance			

Table 28 *Summary of technical performance for all cable options*

8.3 Economic Assessment

The economic performance of the options is represented using our colour scale with the individual performance of an option assessed relative to the performance of the other solution options.

8.3.1 Input cost to economic appraisal

8.3.1.1 Pre-engineering cost

The associated pre-engineering costs for the three cable options are presented in this section in turn.

The pre-engineering costs for Options 3A (220 kV UGC) and 3B (400 kV UGC) are estimated to be €8.4 million each. In the economic appraisal, a contingency provision of 5% has been applied to this amount.

The phasing of the pre-engineering costs is as follows:

Option 3A and Option 3B	*2021*	*2022*	*2023*	*2024*	*2025*
Phasing of Pre-Engineering Spend	33%	27%	18%	15%	7%

Table 29 *Phasing of pre-engineering spend for Option 3A & 3B*

The pre-engineering costs for Option 3C (400 kV UGC) is estimated to be €8.9 million. In the economic appraisal a contingency provision of 5% has been applied to this amount.

The phasing of the pre-engineering costs is as follows:

Option 3C	*2021*	*2022*	*2023*	*2024*	*2025*
Phasing of Pre-Engineering Spend	35%	27%	17%	14%	7%

Table 30 *Phasing of pre-engineering spend for Option 3C*

8.3.1.2 Implementation cost

The associated implementation cost (rounded values).for the three cable options are presented in this section.

The capital investment required to deliver the reinforcement for Option 3A (220 kV UGC) is estimated to be €372 million.

The capital investment required to deliver the reinforcement for Option 3B (400 kV UGC) is estimated to be €356 million.

The capital investment required to deliver the reinforcement for Option 3C (400 kV UGC 2 routes) is estimated to be €679 million.

A provision for Transmission System Operator (TSO) related implementation cost and landowner payments, proximity allowance and local community fund has been included in this cost. In the economic appraisal a contingency provision of 10% has been applied to this amount.

The estimated implementation cost is categorised into its general components and is summarised in the table below. No filters are associated at this stage of the development as these would have to be designed closer to the time of connection to achieve the best tuning and, as such, no provision for potential requirement for filters has been made in the cost.

Cost category	Implementation cost (€m)		
	Option 3A UGC 220kV	Option 3B - UGC 400kV	Option 3C - UGC 400kV (2 routes)
Overhead line	1.8	N/A	N/A
Underground cable	308.9	315.8	634
Stations	20.7	N/A	N/A
STATCOMs	33	33	33
Other (flexibility & proximity payments and other allowances)	7.4	7.1	11.6
SUB-TOTAL	371.8	355.9	678.7
Contingency (10%)	37.1	35.5	67.8
TOTAL	409	391	746

Table 31 *Categorised implementation cost for UGC Options 3A, 3B and 3C*

The phasing of spend of the implementation cost is as follows for both Options 3A and 3B:

Option 3A and Option 3B	*2025*	*2026*	*2027*	*2028*	*2029*
Phasing of Implementation Spend	7%	23%	35%	35%	-

Table 32 *Phasing of implementation cost spend for Option 3A & 3B*

The phasing of spend of the implementation cost is as follows for Option 3C.

Option 3C	*2025*	*2026*	*2027*	*2028*	*2029*
Phasing of Implementation Spend	7%	23%	35%	28%	7%

Table 33 *Phasing of implementation cost spend for Option 3C*

8.3.1.3 Life-cycle cost

This sub-criterion consists of three separate inputs incurred over the useful life of the option, namely operation and maintenance cost, electrical losses and replacement cost.

The equipment associated with the cable options is expected to be maintained in accordance with the well-established existing practices. The operation and maintenance cost varies over the assets' life time and, as such, three periods of approximate costs are assumed. Table 34 below displays rounded figures to nearest thousand.

A replacement cost is assumed for all underground cable options as it is assumed that cables will have a life expectancy of 40 years which is less than the 50 year period for the economic assessment. The cost of replacement is taken to be precisely the same as the project pre-engineering and implementation cost. A residual value will be applied at the end of the 50 years to account for the remaining value of the investment and make it comparable with the other options which has a life cycle of 50 years.

Life-cycle cost for cable options				
		Option 3A 220 kV UGC	**Option 3B 400 kV UGC**	**Option 3C 400 kV UGC (2 routes)**
Annual Operation and maintenance cost (€k)	0-20 year period	€96k	€129k	€244k
	21-40 year period	€259k	€252k	€491k
	41-50 year period	€96k	€129k	€244k
Annual Electrical losses cost (€k)		-€1280k*	-€1280k*	-€1760k*
Replacement cost (€m)		380.3	364.3	687.6

Table 34 *Life-cycle cost for UGC Options*

*This option will reduce the losses and as such is a saving.

