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## 4 TRANSMISSION AND TECHNOLOGY ALTERNATIVES

### 4.1 INTRODUCTION

- 1 EirGrid is obliged, pursuant to the terms of its licence as Transmission System Operator (TSO), to develop the electricity transmission system using cost effective, technically and environmentally acceptable solutions. This chapter sets out the context in which the main alternatives were considered by EirGrid for the proposed development and an indication of the main reasons for the final project chosen, taking into account the effects on the environment. It outlines the main transmission and technology alternatives considered by the respective applicants to meet the identified need set out in **Chapter 2** of this volume of the Environmental Impact Statement (EIS). It addresses the alternative technologies and methods for delivery considered appropriate for transmission interconnection design, capacity and circuit operation. The alternative route options for the proposed development are outlined in **Chapter 5** of this volume of the EIS.
- 2 This chapter also identifies the project objectives / design criteria required of the proposed development and considers and assesses the technology options including the form of electrical current (Alternating Current (AC) or Direct Current (DC)) and design (overhead line (OHL), underground cable (UGC) and off-shore submarine cable). It also considers the option of partial undergrounding - that is a combination of 400 kV AC UGC and 400 kV AC OHL (for this project) and alternative OHL support structures.
- 3 The consideration of transmission and technology alternatives as set out in this chapter has always been and will continue to be an ongoing activity in developing the transmission network. Of importance, it should be noted that the consideration of the alternative transmission and technology alternatives as set out in this chapter did not occur in a chronological format. For clarity, however, the various issues are set out under clear subject headings.
- 4 Where appropriate, reference is made to studies and reports which have informed EirGrid and Northern Ireland Electricity (NIE) in their consideration of transmission alternatives for the proposed project. In this context five studies were commissioned jointly by EirGrid and NIE or by Government to evaluate potential transmission alternatives specifically for the proposed project. A summary of these studies and their findings is included in this chapter. The overall process has also included reviews and updates to ensure that the conclusions drawn by EirGrid (in association with NIE) have been fully informed by the latest developments in worldwide power transmission technology and practice. A summary of these updates and reviews is also included in this chapter.

5 This chapter of the EIS also relies on the considerable body of work undertaken during the previous evaluation of the transmission and technology alternatives for the Meath-Tyrone 400 kV Interconnection Development application to An Bord Pleanála (the Board) for planning approval in 2009 (which was subsequently withdrawn) and the comprehensive re-evaluation of that portion of the proposed interconnector occurring within Ireland since the withdrawal of that previous application. This re-evaluation process (which is described in **Chapter 1** of this volume of the EIS) had regard *inter alia* to the findings of the International Expert Commission (IEC) who were appointed by the Minister for Communications, Energy and Natural Resources to:-

- Examine the case for, and cost of, undergrounding all or part of the Meath–Tyrone 400 kV line (now known as the North-South 400 kV Interconnection Development – the subject of this application); and
- Review expert literature already available both in Ireland and internationally in relation to undergrounding high voltage (HV) power lines.

6 The re-evaluation process included *inter alia* a review of the transmission and technology alternatives considered for the previous Meath-Tyrone Interconnection Development to ascertain whether they remain applicable for the proposed development and accordingly, it is relevant as background to this chapter. This work is detailed in the following publications:

- *North-South 400 kV Interconnection Development Preliminary Re-evaluation Report* (May, 2011);
- *North-South 400 kV Interconnection Development Final Re-evaluation Report* (April, 2013); and
- *North-South 400 kV Interconnection Development Preferred Project Solution Report* (July 2013).

7 A summary of these can be found in **Table 4.4**.

8 These reports are provided in **Volume 3B Appendices**. Other background / historic reports and reference material, particularly those published by or on behalf of EirGrid, referred to in this Chapter, are provided in **Volume 3B Reference Material**. The Bibliography at the end of this volume of the EIS identifies those reports and material included in **Volume 3B Reference Material**.

### 4.1.1 Legislative Context

9 Annex IV to the Environmental Impact Assessment (EIA) Directive and Schedule 6 of the *Planning and Development Regulations 2001* (as amended), both require that information to be contained in an EIS includes “*An outline of the main alternatives studied by the developer and an indication of the main reasons for his or her choice, taking into account the effects of the environment.*” In preparing this chapter of the EIS we have referred to the *Guidelines on the information to be contained in Environmental Impact Statements* (March 2002), *Advice Notes on Current Practice* (in the preparation of Environmental Impact Statements) (September 2003), published by the Environmental Protection Agency (EPA) and the *Guidelines for Planning Authorities and An Bord Pleanála on carrying out Environmental Impact Assessment* (2013). (Additional specialist EIA guidance documents are referenced throughout this EIS).

10 Paragraph 2.4.3 of the *Guidelines on the information to be contained in Environmental Impact Statements*, notes that it is important to acknowledge the existence of difficulties and limitations when considering alternatives. These include:

*“Hierarchy*

*“EIA is only concerned with projects. Many projects, especially in the area of public infrastructure, arise on account of plans, strategies and policies which have previously been decided upon. It is important to acknowledge that in some instances neither the applicant nor the competent authority can be realistically expected to examine options which have already been previously determined by a higher authority (such as a national plan or regional programme for infrastructure or a spatial plan).*

*Non Environmental Factors*

*EIA is confined to the environmental effects which influence the consideration of alternatives. It is important to acknowledge that other non-environmental factors may have equal or overriding importance to the developer, e.g. project economics, land availability, engineering feasibility, planning considerations.”*

*Site-Specific Issues:*

*The consideration of alternatives also needs to be set within the parameters of the availability of land (it may be the only suitable land available to the developer) or the need for the project to accommodate demands or opportunities which are site specific. Such considerations should be on the basis of alternatives within a site e.g. design and layout.”*

11 These matters are of relevance to the proposed development. In relation to the strategic matter of determined policy, reference is made to EirGrid plans and strategies including *Grid25 – A*

*Strategy for the Development of Ireland's Electricity Grid for a Sustainable and Competitive Future (2008)* and its subsequent reviews, *Grid25 Implementation Programme 2011-2016* (which was the subject of a Strategic Environmental Assessment (SEA)) and the *Transmission Development Plan 2013-2023* (and environmental appraisal report which assesses the draft plan against the provisions of the Grid25 Implementation Programme 2011 – 2016 SEA). In addition, the *National Spatial Strategy 2002-2020*, the *National Development Plan 2007-2013*, the *Border Regional Authority Planning Guidelines 2010-2020*, the *Regional Planning Guidelines for the Greater Dublin Area 2010-2022*, and the Monaghan, Cavan and Meath County Development Plans have recorded strong energy policies in support of projects to generally deliver high voltage electrical infrastructure and future corridors for energy transmission. Strategic and Statutory policy also records strong energy policies in support of projects linking the electricity transmission systems of Ireland and Northern Ireland. Other policies such as reducing dependence on fossil fuels, accelerating the growth of electricity by renewable sources and achieving EU-wide targets for renewable energy by 2020, all point to a determined policy context within which the consideration of this Interconnector project is merited. (Refer to the *Planning Report, Volume 2A* of the application documentation for details of this policy context).

- 12 With regard to non-environmental factors, as described by the EPA, a central aspect of material relevance to the proposed project is the EU led requirement to establish a Single Electricity Market (SEM) (refer to **Chapter 2** of this volume of the EIS). Interconnector projects are considered crucial to secure both the commercial capacity and the security of the transmission network. The proposed second interconnector will have the strategic benefits of improving market competition in the context of the SEM, of supporting the development of renewable power generation, and of improving security of supply.
- 13 On the matter of site specific issues, and as per the guidance of the EPA, varying configurations of feasible route corridor options for the proposed second interconnector were mapped and assessed (refer to **Chapter 5** of this volume of the EIS).
- 14 The EPA report, *Advice Notes on Current Practice (in the preparation of Environmental Impact Statements)* (2003), elaborate on the manner of presentation as to 'Alternatives Considered' in an EIS. Specifically the report states that:

*"Alternatives, where relevant, may be described at three levels indicating the main reasons for choosing the proposed development. These consider alternative locations, designs and processes."*

#### 4.1.2 Outline of Main Alternatives Considered

- 15 The consideration of the main alternatives in respect of the proposed development was undertaken jointly by the respective applicants and has occurred throughout an extensive and coordinated decision-making process, over a considerable period of time. The main alternatives considered relate to transmission, technological and route alternatives.
- 16 The main alternatives considered for the proposed development, and where they are addressed in the EIS, are identified in **Table 4.1**.

**Table 4.1: Consideration of the Main Alternatives**

Alternative	Context	EIS Chapter
<b>Designs</b>	<p>A number of different solutions are available for most design issues such as varying the site layout, building massing or location of facilities. Where designers are briefed at an early stage about environmental factors, these can usually be incorporated along with other design parameters.</p> <p>For the proposed development, the consideration of alternative designs focuses on Transmission and Technology Alternatives relating to the character and physical form of the planned transmission infrastructure, including alternative tower design.</p>	Chapter 4 of Volume 3B
<b>Locations</b>	<p>Some locations have more inherent environmental problems than others. Such sites can usually be avoided in favour of sites which have few constraints and the maximum capacity to sustainably assimilate the development.</p> <p>For the proposed development, the consideration of alternative locations focuses on Route Alternatives relating to the identification of the route alignment.</p>	Chapter 5 of Volume 3B
<b>Processes</b>	<p>Within each design solution there can be a number of different options as to how the process or activities of the development can be carried out. These can include management of emissions, residues, traffic and the use of natural resources. Consideration of environmental factors can influence the selection of processes which avoid adverse impacts.</p> <p>For the proposed development, the consideration of alternative processes will focus on the environmental</p>	Chapters 2-14 of Volumes 3C and 3D

Alternative	Context	EIS Chapter
	topics considered and will comprise the description and analysis of impacts on specific environmental topics and suggested mitigations measures.	

## 4.2 DO NOTHING ALTERNATIVE

- 17 It is best practice in Environmental Impact Assessments (EIA) to consider the ‘Do Nothing’ alternative – i.e. where no development occurs. Under a ‘Do Nothing’ alternative, the strategic transmission infrastructure and its associated development would not be constructed. The land upon which such development is proposed to occur – primarily comprising agricultural land - would remain unchanged (unless developed for some separate purpose). As a consequence, the environmental impacts, identified in this EIS, positive and negative, would not occur.
- 18 Furthermore, under a ‘Do Nothing’ scenario, there would remain a single interconnector between the transmission systems of Ireland and Northern Ireland, with consequent limitations, as set out at **Chapter 2** of this volume the EIS. Of particular note, there would remain an inherent risk of system separation, requiring a constraint on the total transfer capacity available on the existing interconnector. This would serve to frustrate the operation of the SEM, as per the Single Electricity Market Directive (2003/54/EC); it would also significantly frustrate current Government targets for 40% of National electricity consumption from renewable sources by 2020. The ‘Do Nothing’ scenario would also fail to offset the likely environmental impact of any alternative options to secure the future reinforcement of the transmission infrastructure in the north-east area of Ireland.
- 19 Having regard to all of the above, the ‘Do Nothing’ alternative is not considered to be appropriate.

## 4.3 STRATEGIC NEED

- 20 **Chapter 2** of this volume of the EIS sets out the ‘case for need’ for the proposed interconnector and shows that there are three key drivers for the proposed interconnector:
- i. Improving all-island electricity market competition;
  - ii. Improving the security of supply; and
  - iii. Supporting the development of renewable generation.

- 21 The proposed interconnector is being developed jointly by the respective applicants in response to all three of these fundamental and inter-related strategic needs.

## 4.4 ALTERNATIVES TO TRANSMISSION NETWORK SOLUTIONS

### 4.4.1 Context

- 22 The 'all-island' Single Electricity Market (SEM) structure has been designed to separate the electricity supply chain into three fundamental parts:

- Power generation (production);
- Electricity transmission and distribution (delivery); and
- Electricity supply (retail sales).

- 23 This market structure relies fundamentally upon the transmission and distribution network infrastructure to link the sources of electricity production to the points of electricity demand. The owners and operators of the networks on the island of Ireland are required, under their respective Licences, to provide generators and suppliers with effective and efficient pathways for the delivery and sale of electricity to electricity users, if the cross-border transmission network is not developed, the following considerations become relevant.

### 4.4.2 Transmission System Limitations and Consequences

- 24 The existing Louth-Tandragee 275 kV double circuit OHL forms the primary existing interconnection pathway between Northern Ireland and Ireland, but further and more effective interconnection arrangements are required to meet the three strategic objectives listed in **Section 4.3**.

- 25 Due to the fact that both of the existing 275 kV interconnection circuits are supported on the same set of structures, there is a real risk that they could both be forced out of service simultaneously by a single event. Such a loss of interconnection would bring about an electrical separation of the transmission networks in Northern Ireland and Ireland and depending upon the operating conditions at the time, could lead to widespread outages of electricity supply and the potential collapse of the importing transmission network.

- 26 The risk of such an event is unacceptable, and for this reason the TSO currently impose a transfer capacity restriction on the existing Interconnector. This ensures that if there is a

sudden loss of the interconnector, the shock to the network is limited to a level that can be managed without widespread black-outs.

- 27 Without additional interconnecting circuits the risk of system separation will continue, and consequently any potential benefit from increased rated capability for power transfer of the existing 275 kV or 110 kV lines could not be realised i.e. through conductor replacement or new power flow management devices.
- 28 The restriction described creates a 'bottleneck' in the network, seriously limiting the scope for commercial exchanges of electricity between generators and suppliers in each part of the all-island electricity market, and leading to inefficiencies and costs that are passed through to final customers as part of their electricity prices.
- 29 Another issue of increasing concern, as more fully explained in **Chapter 2** of this volume of the EIS, is that future reductions in generation capacity within Northern Ireland could lead to a shortfall in available electricity supply north of the border in the years beyond 2016. In these circumstances, the 'bottleneck' described, which limits the ability of the network to transfer electricity from available spare power generation capacity in the south, could seriously threaten electricity supply security in Northern Ireland.

#### **4.4.3 Potential Alternatives for Addressing the Emerging Shortfall in Generation Capacity in Northern Ireland**

##### **4.4.3.1 Potential Alternative: New Conventional Generation in Northern Ireland**

- 30 One measure to reduce the impact of the transmission capacity restrictions described could be to build further generation in Northern Ireland.
- 31 It is conceivable that a new conventional generation plant constructed in Northern Ireland would improve security of supply issues in the medium term; however, it must be recognised that investment in new generation is at the discretion of independent commercial ventures, and market forces have not produced any proposal for new conventional generation to date.
- 32 Enforcing the construction of a new power station to improve security of supply in Northern Ireland could not be achieved without creating fundamental distortions in the SEM. Such distortions would, in their turn, have a consequential adverse impact on other existing generators, further jeopardising future investment in generation.



33 It should also be noted that this solution to electricity security concerns would not address either of the other two primary strategic needs, i.e. improving market competition or enabling the increased use of renewable energy.

34 The addition of further power generation capacity in Northern Ireland, without addressing the need to transfer and exchange power flows across the border, would further exacerbate distortions in the electricity market, and would perpetuate conditions in which all-island electricity prices would remain higher than necessary.

#### **4.4.3.2 Potential Alternative: Longer Life for Existing Conventional Generation in Northern Ireland**

35 The generation shortfall in Northern Ireland is exacerbated by European emission restrictions that are precipitating the closure of its existing generation before its mechanical end-of-life. It is possible that the security of supply shortfalls described in **Chapter 2** of this volume of the EIS could be deferred for a period by the introduction of time limited derogations such that certain generators may be able to continue to operate for a longer period of time. However, such a move would introduce significant market costs and would prolong elevated environmental emissions associated with the use of older plant. At best, it would also be a short term market solution, and would not therefore remove the need for additional interconnection.

36 It should also be noted that this potential solution to electricity security concerns would not address either of the other two primary strategic needs, i.e. improving market competition or enabling the increased use of renewable energy.

37 The life-extension of additional conventional generation in Northern Ireland, without addressing the need to transfer and exchange power flows across the border, would extend conditions in which all-island electricity prices would remain higher than they should be.

#### **4.4.3.3 Potential Alternative: Increased Dependence on Renewable Energy**

38 Whilst there are ambitious plans for onshore and offshore renewable generation to connect in Northern Ireland and Ireland in future years, the intermittent nature of wind, wave or solar generation precludes it from being relied upon for secure electricity supplies in the way that conventional power stations are. The future connection of renewable sources of electricity generation would therefore not remove the need for a level of access to conventional generation in the SEM to supply NI electricity needs.

39 It is also important to note that investment proposals for renewable energy projects invariably depend upon an expectation that there will be a network pathway to transport the electricity

produced to a party that wishes to purchase and use that electricity. If there is no development of increased interconnection capacity between Northern Ireland and Ireland, and there are therefore continuing restrictions in access to the all-island network, then these restrictions will continue to limit the viability of investment cases for renewable energy, and will therefore limit the number of such developments that can be achieved in reality.

#### 4.4.3.4 Conclusion on Non-Transmission Network Solutions

40 It is considered that to achieve the objectives listed in **Section 4.3** whilst avoiding the security of supply, economic and environmental risks discussed, there is no feasible or desirable alternative to the development of a transmission network solution. The only way to meet the strategic needs described in **Chapter 2** of this volume of the EIS whilst also delivering a downward pressure on electricity prices is to enhance the transmission interconnection capacity between Ireland and Northern Ireland.

## 4.5 PROJECT OBJECTIVES / DESIGN CRITERIA

41 In assessing technical alternatives for the design and construction of the proposed interconnection infrastructure, it is necessary to acknowledge the need for a technical solution that ensures a transmission system that, although connecting two separately owned systems within two separate jurisdictions, will be operated as an integrated transmission system and which will service a single integrated market in which operational constraints are minimised.

42 It is also a requirement of this development that the new interconnector connects between appropriately robust points on the transmission networks north and south of the border and that it be physically remote from the existing north-south interconnector. This strategic technical consideration, which has implications for the choice of study area, is addressed in **Chapter 5** of this volume of the EIS.

