# Grid West Project

# Appendix 3.1 – Grid West Initial Technical Studies

**Revision History:**

| Date | Version | Summary of Changes |
|---|---|---|
| | | |
| March 2013 | 1.0 | Approved by EirGrid |
| | | |

# Appendix: 3.1

# Grid West Initial Technical Studies

This appendix describes the analysis carried out by EirGrid to establish the Grid West project. This analysis was completed in February 2011.

## Contents

## Summary

Grid**25**, published in October 2008, identified the requirement for high capacity transmission infrastructure to connect large quantities of renewable generation in the north west of the country and therefore contribute to meeting the 40% target by 2020. Since then, the Gate 3 group process has brought a greater degree of clarity to the requirements for renewable energy connections. The total capacity with applications in the Gate 3 process within the proximity of the existing Bellacorick 110 kV station amounts to 646.5 MW. This capacity, which is made up entirely of wind generation, represents a significant proportion of the Gate 3 renewable total of circa 4,000 MW.

Generation connections are also being processed in Gate 3 in the area at Castlebar, Corderry, Cunghill, Glenree, Moy, Sligo and Tawnaghmore 110 kV stations.

Network analysis has shown that the capacity on the existing local 110 kV network is limited. The red lines in Figure ES1 illustrate the extensive nature of potential overloads if all Gate 3 applicants in the region connect to the existing 110 kV network. It is evident from this analysis that this quantity of generation at Bellacorick cannot be supported by the existing local 110 kV network, even if it is uprated.

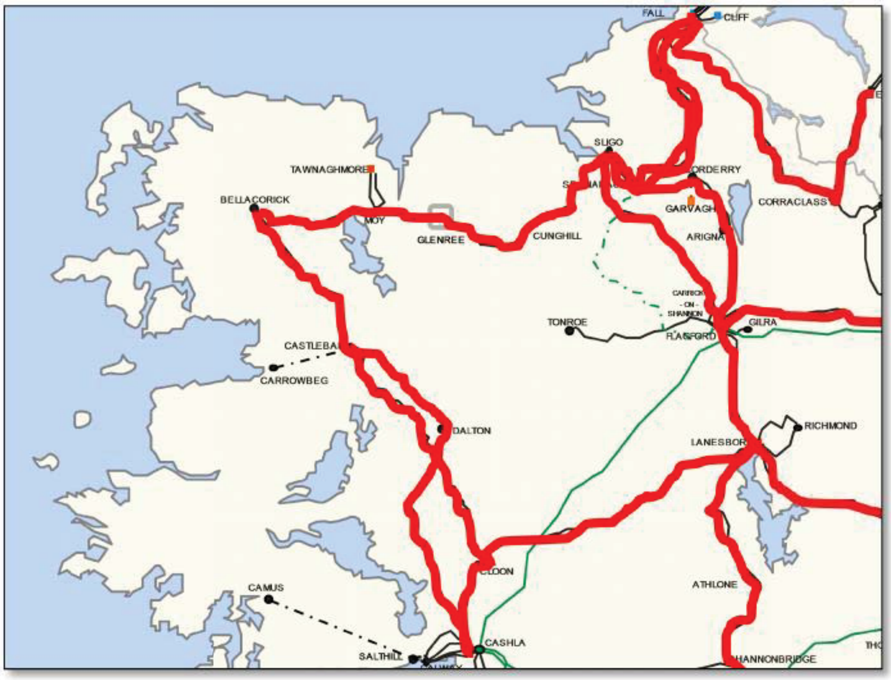


*Figure ES1 - Map Illustrating the Overloaded Circuits in the Bellacorick Area*

This generation must therefore be exported out from the Bellacorick area by a high capacity connection to the Extra High Voltage (EHV) network (i.e. 220 kV and 400 kV) for onward transmission throughout the grid.

In addition, connection applications for generation beyond Gate 3 have been received for this area, underlining the requirement for a strategically-focused EHV grid development. Applications include biomass, pumped storage and further wind generation. The North Mayo coastline has also been highlighted by the Marine Renewables Industry Association (MRIA) as a priority zone for the development of ocean-based technologies.

### *Consideration of Number of Circuits Required*

There are a number of technology options available that have adequate capacity on a single circuit to connect the full 646.5 MW to the EHV grid. However, connecting this much generation on a single circuit introduces considerable operational risk, as a single event such as the loss of the connecting circuit could instantaneously disconnect up to 646.5 MW from the system. At present the largest infeed that could be disconnected by a single event is 450 MW.