8.3.1.1 Cost to Single Electricity Market

As described in Section 4.2.2, Economic performance criteria, the cost to the Single Electricity Market represents the cost for the periods when the reinforcement is unavailable. The unavailability is based on the reliability performance of the option. This is the cost to the Single Electricity Market and is calculated as a combination of the benefit in production cost saving (project benefit) and reliability performance of the option. The reliability performance of the option is taken from Section 8.2.3 Reliability.

The production cost savings assessment used the TES 2019 scenarios and, as such, a range of annual production cost savings are used in the assessments as the different scenarios have different demand and generation patterns. Table 35 show the inputs for this criterion.

Cost to Single Electricity Market for cable options			
	Option 3A 220 kV UGC	**Option 3B 400 kV UGC**	**Option 3C 400 kV UGC (2 routes)**
Annual Production cost saving (Benefit) (€m/annum)	Range €0 to 16m	Range €1m to 20m	Range €1m to 21m
Annual unavailability of option during which benefits cannot be attributed	Unavailable for 8.5 days, available 97.6%	Unavailable for 8.5 days, available 97.6%	Unavailable for 14.5 days, available 96.03%
Annual Cost (saving) to SEM	Range €0 to 15.633m	Range €0.97m to 19.53m	Range €0.96m to 20.17m

Table 35 *Cost to single electricity market for UGC Options*

8.3.2 Economic performance for UGC Options

Table 36 shows the economic result for the three cable options when all of the above input costs and savings are considered. To be able to differentiate between competing options in a measured way and to check the options' performance in different credible future energy scenarios, a robustness and sensitivity test was carried out. The objective is to identify the option that is impacted the least in its economic result for a range of credible future energy scenarios. The combined economic performance is then presented.

Summary of economic performance of cable options			
	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Economic result			
Robustness			
Combined Economic Performance			

Table 36 *Summary of economic performance for cable options*

Option 3B has a good economic result compared to the other options and the robustness test indicates a similar performance across all the future energy scenarios. Option 3B is considered to have a low to moderate (**Green**) impact in regards to the economic performance and has the best economic performance of out of the cable options.

It is clear that Option 3C has the worst economic result of all of the options across all future energy scenarios and hence Option 3C is considered to have a high significant (**Dark Blue**) impact in regards to the economic performance. This option has a very high capital cost and not enough savings are generated during the period for the economic assessment in comparison with the other options.

Similarly, Option 3A does not provide a good economic result and this result is consistent across all future energy scenarios and hence Option 3A is considered to have a high to moderate significant (**Blue**) impact in regards to the economic performance.

8.4 Deliverability

8.4.1 Implementation timelines

The expected timeline for the implementation of the 220 kV and the 400 kV single circuit cable options (3A & 3B) is a period of 7.75 years in total. The equivalent timeframe for the 400 kV cable with two parallel cables in separate routes (3C) is a period of 8.25 years in total. This is subject to and following statutory consenting for the structures and associated access routes. This time frame can be divided into two phases.

The first phase for all options is based on 4.5 years for the outline design, environmental assessment and the planning and permits process.

The second phase for the 220 / 400 kV single circuit cable (3A & 3B) options totals 3.25 years with the timeframe for the 400 kV cable with two cables per phase (3C) totalling 3.75 years and includes detailed design, procurement of materials and construction works. This assumption includes time for the design to be confirmed, landowner consents being obtained by EirGrid and materials ordered in the first 1.5 years of this period.

The design works, material procurement and construction period for the works required in the existing stations will be incorporated into the timeline. The installation of the dynamic reactive support device at Belcamp 220 kV station is anticipated to take 3 years.

To facilitate the cable connections to the network, there is a need to install reactor devices and associated equipment at either end of the cable circuit. The size of the reactor is dependent on the cable option, but the anticipated construction timeline is the same for all options, approximately 2 years.

In addition, for Option 3A, Woodland station will require an extension to the 220 kV busbar to accommodate the connection with a construction timeline of 2.5 years. . This option does also have a further required reinforcement. The Oldstreet – Tynagh 220 kV OHL would need to be uprated and the construction timeline for the completion of this would be 1.5 years.

For options 3B & 3C, the two new 400 kV bays at the Dunstown and Woodland 400 kV stations are estimated to take 1.5 years.