43 Transmission alternatives were therefore considered against a number of key performance objectives which must be achieved regardless of the particular technological alternative that is actually employed. These objectives derive from the overall performance requirements of the proposed interconnector as described in **Chapter 2** of this volume of the EIS, and also from EirGrid's statutory obligations.

44 The objectives and / or design criteria for the proposed development are to:-

- a) Comply with all relevant safety standards;
- b) Comply with all system reliability and security standards;

- c) Provide an environmentally acceptable and cost effective solution;
- d) Have a power carrying capacity in the region of 1,500MW, and connect between appropriately robust points on the transmission networks north and south of the border;
- e) Facilitate future reinforcement of the local transmission network in the north-east area;
- f) Facilitate future grid connections and reinforcements; and
- g) Comply with 'Good Utility Practice'<sup>31</sup> or 'best international practice'.

45 EirGrid's statutory obligations are noted in the recent *Government Policy Statement on the Strategic Importance of Transmission and Other Energy Infrastructure* (July 2012) where it states that:

*"The State network companies are mandated to plan their developments in a safe efficient and economic manner. They are also required to address and mitigate human, environmental and landscape impacts, in delivering the best possible engineering solutions.*

*The major investment underway in the high voltage electricity transmission system under EirGrid's Grid 25 Programme is the most important such investment in Ireland's transmission system for several generations.*

*While the Government does not seek to direct infrastructure developers to particular sites or routes or technologies, the Government endorses, supports and promotes the strategic programmes of the energy infrastructure providers, particularly EirGrid's Grid 25 investment programme across the regions, and reaffirms that it is Government policy and in the national interest, not least in the current economic circumstances that these investment programmes are delivered in the most cost efficient and timely way possible, on the basis of the best available knowledge and informed engagement on the impacts and the costs of different engineering solutions". (p.6)*

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<sup>31</sup>In this Chapter of the EIS the terms 'Good Utility Practice' and 'best international practice' are interchangeable. The term 'Good Utility Practice' is widely recognised and adopted as a policy, either voluntarily or by regulation, within the industry. The principle behind good utility practice is that electric utilities will adopt the practices and methods of a significant portion of utilities within a specified geographic boundary. In the case of EirGrid the relevant utilities are the 41 members of ENTSO-E (European Network of Transmission System Operators for Electricity) that are drawn from 34 countries in Western Europe.

It should also be noted that compliance with good utility practice does not preclude the use of innovative practices, methods or technologies; however, when such innovative practices, methods or technologies are under consideration, the accompanying risk of failure and consequence of such failure must also be considered.

46 The project objectives / design criteria outlined guide the consideration and assessment of the alternative technology options for the proposed interconnector. It is within this context that the application of “*the best available knowledge and informed engagement on the impacts and the costs of different engineering solutions*” will ensure compliance with the Government Policy Statement.

#### 4.6 SPECIFIC STUDIES COMMISSIONED BY THE RESPECTIVE APPLICANTS ON ALTERNATIVE TRANSMISSION TECHNOLOGIES

47 The respective applicants have worked together over many years to jointly consider and assess the various technological alternatives available for the proposed second interconnector. In order to ensure that the development process was fully and properly informed with respect to the available technological alternatives (notwithstanding the initial presumption that OHL would represent a superior solution and that an acceptable OHL route could be identified for the proposed interconnector) the respective applicants jointly commissioned five studies to evaluate potential transmission alternatives specifically for the proposed interconnector. The main objective of the studies was to inform both companies about the latest available alternative transmission technologies, and also to assist the on-going consultative and planning processes relevant to the overall project as applicable to elements being proposed within each jurisdiction.

48 Four of these studies were informed by specific data on the actual technical characteristics of the transmission systems within each jurisdiction on the island of Ireland and by reference to the geographic locations and prospective routes applicable to the required transmission circuits. The studies were:

- **The PB Power Preliminary Briefing Note** (Parsons Brinckerhoff, Power Division [PB Power], 2008). A short report, published at an early stage in the project development process, drawing upon generic information to summarise in general terms the technical and cost issues associated with implementing the proposed transmission circuit.
- **The PB Power Study** (PB Power, 2009). A thorough report describing the conclusions drawn from a detailed study by PB Power following the publication of the Preliminary Briefing Note. The study was specific to the proposed project, and compared a high voltage OHL transmission option with UGC options utilising either HVAC or HVDC technologies.
- **The TEPCO Study** (TEPCO, 2009). A system wide study that considered the implications, for transmission system reliability and stability, of incorporating very long lengths, and large quantities, of High Voltage (HV) UGC transmission infrastructure on the all-island AC transmission network. The study was performed by Tokyo Electric Power Company of Japan (TEPCO) who, as owner and operator of the world’s longest

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existing UGC circuit operating at a voltage of 400 kV or above, is uniquely placed to bring its specific experience to bear on the subject.

- **The TransGrid Study** (TransGrid, 2009). A system wide study that considered the implications for transmission system reliability and stability of incorporating HVDC circuits into the integrated all-island AC transmission network. This study was performed by TransGrid Solutions (of Winnipeg, Canada), a consultancy with extensive international experience in the evaluation of HVDC technology. The study included specifically an examination of the viability of using this technology for a second north-south interconnector.
- **The PB Power Technology and Costs Update** (PB Power, April 2013 and Supplementary Note July 2013). A report summarising the results of a further study carried out to update the information provided in the *PB Power Study* of 2009. This report includes a review of up to date technology and application developments worldwide. It also draws upon information and conclusions published within a number of recent relevant studies (including the IEC Report of 2012) into the subject of transmission technology alternatives. A key output from the updated study has been to provide up to date comparative costs for the identified alternatives.

49 The objectives of each of these studies, and the conclusions set out in each of the associated reports, are described in further detail in **Table 4.2**. A copy of each report is provided in **Volume 3B Reference Material**.

**Table 4.2: Reports on Alternative Transmission Technologies Commissioned Jointly by the Respective Applicants**

Report Title	Context of Report	Main Findings / Observations of Report
<p><b>PB Power Preliminary Briefing Note - Island of Ireland Cavan-Tyrone and Meath - Cavan 400 kV projects Preliminary Briefing Note Overhead and Underground Energy Transmission Options</b></p> <p>Prepared by Parsons Brinckerhoff this was issued as an interim report</p> <p><b>February 2008</b></p>	<p>The <i>Preliminary Briefing Note</i> sets out a comparative overview of the technical and economic issues arising in respect of OHL and UGC transmission infrastructure options, with particular reference to the proposed Tyrone to Cavan element of the proposed interconnector. The document notes that both OHL and UGC technologies are proven in service, but includes a number of observations.</p> <p>The Briefing Note focused primarily on HVAC technology. The document did not include a review of HVDC technology because, at this early stage in the project, it appeared that the high land-take and high costs of terminal stations would not offer any benefits over the AC solutions.</p>	<p>UGC technology has not yet been tried anywhere in the world for an appropriate transmission infrastructure circuit approaching the route length of that proposed.</p> <p>HVAC OHL technology accounts for over 99% of Extra High Voltage (EHV) transmission infrastructure worldwide as it is considered to represent the best balance from an economic, technical and environmental perspective.</p> <p>UGC technology is noted to play an important role in urban and congested areas, or where site specific environmental constraints occur, for example within an area of outstanding scenic beauty.</p> <p>UGC technology is significantly more expensive than OHL technology. There can be considerable variation in cost ratios dependent upon the terrain and the circumstances.</p> <p>The Briefing Note stated that further work would be undertaken to examine the specific feasibility issues relevant to the prospect of undergrounding the proposed interconnector.</p>
<p><b>The PB Power Study - Cavan-Tyrone and Meath-Cavan 400 kV Transmission Circuits Comparison of high-voltage transmission options: Alternating current overhead and underground, and direct current underground</b></p> <p>Prepared by Parsons Brinckerhoff</p>	<p>This study considers use of alternative technologies for the proposed interconnector. It makes two sets of comparisons:</p> <ul style="list-style-type: none"> <li>• HVAC UGC as an alternative to the proposed HVAC OHL; and</li> <li>• HVDC UGC as an alternative to the proposed 400 kV HVAC technology.</li> </ul> <p>In each case the comparison of the technologies addresses routing feasibility, high-level environmental considerations, and the installation and cost differences</p>	<p>HVAC OHL transmission is the most widely used method of bulk power transfer in Europe and represents the lowest cost technically feasible approach to establishing and maintaining a secure electrical power grid.</p> <p>Global transmission development activity suggests that this preference by utilities for the use of OHLs is likely to persist into the future.</p> <p>The longest XLPE transmission cable (in the range 380 kV to 500 kV) is 40km and runs in a tunnel. If implemented using AC UGC the proposed interconnector would be the longest such cable circuit worldwide at approximately 135km.</p> <p>HVAC OHLs are susceptible to environmental effects and thus normally exhibit fault rates higher than those of UGC circuits. However, average repair times of UGC are</p>

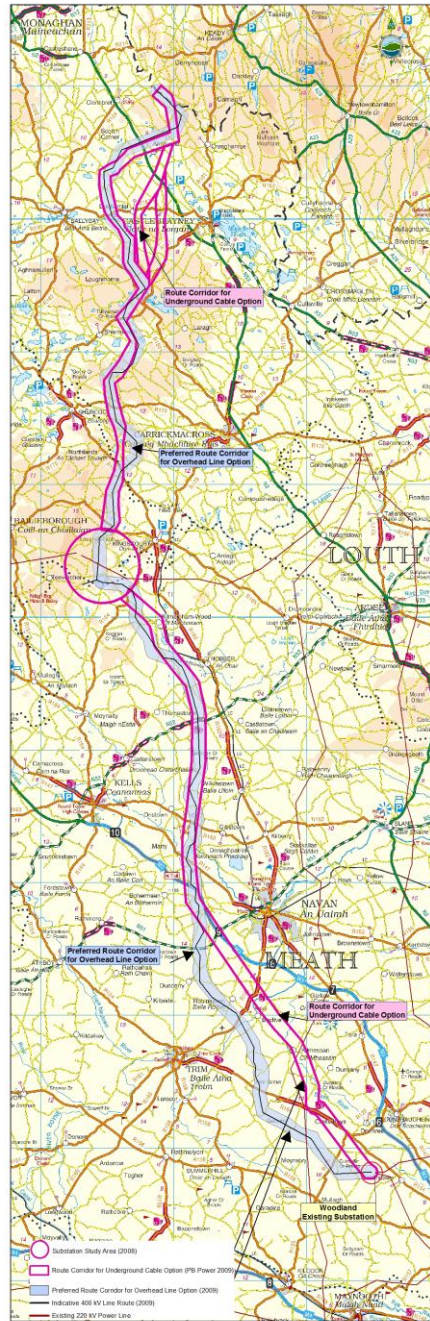
Report Title	Context of Report	Main Findings / Observations of Report
<p><b>February 2009</b></p>	<p>that would be associated with the alternatives.</p>	<p>much higher than those of OHL.</p> <p>High voltage UGC has the capacity to inflict considerable short term (construction period) and long term operational negative impact on the environment - however, mitigation measures can be put in place.</p> <p>Both high voltage OHL and UGC produce power frequency magnetic fields whose strengths would be directly proportional to the electrical load being carried at any instant.</p> <p>The insertion of a HVDC transmission circuit into the HVAC transmission network would introduce more system complexity than an HVAC OHL.</p> <p>Cost estimates for each option were calculated.</p> <p>The construction cost estimate for the UGC option was calculated by firstly identifying a potential route for the UGC alternative from County Meath to County Tyrone (See <b>Figure 4.1</b>); then identifying the different types of landscape along this route as well as all rivers and roads that would have to be crossed; then calculating a cost per km per landscape type, a cost per major and per minor river and road crossing and using this data to build up a cost for installing UGC along the entire route.</p> <p>The cost of the OHL option was calculated by estimating a cost per km for 400 kV OHL (based on PB Power's international experience) and multiplying this by the length of the OHL in kilometres.</p> <p>Whole-of-project cost estimates (construction and lifetime running costs) for high voltage AC and DC UGC compared to 400 kV OHL shows OHL to be significantly more cost effective.</p>

Report Title	Context of Report	Main Findings / Observations of Report
<p><b>The TEPCO Technical Study</b> <i>Assessment of the Technical Issues relating to Significant Amounts of EHV Underground Cable in the All-Island Electricity Transmission System</i></p> <p>Prepared by Tokyo Electrical Power Company of Japan (TEPCO)</p> <p><b>November 2009</b></p>	<p>The respective applicants jointly commissioned TEPCO to undertake a system-wide study that considers the implications, for transmission system reliability and stability, of incorporating very long lengths, and large quantities, of HV UGC transmission infrastructure on the AC transmission network of the island of Ireland.</p> <p>The Study was carried out in 3 parts:</p> <p>Part 1: Evaluation of the potential impact on the all-island transmission system of significant lengths of EHV UGC, either individually or in aggregate.</p> <p>Part 2: Feasibility study on the 400 kV Woodland – Kingscourt – Turleenan line as AC UGC for the entire length.</p> <p>Part 3: Feasibility study of the 400 kV Woodland – Kingscourt – Turleenan line as mixed OHL / UGC.</p>	<p>The study concludes:</p> <p>Part 1: Identified a potential for the occurrence of ‘severe’ Temporary Overvoltage’s (TOVs) which would exceed the withstand capability of the installed equipment. The Study concludes that the magnitude of these TOV’s is such that there are no technical solutions currently available to mitigate this risk and the only option available would be to use operational counter measures.</p> <p>Part 2: To achieve the required 1,500MW capacity, the optimum UGC solution is a 400 kV double circuit 1,400mm<sup>2</sup> aluminium cable - requiring a total of 2,600MVARs (1,300MVARs per circuit) of reactive compensation would be required at the proposed terminal points and an additional reactive compensation installation approximately half-way between Turleenan and Moyhill (Kingscourt).</p> <p>Part 3: No significant TOVs were identified for the mixed OHL / UGC. However, further detailed studies relating to the particular positions and lengths of cable sections in order to determine the measures that may be taken to ensure safety and stability from the overall circuit would be necessary.</p>
<p><b>The TransGrid Study</b> - <i>Investigating the Impact of HVDC Scheme in the Irish Transmission Network</i></p> <p>Prepared by TransGrid solutions Inc. of Canada</p> <p><b>October 2009</b></p>	<p>The study involved a technical comparison of HVAC OHL versus HVDC UGC and one section dealt in particular with the proposed Meath-Tyrone 400 kV Interconnection Development.</p>	<p>There are no working examples in the world of a multi-terminal HVDC scheme, embedded in a meshed AC network as would be required for the proposed Meath-Tyrone Interconnection Development. Such a scheme is however in theory at least, technically feasible.</p> <p>Having carried out a technical comparison of HVDC versus HVAC technology for this proposed development it was found that there are no significant reasons to select HVDC over HVAC. The AC option showed significantly lower losses, fewer overloads in the Louth / Tandragee / Turleenan area, a stronger system at the Moyle Interconnector terminal and a less complex control and protection scheme.</p> <p>Embedding a HVDC circuit in a meshed AC network “<i>can impose an added complexity</i>”</p>



Report Title	Context of Report	Main Findings / Observations of Report
		<p><i>to future network planning and expansion. For instance when planning the system it is difficult and expensive to tap into an existing HVDC circuit whereas an AC circuit can be easily tapped to serve new load or build a new AC station and lines.”</i></p> <p>A technical comparison of the two technologies (HVAC and HVDC) concluded that, for the scenarios and contingencies studied, there were no significant technical advantages identified for the use of a HVDC circuit in place of the HVAC circuit proposed.</p>
<p><b>The PB Power Technology and Cost Update - Comparison of High Voltage Transmission Options: Alternating Current Overhead and Underground and Direct Current Underground</b></p> <p>[This is an addendum to the 2009 PB Power Study and should be read in conjunction with that 2009 report]</p> <p><b>April 2013</b></p>	<p>EirGrid and NIE requested PB Power to update their 2009 report to take account of scientific advances in the development of new, feasible transmission technologies, and also to review the cost estimates for practical transmission configurations. The updated PB Power Report does not revisit the landscape aspects and most of the technical aspects as these remain unchanged.</p> <p>The <i>PB Power Electricity Transmission Costing Study</i> published in 2012 by the UK Department of Energy and Climate was used as a source of information for the technology and cost update.</p>	<p>The most cost effective solution for the proposed scheme would be a 400 kV AC OHL, estimated to cost around €165 million to construct</p> <p>A 400 kV AC UGC is estimated to cost €935 million, or over 5.7 times as much as an equivalent OHL to construct, and would also cost significantly more than an OHL to operate and maintain over its lifetime.</p> <p>A HVDC UGC is estimated to cost €1,005 million, or 6 times as much as an equivalent 400 kV AC OHL to construct, and twice as much as an OHL to operate and maintain over its lifetime.</p>

Report Title	Context of Report	Main Findings / Observations of Report
<p><b>The PB Power Technology and Cost Update – Cavan-Tyrone &amp; Meath-Cavan 400 kV Transmission Circuits Technology and costs Update.</b></p> <p><i>Supplementary Note to the April 2013 Addendum</i></p> <p><b>July 2013</b></p>	<p>In April 2013 EirGrid published its <i>Final Re-evaluation Report</i> and at the same time announced its decision to defer the previously proposed intermediate substation near Kingscourt, Co. Cavan. A consequence of the deferment of this substation, regardless of which technology option is chosen, is that it would reduce the initial investment required to develop the interconnector so EirGrid requested PB to provide, in a supplementary note, an indication of the impact of the deferment on the initial investment.</p>	<p>The most cost effective technology option remains a 400 kV AC OHL, estimated to cost around €140 million.</p> <p>With the deferment of Kingscourt, 400 kV AC UGC becomes the most costly option, estimated at around €880 million, or €740 million more than the equivalent AC OHL. The deferment of Kingscourt has little or no impact on the cost differential with the AC OHL as similar costs are deferred in the case of both options.</p> <p>The deferment of the substation near Kingscourt will however have a significant impact on the initial investment required to develop the HVDC option. This is due to the very high cost of HVDC converters, and the fact that, with the deferment, converters would only be required initially at Turleenan and Woodland not Kingscourt. Under this scenario, the HVDC option, at an estimated cost of around €810 million, is no longer the most costly option. It is still, however, €670 million more costly than the least cost option, the 400 kV AC OHL.</p> <p>The initial investment cost of the HVDC option is reduced, due to the deferment of the substation near Kingscourt, by around €160 million (€970M - €810M), whilst the initial investment costs of the two AC options are only reduced by around €20 - €25 million. The disparity of the effects on the AC and HVDC options highlights one major disadvantage of the HVDC option for the Ireland N-S Link. This is that, if the N-S Link is developed using HVDC technology, future ‘tap-ins’ to the circuit for the substation near Kingscourt and / or for some other (as yet unknown) requirement at some other location along the route, will be many times more expensive than tapping into an AC circuit.</p>



**Figure 4.1: Composite Map showing UGC Corridor from Woodland to border (PB Power - 2009) and the Preferred OHL Corridor<sup>32</sup>**

[This map is also provided in A3 format in **Volume 3B Figures**]

<sup>32</sup> In 2009 PB Power identified a potential route corridor for high voltage underground cable. The UGC corridor was compared with the 2009 OHL corridor which is broadly the same as the 2013 OHL corridor. The potential UGC route was identified by PB Power for the purposes of developing a well-informed cost estimate for UGC.