Variations of connections with one or two EHV circuits were considered. However the preferred approach is to split the connection, with part connected to the 110 kV network and the remainder to the EHV network. Studies have shown that up to 170 MW of the total amount could be connected to the 110 kV network following the additional uprating of two existing 110 kV lines and the construction of a new 110 kV circuit from north Mayo to south Mayo. This would leave 476.5 MW to be evacuated on a high capacity circuit and would not introduce additional system risk or reserve cost. This approach is preferred on the basis of minimising costs and operational risk.

The associated 110 kV reinforcements are part of the overall solution for this connection but will be dealt with as separate projects if and when required.

### *Connection Termination Options*

Based on this split connection approach, a number of options were considered for the termination points of the proposed single high capacity circuit. One end of the new high capacity circuit will evidently be in the vicinity of the existing Bellacorick station as the purpose of the project is to connect wind generation in this area. The other end must be part of the existing EHV network. Eleven options were assessed from a technical and economic perspective, taking account of the likely length of the connection and the impact of an injection of up to 476.5 MW on the network around the termination point.

From this consideration, Flagford and Cashla emerged as the preferred connection termination points based on least overall circuit build and cost. The estimated length of the connection is approximately 130 km [1] in both cases.

[1] The estimated length of the connection to either Flagford or Cashla is assumed to be approximately 130 km, having regard to line routing considerations.

There was very little to distinguish between these two options at this point in time, and hence it is proposed that both are brought forward for further more detailed evaluation in the Stage 1 process.

The results of an initial assessment of environmental issues concluded that there is no environmental impediment identified at this stage to progressing either option.

### *Technology and Voltage Options*

A range of standard and non-standard technologies and voltage levels were considered for the EHV connection to either Flagford or Cashla. In accordance with EirGrid's published policy[2] on use of underground cables, it was assumed at this stage of the studies that the HVAC solutions would be constructed as overhead lines. It is recognised, however, that the undergrounding option may be revisited during the Stage 1 route option investigations. There is no experience of HVDC circuits embedded in the Irish system and as it is a developing technology in the context of meshed applications no policy has yet been developed for its use. Nevertheless, both underground and overhead HVDC options were included in the assessment.

The list of options evaluated was:

1. Build a single 220 kV overhead circuit from a new Bellacorick 220 kV station to the existing Flagford or Cashla 220 kV stations.
2. Build a 220 kV double circuit from a new Bellacorick 220 kV station to the existing Flagford or Cashla 220 kV stations.
3. Build a single 400 kV overhead circuit from Bellacorick to connect to a new 400/220 kV transformer in the existing Flagford or Cashla 220 kV station.
4. Build a single overhead HVDC circuit from Bellacorick to Flagford or Cashla and the associated converter stations at each end.
5. Build a single underground HVDC circuit from Bellacorick to Flagford or Cashla and the associated converter stations at each end.

These connection options were subject to technical and economic analysis and evaluated and compared against the following criteria:

- Provision of sufficient capacity for the connection of at least 476.5 MW at Bellacorick.
- Facilitation of strategic development for longer-term needs beyond Gate 3.
- Cost effectiveness.
- Operability.

[2] http://www.eirgrid.com/media/EirGridPolicy.pdf

All options were found to have adequate capacity to connect the 476.5 MW of Gate 3 generation at Bellacorick. In all cases, to provide additional capacity for further generation development in North West Mayo, a second EHV circuit will be required.

Table 1 illustrates a comparison of the lifetime costs for each option. The calculation of losses was based on the forecast annual hourly profile of wind generation using the connection circuit.

**Table 1: Cost Comparison of Technology Options**

| | 220 kV Single Circuit | 220 kV Double Circuit | 400 kV Single Circuit | HVDC Overhead | HVDC Under-ground |
|---|---|---|---|---|---|
| Circuit Costs | | | | | |
| Station Costs | | | | | |
| Present Value of Initial Investment Cost | | | | | |
| Present Value of Lifetime Losses Cost | | | | | |
| Present Value of Total Lifetime Cost | | | | | |
| Circuit Capacity – Summer Rating | | | | | |
| Cost of Capacity (€M/MVA) | | | | | |

Legend:

| | |
|---|---|
| | Least preferred |
| | Preferred |
| | Most preferred |

Table 2 summarises the scoring of each option against the four criteria. The conclusion of the evaluation is that the 220 kV double circuit option and the 400 kV single circuit option were the most preferred of the five technology options considered.