Both Option 3A and 3B have the same estimated implementation timeline and this is the shortest timeline of all of the options. The impact of the implementation timelines on the project is assessed to be low to moderate (**Green**) for these options.

The impact of the implementation timelines on the project for Option 3C is assessed to be moderate (**Dark Green**) compared to the other options.

8.4.2 Project plan flexibility

Routes for the cables will be developed in Step 4 of our grid development process should they be brought forward to that step. The cable route would be developed in line with EirGrid standard practices. It is established practice in grid development that transmission cables should be constructed in the existing public road network if possible. This is to make access and maintenance to the cable easier once the project is constructed.

One consideration in the selection of a suitable road to accommodate the cable options is the width of the required cable trench. All the cable options will require a 4 metre wide trench and a working strip area wide enough to accommodate the required machinery. The road network in the study area will provide some flexibility in the identification of the best performing route for the single circuit options of 3A and 3B. As Option 3C uses two routes, the flexibility will be somewhat limited compared to the other two cable options. The use of Horizontal Directional Drill (HDD) technology to cross existing rivers, rail and roads will provide flexibility to avoid crossing point constraints.

Once the emerging preferred route has been submitted for planning consent, there is limited flexibility as we would need to work within the constraints of the site development boundary (otherwise known as the redline) of the route and the technical limitations of the cable route such as bending radius and fixed joint bay locations of the cable.

Options 3A and 3B are considered to have a high to moderate (**Blue**) impact on the project plan flexibility.

Based on the fact that Option 3C requires two routes, the project plan flexibility is deemed to be reduced compared to the other cable options and based on this, Option 3C is considered to have a high (**Dark Blue**) impact on the project plan flexibility.

8.4.3 Risk to untried technology

In general, cables are increasingly used in transmission systems across the world and the mitigations to technical issues that arise with the technology are well known, and generally tried, and tested. In an Irish context, the first 220 kV XLPE cable was installed in 1984, and there are a number of recent projects on the Irish transmission system using this technology.

That being said, every project has its own particular requirements and the non-standard 4 metre trench width to achieve the required capacity may pose challenges in delivery.

Another consideration in terms of untried technology is the use of long sections of UGC. This can lead to many technical issues which require specialised technical studies to determine if it is technically feasible to use a particular length of cable. Although, these studies have been carried out in Step 3 they will have to be repeated in Step 4 if any cable option is progressed to take account of the actual cable route determined. All cable options will require shunt reactors at either end of the cable to compensate the cable capacitance to keep the voltage within standards under normal operation.

Although shunt reactors are in place in the transmission system today, the size of the required shunt reactors for some of the UGC options is large and there is limited experience with these types of installations. The cable option may also require installation of filters in several stations in the network to mitigate any harmonic voltage distortions. The location of the filters cannot be determined until the design of the cable is known and this poses a risk for UGC options.

The installation of long lengths of 400 kV XLPE UGC became possible in the late 1990s with the development of a suitable cable joint for connecting lengths of such cable together. Nevertheless, EirGrid's experience with 400 kV cable is limited, with only a very small amount currently installed on the network.

Furthermore, it is worth noting that Option 3C requires two separate cable routes merging into a single bay in the station. As the cables follow two different routes, this could lead to different impedances of the two cables and this could potentially cause technical issues which will have to be resolved. This is a non-standard solution which has not been tried on the system before.

Another aspect in relation to the UGC option is that Horizontal Directional Drilling (HDD) technology will very likely have to be used to cross specific obstacles within the study area, such as rivers, for short lengths of the cable route. This poses another risk to the UGC options as it is an expensive methodology, requiring the use of specialist equipment.

Overall, the risk to untried technology for the 220 kV cable option (3A) is considered to be moderate (**Dark Green)**. The risk to untried technology for the 400 kV single route cable option (3B) is considered to be greater than option 3A and the risk to untried technology is therefore considered to be high to moderate (**Blue**). The 400 kV UGC option (3C), using two parallel routes, is considered to have the highest risk to untried technology of the three cable options and is therefore deemed high (**Dark Blue)**.

8.4.4 Dependence on other projects (outages)

The UGC options would require a number of elements which would require planned outages, with some options requiring more outages than others.

All UGC options would require work in both Woodland and Dunstown stations that would need proximity and commissioning outages.

Options 3B and 3C would require work in both stations in relation to the construction of the 400kV bays.