#### 4.6.1 Further Specific Technical Studies and Reports of Direct Relevance to the Proposed Interconnector

50 There are two other technical studies of relevance, which were specifically focused on the proposed interconnector. These are:

- **The Ecofys Study** (Department of Communications, Energy and Natural Resources (DCENR) 2008). *A Study on the Comparative Merits of Overhead Electricity Transmission Lines Versus Underground Cables*, carried out by Ecofys on behalf of the Department of Communications, Energy and Natural Resources.
- **The International Expert Commission (IEC) Report** (2012). A review of the case for, and cost of, undergrounding all or part of the Meath–Tyrone 400 kV line (now known as the North-South 400 kV Interconnection Development – the subject of this application for planning approval).

51 The objectives of these studies, and the conclusions set out in each of the associated reports, are described in further detail in **Table 4.3**. A copy of each report is provided in soft copy as part of the Bibliography for this volume of the EIS.

**Table 4.3: Other Reports Prepared on Alternative Transmission Technologies**

Report Title	Context of Report	Main Findings / Observations of Report
<p><b>The Ecofys Study - Study on the Comparative Merits of Overhead Electricity Transmission Lines versus Underground Cables</b></p> <p>Prepared by Department of Communications, Energy and Natural Resources (DCENR)</p> <p><b>May 2008</b></p>	<p>The aim of the study was to provide the best available professional advice on the relative merits of constructing and operating OHL compared to UGC, having regard to technical characteristics, reliability, operation and maintenance factors, environmental impact, possible health issues, and cost.</p>	<p>Globally the vast majority (approximately 99.5%) of UGC is generally used in areas of high population density or high land values – generally urban areas - where it is difficult to find suitable OHL routes.</p> <p>International experience shows that extra high voltage (EHV) UGC is generally not used for any great distance, e.g. the longest such UGC is in Tokyo and is only 40km in length.</p> <p>Whilst decisions may be taken to underground lower voltage networks of distribution systems, this is not normally applied to the higher voltage networks of transmission systems, as the technology involved is substantially different and more demanding.</p> <p>Both EHV UGC and OHL are found to have an environmental impact but these impacts are different for the different technologies, and in most cases mitigation measures are available, e.g. UGC has a greater impact on water resources and soils and geology, whereas OHL has a greater impact on Landscape and Visual and Communities.</p> <p>The study distinguishes between the perceived health risks associated with Electro-Magnetic Fields (EMF) and actual health risks associated with EMF and cites the International Commission of Non-Ionising Radiation Protection (ICNIRP) recommendation.</p> <p>The study concludes that the construction and operation of an EHV UGC in Ireland with a length of 100km would not be backed by worldwide experience. Mitigation measures are proposed to reduce the potential impact of the planned Interconnector on the environment.</p>

Report Title	Context of Report	Main Findings / Observations of Report
<p><b>The IEC Report - Meath- Tyrone Report Review by the International Expert Commission August – November 2011. (A review of the case for, and cost of undergrounding all or part of the Meath-Tyrone 400 kV Interconnection Development.)</b></p> <p>Prepared by Normak B., et al.</p> <p><b>November 2011</b></p>	<p>In July 2011 the Minister for Communications, Energy and Natural Resources appointed the IEC to:-</p> <p>Examine the case for, and cost of, undergrounding all or part of the Meath–Tyrone 400 kV line (now known as the North-South 400 kV Interconnection Development – the subject of this instant application);</p> <p>Review expert literature already available both in Ireland and internationally in relation to undergrounding high voltage [HV] power lines;</p> <p>Consider the route or routes proposed by EirGrid (see <b>Figure 4.1</b>); and</p> <p>Consult with EirGrid, the North East Pylon Pressure Committee and the County Monaghan Anti-Pylon Committee, and other bodies / organisations.</p>	<p>The main findings of the report are as follows:-</p> <p>Based on an analysis of a number of different high capacity transmission projects in Europe, it is clear <i>“that there is no single “right” solution. Each project must be judged on its own merits and hybrid solutions, i.e. combining different technologies, have been applied in many cases, for instance partially undergrounding a link. A specific technical solution must be derived accounting for local conditions”</i>;</p> <p>There have been advances in transmission technology in recent years, examples being <i>“the development of VSC HVDC technology and its deployment in transmission projects and the introduction of new tower designs for overhead lines”</i>;</p> <p>The only recommendation the IEC made was <i>“against fully undergrounding using an AC cable solution”</i>;</p> <p>While the report does not recommend that the interconnector be undergrounded it does find that if the interconnector has to be undergrounded for all, or a significant portion, of its length then with today’s technology the best solution would be <i>“a VSC HVDC solution combined with XLPE cables”</i>; and</p> <p>The report concludes that a high voltage AC OHL solution for the proposed interconnector still offers <i>“significantly lower investment costs than any underground alternative and could also be made more attractive by investing slightly more in new tower designs than the classical steel lattice towers now proposed”</i>.</p>

## 4.6.2 Other Third Party Reports

52 There are a number of other studies which are also referred to in this chapter. These are:

- **Denmark's Strategy for the Development of its 400 kV Network<sup>33</sup>** – (*Technical Report on the Future Expansion and Undergrounding of the Electricity Transmission Grid –: Summary – April 2008* and the *Cable Action Plan: 132-150 kV Grids – March 2009*). The first report considers the long term strategy for the development of the electricity transmission network in Denmark. Six 'Expansion Principles' were considered. These ranged from 'Expansion Principle A - complete undergrounding' to 'Expansion Principle F - no further expansion of the grid'. Subsequently the mid-range strategy known as 'Expansion Principle C' was adopted. The second report, the *Cable Action Plan* outlines how and over what period this strategy will be implemented.
- **Askon Report<sup>34</sup>** (*Study on the Comparative Merits of Overhead Lines and Underground Cables as 400 kV Transmission Lines for the North-South Interconnector Project* (2008) commissioned by North East Pylon Pressure (NEPP)).
- **Cigré<sup>35</sup> Technical Brochure 379 - Update of Service Experience of HV Underground and Submarine Cable Systems**, ISBN 978 -2-85873-066-7 (April 2009). The study collected and analysed data relating to the installed quantities of underground and submarine cable systems rated at 60 kV and above together with the service experience and the performance of existing underground and submarine cable systems.
- **UK Electricity Transmission Costing Study (2012)<sup>36</sup>**. This study was performed on behalf of the UK Department of Climate Change (DECC) with the purpose of informing the Infrastructure Planning Commission (IPC) in regard to the costs of feasible transmission options.

## 4.6.3 Review Carried Out by EirGrid - 2010 to 2013

53 Since the withdrawal of the previous application for approval of the Meath-Tyrone Interconnection development, EirGrid separately carried out three further studies providing an

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<sup>33</sup> Available at [www.Energinet.dk](http://www.Energinet.dk).

<sup>34</sup> This report is not publically available but can be obtained from NEPP, refer to [www.nepp.ie](http://www.nepp.ie) for further information.

<sup>35</sup> The technical brochure is available from Cigré. Cigré is an acronym in the French language for 'The International Council on Large Electric Systems'.

<sup>36</sup> Available at <http://www.theiet.org/factfiles/transmission-report.cfm>.

update on available technological alternatives; an update on reliability statistics for high voltage AC UGC and OHL; and an update on the world's longest high voltage AC XPLE cable circuits and the cost comparison between AC UGC and AC OHL. These reports are summarised below and their findings are contained in **Table 4.4**.

- **The *Preliminary Re-evaluation Report* (PRR)** (May, 2011). The PRR was published as part of the comprehensive re-evaluation of the previous application for the Meath-Tyrone Interconnector Project which was subsequently withdrawn. It included *inter alia* a review of the alternative technological alternatives for the proposed development
- **The *Final Re-evaluation Report* (FRR)** (April, 2013). The FRR represents the culmination of a detailed re-evaluation process, undertaken by EirGrid and its consultants, of all aspects of the proposed development. It considered documents issued since the publication of the PRR, which are relevant to the overall re-evaluation process including the IEC Report. It considers DC technology as an alternative to AC technology for this development, provides an update on reliability statistics for high voltage AC UGC and OHL, updates on the world's longest extra high voltage AC XPLE cable circuits and the cost comparison between 400 kV AC UGC, DC UGC and AC OHL.
- **The *Preferred Project Solution Report* (PPSR)** (July 2013). The PPSR provides detail on the preferred line design for the proposed development. It includes the identification of feasible locations for, and design of, the planned transmission line infrastructure, such as tower positions, tower types and associated construction related details (e.g. indicative access tracks). It includes reference to EirGrid's consideration of tower designs and the basis for confirmation of the IVI tower as the preferred support structure for the development.

54 A copy of the *Preliminary Re-evaluation Report* is included in **Appendix 1.1**, the *Final Re-evaluation Report* is included in **Appendix 1.2**, and the *Preferred Project Solution Report* is included in **Appendix 1.3**, all in **Volume 3B Appendices** of the EIS.



**Table 4.4 Reports Prepared by EirGrid on Technology Updates**

Report Title	Context of Report	Main Findings / Observations of Report in Respect of the Different Technologies
<p><b>North-South 400 kV Interconnection Development Preliminary Re-evaluation Report (PRR)</b>, EirGrid <b>May 2011</b></p>	<p>This report comprises a comprehensive re-evaluation of EirGrid's previous application to An Bord Pleanála for approval of the Meath-Tyrone 400 kV Interconnection Development, being that portion of the proposed interconnector occurring within Ireland.</p> <p>It includes review and consideration of the approximately 950 submissions to An Bord Pleanála in respect of that previous application and the statements presented at the associated oral hearing of 2010.</p>	<p>Having reviewed all the technology options the report concludes that:</p> <p>HVDC technology and HVAC undersea cable do not comply with the project objectives / design criteria for the proposed interconnector.</p> <p>There have not been any developments in transmission technology which would alter EirGrid's opinion that the use of long HVAC cables on the Irish transmission system is not feasible within the constraints of EirGrid's statutory obligations.</p> <p>No new information has come to EirGrid's attention which would alter its opinion that a 400 kV AC OHL is the best technical solution for this development.</p> <p>Partial undergrounding using 400 kV AC technology may be feasible, but only if the length to be installed is relatively short.</p>
<p><b>North-South 400 kV Interconnection Development Final Re-evaluation Report (FRR)</b> EirGrid <b>April, 2013</b></p>	<p>The FRR represents the culmination of a detailed re-evaluation process, undertaken by EirGrid and its consultants, of all aspects of the proposed development.</p> <p>It includes consideration of the feedback received during the public consultation in respect of the PRR. It also considered documents issued since the publication of the PRR, which are relevant to the overall re-evaluation process including the IEC Report. It provides an update on reliability statistics for high voltage AC UGC and OHL, and updates on the world's longest high voltage AC XPLE cable circuits and the cost comparison between 400 kV AC UGC and AC OHL.</p>	<p>Having reviewed all the technology options the report concludes that:</p> <p>The DC option, even one using the latest VSC HVDC technology, is not acceptable for the proposed development as it would be too costly and (for this specific application) would not operate as effectively as a standard 400 kV AC OHL.</p> <p>An entirely underground 400 kV AC option is not an acceptable solution.</p> <p>There have not been any developments in transmission technology which would alter EirGrid's opinion that the use of long HVAC cables (that is greater than approximately 10km in length) on the Irish transmission system is not feasible.</p> <p>A 400 kV AC OHL is the best technical solution for this development and would be significantly less costly than any UGC alternative.</p> <p>Partial undergrounding using 400 kV AC UGC will be considered, but only if the</p>

Report Title	Context of Report	Main Findings / Observations of Report in Respect of the Different Technologies
	<p>It includes an Appendix setting out the review and consideration of the approximately 950 submissions to An Bord Pleanála in respect of that previous application and the statements presented at the associated oral hearing of 2010.</p>	<p>length of UGC to be installed is relatively short (less than approximately 10km in one continuous length or an accumulation of shorter lengths).</p> <p>The emerging preferred support structure for use on the proposed 400 kV OHL development is the lattice steel structure known as the 'IVI' tower. However, EirGrid will further consider alternative structures, including consideration of any feedback on the matter received during the public engagement in respect of the FRR, before finalising the preferred project solution.</p>
<p><b>North-South 400 kV Interconnection Development Preferred Project Solution Report (PPSR)</b> EirGrid <b>July 2013</b></p>	<p>The PPSR provides detail on the preferred line design for the proposed development. It considers and includes responses to the feedback received during the public engagement in respect of the FRR. It includes the identification of feasible locations for, and design of, the planned transmission line infrastructure, such as tower positions, tower types and associated construction related details (e.g. indicative access tracks). It includes reference to EirGrid's consideration of tower designs and the basis for confirmation of the IVI tower as the preferred support structure for the development.</p>	<p>This report outlines the background to the identification of the preferred line design of the proposed development.</p> <p>It explains how the process generally involves consideration of a range of environmental and technical matters relevant to OHL design and how other considerations specific to the particular development (including feedback from stakeholders and landowners) have fed into the process.</p> <p>It identifies feasible locations for, and design of, the planned transmission line infrastructure, such as tower positions, tower types and associated construction related details (e.g. indicative access tracks).</p>

#### 4.6.4 Conclusions on Background to Identifying Strategic Technical Alternatives

55 The respective applicants have jointly carried out a comprehensive analysis of the various technological alternatives available for the proposed interconnector, over a period of many years. They commissioned a number of studies, supplemented with further internal analysis, in order to ensure that the development process was fully and properly informed with respect to the latest available technological alternatives. The studies informed the transmission technologies proposed, by EirGrid, for the previous application for approval of the Meath-Tyrone Interconnection Development (subsequently withdrawn).

56 Since the withdrawal of the previous application EirGrid has undertaken a comprehensive re-evaluation of that portion of the proposed interconnector in Ireland. The re-evaluation process included a review of the alternative transmission technologies. EirGrid has also considered documents issued since the withdrawal of the previous application including the *Report of the International Expert Commission*. EirGrid and its consultants are satisfied that, on the basis of the re-evaluation of updated environmental constraints and other information, a 400 kV OHL is the best technical solution for this development and would be significantly less costly than any UGC alternative. It was also concluded by EirGrid that there are no material considerations which would warrant the use of UGC along any part of the indicative line route.

57 The main strategic technical alternatives themselves and EirGrid's conclusions in respect of the preferred technical solution having regard *inter alia* to the conclusions of analysis and published studies are described in **Section 4.7**.

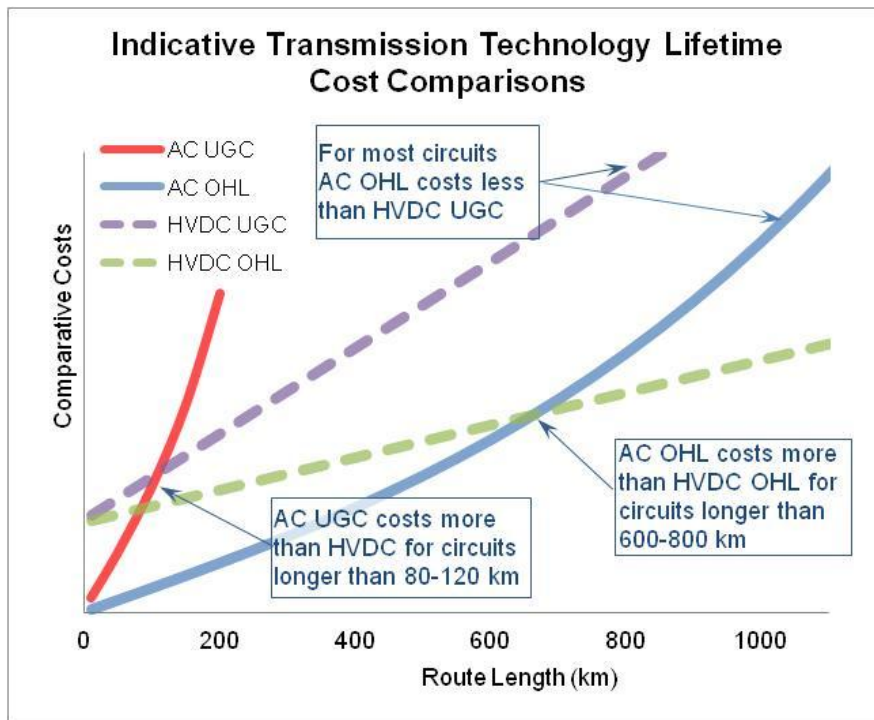
#### 4.7 TRANSMISSION TECHNOLOGY ALTERNATIVES CONSIDERED FOR THE PROPOSED DEVELOPMENT

58 There are several technological alternatives by which a transmission circuit of the capacity required for the proposed development could, in theory, be implemented. Some of these alternatives utilise AC technology while others utilise DC technology.

59 Until relatively recently, DC technology was only used for high capacity electricity transmission in circumstances where it was the only technically feasible or cost effective option. In recent times, however, during consultations associated with transmission projects (including in the case of this proposed development) stakeholders have suggested that DC technology should be used not because of any technical, operational or cost advantage that might accrue but rather because it is seen as a way of facilitating the undergrounding of the proposed development.