Of these two, the double circuit 220 kV solution integrates better initially than the 400 kV option as it will connect into an existing 220 kV station at the same voltage. The 400 kV circuit will also connect into a 220 kV station and, while technically feasible, it will not be integrated with the rest of the 400 kV network until such time as the 400 kV network is extended from the new 400 kV termination point at Flagford or Cashla to the rest of the existing 400 kV network. However, even as currently proposed, a single 400 kV circuit solution is significantly more efficient (i.e. incurs lower transmission losses) than the double circuit 220 kV option and has a marginally lower overall lifetime cost. Building this circuit at 400 kV conforms to the strategy for new development outlined in Grid**25**.

**Table 2: Comparison of Options against Criteria**

| Criteria | 220 kV Single Circuit | 220 kV Double Circuit | 400 kV Single Circuit | HVDC Overhead | HVDC Underground |
|---|---|---|---|---|---|
| **Facilitate Gate 3 Connections at Bellacorick** | | | | | |
| **Maximise Future Extensibility** | | | | | |
| **Minimise Lifetime Cost** | | | | | |
| **Maintain System Operability** | | | | | |

Legend:

| | |
|---|---|
| | Least preferred |
| | Preferred |
| | Most preferred |

For these reasons the 400 kV single circuit solution is the preferred technology and voltage for the high capacity connection of the Bellacorick subgroup.

In summary the preferred option for this connection is a single 400 kV overhead line from Bellacorick to Cashla or Flagford. This is regarded as being the most optimum long-term transmission reinforcement considering technical and economic merits.

The scope for Stage 1 is to investigate the two circuit options to Cashla and Flagford, indentifying a preferred option and associated corridor and route and to progress through to planning consent.

# 1 Background

In the 2007 White Paper on *Delivering a Sustainable Energy Future for Ireland* the Irish Government set a target of meeting 33% of electrical consumption from renewable sources by 2020. In 2008 the Government revised this target upwards to 40%. The White Paper also includes an ambition to have 500 MW of wave and tidal capacity operational by 2020.

Following on from this, Grid**25** published in October 2008 identified the requirement for high capacity transmission infrastructure to connect large quantities of renewable generation from the north west of the country to the east coast, contributing to achievement of the 40% target by 2020.

Since then, the Gate 3 group process has brought a greater degree of clarity to the requirements for renewable energy connections. The Gate 3 renewable generation in the Bellacorick vicinity consists entirely of wind generation. The total expected to connect within the proximity of the existing Bellacorick 110 kV station amounts to 646.5 MW; a significant quantity of Gate 3 which totals circa 3,900 MW. Table 3 lists the proposed Gate 3 wind farms assigned to the Bellacorick node.

**Table 3 – Proposed Gate 3 wind farms at the Bellacorick node**

| Code | Name | MEC (MW) |
|---|---|---|
| TG33 | Ederglen (1) | 16.8 |
| DG143 | Bunnahowen (1) | 2.55 |
| DG202 | Bunaveala (Keenagh) (1) | 9.2 |
| DG168 | Dooleeg More (1) | 2 |
| DG247 | Gortnahurra (1) | 33.9 |
| DG186 | Tawnaghmore 1 & 2 and 3 Merge | 16.1 |
| TG57 | Dooghbeg (1) | 45 |
| TG90 | Cluddaun (1) | 52 |
| TG91 | Cluddaun (2) | 64 |
| TG92 | Cluddaun (3) | 34 |
| TG25 | Oweninney (1) | 34 |
| TG26 | Oweninney (2) | 48 |
| TG27 | Oweninney (3) | 56 |
| TG28 | Oweninney (4) | 34 |
| TG71 | Oweninney (5) | 198.9 |
| | **TOTAL** | **646.5** |

In addition to the Gate 3 process, connection applications have been submitted for biomass, pumped storage and ocean-based generation as well as further development of wind generation in the Bellacorick area. In June 2010, the Marine Renewables Industry Association (MRIA) published a White Paper called *Priority Development Zones: A Key Initiative to Realising Ireland's Ocean Energy Potential*[3]. The report classified 'North Mayo' as a priority development zone for the development of wave generation technologies. The preferred solution as outlined in this report has been assessed taking account of these potentially larger volumes of generation in north Mayo.

Mayo County Council has prepared a Renewable Energy Strategy for County Mayo 2010-2020. The purpose of the strategy is to guide renewable energy developments in the county for the period 2011 to 2020. The document notes that there is an expectation that the use of 400 kV technology will be required.