Other on-going projects in both these stations may cause conflicting outages depending on the projects' individual programmes and this would have to be taken into consideration and could have impacts on granting necessary outages.

Option 3A would require some work in Woodland. The work involves the construction of an extension to the 220 kV busbar to accommodate an additional bay for the connection of the option at 220 kV.

Option 3A is dependent on uprating the Oldstreet – Tynagh 220 kV overhead line circuit. This would require transmission outages including a 1 km double circuit section of the Cashla – Tynagh 220 kV circuit that would have a significant impact on the operation of the transmission network and could become critical to the delivery of the project.

The dependence on other projects for Option 3A is considered to have a moderate (**Dark Green**) level of impact.

Option 3B and Option 3C are both considered to have a low to moderate (**Green**) impact in terms of the dependence on other projects.

8.4.5 Supply chain constraints, permits, wayleaves

For the purposes of this analysis, it is assumed that 220 kV UGC will be equivalent, if not similar in terms of nature and extent of materials, to that occurring on the Irish grid network. There is an assumption that there would be no significant supply chain constraints envisaged with the increased distance of cable, with known procurement and design timelines and scopes involved.

With the two 400 kV options – one involving a single circuit, and the other involving two circuits, there may be significant supply chain constraints. This relates to the procurement and delivery of significant lengths (either approx. 50km or 2 x 50km) of 400 kV UGC, the required reactive compensation, required filters, and other associated large-scale equipment and testing apparatus. Cumulatively, this could result in significant supply chain constraints.

Permitting is likely to be challenging, with the provision of either new 220 kV or 400 kV UGC infrastructure in a peri-urban commuter belt of the Greater Dublin Area, irrespective of final design and location. It is confirmed, for the purpose of this analysis, that cable trenches will require to be 4m in width; in addition, it is envisaged that an 8m working width corridor will be required adjacent to the cable trench, thereby requiring an overall cable alignment width (permanent and temporary) of approx. 12m.

There are no roads within the receiving environment that could accommodate this width of construction corridor without significant temporary and/or permanent alteration, such as the removal of ditches, boundary vegetation, front gardens, walls and piers etc. Moreover, such roads would have to be closed for a considerable period of time, with potentially significant implications for traffic movements for both local access and commuter traffic. Overall, this would result in an impact of some significant scale and extent along the entire width of any UGC route. In the case of the 400 kV double circuit option, this would require two separate roads within the receiving environment and the impact as a result of this option would be greater than the other two UGC options.

It is currently considered that the UGC options, due to their size, scale and likely impact, are likely to require planning permission. While there is precedent for 220 kV UGC within the public road to comprise exempted development, it is considered that the scale of the overall UGC development, combined with the new associated infrastructure likely to be required as outlined above, will result in the overall development not comprising exempted development.

If statutory consent is required, it is likely to be the subject of an application directly to An Bord Pleanála (ABP) as Strategic Infrastructure Development (SID). It is considered likely that, given the nature and extent of the development and its potential environmental and community impact, as well as the potential public interest in the proposed development, ABP would hold a full Oral Hearing in respect of either a new 220 kV or 400 kV UGC development.

There is the potential for the UGC circuits to occur cross-country – i.e. away from public roads. This brings its own significant challenges in terms of landowner engagement and concerns, environmental and land use impacts – in particular the inability to undertake certain types of agricultural activity thereon.

It is assumed that significant engagement with landowners with properties along public roads would be required in the delivery of either a new 220 kV or 400 kV circuit, for such purposes as surveying, siting and construction. These landowners may be new to accommodating electricity infrastructure on their landholdings. New temporary and permanent easements would be required to facilitate construction of the new circuit. Based on recent precedent in terms of the provision of new high-voltage UGC transmission infrastructure, there is the potential for significant landowner opposition to this option.

Having regard to all the above, Options 3A and 3B is considered to have a high to moderate (**Blue**) impact in relation to the Supply Chain Constraints, Permits and Wayleaves criterion. Option 3C is considered to have a high (**Dark Blue**) impact in relation to the Supply Chain Constraints, Permits and Wayleaves criterion.

8.4.6 Conclusion of deliverability performance

There are five aspects considered when the overall deliverability performance is assessed. The UGC options have the best implementation timelines when compared to the other options under consideration. This is a benefit to these options as implementation timelines for any network reinforcement are important to be able to assure that the transmission network will be in compliance with security standards and that all consumers have a secure electricity supply.