#### 4.7.1 High Voltage Direct Current (HVDC) as an Alternative to High Voltage Alternating Current (HVAC)

- 60 The first step in the in-depth consideration of the technological alternatives that are potentially feasible for this development is to carry out a general evaluation of HVDC technology, as an alternative to the standard HVAC technology regardless of whether the scheme is to be implemented using OHL, UGC or a combination of both.
- 61 The existing electricity transmission system in Ireland is, as in every other country in the world, a HVAC (or AC) system. Any new transmission project that utilises HVAC would therefore be an extension of the existing technology.
- 62 HVDC is an alternative method of transmitting electricity. HVDC technology is mostly used to transmit bulk power from one point to another over long distances where HVAC is not technically and / or environmentally acceptable (e.g. a long (> 50 km) high capacity submarine cable).
- 63 HVDC can also be the most effective option for very long transmission circuits. **Figure 4.2** illustrates graphically how the cost differential of HVDC UGC, HVDC OHL, HVAC UGC and HVAC OHL varies with circuit length. The HVDC options start at a cost disadvantage to any HVAC option due to the relatively high cost of the converter stations at the terminals however as the circuit length increases the difference in cost declines until eventually a breakeven point is reached and thereafter the HVDC option becomes the most effective. For example in the graph below the cost breakeven point for the HVDC UGC option versus the HVAC OHL option occurs when the circuit length is in the region of 600-800km whereas in the case of the HVDC UGC option the breakeven point with HVAC UGC is in the region of 80-120 km. On the graph the curve representing the HVDC UGC option (dashed purple) and the curve representing the HVAC OHL option (light blue) do not intersect within the 0 to 1,000 km range thus indicating that under these circumstances a HVDC UGC would never be more cost effective than a HVAC OHL option. In addition the graph would suggest that the breakeven or crossover point between these options would occur at some circuit length far in excess of 1,000 km, a distance that is of no relevance for a country the size of Ireland.



**Figure 4.2: Comparison of HV Transmission Options – Cost versus Circuit Length**

(Source: Parsons Brinckerhoff, incl. *Electricity Transmission Costing Study 2012*)

- 64 HVDC is also used for linking independently operated (synchronous) HVAC systems (e.g. an interconnector such as EirGrid's East West Interconnector) where it is impossible to link such systems using a standard HVAC circuit.
- 65 Inserting a HVDC circuit between any two points in a HVAC network would require the HVAC electricity to be converted into HVDC electricity at one end, transmitted through cable or OHL to the other end, where it would be converted back from DC to AC, and then transmitted back into the HVAC network. This is inefficient (unless the HVDC circuit is very long) and costly (in terms of the requirement for converter stations) but it is technically feasible.
- 66 There are two main HVDC convertor station technologies – Current Source Convertors (CSC) also known as Line Commutated Convertors (LCC) and the emerging Voltage Source Convertors (VSC). Both can be applied in combination with OHL and UGC.

- 67 VSC DC is considered a more flexible technology than LCC DC as it can be less difficult to integrate into an AC grid. This VSC DC technology continues to develop with converter stations becoming more efficient, reliable and compact; these advances were specifically referred to in the findings of the IEC Report.
- 68 In response to the *IEC Report*, EirGrid in its FRR reviewed its comparative assessment of an UGC VSC HVDC circuit<sup>37</sup> versus a standard high voltage OHL AC circuit for the implementation of the proposed development against the previously identified project objectives / design criteria. The findings are as follows:-
- a) Comply with all relevant safety standards;**
- 69 Both options are equally compliant. In the case of this criterion EirGrid does not see any difference in the two technology options.
- b) Comply with all system reliability and security standards;**
- 70 The proposed development as part of the 400 kV network will form a necessary extension of the backbone of the 'all-island' transmission network, and is required in order to enable the two networks, north and south, to operate as if they were one network. It will be an integral part of the 'all-island' meshed network, and as such the power flow (quantity and direction) in the circuit is required to react instantaneously to dynamic system changes such as rises and falls in system demand, and sudden and unplanned changes in system configuration due to unplanned outages of other circuits or generators. If the proposed interconnector is a standard AC circuit then the power flow will react naturally and instantaneously, without any input from a control system or human operator, to such dynamic changes to the system.
- 71 The power flow on DC circuit on the other hand will not react naturally to such changes. The DC circuit will only react if prompted to do so by a controller. However, a human operator would not be able to react quickly enough, so the control would have to be by means of a computerised control system. Such a control system would be bespoke and very complex, and would therefore introduce the very real risk of mal-operation. Analysis of the risk of mal-operation of the computerised system controlling the operation of a HVDC north-south interconnector has shown that this could (due to its relatively high capacity and strategic location within the network) result in the collapse of the entire 'all-island' electricity system.

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<sup>37</sup> The IEC disregarded DC OHL in its report (page 18) on the basis that the cost of a DC OHL option would be similar to a DC UGC option if the cables were to be installed under optimum conditions (as described in point c below). While this is debatable it can be said that from a technical and operational perspective there is no difference between DC OHL and DC UGC other than the fact that the time required to repair a fault on a DC UGC would be considerably longer (many weeks longer) than that required to repair a fault on a DC OHL.

Taking such a risk is unnecessary when there is a technically superior (for this type of application) and less risky option readily available. Therefore it is EirGrid's opinion that under the heading of 'comply with all system reliability and security standards', a standard AC circuit is preferable to a DC circuit for the specific characteristics of the proposed development.

**c) Provide an environmentally acceptable and cost effective solution;**

- 72 Both the DC UGC option and the AC OHL option can be installed in such a way as to be environmentally acceptable. It is the cost difference therefore which will be the deciding factor in the case of this criterion.
- 73 The IEC estimated that the standard AC OHL circuit would cost €167 million whereas the DC UGC alternative would cost €500 million. That is a difference of €333 million. The PB Power Technology and Costs Update Report (July 2013),<sup>38</sup> on the other hand, found that the standard AC OHL circuit would cost €140 million whereas the DC UGC alternative would cost €810 million (see Table 3-2, page 3 of the Supplementary Note). That is a difference of €670 million.
- 74 This significant variation between the cost estimates in the IEC Report and the PB Power Update Report for the DC alternative can be explained as follows. Both reports agree that the converter stations will cost approximately €300 million (that is €150 million each). The cost difference arises in the difference in cost per km for the DC UGC connecting between the two converter stations.
- 75 The IEC assumes optimum conditions are available for the installation of the DC cables. By 'optimum conditions' they mean that the cables will be installed in the wide soft margin of a major road for almost the entire length and that the cables will be installed side by side in a single 3 metre wide trench (**Figures 4.3** and **4.4** are extracted from the IEC Report and were included in that report for the purpose of illustrating the assumptions that formed the basis for the UGC cost estimate). This results in a cost per km of €1.36 million for 140km<sup>39</sup> giving a total cable cost of €190 million.

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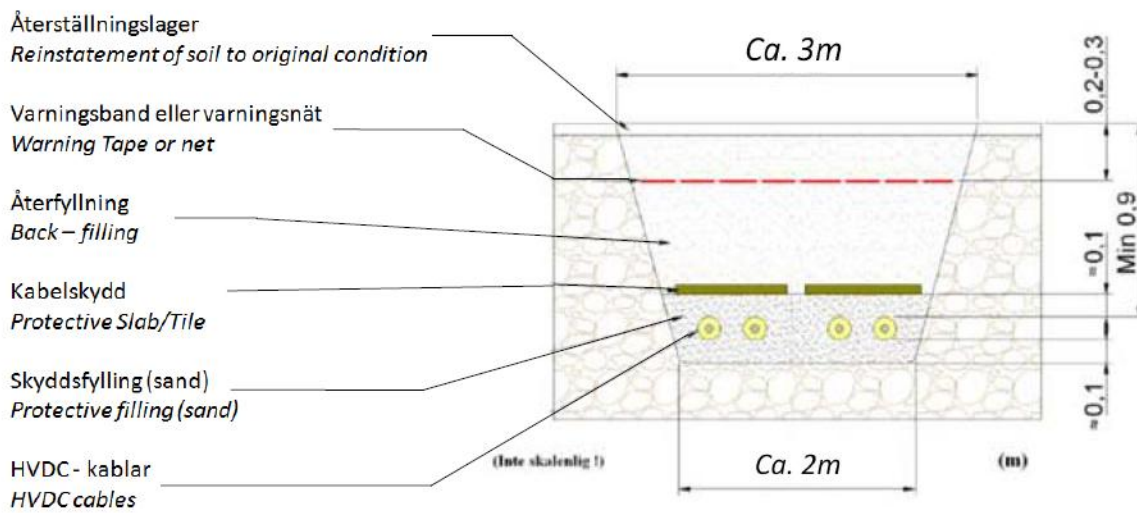
<sup>38</sup> The *Supplementary Note* of July 2013 to the *PB Power Technology and Costs Update Report* of April 2013 revise the comparative cost estimates by excluding any provision for the intermediate substation near Kingscourt (refer to summary details of report in Table 4.2). This results in the PB estimates being directly comparable with those of the IEC as the IEC also excluded any provision for the intermediate substation.

<sup>39</sup> The IEC assumed that the route for UGC would be 140km in length whereas PB Power identified a route for UGC and measured it at 135km in length.



**Figure 4.3: Wide Soft Margin of a Major Road**

(Source: IEC Report p. 46)



**Figure 4.4: Section through cable trench for two parallel HVDC circuits**

(Source: IEC Report (p. 46) with translation to English by EirGrid)



- 76 The PB Power estimate is based on the assumption that the DC cables will be installed along a route across country through farmland in the corridor identified in the PB Power Report of 2009. This results in a cost per km of €3.76 million for 135km giving a total cable cost of €508 million.
- 77 In EirGrid's view, the IEC estimate is understated. A long major road, with a wide soft margin, linking Batterstown in County Meath to Turleenan in County Tyrone does not exist. Instead the roads in the five counties to be traversed are generally narrow and winding. The IEC itself recognises that installing cables under such roads would result in a higher cost per km than the €1.36 million previously indicated. It is also the case that due to the winding nature of the roads that any route that follows the public roads will be longer than a more direct cross country route.
- 78 In their consideration of the DC option, the respective applicants follow the costing approach adopted by PB Power for the following reasons:
- It will allow the two pairs of DC cables that would be required for such a scheme to be installed in two separate trenches that are sufficiently far apart (> 5 metres) that it reduces the likelihood, to a level that can be considered to be negligible, of a single event causing damage to both sets of cables at the same time. This will result in a significantly better level of service availability and as a result improved security of supply.
  - It will result in a shorter more direct route.
  - It will avoid extensive road closures and the considerable disruption to local communities that that entails.
- 79 Installing cables along a cross country route would likely however result in a greater environmental impact than that of any option that involves their installation under or adjacent to public roads.
- 80 However no matter which approach is assumed for routing the DC UGC, across country or under public roads, the cost difference between the proposed AC OHL and the DC technology options is so great that it renders the HVDC UGC option unacceptable under this criterion.
- 81 While not the only reason the excessive cost of the HVDC technology is, on its own, sufficient reason for EirGrid to discount it as an option for the implementation of the proposed development. In this regard, Regulation 8(3) obliges the TSO, when discharging its functions to take into account the objective of minimising overall costs of the generation, transmission, distribution and supply of electricity to final customers.

**d) Have a power carrying capacity in the region of 1,500MW, and connect between appropriately robust points on the transmission networks north and south of the border;**

82 Both technology options are equal under this criterion.

**e) Facilitate reinforcement of the local transmission network in the north-east area**

83 Both technology options are equal under this criterion. Although the need to reinforce the north-east area for security of supply reasons is no longer an immediate driver of the delivery of the proposed development (as that reinforcement is not now expected to be required for at least a decade), the early presence of the interconnector will nevertheless provide reinforcement to the area by increasing interconnection between Ireland and Northern Ireland. Based on current predictions, such reinforcement will provide sufficient additional transmission capacity in the area to cater for growth in electricity consumption for many years (assuming median growth rates) and will also put the north-east area in a good position if an even stronger economic recovery should emerge in the coming years.

**f) Facilitate future grid connections and reinforcements**

84 All circuits forming a meshed transmission network have the potential to be 'tapped' into at an intermediate point to provide a new grid connection or reinforcement sometime in the future. It is envisaged that the circuit that forms the proposed development will require an intermediate substation in the vicinity of Kingscourt at some future point in time (although not now expected to be required for at least a decade), and others (where and when they will be required cannot be predicted at this juncture) are probable. The facilitation of future grid connections and reinforcements is therefore an important consideration of the technology choice.

85 As stated previously, a DC circuit does not naturally integrate within an AC network and a consequence of this is that a DC circuit embedded in an AC network would not facilitate future grid connections and reinforcements. If the north-south interconnector were to be developed using HVDC technology, then the cost of the planned 'tap in' to the circuit near Kingscourt, based on the estimates of the IEC, would be in of the region of €150 million more than the cost of tapping into an equivalent AC circuit. This would in all likelihood make the plan ultimately to reinforce the north-east area by developing a new substation near Kingscourt uneconomic. Consequently that reinforcement would have to be achieved by some other means, such as the building of new AC transmission lines into the area.

86 In addition to the excessive cost of tapping into a DC circuit, the only practical way of tapping into such a circuit would result in the creation of a 'multi-terminal' DC circuit (i.e. a DC circuit with more than two terminals). A multi-terminal DC circuit would require an even more complex

control system than a two terminal circuit, thus increasing the already unacceptable risk of mal-operation.

- 87 The poor facilitation of future grid connections and reinforcements presented by the DC option makes the use of HVDC technology less preferred than a standard AC circuit when compared against this criterion for the implementation of the proposed development.

**g) Comply with good utility practice**

- 88 There are no working examples in the world<sup>40</sup> of a DC circuit embedded in a small and isolated AC transmission network, such as that on the island of Ireland. The examples of planned DC interconnectors in Europe that were identified in the IEC Report (that is the proposed France-Spain Interconnector and the proposed Norway-Sweden Interconnector) are not comparable with the proposed interconnector. The electricity networks in those four countries are much larger (six times larger in the case of Norway-Sweden and almost 20 times larger in the case of France-Spain) and stronger than those on the island of Ireland and they already have multiple AC interconnections with each other.
- 89 The risk of failure, and the consequence of failure, is an important factor in deciding whether the embedding of a DC circuit in an interconnected network is, or is not, good practice. There is currently only one interconnector between Ireland and Northern Ireland and these two networks are required to merge into each other and to operate as if they were one network. The proposed development, with a power carrying capacity of 1,500MW, will become the 'backbone' of this 'all-island' network.
- 90 By contrast the proposed France / Spain and Norway / Sweden DC Interconnectors are upgrades in cross border power transfer capacity between networks that are already highly interconnected<sup>41</sup> with each other. Also unlike the network on the island of Ireland the Norway / Sweden and France / Spain networks form part of a wider continental network and have multiple interconnections (both synchronous and non-synchronous) with other third party countries. In addition **Table 4.5** illustrates that the power carrying capacity of the proposed north south interconnector relative to the combined 'all-island' system demand is far greater than the comparable figure in the case of the proposed France / Spain and Norway / Sweden Interconnectors. The North South Interconnector would have the capacity to carry 23.8% of the

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<sup>40</sup> There are a few working examples in the world (December 2013) of a DC circuit embedded in an AC transmission network however these networks are not representative of the small and isolated AC transmission network on the island of Ireland. The closest comparable scheme is probably the 1,400MW Kii Channel project in Japan which uses OHL and submarine cable. Although an island network, Japan represents a much larger generation and load base than Ireland.

<sup>41</sup> There are five existing AC transmission interconnectors between Norway / Sweden, four between France / Spain and one between Ireland / Northern Ireland.

'all-island' peak demand whereas the comparable figures for the France / Spain and Norway / Sweden Interconnectors are 2.9% and 1.4% respectively and that this in turn results in the north south interconnector having a far greater level of strategic importance than those proposed interconnectors.

**Table 4.5: Comparison of Interconnected Networks and the Relative Importance of Proposed Interconnectors**

Interconnected Countries	Power Carrying Capacity of Proposed Interconnectors	Combined System Peak Demand <sup>42</sup>	Capacity of Proposed Interconnectors as a % of Peak Demand
Ireland - Northern Ireland	1,500 MW	6,311 MW	23.8%
Norway – Sweden	2 X 720 MW	49,643 MW	2.9%
France – Spain	2 X 1,000 MW	145,625 MW	1.4%

91 The capacity of the proposed North-South Interconnector relative to the 'all-island' system peak demand together with the relatively limited level of interconnection with each other and with third party networks means that the North-South Interconnector will have a far greater level of strategic importance to Ireland

92 The strategic importance of the proposed new France /Spain and Norway / Sweden DC interconnectors will be far less critical to the overall system security of their combined networks than the proposed north south interconnector will be to the 'all-island' network. These proposed DC interconnectors are therefore not representative of a DC circuit embedded in a small and isolated AC transmission network, such as that on the island of Ireland.

93 It is on this basis that implementing the proposed development using HVDC technology would not be considered as complying with 'good utility practice' or complying with 'good international practice'.

<sup>42</sup> The annual instantaneous peak loads were obtained from the Entso-e website. The instantaneous peak loads for the respective pairs of networks did not occur at the same time (although they were within days of each other). The combined figures are therefore a slight over statement of the actual combined instantaneous system peak demand.

94 The re-evaluation of the HVDC VSC (OHL or UGC) option and the standard AC OHL option which included regard for the findings of the IEC report is outlined above (i.e. points a to g) and a summary of same is shown in **Table 4.6**. The overall conclusion is that the DC option is least preferred, primarily on the basis of cost effectiveness, its poor ability to facilitate future grid connections and because it would not be considered as complying with 'best international practice'.