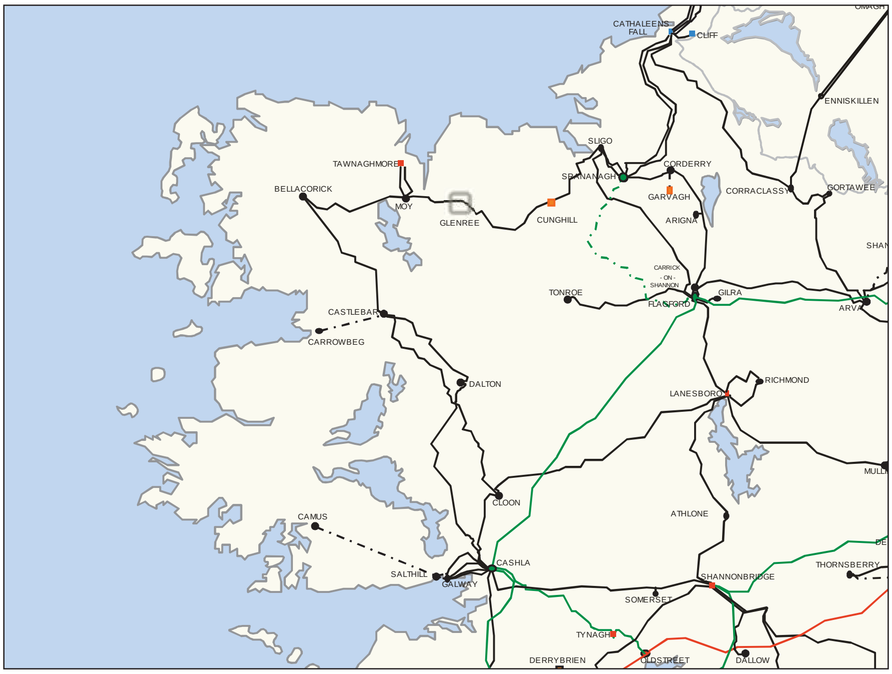


*Figure 2 – Map Illustrating the Location of the Bellacorick 110 kV Station (110 kV lines are shown in black, 220 kV lines in green and 400 kV lines in red)*

The Bellacorick 110 kV station is located in the north west of Co. Mayo. Figure 2 shows that the station is geographically and electrically remote and is connected to the transmission network via two 110 kV overhead transmission lines;

[3] Available at http://www.mria.ie/documents/19e0290049ea2b4cb770f70fc.pdf

Bellacorick – Castlebar and Bellacorick – Moy 110 kV. These circuits have summer and winter thermal ratings of 107 and 126 MVA respectively.

At present there is a total of 6.5 MW of distribution-connected wind generation fed into the Bellacorick 110 kV station. Peak demand at Bellacorick station is around 6 MW (growing to 7 MW in 2016 according to Transmission Forecast Statement 2010-2016). This is very low in relation to the proposed connection, meaning that most of the generation at Bellacorick will have to be evacuated to the rest of the network.

# 2 Statement of Need

The main driver for this project is the connection of Gate 3 generation at Bellacorick.

## 2.1 Drivers of Need

EirGrid has a statutory duty to provide connections to the transmission grid for generation developments. The developers in the Bellacorick subgroup have made applications for connection to the grid for a total capacity of 646.5 MW and are being processed under Gate 3. Applications for Gate 3 generation at other locations in Connaught are also being processed.

Connection applications for generation beyond Gate 3 have been received for this area. Applications include biomass, pumped storage and further wind generation. The Marine Renewables Industry Association (MRIA) has identified the North Mayo coastline as a priority zone for the future development of wave generation technologies.

## 2.2 Assessment of Network Capability

An inspection of the facts highlights the deficiencies of the existing network for accommodation of the Bellacorick subgroup. Bellacorick 110 kV station is connected to the rest of the grid by two 110 kV lines – one to Castlebar and the other to Moy – each with a summer capacity rating of 107 MVA. As the network must be capable of operating securely with any circuit out of service (the n-1 criterion), the secure network capacity available for generation at Bellacorick is 107 MVA, or approximately 107 MW. This available capacity is significantly short of the 646.5 MW required by the Gate 3 applicants. Even if these lines were uprated to about 200 MVA (the highest nominal rating for a 110 kV line in the Irish system), there would be a major capacity deficit in the area.