It is likely that all of the UGC options would require planning permission or statutory consent, due to their size, scale and likely impact on the receiving environment. They would preferably be accommodated in the public road network and would require a 4 metre wide cable trench and an additional working strip, thereby requiring an overall cable alignment width (permanent and temporary) of up to 12 metres in certain places. This could have significant impacts and may impact deliverability of these UGC options. Road closures and potentially significant implications for traffic movements for both local access and commuter traffic would be a factor for all the UGC options during construction

For Option 3C, which would require two separate routes or roads, the impact is greater than for Options 3A and 3B. Three of the criteria indicate a significant risk to the deliverability of the reinforcement for this option. The three areas that have a significant risk identified are risk of untried technology, required permits and wayleaves and project plan flexibility, and this is reflected in the assessments. When all of these deliverability aspects are considered for Option 3C the impact on the deliverability aspects for this option are high (**Dark Blue).**

For Options 3A and 3B, some of the aspects are considered to have high to moderate impact on the deliverability of the option. The aspects with the highest risks for these options are required permits and wayleaves and project plan flexibility. Option 3B has a higher impact of risk of untried technology than Option 3A due to the voltage level. Option 3A has higher impact in regards to dependence of other projects than Options 3B and 3C and this could ultimately affect the deliverability. When all of these deliverability aspects are considered Option 3A and Option 3B are both deemed to have a high to moderate impact (**Blue)** from a deliverability point of view.

Summary of deliverability performance of cable options			
	Option 3A 220 kV cable	**Option 3B 400 kV cable**	**Option 3C 400 kV cable (2 routes)**
Implementation timelines			
Project plan flexibility			
Risk of untried technology			
Dependence on other projects			
Supply chain constraints, permits, wayleaves etc.			
Combined Deliverability Performance			

Table 37 *Summary of deliverability performance for cable options*

8.5 Environmental

This assessment was carried out by Jacobs and a summary of its findings are presented in this report. The detailed Jacobs report (321084AE-REP-002 – CP 966 Environmental Constraints report) is available on our website – see Section 2.1 for the link.

8.5.1 Biodiversity

The greatest effects on biodiversity would be during construction, where despite cables being primarily laid in public roads, there is potential for impacts on hedgerows and aquatic ecosystems in particular; other habitats may also be disturbed or fragmented during the construction phase and effects could be permanent in some cases. Options 3A and 3B would have the same effects on biodiversity and are considered to have a moderate (**Dark Green**) impact. Option 3C could have a greater magnitude of effects on biodiversity, depending on the route chosen, and the impact is considered to be moderate to high (**Blue**).

8.5.2 Soils and water

The greatest impacts on soils and water would be during construction for all UGC options. The risk to watercourses from silt and spillages during the construction process is moderate (**Dark Green**) for Options 3A and 3B as there would be a high number of water bodies crossed by the cables and there is potential for effects on roadside ditches during construction.

For Option 3C, the impacts on soils and water are considered to be moderate to high (**Blue**), as this option would require twice the route length compared to Options 3A and 3B. If the cables were to be installed in third party lands, the risks would be higher for all options.

8.5.3 Planning Policy and Land Use

The UGC would accord with the ambitions of county development plans to install new services underground wherever possible. There would be temporary disruption to the road network; the use of regional roads reduces this risk as any routes chosen would be ones large enough for the swathe to be within one carriageway only, however carriageway closures could be for a prolonged period of time. As such, it is anticipated that there would be no third-party land take except for the connection into Woodland.

At the connection into Woodland, it is likely that the cable would have to be installed across third party land. This would require a significant temporary land take during construction, but limited during operation, although a permanent wayleave and some restriction of agricultural practices above the UGC is likely. Options 3A and 3B are considered to have a moderate to low risk of impact (**Green**) on planning policy and land use, while Option 3C is considered to have a moderate risk of impact (**Dark Green**) on planning policy and land use, as the route is twice as long as for Options 3A and 3B.

8.5.4 Landscape and Views

For all three options, the effects on landscape and views from the UGC would be greatest during construction; although this would be temporary, it may take three years or more to install the UGC for Options 3A and 3B (one conductor per phase). Option 3C could also take three years if both phases were constructed at the same time, however the effects on landscape and for views would be greatest for Option 3C (moderate risk) as this has twice the footprint compared to Options 3A and 3B (low to moderate).

During operation, the effects would be limited: there would be visible joint boxes periodically along the cable, although these would be quite small; and some loss of hedgerows at Woodland station. These effects would be greatest for Option 3C as it is twice as long and would have twice the number of joint boxes and a higher loss of hedgerows. Overall Option 3A and 3B are considered to have a moderate to low risk of impact (**Green**) on landscape and views, while Option 3C is considered to have a moderate risk of impact (**Dark Green**).