**Table 4.6: Overview AC versus DC - Strategic Constraints of Potential AC and DC Transmission Alternatives**

Points	Description	AC OHL	DC (UGC or OHL)
Comply with EirGrid's Statutory and Regulatory Obligations			
a)	Safety	***	***
b)	Reliability and security	***	**
c)	Cost effectiveness	***	*
	Due regard to the environment	**	**
Meet the Specific Needs of the Project			
d)	1500MW capacity and appropriately strong points of interconnection	***	***
e)	Reinforce the North-East transmission network	***	***
Meet the General Objectives for All Projects of this Type			
f)	Facilitate future grid connections and reinforcements	***	*
g)	Good Technical Solution – Be 'best international practice' with proven technology	***	*

***	Preferred, limited impact, acceptable
**	Some impact, some difficulty
*	Least preferred, major impact, unacceptable

#### 4.7.1.1 HVDC Offshore Submarine Cabled Alternative

95 During public consultation some stakeholders suggested that consideration be given to an offshore cable that is a submarine cable off the east coast, for linking the two transmission networks on the island of Ireland. This suggestion was made without specifying whether the submarine cable would utilise AC or DC technology. The DC submarine option is considered here while the AC submarine option is considered later in **Section 4.7.2.2**.

- 96 There are numerous examples of long high capacity DC submarine cables in Europe so this alternative is potentially feasible. However, all of the disadvantages of the 'on-land' DC option vis-a-vis a standard AC transmission technology option identified in **Section 4.7.1** apply in the case of the sub-sea DC option. In addition to those disadvantages the following also applies.
- 97 For any on-land UGC option there is a concern about the relatively long time it takes to find and repair faults. In the case of the undersea options the time to repair will be significantly greater than for the equivalent on land option. Reference can be made to the example of the six months that it took to repair a fault on the NorNed<sup>43</sup> HVDC cable during commissioning in 2007 / 2008. Much of the delay was due to poor weather conditions during the winter months and the resulting concerns for health and safety of repair crews. For this reason a DC submarine cable off the east coast, is considered to be even less preferred when rated against the criteria of 'Reliability and Security' than an on-land DC cable.
- 98 The circuits required for the proposed development must connect into the existing transmission grid at appropriately strong points north and south of the border. In the case of the undersea option long on land cables are required to reach the coast (in excess of 40km from Woodland to the coast). An entirely on-land cabled option can take a more direct cross country route and as a result be considerably shorter and by implication less expensive than its undersea equivalent. For this reason a DC submarine cable, is considered to be even less preferred when rated against the criteria of 'Cost Effectiveness' than an on-land DC cable.
- 99 EirGrid's overall conclusion on the HVDC offshore submarine alternative is that it is not acceptable for this development and merits no further consideration.

#### **4.7.1.2 Overall Conclusion on High Voltage Direct Current (HVDC) as an Alternative to High Voltage Alternating Current (HVAC)**

- 100 The respective applicants have considered the option of using HVDC technology for implementing the proposed interconnector. This consideration is supported by the findings of the PB Power Study (2009, April 2013 and July 2013) and the TransGrid Study (see summary in **Table 4.2**). In addition consideration has been given to the findings of the International Expert Commission (see summary of IEC Report in **Table 4.3**).

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<sup>43</sup> NorNed is a HVDC undersea interconnector between Norway and the Netherlands. It was first put into service in May 2008.

- 101 The overall consideration found that any DC option whether implemented using UGC, OHL or off-shore submarine cable would not facilitate the future development of the transmission network as well as any AC option. Nor would the DC option be considered as complying with 'best international practice'.
- 102 While the cost of the DC options (UGC or OHL) would be comparable with an AC UGC option they would all be significantly more expensive to implement than the proposed 400 kV AC OHL option, €670 million more according to the findings of the *PB Power Technology and Cost Update* (July 2013) and €333 million according to the findings of the IEC Report.
- 103 In addition the proposed interconnector is required to be an integral part of the 'all-island' AC transmission network and will therefore be required to operate like any other AC circuit within the network. It is possible, in theory at least, to embed a DC circuit into an AC transmission network and make it operate like an AC circuit however this would require a complex and be-spoke control system. The risk of failure, and the consequence of failure, must be a factor in the consideration of any technical alternative. Introducing a complex and be-spoke control system into the operation of a strategically important part of the 'all-island' transmission network brings with it considerable risk for system security and stability. Such risk taking is unnecessary in the case of this proposed development as there is a technically superior and less risky option readily available.
- 104 As a result of all of the foregoing it was concluded that any option using HVDC technology is not an appropriate or acceptable option for implementing the proposed interconnector.

#### **4.7.2 Consideration of High Voltage Alternating Current (HVAC) Options**

- 105 The use of HVDC technology whether implemented by OHL or UGC, on-land or offshore, has been discounted in **Section 4.7.1**. All further consideration and comparison of OHL and UGC is therefore restricted to HVAC technology particularly at the 380 kV / 400 kV level.

##### **4.7.2.1 High Voltage AC Overhead Line (OHL)**

- 106 Over 98% of the on land Extra High Voltage (EHV - 315 kV to 500 kV) electricity transmission network in Europe is of HVAC OHL construction. For comparative purposes the extent of the 380 kV / 400 kV network in ten Western European countries including Ireland, is shown in **Table 4.7**.

**Table 4.7: Extent of the 380 kV / 400kV AC OHL and UGC Installations in Western Europe**<sup>44</sup>

Country	Overhead Line (km)	Underground Cable (km)	% Cable
Belgium	1,335	0	0.00%
France	21,361	3	0.01%
Germany	20,237	70	0.34%
Great Britain	11,979	229	1.91%
Ireland	439	0	0.00%
Netherlands	2,061	30	1.43%
Portugal	2,236	0	0.00%
Spain	19,567	55	0.28%
Sweden	10,700	8	0.07%
Switzerland	1,780	8	0.45%

(Source: ENTSO-E Statistical Yearbook 2011)

- 107 400 kV OHL technology conventionally utilises steel lattice towers to support the electricity conductors. As the construction of a 400 kV OHL requires limited civil works with a simple mechanical construction, it is very cost effective compared to an equivalent UGC system which has a more complicated construction and design. **Chapter 6** of this volume of the EIS provides a description of the proposed OHL structures for this development.
- 108 400 kV OHLs have a high level of availability for service, that is, most faults are temporary and automatically cleared without impacting the integrity of the transmission network, and the permanent or persistent faults can be located easily and quickly repaired. Where there is a temporary fault (e.g. a lightning strike), restoration can occur within a number of seconds. In the case of permanent faults, restoration times are on average, less than 48 hours<sup>45</sup>.
- 109 Compared to equivalent UGCs, 400 kV OHLs result in a relatively low physical impact to the land they cross (limited to the tower locations and land within the OHL corridor). It is a very flexible technology which can be routed and constructed in a wide variety of topographies. With longer spans it can also be constructed to pass over waterways or obstacles.

<sup>44</sup> Denmark is deliberately excluded from Table 4.6 as it is a special case and is discussed in greater detail in **Section 4.7.2.4**.

<sup>45</sup> Refer to **Section 4.7.2.5**.



110 HVAC OHL 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. It is the clear position of the respective applicants, based upon professional and technical expertise, extensive experience, and international best practice that, on the grounds of achieving an overall balance between environmental, economic and technical objectives, the approach to the establishment and routing of high voltage transmission circuits in rural areas will normally be effected through an OHL construction methodology (refer to **Chapter 5** of this volume of the EIS for routing considerations).

#### 4.7.2.2 High Voltage AC Underground Cable (UGC)

111 High voltage UGC technology involves installation of specialised insulated cables under the ground. The cables can either be direct buried or placed within ducts / concrete trenches or tunnels. Direct burial installation requires the use of heavy equipment along the entire length of the route, not only for excavation but also for the transport and installation of the cables. However, it does not require the level of civil engineering required by cut and cover tunnels and deep bore tunnelling type installations. Cable tunnels in contrast to cable trenches are very costly to build and are normally used over short distances and typically only in densely developed urban areas where lack of space precludes the use of OHLs and direct buried cables.

112 The installation of direct buried UGC is highly dependent on soil type. There are two main influences: excavation and backfill. Trenching for UGC requires the excavation of significant quantities of soil. The suitability of the excavated soil as a backfill material and its thermal resistivity are important considerations. Special techniques such as directional drilling are also used for crossings under roads, railways and waterways resulting in a reduced disturbance to the surrounding environment.

113 In terms of reliability of UGCs, reference is made to the most comprehensive study to date carried out by Cigré *Update of Service Experience of HV Underground and Cable Systems*, ISBN 978 -2-85873-066-7 (2009). This study was based on the results of a survey of 73 utilities from around the world. The study found, that once located, the average time taken to repair a fault on a 400 kV XLPE cable (a cable type which would be considered for the proposed interconnector) is 25 days if the cable is direct buried, and 45 days if installed in a tunnel. On the basis of potential for prolonged unplanned circuit outages, 400 kV OHLs are therefore considered to have a better service availability than equivalent UGCs (this is discussed in greater detail in **Section 4.7.2.5**).

- 114 Long term reliability is also considered to be an issue. The expectation and international experience is that as an UGC gets older, it becomes less reliable. This is principally due to deterioration of the material used in the manufacture of the cable and the long term impact of electrical and thermal stresses over the operational life of the cable.
- 115 In relation to the use of UGC for HVAC transmission, the high capacitance of the cable presents design and operational difficulties. The most notable of these is the risk of temporary high voltages within the network which exceed the rating of the cable and can cause critical failure of either the cable equipment or transmission assets in a wider area. The TEPCO report and subsequent internal analysis has shown that equipment ratings could be exceeded.
- 116 The IEC Report recommended against using a total HVAC UGC solution for this particular project advising that *“AC cables are technically possible, but have never been found attractive for long distance, high power transmission”* and *“For AC connections, the solution by underground cables is only used for limited distances”*. In fact, there are no 400 kV HVAC UGC in the world that approach the length required for the proposed development.
- 117 One of the main advantages of installing UGCs is the reduction in landscape and visual impacts associated with the OHL option. However installing buried cables across the country side introduces environmental issues specific to that technology, e.g. potential impact on archaeology as a result of excavation works and permanent loss of habitat due to removal of hedgerows.
- 118 Because of their higher cost and lower level of availability for service, high voltage transmission cables are generally only used in urban areas or wherever a constraint has been identified such that no alternative exists other than to use a cable. In Europe some examples of circumstances where such cables have been used would be :
- In densely populated areas and where no alternative exists;
  - In congested areas of infrastructure where no alternative exists;
  - Where it is necessary to cross water and no alternative exists; and
  - Where no alternative exists but to route through an environmentally sensitive area and undergrounding is deemed to be less of an impact on the environment.

#### 4.7.2.3 Undergrounding the Entire Interconnector Using AC UGC

119 In 2009, when preparing the EIS associated with the previous application for approval (which was subsequently withdrawn) EirGrid considered the option of undergrounding the proposed development using AC UGC. EirGrid's conclusion at that time was that the entirely undergrounded AC alternative would not be an acceptable solution as:

- It would not be the least cost technically and environmentally acceptable solution; and
- Its use would not be in compliance with good utility practice.

120 Many of the observers who participated in the consultation process associated with the previous application disagreed with EirGrid's conclusion, and referenced, either directly or indirectly, the Askon Report (*Study on the Comparative Merits of Overhead Lines and Underground Cables as 400 kV Transmission Lines for the North-South Interconnector Project*) which was commissioned by North East Pylon Pressure (NEPP) in support of their contention that the development should be undergrounded.

121 The IEC reviewed the Askon Report as part of its review of the proposed development. The IEC Report stated that, while the author of the Askon Report, Professor Noack "*is well known in the industry for his work on lightning protection and overvoltages*" the "*Commission, is however, not aware of his expertise in grid development, grid operation, economic aspects and undergrounding*". The IEC then went on to state that it had found "*several questionable statements*" in the Askon Report. The more significant of these were:–

- The IEC does not agree with the Askon Report when it states that long 400 kV AC UGC "*are not really a problem and that experience is there*". The IEC found that there are no 400 kV UGC circuits in the world that approach the length required for the proposed interconnector and that this is because of sound technical reasons;
- The analysis by Askon of the reliability of AC UGC circuits is not valid as it "*is not backed up by actual data*"; and
- The costs estimates for AC UGC in the Askon Report are significantly understated as insufficient provision is made for the cost of installation.

122 Overall, the IEC concluded that the findings of the Askon Report "*are not consistent with industrial practice for other projects in Europe*" that are similar in size and form to the proposed development and which "*have been executed, are under construction or are in planning*". The IEC Report goes on to make only one recommendation and that is that the proposed development should not be implemented using the entirely undergrounded AC cable option.

- 123 The position of the IEC regarding the Askon Report is consistent with EirGrid's position on that report. Having reviewed the undergrounding issue as part of the re-evaluation process and, in particular, having considered the IEC Report, EirGrid concurs with the recommendation of the IEC that the proposed development should not be implemented using the entirely undergrounded AC cable option.
- 124 Undergrounding the entire interconnector, approximately 135km in length, using AC UGC is therefore eliminated from further consideration for this development.
- 125 It is stated in **Section 4.7.1.1** that during public consultation some stakeholders suggested that consideration be given to an offshore cable that is a submarine cable off the east coast, for linking the two transmission networks on the island of Ireland. As an AC offshore option would require an even longer length of AC cable than the approximately 135km length of the on land option it is also eliminated from further consideration for this development.

#### 4.7.2.4 High Voltage AC XPLE UGC and Extent of its Use

- 126 Although the entirely undergrounded AC option was eliminated, the option of using a hybrid AC solution, i.e. a combination of AC UGC and AC OHL, commonly referred to, and herein after referred to, as 'partial undergrounding', remains an option for consideration. Indeed the IEC found in this regard that the partial undergrounding is technically feasible but within limitations on the cumulative length of the UGC sections. It is appropriate therefore that consideration continue to be given to the use of high voltage AC UGC for this development but within these recognised constraints.
- 127 XLPE (cross linked polyethylene) insulated cable is the 'state of the art' for HVAC UGC in the world today. EirGrid adopted the use of high voltage XLPE cable at an early stage in its commercial development. The first 110 kV XLPE cable in Ireland was installed in 1978. The first 220 kV XLPE cable in Ireland was installed in 1984. The installation of long lengths (greater than 1000 metres) of 400 kV XLPE UGC only became possible in the late 1990s with the development of a suitable cable joint for connecting lengths of such cable together.
- 128 In the period 1997 to 2009, eleven significant 380 kV / 400 kV XLPE projects<sup>46</sup> (i.e. projects that involved a circuit length in excess of 2km) were completed in Europe. The longest of these was the 20km long Elstree - St John's Wood 400 kV cable project in London. This cable is installed

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<sup>46</sup> Entso-e & Europacable Joint paper to EU Commission: *Feasibility and technical aspects of partial undergrounding of extra high voltage power transmission lines*, December 2010, available at <http://ec.europa.eu/energy>.

in a three metre diameter air conditioned tunnel. The combined circuit length of these eleven European 'projects of significance' amounts to approximately 196km<sup>47</sup>, with a cumulative single phase cable length of some 640km. It should be noted that a minimum of three single phase cables is required per circuit.

129 If the proposed development was to be implemented in its entirety using 400 kV XLPE cable, it would require approximately 810km (2 X 3 X 135km<sup>48</sup>) of single phase cable. This means that this single project would require more 400 kV XPLE cable to be installed in Ireland (in one circuit) than has been installed throughout Europe during the period 1997 to 2009. It appears, based on an analysis of reports (Europacable, Cigré T&D World<sup>49</sup>) of major EHV (extra-high voltage - in the range 315 kV to 500 kV) UGC projects carried out across the world in the fifteen year period up to 2012, that if the proposed interconnector was to be implemented entirely using UGC, there would be more EHV XLPE cable installed on the island of Ireland than in all of mainland Europe or in North America.

130 In contrast to the relatively small quantity of EHV UGC that has been installed in Europe during the period 1997 to 2009, it is interesting to note that in the period 2000 to 2009 over 10,000km of EHV OHL was installed in mainland Europe (17 member states of UCTE<sup>50</sup>). The reason for this overwhelming preference among UCTE members for OHL can be clearly understood in a letter<sup>51</sup>, dated 14 January 2008, from the Secretary General of the UCTE to APG (the Austrian Power Grid Company) wherein it states:

*“For the time being 400 kV AC cable systems cannot compete with overhead power lines in the transmission grid. Using cables for lines in interconnected operation (400 kV backbone) presents serious technical, financial and environmental drawbacks.”*

and

*“UCTE therefore recognizes overhead power lines as the most reliable and most secure technical solution for transmitting electricity over long distances. Furthermore based on different studies within UCTE an overhead line is the more efficient and more economical way for the transportation of electricity compared with underground cables at the 400 kV level”.*

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<sup>47</sup> In the case of some of these projects the circuits consisted of two cables per phase giving a total of six single phase cables per circuit.

<sup>48</sup> The distance of 135 km is derived from the length of the route identified by PB Power in its 2009 report. The requirement for two cables per phase is also identified by PB Power in that report. There are three phases in the AC system.

<sup>49</sup> Transmission and Distribution World magazine, available at <http://www.tdworld.com>

<sup>50</sup> UCTE is an association of Transmission System Operators from mainland Europe (excluding Scandinavia and the countries of the former USSR). UCTE is now a part of ENTSO-E. The data was obtained from the UCTE Statistical Yearbooks 2000 and 2009.

<sup>51</sup> Available at <http://www.eirgridprojects.com/projects/northsouth400kvinterconnectiondevelopment/projectactivity/2008/>

131 This overwhelming preference for OHL among European utilities is expected to continue into the future. In this regard, the *Ten Year Network Development Plan (TYNDP) 2012*<sup>52</sup> issued by ENTSO-E (European Network of Transmission System Operators for Electricity) indicates that in the period covered by the TYNDP, a further 28,400km of new EHV (i.e. greater than 330 kV) AC OHL is planned to be installed in Europe while during the same period only 420km, in predominantly short lengths, of 400 kV AC UGC is planned (p 62). The reason for the preference for 400 kV OHL is explained in the TYNDP (p 81) as follows:

*“New 400 kV AC OHL projects are in technical, economic, and ecological terms the most efficient solution for long distance electricity transmission. Indeed, such reinforcements integrate straightforwardly into the existing grid since this technology has been the standard for a long time”.*

132 It is clear therefore that the electricity utilities of Europe still consider the use of OHL for 400 kV circuits to be best practice, and that 400 kV UGC is only used in very limited situations and only over relatively short lengths. The installation of 270km (2 X 135km) of 400 kV UGC in Ireland in one project, or even in a multiple of different projects, could not be described as complying with good utility practice.