A detailed technical analysis, using load flow software was undertaken to identify the full extent of the impact of connecting the Bellacorick sub-group. This analysis initially also took account of other known needs in the area, including all Gate 3 generation in Mayo and neighbouring counties and up to 160 MW[4] of

[4] *All-Island Grid Study* (2008)

wave generation at Bellacorick representing the evident interest and the Government's ambitions for wave generation.

The technical performance of the planned network (i.e. the existing network reinforced by EirGrid approved projects) was assessed. Results showed significant overloading of many 110 kV circuits throughout the northern part of the network, the worst cases occurring on circuits near Bellacorick.

As expected, the Bellacorick - Castlebar 110 kV line was found to be severely overloaded in the event of the single outage (N-1) of the Cunghill - Sligo 110 kV line. Other circuits such as the Bellacorick – Moy and the Moy – Glenree – Cunghill - Sligo 110 kV circuits were also found to be significantly overloaded for other contingencies.

Figure 4 highlights in red the lines in this region which would be overloaded following the loss of a single circuit (N-1 contingency), illustrating the extent of the problem. The analysis therefore conclusively demonstrated that the existing 110 kV network alone, even if upgraded, cannot absorb this amount of generation.

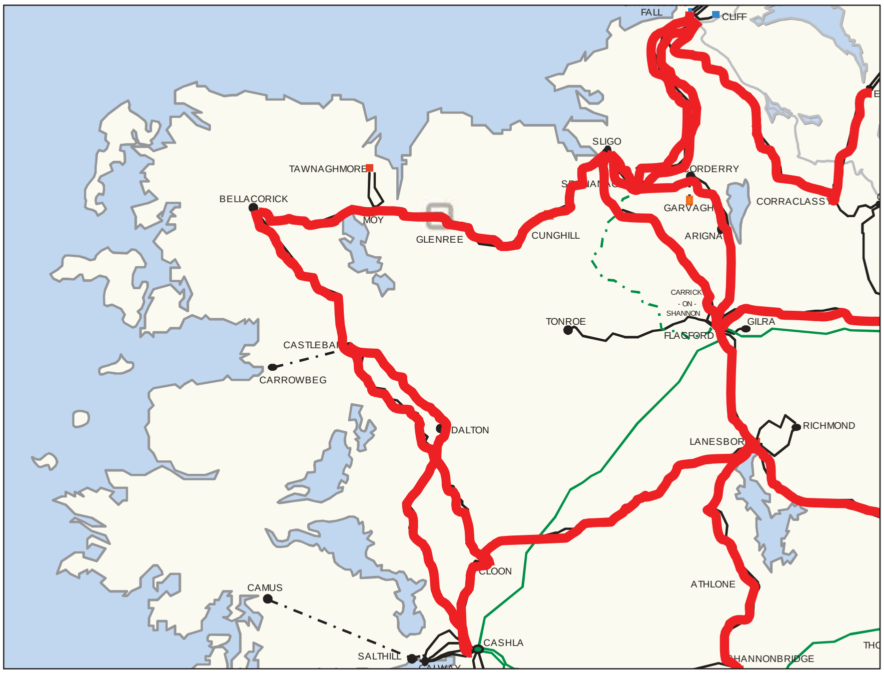


*Figure 4 - Map Illustrating the Overloaded Circuits in Northern Part of the Network*

The option of connecting the 646.5 MW at the existing Bellacorick 110 kV station and adding new 110 kV circuits was considered impractical given that at least four new 110 kV circuits would be required from Bellacorick back to an EHV node. This option would contribute significantly to an increase of transmission losses while not contributing any long-term benefits.

The conclusion of the considerations above is that a 110 kV solution alone is not suitable for connection of this size of generation capacity.

Therefore a high capacity connection to the EHV network is required. A staged approach was undertaken in the studies to determine the number of circuits required, the preferred termination point, and the preferred technology and voltage of the connection.

## 3 Number of Connection Circuits Required

The analysis of need concluded that a high capacity extra high voltage connection will be required to evacuate power from the Bellacorick area. It is known that there are technologies available that would allow the Gate 3 quantity of 646.5 MW to be carried on a single circuit.

However, carrying 646.5 MW on a single circuit could introduce a significant additional operational risk. At present the largest generation infeed is 450 MW; this may be greater at times when the 500 MW East West Interconnector project, due to be completed in 2012, is at maximum capacity. Allowing a single infeed of 646.5 MW to connect to the system would result in additional operational costs and introduce technical risks and challenges in providing additional reserve.