8.5.5 Cultural Heritage

The effects on cultural heritage from the UGC would be greatest during construction, both in terms of ground disturbance and effects on the settings of heritage assets. The risk is identified as low to moderate (**Green**) for Options 3A and 3B, acknowledging there may be some effects given the length of the route.

Option 3C would be more significant in terms of risks to heritage assets and is identified as moderate risk (**Dark Green**). During operation, there is some potential for effects on the setting of heritage assets from the joint boxes; these effects would be greatest for Option 3C as it is twice as long and would have twice the number of joint boxes.

8.5.6 Summary of Environmental assessment of the UGC options

Having considered the potential environmental impacts for the UGC options it is concluded that option variations 3A and 3B will have moderate environmental impact (**Dark Green**). Option 3C is considered to have a moderate to high environmental impact (**Blue**). The environmental impact is related to both the construction and operational phase.

Summary of environmental assessment of New UGC options			
	Option 3A 220 kV UGC	**Option 3B 400 kV UGC**	**Option 3C 400 kV UGC (2 routes)**
Biodiversity			
Soils and water			
Planning policy and land use			
Landscape and views			
Cultural heritage			
Combined Environmental Performance			

Table 38 *Summary of Environmental assessment of the new UGC options*

8.6 Socio-economic

This assessment was carried out by Jacobs and a summary of their findings are presented in this report. It should be noted that this is draft report and it will be finalised after the consultation period has been competed for the project in Step 3. This is normal procedure as this criterion will have to incorporate stakeholder engagement and any feedback resulting from this engagement. The detailed draft Jacobs report (321084AE-REP-003 – CP 966 Strategic SIA Scoping Report) is available on our website – see Section 2.1 for the link.

8.6.1 Amenity and Health

There would be a moderate to high (**Blue**) impact on amenity and health during construction for options 3A and 3B. Combined impacts on communities, especially those linear communities alongside the regional road networks, could come from dust, noise, traffic and visual impacts. The impact for Option 3C would be worse as there are two 'routes' and Option 3C is therefore assessed to have a high risk (**Dark Blue**) on amenity and health during construction only.

8.6.2 Local Economy

The effects on the local economy could be quite mixed; both adverse and beneficial effects are possible. Beneficial effects, whilst welcome, are not likely to be significant in the local economy; disruption to local businesses and tourism venues could have a moderate risk impact as a result of construction works in regional roads over a period of three years.

This is especially the case for Option 3C, as this option requires two separate circuits. For Options 3A and 3B, effects on the local economy are considered to be low-moderate (**Green**) and for Option 3C it is considered to be moderate (**Dark Green**).

8.6.3 Traffic & Transport

For Options 3A and 3B, there is likely to be a moderate to high (**Blue**) risk of disruption to traffic on the regional road networks during the three years it would take to install the cables. This would lead to pedestrian and driver delay and potential local severance issues. Option 3C has the potential for a higher risk impact when compared to the level of impacts of Options 3A and 3B as it is twice as long. Option 3C has therefore been considered to have a high (**Dark Blue**) risk of disruption to traffic and transport.

8.6.4 Utilities

There is some potential for disruption; this would necessarily occur during construction as other utilities may need to be removed or diverted to accommodate the UGC option.

Option 3A and 3B would have a moderate (**Dark Green**) risk of impact to utilities whilst Option 3C would have a moderate to high (**Blue**) risk of impact.

8.6.5 Summary of Socio-economic assessment of UGC options

Having considered the above described socio-economic aspects for UGC options it is considered that Option 3A and 3B would have a high to moderate (**Blue**) socio-economic impact and that Option 3C would have a high (**Dark Blue**) socio-economic impact.

It should be noted that this evaluation could be amended depending on the feedback from the stakeholder engagement in Step 3.

Summary of socio-economic assessment of UGC options			
	Option 3A 220 kV UGC	**Option 3B 400 kV UGC**	**Option 3C 400 kV UGC (2 routes)**
Amenity and Health			
Local Economy			
Traffic and Transport			
Utilities			
Combined Socio-economic Performance			

Table 39 *Summary of Socio-economic performance for UGC options*

8.7 Summary of the assessment for the cable options

Three underground cable variations have been investigated and they all involve a suite of transmission network reinforcements centred on strengthening the network between existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath.