133 During consultation in respect of the previous application for planning approval (and subsequently) it was stated by numerous stakeholders that the strategy adopted by Denmark for the undergrounding of its transmission grid should be considered as the standard for what constitutes ‘best international practice’. EirGrid does not agree and instead considers ‘best international practice’ to be the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry in Europe’ and not just the practice in a single European country. The practices in a broad range of European countries with regard to the undergrounding of 400 kV transmission circuits are set out above.

134 Notwithstanding the fact that the practice in Denmark is not the determinant for what constitutes ‘best international practice’ it is useful to consider the Danish strategy. In 2009 a plan<sup>53</sup> was published in Denmark for the undergrounding of the entire 132 kV / 150 kV grid over a period extending to 2040. The plan for the 400 kV grid is however quite different. Even though there appears to be a national desire and a willingness to pay for the undergrounding of the entire 400 kV grid it was determined that it was not achievable due to the technical difficulties, uncertainties and risks associated with the installation of long lengths of 400 kV UGC.

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<sup>52</sup> Available at <https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2012/>.

<sup>53</sup> Energinet.dk - Cable Action Plan:132 - 150 kV Grids - March 2009.

- 135 The technical difficulties and risks associated with the installation of long 400 kV UGC are explained in a technical report<sup>54</sup> published by the Committee set up by the Danish Government to develop the strategy for the undergrounding of the transmission grid. At page 19 it states:

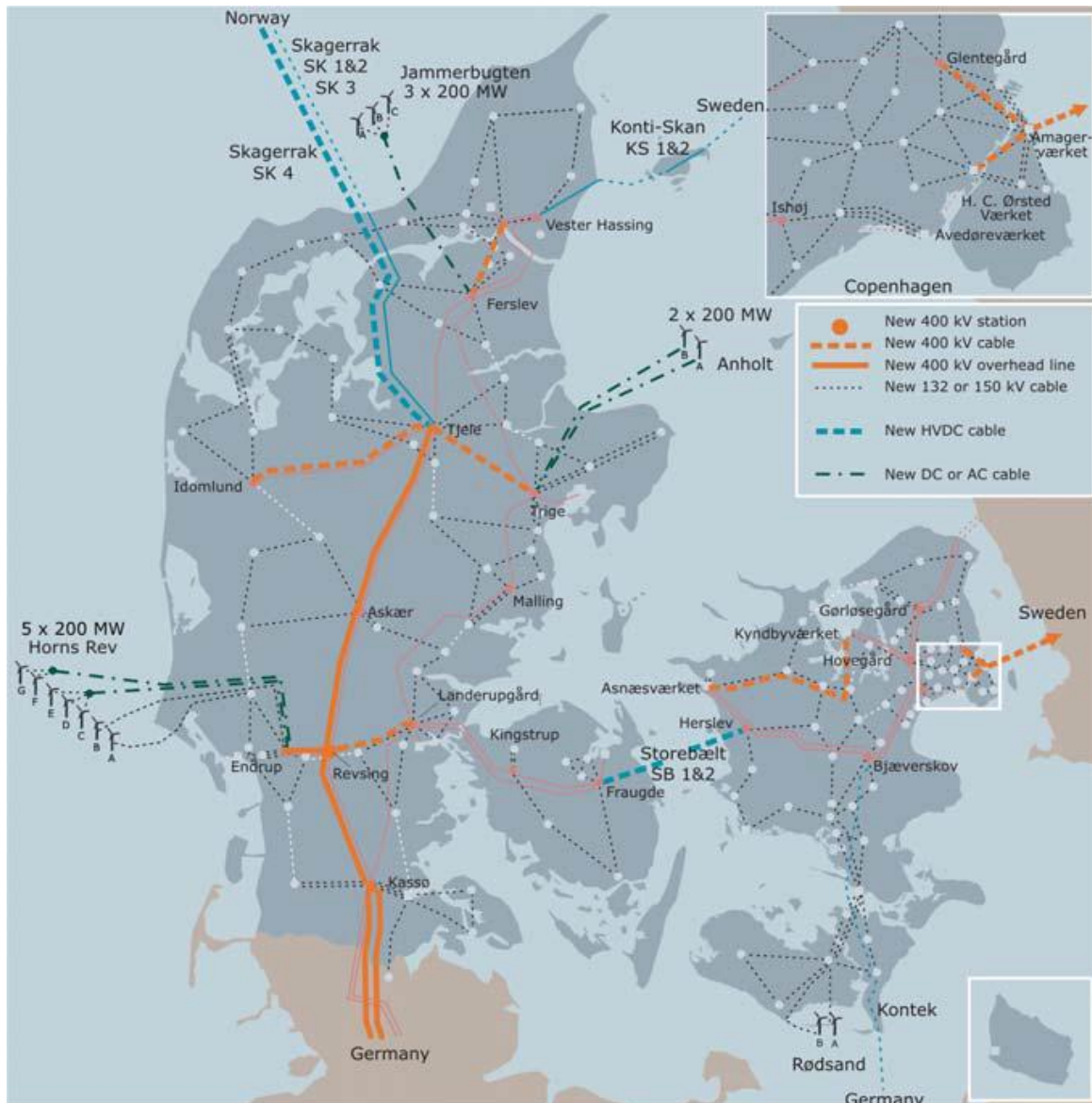
*“When a 400 kV cable is disconnected, the large energy volumes stored in the cable and the cable substations will oscillate and cause overvoltage. The installation of long cables or a large number of short 400 kV cables increases the risk of such phenomena becoming a serious problem. The over voltages may become very large with the ensuing risk of other components being disconnected. This increases the risk of power failures.”*

- 136 It was as a result of these concerns that the Danish Committee recommended that those 400 kV circuits that form the backbone of the transmission grid should not be undergrounded as to do so would carry too high a risk for system security and stability. Based on this it was decided that the required increase in interconnection capacity with Germany would be achieved by constructing a new double circuit 400 kV OHL. That line is now complete and in service since December 2014.

- 137 It is clear therefore that new 400 kV OHLs are being, and will be, constructed in Denmark. The map of Denmark at **Figure 4.5** shows the planned extent of 400 kV grid by 2030. The proposed new OHLs can be seen on this map as solid orange lines.

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<sup>54</sup> Technical Report on the Future Expansion and Undergrounding of the Electricity Transmission Grid – Summary – April 2008 [www.energienet.dk](http://www.energienet.dk).



**Figure 4.5: Planned 400 kV Infrastructure for the Danish Transmission Network**

(Source: *Technical Report on the Future Expansion and Undergrounding of the Electricity Transmission Grid – Summary – April 2008*)

- 138 The longest AC UGC in the world, with a voltage rating greater than or equal to 380 kV, is a 40km long cable in Tokyo, Japan. Denmark aspires to having the longest such UGC in the world. However recognising the technical difficulties, uncertainties and risks associated with such long 400 kV UGC a research and development programme has been instituted, in cooperation with Danish universities which, it is hoped, will conclude with the installation and testing of a long length (between 40km and 60km) of 400 kV UGC. The Technical Report states (p.8) that “if targeted efforts are made, these tests can be implemented within 6 – 10 years”. If successful, plans will proceed to underground all future “non-vital backbone” 400 kV



circuits. The 400 kV circuits proposed for undergrounding over the following decades can be seen on **Figure 4.5** as dashed orange lines.

- 139 The *Denmark Cable Action Plan*<sup>55</sup> envisages that the expansion of the 400 kV network will proceed as shown in **Table 4.8**. From this it can be seen that (assuming the technical uncertainties mentioned in the previous paragraph are resolved) approximately 55% (290km) of the expansion will be achieved by means of 400 kV OHLs and the remaining 45% (240km) by 400 kV UGC.

**Table 4.8: Denmark 400 kV Network Expansion Plan**

Year	400 kV Overhead Line	400 kV Underground Cable
2009	1,270 km	80 km
2030	1,560 km	320 km

#### 4.7.2.5 Reliability Statistics for High Voltage AC UGC and OHL

- 140 From a transmission adequacy point of view the availability for service, or more correctly the lack of availability for service, of a transmission circuit is a more important measure of reliability than simple 'failure rate'. A circuit's 'availability' is derived from the expected failure rate and the average time it takes to repair a fault.
- 141 The vast majority of faults on transmission OHLs are transient in nature. Most of these are caused by lightning; the lightning does not cause any damage; the fault only exists as long as the lightning exists. The protection systems for the OHLs are designed to trip the line when a fault occurs and, based on the assumption that the fault is transient, will automatically switch the line back into service within one second. If the fault is not transient but a 'permanent' fault then the OHL will re-trip and the line will remain out of service until repair crews can find and repair the fault.
- 142 In the case of transmission UGCs however almost every failure can be assumed to be a permanent fault as usually the very act of failing results in an explosion at the point of failure which destroys a section of the cable.

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<sup>55</sup> Energinet.dk - *Cable Action Plan: 132 - 150 kV Grids* - March 2009.

- 143 As the time it takes to repair a 400 kV UGC is much greater than the time to repair a 400 kV OHL it can be expected that such an OHL will have a much better level of availability for service than an equivalent UGC and this is supported by system statistics.
- 144 In April 2009, Cigré<sup>56</sup> published the results of the most comprehensive study of UGC reliability carried out to date (refer to **Table 4.8**). This study was based on the results of a survey of 73 utilities from around the world. Of interest is the information received on the performance of 1,388km of XLPE cable with a voltage rating in the range 220 kV to 500 kV. Applying the calculated fault rates of this 1,388km of installed cable, to the length of cable<sup>57</sup> (2 x 135 km) that would be required for the proposed development, gives a projected fault rate of 'one fault per annum'.
- 145 In addition, the Cigré study found that the average time taken to repair a fault on a 400 kV XLPE cable is 25 days if the cable is direct buried, and 45 days if installed in a tunnel. A direct buried cable is, however, ten times more likely to be damaged due to external factors than a cable installed in a tunnel the study concluded.
- 146 Compare this 'fault rate' and 'average time to repair' of UGC with that of an equivalent OHL. There are 439km of existing 400 kV OHLs in Ireland. This length of 400 kV OHL is too small a sample for determining meaningful performance statistics. Meaningful statistics can, however, be obtained by considering the fault statistics of the combined quantity (approximately 2,245km) of 400 kV, 275 kV and 220 kV OHLs under EirGrid's control<sup>58</sup>. Taking the fault statistics of this existing 2,245km of OHL for the period 2004 to 2012, gives a projected fault rate for the proposed (approximately 140 km long) 400 kV OHL of one permanent fault (that is a fault that requires repairs before the OHL can be returned to service) every 20 years.
- 147 The statistics also show that the average duration that a 400 kV / 275 kV / 220 kV OHL circuit will be out of service for repair after a fault is considerably less than that of an equivalent UGC circuit - less than two days in the case of OHLs, and 25 days in the case of a 400 kV UGC. This is summarised in **Table 4.9**.

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<sup>56</sup> Cigré Technical Brochure 379 - *Update of Service Experience of HV Underground and Submarine Cable Systems*, ISBN 978 - 2-85873-066-7 (April 2009).

<sup>57</sup> The distance of 135km is derived from the length of the route identified by PB Power in its 2009 report. The requirement for two cables per phase is also identified by PB Power in that report.

<sup>58</sup> This is reasonable compromise because the existing 220 kV and 275 kV OHLs are of similar design and experience similar operating conditions to that of the existing 400 kV OHLs.

**Table 4.9: Summary of Comparative OHL and UGC Statistics**

UGC and OHL	Projected Fault Rate for N-S Interconnector	Average Time to Repair
UGC – directly buried cable (statistics based on 1,388 km of XLPE cable with a voltage rating in the range 220 kV to 500 kV) <b>Source:</b> Cigré Technical Brochure 379	1 fault per annum	25 days
OHL (statistics based on 2,245km of 220 kV, 275 kV and 400 kV OHL in Ireland) <b>Source:</b> EirGrid (2004 – 2012)	1 fault (permanent fault requiring repairs) every 20 years	Less than 2 days

148 The comparative analysis indicates that OHLs have a substantially better level of availability for service than UGCs. This result is consistent with the findings of the independent Ecofys Report<sup>59</sup> in which the ‘availability’ (the term Forced Outage Rate is used in the report) of OHLs was found to be at least ten times (at least one order of magnitude) better than that of UGCs. This comparative performance must always be a factor when a TSO is considering UGC particularly when the circuit in question is to be a backbone circuit of the transmission network and therefore of the highest strategic importance<sup>60</sup>.

#### 4.7.2.6 The World’s Longest High Voltage AC XPLE Cable Circuits

149 The longest high voltage AC XLPE cables operating in the world today are submarine cables. The longest is the 105km long 90 kV 40MW interconnector from Great Britain to the Isle of Man. The record for the longest HVAC cable in the world is likely to be broken when the proposed 125km<sup>61</sup> long 220 kV and 200MW interconnector between the islands of Sicily and Malta is commissioned. These long cables are radial connections and as such they do not form part of a meshed transmission network, unlike the proposed development. They also have a much lower power carrying capacity than that which is required of the proposed interconnector (i.e. 1,500MW). The environmental impacts of UGC, the technical difficulties of UGC, and the cost of UGC increase rapidly with increase in voltage rating and power carrying capacity. These

<sup>59</sup> *Study on the Comparative Merits of Overhead Electricity Transmission Lines Versus Underground Cables*, carried out by Ecofys on behalf of the Department of Communications, Energy and Natural Resources and available at [www.dcenr.gov.ie](http://www.dcenr.gov.ie).

<sup>60</sup> Refer to **Section 4.7.2.4** for the impact that this consideration had on the Government approved plan for the extension of the transmission grid in Denmark.

<sup>61</sup> The circuit consists of 100km of submarine cable plus 25km of on-land UGC.

examples of long HV undersea cables are therefore in no way comparable with the requirements of the proposed development.

150 The longest 'on-land' AC XLPE cable circuit, with rated voltage of 400 kV or higher, operating in the world today is a 40km double circuit cable in Tokyo, Japan. These 500 kV, 900MW cables were commissioned in 2000. The longest such cable in Europe, at 20km, is the Elstree - St John's Wood 400 kV 1,600MW circuit in London, which was commissioned in 2005. Unlike the long undersea cables, these cables have power carrying capacities, and voltage ratings, that are comparable with that of the proposed interconnector: There, however, the similarities end, in that:-

- The cables in London and Tokyo are installed under the streets and buildings of two of the largest cities in the world. Both of these cable circuits are installed in air conditioned tunnels. The proposed development would traverse open farm land in the main;
- The proposed interconnector UGC route (as identified by PB Power) is about 135km in length. The cables in London and Tokyo are a fraction of this length. The technical difficulties associated with long lengths of EHV UGC increase with increase in circuit length; and
- The transmission networks in Great Britain and Japan are orders of magnitude bigger and therefore unlike Ireland are far better able to accommodate such long lengths of EHV UGC.

151 One of the project objectives / design criteria for the proposed interconnector, as stated in **Section 4.5**, is that it will have a power carrying capacity in the region of 1,500MW and connect between appropriately robust points on the transmission networks north and south of the border. To try to achieve this using an entirely UGC option would require the installation of two circa 135km-long UGC circuits. It is clear from the above that no country in the world has ever implemented such a project, or anything comparable. It is also evident from ENTSO-E's *Ten Year Network Development Plan 2010-2020* that there are no plans to install anything comparable in Europe in the next ten years.

152 It is concluded therefore that to implement the proposed interconnector using long lengths of high voltage AC UGC would not comply with good utility practice.<sup>62</sup>

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<sup>62</sup> The term 'good utility practice' is defined in this context in a footnote in **Section 4.5**.

#### 4.7.2.7 Cost Comparison of AC UGC and AC OHL

##### Capital Costs

- 153 Three separate comparative studies of UGC versus OHL were carried out in Ireland during the period 2008 / 2009 as follows:
- Askon Report (commissioned by North East Pylon Pressure (NEPP)),
  - Ecofys Report (commissioned by the DCENR) and
  - PB Power Report (commissioned by EirGrid / NIE) supplemented by the *PB Power Technical and Costs Update* (April and July 2013).
- 154 The studies found that the capital cost of UGC ranged from three to eight times that of an equivalent OHL<sup>63</sup>.
- 155 The most up to date site specific comparative cost estimate available for this development can be found in the *PB Power Update Report, Supplementary Note* of July 2013. This report found that the AC UGC option would cost €740 million more than the proposed 400 kV OHL.
- 156 The extent of the cost differential between AC OHL and AC UGC is so great that, and regardless of the additional technical problems of UGC, if EirGrid is to comply with its statutory obligations<sup>64</sup> it effectively discounts using UGC for any significant length in this development.

##### Life Cycle Costs

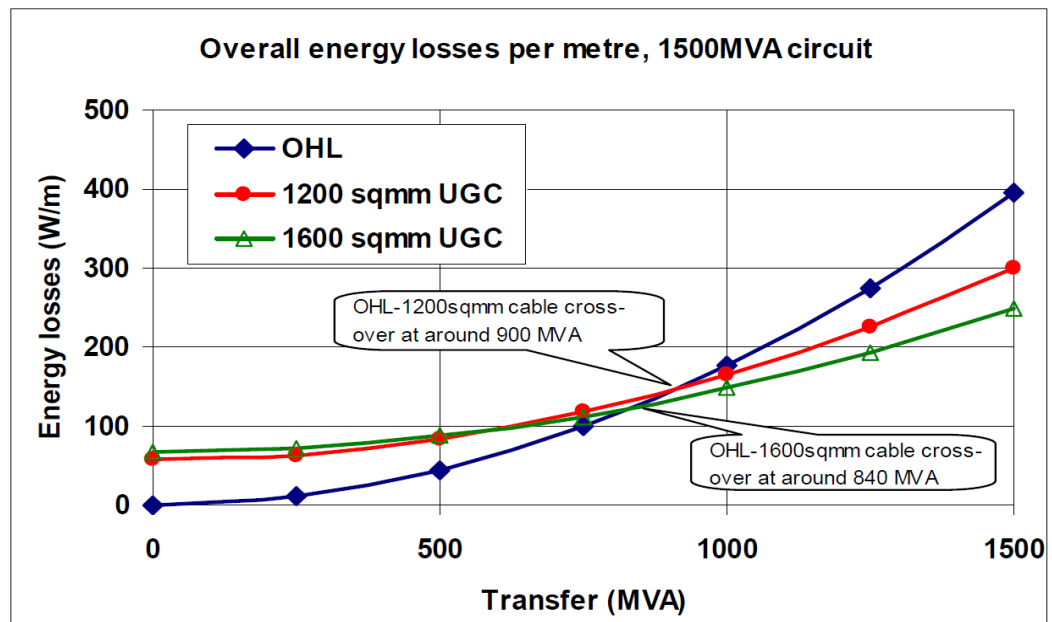
- 157 In some of the written and oral submissions presented by observers during the previous application process, it was acknowledged that the capital cost of UGC was much greater than that of OHL. It was, however, asserted in these submissions that UGC is more efficient than OHL and that over its life cycle a UGC would incur lower electrical losses and, therefore, lower operating costs than an equivalent OHL. It was further stated that if the cost of the two technologies were compared over a typical life cycle, then UGC might well prove to be the more cost effective option.

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<sup>63</sup> Note: As these studies were only interested in calculating the cost differential between the options, they did not include in their estimates provision for project costs that are common to all options. Their cost estimates for each option cannot therefore be considered as 'whole of project' cost estimates.

<sup>64</sup> Regulation 8 of SI 445/2000.

158 These assertions are incorrect as they are based on a misunderstanding of transmission networks operation. UGCs and OHLs have different electrical characteristics with the result that a lightly-loaded UGC (typically less than 50% loaded) will have higher electrical losses than an equivalent lightly-loaded OHL, while a heavily-loaded UGC (typically greater than 50% loaded) will have lower losses than a heavily-loaded OHL. This is well illustrated in the graph in **Figure 4.6** which compares the energy losses of a 400 kV OHL 1,500 MVA circuit with two 400 kV UGC alternatives (2 X 1,200 mm<sup>2</sup> and 2 X 1,600 mm<sup>2</sup> aluminium cables) of comparable capacity. The breakeven point (crossover point) for the 1,200 mm<sup>2</sup> UGC (in comparison with the OHL) is 900 MVA while the comparable breakeven point for the 1,600 mm<sup>2</sup> UGC is lower at 840 MVA.



**Figure 4.6: Comparison of Energy Losses for OHL and UGC**

(Source: Figure 3-7 PB Power Report (2009))

159 Circuits in a meshed transmission network are required, under normal system conditions, to have a contingency capacity. In other words, they are required to have sufficient spare capacity to cater for the sudden loss of another circuit on the network. In practice, this means that transmission circuits, and particularly backbone circuits, typically operate at less than 50% of their power-carrying capacity. Therefore, OHL transmission circuits incur lower electrical losses than equivalent UGC transmission circuits during their lifetime. This is confirmed, in the case of the transmission networks of mainland western Europe, in the letter from the Secretary General of UCTE (as previously referenced), dated 14 January 2008 to the Austrian Power Grid Company (APG), in which it was stated that, "based on different studies within UCTE an overhead line is the more efficient and more economic way for the transportation of electricity compared with underground cables at the 400 kV level".

- 160 The average energy transfer on the proposed interconnector, over its lifetime, is expected to be less than 33% of its nominal power carrying capacity. This is on the basis that the peak load on the circuit (under normal system conditions) should not exceed 50% of capacity<sup>65</sup>. It is therefore the case that using OHL for the new interconnector will incur lower electrical losses than using equivalent UGC alternative.
- 161 The *PB Power Update Report* of 2013 estimated that over its lifetime the cost of operating and maintaining the proposed 400 kV OHL would be €55 million while the comparable cost for the UGC option would be €90 million. This estimate was based on an assumed average loading of 33% of capacity (500MVA).

### 4.7.3 Partial Undergrounding of AC Transmission Circuits

#### 4.7.3.1 Background to Partial Undergrounding

- 162 In the context of this EIS, 'partial undergrounding' is the term used to describe the undergrounding of a short section, or short sections, of a long transmission circuit that is comprised predominantly of OHL.
- 163 As the use of any HVDC technology, whether OHL or UGC is not an appropriate or acceptable option for this development (refer to **Section 4.7.1.2**), the following consideration of partial undergrounding is restricted to high voltage AC technology and has little or no relevance to HVDC technology.
- 164 Partial undergrounding of 110 kV circuits is common practice in Ireland. There are no examples of partial undergrounding at the 400 kV level in Ireland however there are numerous examples elsewhere in Europe. Partial undergrounding of 400 kV AC circuits is therefore technically feasible.
- 165 In the 2009 EIS, it is stated that the joint development philosophy of EirGrid and NIE for the proposed transmission line, which will follow an alignment across a rural area, is "*firstly to seek a viable and environmentally acceptable OHL solution; the use of short lengths of UGC will only be considered in the event that an OHL solution cannot be found, and where it can be confirmed that the use of UGC does not exceed the system's capacity to absorb such cables*".

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<sup>65</sup> See Section 9.2.2 of the Ecofys Report (summarised in **Table 4.3**) for further discussion on this point.

166 As part of the previous application for approval, EirGrid identified a short section of the overall proposed circuit where UGC was deemed to be the most appropriate option. This short section of UGC was to be fully contained within the confines of Woodland Substation. During the subsequent review and Confirm Design Stage associated with the current application for approval EirGrid decided to alter the point of connection at Woodland Substation of the proposed new 400 kV circuit in order to eliminate the requirement for this short section of 400 kV UGC. Such a section of UGC within the confines of Woodland Substation does not therefore form part of this application for development consent.

#### 4.7.3.2 Consideration of Partial Undergrounding for this Development

167 When considering partial undergrounding for a 400 kV project, it is essential to understand the environmental, technical and cost implications of such a development. These issues are assessed in general terms in a joint position paper prepared by Europacable and ENTSO-E that was submitted to the European Commission in December 2010 (*Feasibility and Technical Aspects of Partial Undergrounding of Extra High Voltage Power Transmission Lines* (December 2010)). The joint paper “*merges the experience European Transmission System Operators (TSOs) have gained with the inclusion of underground EHV cables into their transmission networks over many years with the technical expertise of the leading XLPE EHV cable systems manufacturers in Europe*”. The implications, for the proposed interconnector are considered below.

#### 4.7.3.3 Partial Undergrounding – Environmental Issues

168 The size of the AC UGCs required for the proposed interconnector would be such that they could not be installed under public roads or under the disused railway line (refer to **Chapter 5** of this volume of the EIS for consideration of potential route corridor alternatives), as these roads and railways are not sufficiently wide. The only practical option would be to install the cables directly across farmland. This would have the following environmental implications:

- The construction effort associated with the installation of the UGC section would be considerably greater than that of the OHL. The UGC would require a construction swathe of 20 to 22 metres, as wide as a dual carriageway<sup>66</sup>, to be cut through the countryside. This would result in much greater disruption to farming and other activities during the construction phase than would arise from the construction of the OHL.

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<sup>66</sup> High Quality Dual Carriageway as per the National Roads Authority.



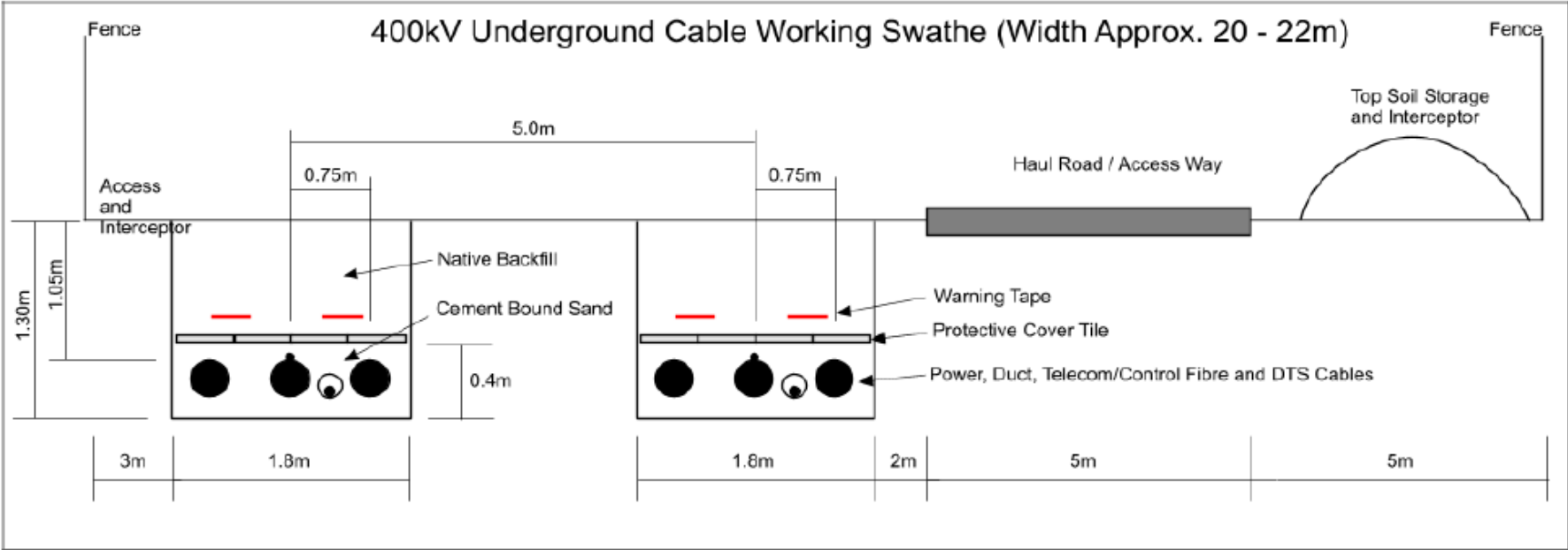


Figure 4.7: 400 kV Single Circuit, Two Trench, Working Swathe

(Source: Figure 7.1(b) PB Power Report (2009))

- The UGC construction swathe would cut through every hedgerow in its path, leaving a permanent gap. The hedgerow would not be allowed to re-establish itself as deep rooted vegetation cannot be permitted to grow in proximity to UGCs.



**Figure 4.8: Photographs of a 400 kV Double Circuit Cable Being Installed Cross-Country**

(**Note:** The first photograph shows the construction swathe with one trench and the haul road, the second photograph shows the construction swathe with two open trenches and haul road in the centre – Source National Grid Company, UK.)

- This is unlike the case of the OHL where in many cases the OHL will oversail hedgerows without unduly interfering with them. Where a tower is positioned straddling a hedgerow, a section of the hedgerow will be removed during construction, but it can

be allowed to re-establish itself afterwards (see **Figure 4.9**), and management of the hedgerow thereafter will be required only to prevent its interference with the OHL.



**Figure 4.9: Photograph of a Tower Straddling a Hedgerow with Vegetation Re-established**

- Two underground chambers would be constructed approximately every 650m along the UGC route to accommodate the 400 kV cable joints. At these locations two inspection enclosures, either underground chambers accessed via a surface manhole or above ground kiosks similar to that shown in **Figure 4.10** are required.



**Figure 4.10: Photograph of Above Ground Inspection Kiosks for UGC**

(Source: PB Power (2009) Report, page A6 11)

- No buildings are permitted within a UGC reserve<sup>67</sup>. Buildings can, and have been, constructed below high voltage OHLs, most notably in the UK.
- It would be necessary to have a substation at every location where the 400 kV circuit changes from OHL to UGC. Where a substation is required solely for the purpose of accommodating a transition from UGC to OHL, it is known as a 'transition station' or as a 'sealing end compound'. A typical 400 kV transition station has the same appearance as a small 400 kV substation. It would require a land take of about one-half of a hectare. It would consist of an inner compound enclosing the live equipment and a small building, with a buffer strip around the compound to accommodate an earth berm, and / or vegetation, for screening and an access road.



**Figure 4.11: Example of a 400 kV Underground Cable to Overhead Line Transition Station**

(Source: 380-kV-Salzburgleitung Auswirkungen der möglichen (Teil) Verkabelung des Abschnittes Tauern-Salzach neu - Gutachten im Auftrag von Energie-Control GmbH Wien – Professor B. R. Oswald)

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<sup>67</sup> Note: This applies where the cables are buried directly into the ground. If the cables are installed in a tunnel, and can be accessed via the tunnel, then buildings and other infrastructure can be constructed above, provided there is sufficient clearance.

#### 4.7.3.4 Partial Undergrounding – Technical Issues

- 169 Inserting a section of UGC into an OHL circuit will have a negative effect on the reliability performance of the overall circuit. The latest performance statistics (refer to **Section 4.7.2.5**) confirm that, on a kilometre for kilometre basis, 400 kV OHLs have a much better service availability record than 400 kV UGCs.
- 170 The risk to transmission system stability associated with the installation of a long length of EHV UGC exists, regardless of whether that long length of cable forms an entire UGC circuit, a single section of partial undergrounding, or is made up of multiple shorter sections of UGC within a single hybrid OHL / UG circuit. As a result, some utilities have set down the maximum permissible length of EHV UGC that can be installed on their transmission system whether installed as a single UGC circuit or as part of a hybrid UGC / OHL circuit and the maximum permissible cumulative length of EHV UGC on the system. In the Netherlands, for example, the maximum permissible length of a single 400 kV UGC is 20km. It is also the case that the longest 400 kV UGC in Europe is a 20km cable installed in an air conditioned tunnel in London.
- 171 When considering what should be the maximum permitted length of 400 kV UGC on the island of Ireland, the respective applicants must take account of the accompanying risk of failure and consequence of such failure. The transmission system on the island of Ireland is much smaller than that on the island of Great Britain and of course much smaller than that of mainland Europe, to which the system in Netherlands is connected. The transmission system in Ireland is therefore able to accommodate much shorter lengths of 400 kV UGC than is the case in Great Britain or the Netherlands, for example. The Transmission System Operator (TSO) and the Transmission System Owner (TAOs) in Ireland are also much smaller than their counterparts in Great Britain and the Netherlands and must, therefore, carry correspondingly smaller risk.
- 172 Accordingly careful consideration was given to the issue of partial undergrounding as part of the overall re-evaluation process. Based on the present extent and configuration of the Irish network, EirGrid considers that the maximum length of 400 kV UGC that would be technically feasible to install as part of the proposed development (inclusive of that part of the interconnector located in Northern Ireland) is approximately 10km, whether installed in one continuous length or in an accumulation of shorter lengths. However, there are a number of environmental factors and costs issues which must also be considered in any appraisal of the alternative technological option of partial undergrounding.

#### 4.7.3.5 Partial Undergrounding – Cost Issues

- 173 The *PB Power Technology and Costs Update Report*<sup>68</sup> of July 2013 (see **Table 4.2**) contains the most up-to-date detailed site specific cost comparison of UGC and OHL for the proposed interconnector. The Update Report found (Table 8-16 on page 27) that AC UGC would cost on average €5.4 million per km more to install than the AC OHL.
- 174 At least one, and potentially two, transition stations are required for each section of the circuit that is undergrounded. Depending upon the length of an underground section (and therefore the facilities required at each end), transition stations could add an additional €5 - €15 million (approximately) per installation.
- 175 Unlike OHL, long sections of UGC would require electrical compensation equipment to be installed along its route to counteract the effects of the underground cable on the transmission network; a 10km section of UGC would require around 0.5 hectares of land to accommodate such equipment. The costs for this transition station compensation equipment are included in the overall cost estimate updates for the AC UGC option but may not be required for short sections of partial undergrounding - hence the spread in estimated costs. Likewise, the land-take of the transition station for a short section of undergrounding which would not require the installation of reactive compensation equipment could be reduced to around 0.3 hectares.

#### 4.7.3.6 Conclusion on Partial Undergrounding for the Proposed Interconnector

- 176 Partial undergrounding is feasible if:
- The length to be undergrounded is restricted, for technical and operational reason, to less than approximately 10km in one continuous length or an accumulation of shorter lengths; and
  - The cost of using the short length(s) of UGC can be proven to be an environmentally advantageous and cost-effective way of overcoming an otherwise unavoidable environmental or technical constraint to the preferred OHL.
- 177 Neither of the respective applicants have identified any section of the route of the proposed development where the above applies and are therefore proposing that the entire 400 kV circuit be implemented using 400 kV AC OHL.

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<sup>68</sup> Cavan-Tyrone and Meath-Cavan 400 kV Transmission Circuits: Technology and Costs Update – Addendum to the 2009 Report and Supplementary Note – July 2013 by Parsons Brinckerhoff.

## 4.8 OVERHEAD LINE (OHL) DESIGN CONSIDERATIONS

### 4.8.1 Operating Voltage and Circuit Configuration

178 It is concluded in **Section 2.2.4, Chapter 2** of this volume of the EIS that the appropriate nominal capacity for the proposed interconnector is 1,500MW. It is further concluded in **Section 4.6** that the only technical alternative that provides an acceptable method for achieving the strategic and specific objectives of the proposed interconnector is AC OHL. Based on the foregoing, consideration is now given to the configuration of such an AC OHL development.

179 As noted in **Chapter 2**, of this volume of the EIS, the EHV transmission network of the Northern Ireland system although operated at 275 kV, is constructed to a 400 kV standard. These 275 kV double circuits OHL comprise the most robust part of the Northern Ireland network. In Ireland, the 400 kV network extends between the Moneypoint Generation Station in County Clare, and Woodland Substation in County Meath, and Dunstown Substation in County Kildare (both within the Greater Dublin Area), again comprising the most robust part of the transmission network in Ireland. It is entirely appropriate that an interconnection development with a nominal capacity of 1,500MW<sup>69</sup> provide interconnection between the 'most robust parts' of the respective networks namely the existing Woodland 400 kV Substation in County Meath and a proposed new substation adjacent to the existing double circuit 275 kV OHL in County Tyrone (Turleenan) see **Figure 4.12**.