	Option 3A 220 kV UGC)	Option 3B 400 kV UGC)	Option 3C 400 kV UGC (2 routes)
Technical Performance			
Economic Performance			
Deliverability			
Environmental			
Socio-economic			
Combined Performance			

Table 40 *Overall assessment outcome for the Underground cable options*

Having considered all of the five criteria, the outcome of the multi-criteria assessment indicates that Option 3A (a 220 kV UGC) will not perform very well overall. The option's performance for the technical criterion is of particular concern. Connecting the Woodland and Dunstown stations using a 220 kV voltage level will not support the network as effectively as the other options in transferring the electricity to where it is needed. It also does not solve some of the technical aspects as well as the other options. In addition, this option does not perform very well in some of the other criteria and hence has been given a high impact (**Dark Blue**) on its overall performance, the worst performance in terms of the colour scale used.

Having considered all of the five criteria, the outcome of the multi-criteria assessment indicates that Option 3B (a 400 kV UGC, one circuit constructed along one route) performs equally or better in all of the criteria compared with the other UGC options. Some of the criteria indicate challenges and risks and hence this option has been given a high to moderate (**Blue**) impact in its overall performance.

Having considered all of the five criteria, the outcome of the multi criteria assessment indicates that Option 3C (a 400 kV UGC, two circuits constructed along two routes) has the worst performance in three of the five criteria compared to the other options and hence has been given a high impact (**Dark Blue**) on its overall performance, the worst performance in terms of the colour scale used.

9 Conclusions

The Kildare Meath Grid Upgrade (Capital Project 966) is a proposed reinforcement of the electricity network between Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath. The project is in Step 3 of the six step approach that we use when we develop and implement a solution to any identified transmission network problem.

The project is essential to enable the further integration of renewable energy in line with Government policy ambitions. It will further be a key enabler in meeting the growing demand for electricity in the east region. The development involves a suite of transmission network reinforcements centred on strengthening the network between the existing Dunstown 400 kV station in County Kildare and Woodland 400 kV station in County Meath, and some dynamic reactive devices to support the voltage will also be required. The purpose of Step 3 is to decide on the Best Performing Option. In Step 3, there were five options investigated.

- Option 1: Up-voltage existing 220 kV OHL circuits;
- Option 2: New 400 kV OHL circuit;
- Option 3A: New 220 kV UGC circuit;
- Option 3B: 400 kV UGC: one circuit constructed along one route;
- Option 3C: 400 kV UGC: two circuits constructed along two separate routes

Each of these options has been assessed against the five criteria covering technical performance, economic performance, deliverability performance, environmental impacts and socio-economic impacts.

Based on the multi-criteria assessment, Option 1, the up-voltage option, is the Emerging Best Performing Option (EBPO). Option 3B, which is the emerging best performing alternative, does not perform as well as Option1 for three of the five criteria.

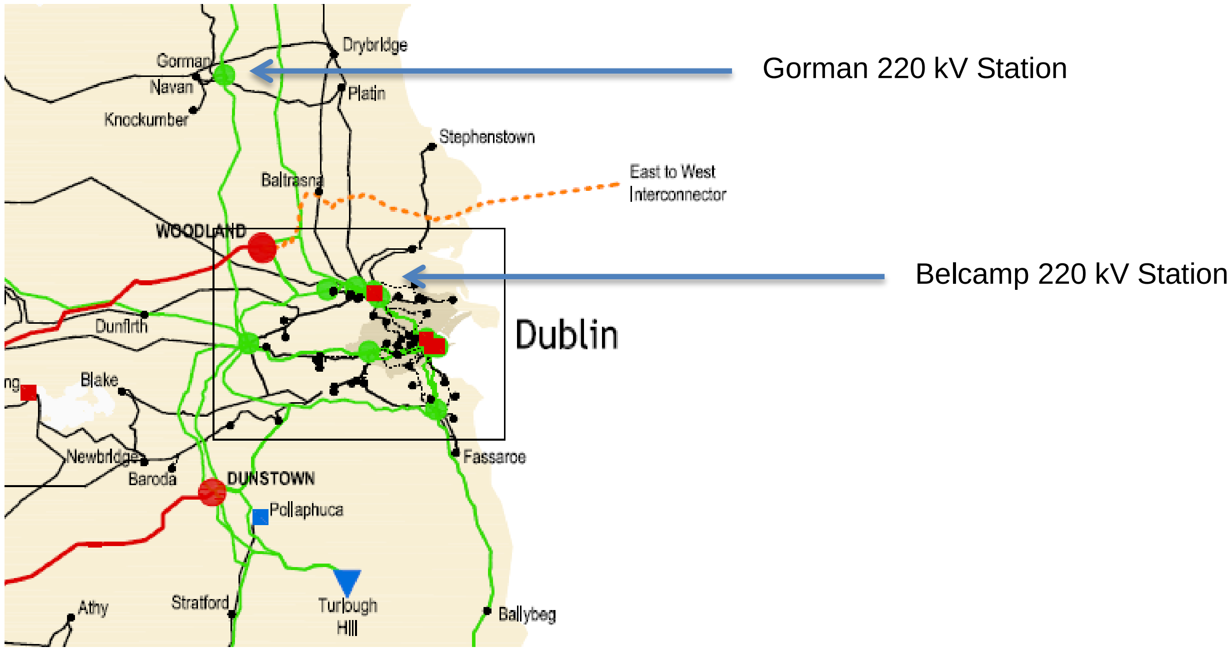
A period of public consultation will focus on the EBPO and the analysis that underpins it and the possible alternatives. All feedback received will be carefully considered before the Best Performing Option (BPO) or options are identified and taken forward to Step 4 for further investigations.