180 Consideration has been given to constructing the proposed Interconnector using a double circuit design of 275 kV, matching existing circuit operation in Northern Ireland, thereby meeting minimum technical requirements in the short term. However, such an alternative would have no longer-term or lifetime cost saving in comparison with a single circuit 400 kV option. The 400 kV option will result in better voltage performance and reduced power losses.

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<sup>69</sup> The capacity of an OHL is determined by the maximum permitted operating temperature of its electricity conductors (wires). While the maximum operating temperature is mostly influenced by the quantity of electrical current passing through the wires, the ambient temperature and ambient weather conditions are also important factors. In Ireland therefore, OHL have a 'winter rating' based on average winter weather conditions and a 'summer rating' based on average summer conditions. The 'nominal capacity' of an OHL is a rounded off figure, somewhere between the higher 'winter rating' and the lower 'summer rating' and is only used for comparative purposes. As stated previously MVA (megavolt-amperes) is the technically correct unit of measurement for describing the capacity of transmission circuits however in this context and in this EIS MW is interchangeable with MVA.



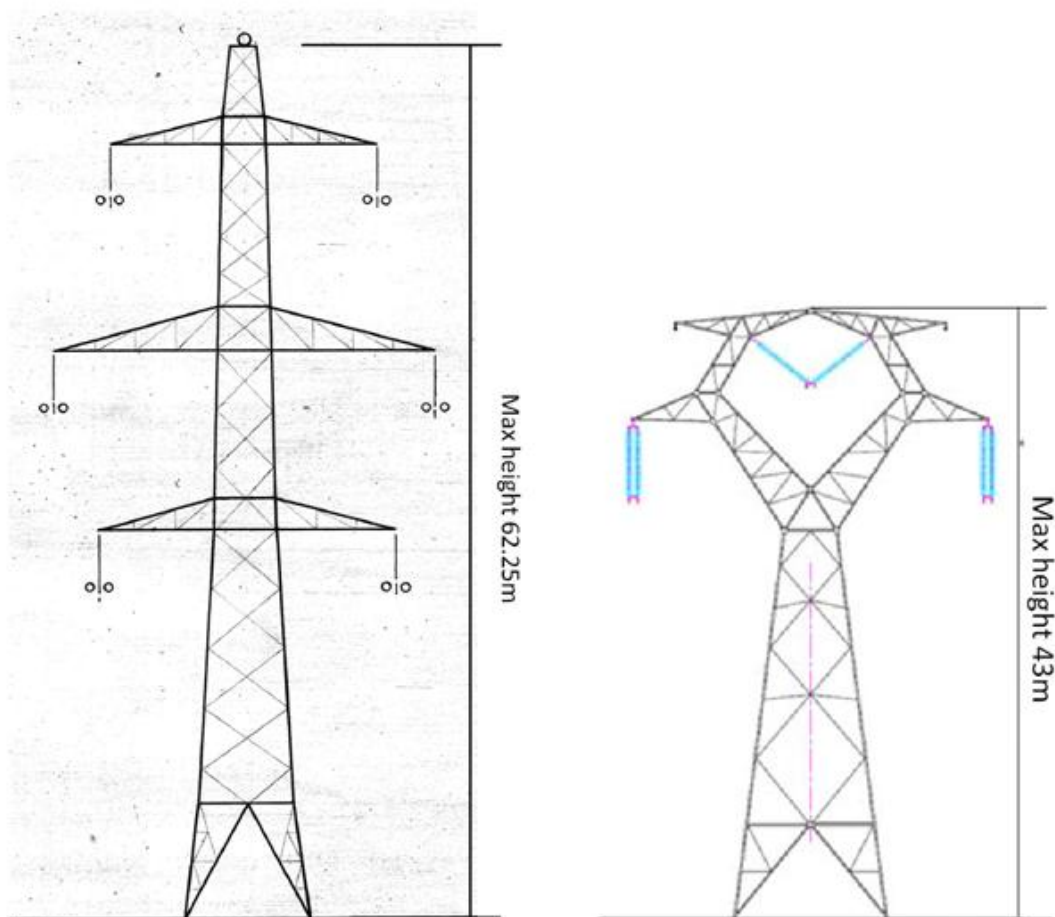
**Figure 4.12: Map Showing Transmission Network and Proposed Interconnector**

(The proposed interconnector is indicated in dashed red)





181 The circuit design and operating voltage are both important variables which determine the eventual size, scale, and ultimately, appearance of the support structures that would need to be constructed to facilitate an overhead transmission line. These variables therefore have a direct influence on potential landscape and visual impacts arising from the proposed OHL. It is acknowledged that the scale of a single circuit 400 kV OHL is likely to have a greater environmental impact than a single circuit 275 kV OHL. However, a single circuit 275 kV OHL would not be able to deliver the required 1,500MW capacity (see **Section 2.2.4 of Chapter 2** of this volume of the EIS). The towers required for the double circuit 275 kV line that would be necessary in order to deliver the required 1,500MW capacity would be taller (see **Figure 4.13**) and likely to therefore have a greater visual impact than those required for a single circuit 400 kV OHL. There would effectively be no difference between the two options in terms of land requirements.



**Figure 4.13: Outline Drawing of a 275 kV Double Circuit Tower and 400 kV IVI Tower**

(Not to be scaled - for illustrative purposes only)

182 Overall, having regard to these factors, and including due consideration of environmental impact, the respective applicants determined that a 400 kV single circuit arrangement represented the most appropriate selection for the proposed Interconnector. This conclusion was accepted by both of the relevant regulatory authorities (CER and NIAUR).

#### 4.8.2 400 kV Single Circuit Support Structure: Type Selection and Design

183 The type and design of support structure that is chosen has implications for the maximum achievable span length, angles of deviation and clearance requirements over obstacles (all of which need to be in accordance with the current EirGrid / ESB standards and specifications, which in turn are based on best international practice). Therefore support structure design is an important consideration for the detailed line design process.

##### 4.8.2.1 Background to Support Structure Selection

184 In considering alternative designs for the 400 kV OHL support structures, the respective applicants commissioned a variety of studies which looked at a range of issues from visual impact on the landscape to electrical considerations. The studies evaluated a range of designs that included a number of lattice steel structures, wooden structures and steel monopole structures. A summarisation of these studies can be found in the *EirGrid / NIE Meath-Tyrone 400 kV Interconnection Development: Tower Outline Evaluation and Selection Report* (October 2009). This report reviews the methods and results of the previous studies.

185 The studies concluded that wooden structures would not be technically feasible for 400 kV OHLs in Ireland due to the heavy mechanical loading requirements and electrical clearance requirements. Steel monopole designs were found to be technically feasible with some benefits such as a small footprint requiring a reduced corridor width and relatively short construction duration when compared with traditional lattice steel structures. Due to these benefits a steel monopole design has already been used in Ireland to good effect for a 110 kV OHL running through an urban area in Cork (refer to **Figure 4.14**).



**Figure 4.14: 110 kV Monopole Overhead Line in Cork**

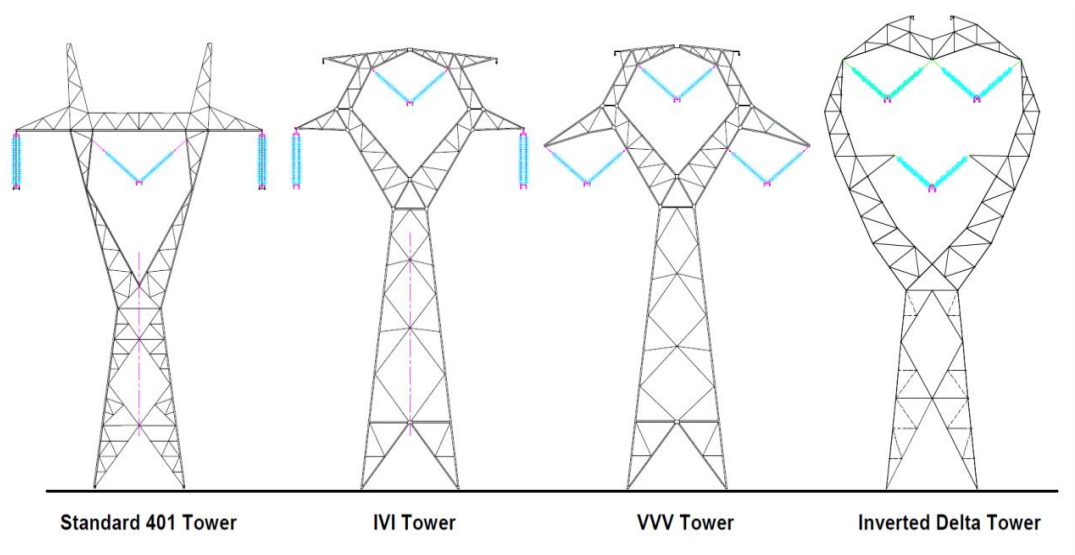
186 On balance however the studies found that for a 400 kV OHL, located in a rural setting in Ireland, a lattice steel structure is preferred. This was on the basis that while monopole designs are sometimes preferred in urban and suburban areas due to a combination of their reduced visual impact and reduced corridor width; the same advantages would not apply for a 400 kV OHL in an entirely rural setting. At 400 kV the superstructure of the monopole design would be a large dense visually intrusive steel pole with a diameter of up to six metres at its base. In addition due to the shorter maximum span that can typically be achieved with a monopole design a greater number of structures are required per kilometre than is the case with the lattice steel design.

187 Having identified lattice steel as the preferred design for the support structures for the proposed 400 kV OHL, a range of designs was considered in consultation with a designer / manufacturer of lattice steel structures. This resulted in four options being advanced for detailed comparative assessment. These were the classic or standard 401 type structure as used in the mid-1980s for the existing 400 kV OHLs in Ireland and the modern designs of the IVI type, VVV type and inverted delta type (refer to **Figure 4.15**).

188 For many stakeholders the visual impact of the proposed development was a significant concern (refer to **Chapter 3** of this volume of the EIS for details). In recognition of this, a visual assessment report which looked at delivering a reduced visual impact of a 400 kV OHL on the

landscape was commissioned by the respective applicants from AECOM. The four alternative lattice steel tower designs were subject to a comparative visual impact appraisal and ranked in order of preference.

- 189 The four options are illustrated in **Figure 4.15**. The preferred tower type represents a balance between landscape and visual impacts and technical requirements.



**Figure 4.15: Outline Drawings of Lattice Steel Towers (not to scale)**

- 190 All of the tower designs were symmetrical in form, with similar weight, footprint and finish. The span lengths were also the same, thereby resulting in a similar frequency of supports along a length of OHL. They also have a similar capacity for flexible routing. The overall height of the towers is also similar with the exception of the Inverted Delta tower type which is some 2.5m taller than the other alternatives.

- 191 The main difference in the visual appearance of the towers, and consequently their ability to more or less successfully be accommodated into the landscape, was related to specific design features, density, outline complexity and phasing arrangements. The 401 design features were such that a relatively denser and more complex structure was created, although the phasing arrangement was relatively compact and simple. Tower designs IVI and VVV followed a relatively similar structure, although the phasing arrangement and design density was more complex in tower VVV than IVI increasing the former's visual prominence in the landscape. The increased height of the Inverted Delta tower combined with its greater width and bulk creates the most substantial and visually prominent form out of all the structures.

192 Tower design alternative IVI had the lowest appraisal score (that is the best score) which was supported by a more qualitative analysis undertaken, including the use of photomontages. For these reasons it was considered to have the lowest visual impact in comparison with the other tower alternatives. As such, tower design alternative IVI was considered as the preferred tower type for the proposed development.

193 Additional studies examined matters such as foundation design, electrical parameters, insulation coordination and manufacturing processes.

194 From the results of each study, the following conclusions were made:

- Following the visual impact evaluation performed by AECOM it was considered that the IVI tower design visually imposes least on the landscape.
- It was considered that the costs of the cold formed tower compared to that of its hot rolled counterpart would be higher due to the limited availability of manufactures of this style of tower.
- Visually it was considered that the composite insulator type would have a lesser impact to that of glass insulators and given the comparative cost of both materials be the recommended insulator material to be used.
- Following a foundation study on each of the tower designs the small variation of the size and load of each foundation does not constitute preference of any design.
- In an electrical study performed by SAE Power Lines it was found that from an electrical performance perspective there is not much difference between the four lattice steel options.

195 From all the studies it was considered that the tower design that would most satisfy all required criteria is a hot rolled steel IVI tower with composite insulators. Accordingly, this tower was adopted as the support structure design for the previous application for approval for the Meath-Tyrone 400 kV Interconnection Development project (subsequently withdrawn).

#### **4.8.2.2 Review and Confirmation of the Selection of a Single Circuit Support Structure for the Proposed Development**

196 The *Final Re-evaluation Report* reviewed the pre 2009 studies and concluded that the lattice steel structure known as the 'IVI Tower' shall be put forward as the emerging preferred option.

197 It also noted that in a report by the Government appointed IEC<sup>70</sup> it was concluded that while a high voltage AC OHL “still offers significantly lower investment costs than any underground alternative” it “could also be made more attractive by investing slightly more in new tower designs than the classical steel lattice towers now proposed<sup>71</sup>”. The IEC also identified that it may be possible to “reduce the visual impact of traditional lattice steel towers” by “painting the steel dark green or another colour somewhat matching the terrain around. This method is efficient to reduce the visibility as most people will see the tower with nature as a background.” On the basis of the findings of the IEC Report, EirGrid committed to giving further consideration to alternative structures before finalising its preferred project solution.

#### 4.8.2.3 Re-evaluation of Feasible Alternative Tower Overhead Line Structures

198 Separately to, and independent of, the proposed development, EirGrid had commissioned the consultants Atkins (with LSTC as sub-consultants) to develop conceptual 400 kV and 110 kV steel monopole designs. In the course of this study, Atkins identified a conceptual design for a single circuit 400 kV steel monopole that is potentially suitable for use on the Irish transmission system.



**Figure 4.16: ‘Atkins’ Monopole Design and Proposed IVI Lattice Tower**

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<sup>70</sup> Available at [www.dcenr.gov.ie](http://www.dcenr.gov.ie).

<sup>71</sup> EirGrid considers the Type 401 tower to be the ‘classical’ or ‘traditional’ design for a 400 kV single circuit lattice steel tower. The Type 401 was never proposed for this development instead the modern IVI design with lower visual impact is the preferred option.

- 199 EirGrid asked ESBI to carry out a comparative assessment of the 'Atkins' monopole versus the IVI tower specifically for use on this proposed development. In addition, as the option was raised by the IEC in its report, EirGrid requested that ESBI comment on the effectiveness of the painting of galvanised steel OHL structures as a visual impact mitigation measure in the Irish landscape in general and for this proposed development in particular.
- 200 ESBI concluded that, in general, the 400 kV monopole design identified by Atkins is technically feasible for use on the Irish transmission system, including for use on the proposed development. However, following a comparative assessment of the Atkins monopole versus the IVI tower for use specifically on the proposed development ESBI found that:
- A monopole design may provide some advantages over a traditional lattice steel design when set in an urban or semi-urban landscape. This proposed development however is set entirely within a rural landscape and in such circumstances it is not clear that the Atkins monopole design would provide any advantages over that of the IVI tower design.
  - It is considered that due to the nature and size of the monopole structures (which are of similar heights to IVI towers), and the requirement for about 25% more structures in the case of the monopole design, there may be increased visibility.
  - The construction effort and consequently the environmental impact of the construction, is considerably greater in the case of the monopoles due to a combination of the larger size and weight of the steel members, the larger foundations and the greater number of structures required.
  - The monopole design will be more costly to implement in comparison with the IVI design in terms of raw materials and number of individual structures.
  - The programme for delivery of the proposed development will be six to eight months longer if a monopole design is used as opposed to an IVI tower design.
- 201 Accordingly, it was recommended that the IVI tower be adopted by EirGrid as the preferred structure for the proposed development.
- 202 It was noted that it was technically feasible for a development that consisted primarily of IVI towers to insert monopoles in very specific and localised areas where doing so would result in a lesser impact than that of the IVI towers.
- 203 It was also noted that the painting of towers as a camouflage effect and the use of specially treated non-shiny 'shadow' conductor can be a mitigation measure in specific situations.

#### 4.8.2.4 Modifications to Existing 110 kV Transmission Overhead Lines

204 The standard structure used for intermediate positions on existing single circuit 110 kV transmission OHLs in Ireland is a wood poleset. Having regard to *inter alia* the nature of the works proposed and the nature of the receiving environment the advance modifications proposed to the existing Louth-Rathrussan 110 kV, Lisdrum–Louth 110 kV and Arva-Navan 110 kV OHLs will also use the standard wood poleset.

### 4.9 CONCLUSIONS

205 Having re-considered all the technology options, EirGrid concludes as follows:

206 Any option using DC technology, even one using the latest VSC HVDC technology, is not an acceptable option for the specific nature, extent, and intended function of the proposed development. Implementing the development using VSC HVDC would be significantly more expensive and technically inferior to a standard AC solution. For these reasons, EirGrid is proposing a standard AC solution.

207 The Government appointed International Expert Commission (IEC) concluded that an entirely undergrounded AC option is not an acceptable solution for this project for technical reasons. EirGrid concurs with this conclusion.

208 Partial undergrounding may be feasible, but only if the length of UGC to be installed is relatively short; and where the cost of using the short length of UGC can be proven to be an advantageous and cost effective way of overcoming an environmental or technical constraint to the preferred OHL; and where it can be confirmed that the use of UGC does not exceed the transmission system's capacity to accommodate such cables.

209 EirGrid is obliged, within the terms of its licence and statutory obligations as TSO, to develop the transmission system using least cost, technically and environmentally acceptable solutions. Based on all of the above and in order to comply with its licence conditions and statutory obligations, EirGrid is proposing that the development is entirely comprised of 400 kV OHL. A 400 kV OHL is the best technical solution for this development and would be significantly less costly than any UGC alternative.

210 The preferred support structure for use on the proposed 400 kV single circuit OHL development is the lattice steel structure known as the 'IVI' tower.