Appendix 1 – Transmission map showing stations locations

An extract of the transmission map is presented below. The entire map can be found on our website in the following link
http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-Transmission-Map-January-2020.pdf

Gorman 220 kV station is located in Causetown County Meath

Belcamp 220 kV station is located in north County Dublin along the R139. This station is relatively new and is not shown in the transmission map yet. The station's location is indicated for clarity.



Appendix 2 – Technical performance of options

Summary of technical performance all options					
	Option 1 Up-voltage option	Option 2 400 kV OHL option	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Health and Safety Standard compliance					
Security & Planning Standard compliance					
Reliability performance					
Headroom					
Expansion or Extendibility					
Repeatability					
Technical Operational risk					
Combined Technical Performance					

Appendix 3 – Economic performance of options

Summary of Economic performance all options 2020 values						
	units	Option 1 Up-voltage	Option 2 400 kV OHL	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Pre-Engineering Costs	[€M]	9.4	11.2	8.4	8.4	8.9
Project Implementation Costs	[€M]	239	168	372	356	679
Project Life-Cycle Costs (Losses)	[€M] pa	1.2	-0.529	-1.28	-1.28	-1.76
Project Life-Cycle Costs (O & M) Presented in period of years (1-20), (20-40), (40-50)	[€k] pa	0.84 0.458 0.14	0.42 0.524 0.86	0.96 0.259 0.96	0.129 0.252 0.129	0.244 0.491 0.244
Project Life-Cycle Costs (Decommissioning & Replacement)	[€M]	N/A	N/A	380.3	364.3	687.6
Cost to SEM based on unavailability of reinforcement (TES Scenario used)	[€M] pa	Range -3 to 13	Range 1 to 20	Range 0 to 16	Range 1 to 20	Range 1 to 21
Combined Economic Performance						

Summary of Economic performance all options 2020 values					
	Option 1 Up-voltage	Option 2 400 kV OHL	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Economic Result					
Robustness					
Combined Economic Performance					

Appendix 4 – Deliverability performance of options

Summary of Deliverability performance of all options					
	Option 1 Up-voltage option	Option 2 400 kV OHL option	Option 3A 220 kV UGC	Option 3B 400 kV UGC	Option 3C 400 kV UGC (2 routes)
Implementation timelines					
Project plan flexibility					
Risk of untried technology					
Dependence on other projects					
Supply chain constraints, permits, wayleaves etc.					
Combined Deliverability Technical Performance					

Appendix 5 – Environmental performance of options

Summary of Environmental performance of all options					
	Option 1 **Up-voltage option**	**Option 2** **400 kV OHL option**	**Option 3A** **220 kV UGC**	**Option 3B** **400 kV UGC**	**Option 3C** **400 kV UGC** **(2 routes)**
Biodiversity					
Soils and water					
Planning policy and land use					
Landscape and views					
Cultural heritage					
Combined Environmental Performance					

Appendix 6 – Socio-economic performance of options

Summary of Socio-Economic performance of all options					
	Option 1 **Up-voltage option**	**Option 2** **400 kV OHL option**	**Option 3A** **220 kV UGC**	**Option 3B** **400 kV UGC**	**Option 3C** **400 kV UGC** **(2 routes)**
Amenity and Health					
Local Economy					
Traffic and Transport					
Utilities					
Combined Socio-Economic Performance					