Taking this identified risk into account, the options considered for the number of connection circuits were:

- Option 1: Two separate EHV circuits from Bellacorick to the EHV network.
- Option 2: A single EHV circuit from Bellacorick to the EHV network and mitigate the risk with additional reserve or wind curtailment.
- Option 3: Split the connection of the Bellacorick generation group between the existing 110 kV network and a single EHV circuit connection.

Option 1 would overcome the risk of disconnecting the Bellacorick subgroup for a single fault, as there would be a second line available to carry the output from the generation. However, this option would require two separate routes and would be significantly more costly than the other options. While a double circuit connection would require just one route and would reduce the risk of a total disconnection of the generation at Bellacorick, it would not eliminate the risk as is evident from an inspection of EirGrid records of unplanned double circuit outages in Ireland.

Option 2 would introduce additional operational costs and a technical challenge in providing the required reserve. This would especially be the case at times of high wind generation when thermal generation plant was turned down or switched off.

Option 3 would require connecting some of the Bellacorick subgroup to the existing 110 kV network. Analysis undertaken as part of the Gate 3 process demonstrated that approximately 170 MW of the Bellacorick generation can be accommodated on the 110 kV network assuming that two additional 110 kV lines are uprated and a new 110 kV circuit is added between north and south Mayo. The remaining 476.5 MW of generation therefore would need to be connected by an EHV shallow connection (220/400 kV) between Bellacorick and the EHV grid. It is estimated that connecting this reduced amount of capacity on a single circuit would not add any discernible costs or risks.

Option 3 is considered the preferred solution on the basis of minimising connection and operation costs and limiting operational risk. The 110 kV reinforcements required to accommodate up to 170 MW on the 110 kV network will be progressed through separate studies and approval process.

It should be noted that the development of renewable generation resources is expected to continue to grow beyond the Gate 3 process as initially considered in the needs analysis for example with the inclusion of 160 MW of wave generation. If generation at Bellacorick EHV node should exceed 500 MW there could be a requirement for a second EHV circuit due to the above issues. A second 400 kV circuit, in addition to the planned 400 kV circuit would provide up to 1,500 MW capacity at Bellacorick.

# 4 Selection of Termination Points for the EHV Connection

The connection approach being adopted is to connect 170 MW to the 110 kV network and the remaining 476.5 MW of the Bellacorick subgroup to the EHV network using a single EHV circuit.

## *4.1 Termination Points of the Connection*

In considering the EHV connection it is clear that one end must be close to the Bellacorick subgroup, the centre of which is close to the existing Bellacorick 110 kV station.

The other termination point for the EHV circuit must logically be at an existing or new EHV station. Eleven possible termination locations were considered as shown in Figure 5. These include all 220 kV nodes in the northern part of the country, a point half-way along the Cashla-Flagford 220 kV line (named Cash-Ford), and at Moneypoint, Woodland and the potential Kingscourt 400 kV stations.

1. **Srananagh 220 kV**
2. **Flagford 220 kV**
3. **'Cash-Ford' 220 kV**
4. **Cashla 220 kV**
5. **Moneypoint 400 kV**
6. **Oldstreet 400 kV**
7. **Shannonbridge 220 kV**
8. **Woodland 400 kV**
9. **Gorman 220 kV**
10. **Louth 220 kV**
11. **Kingscourt 400 kV**

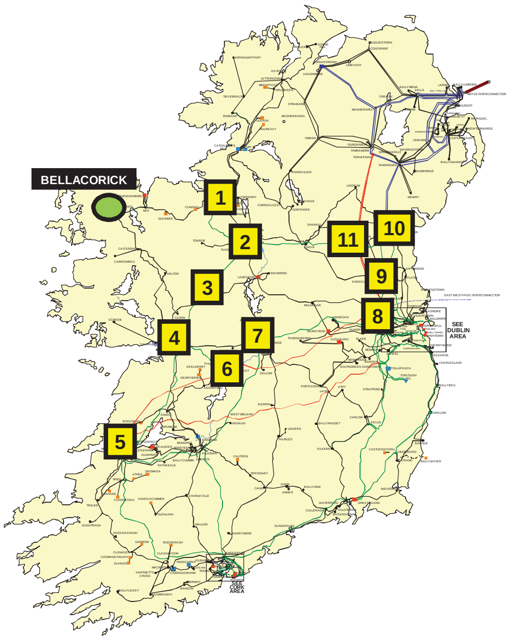


*Figure 5 – The Potential Termination Points Considered*

Incremental transfer capability (ITC)[5] analysis was used to evaluate the capability of the transmission network to carry flows between each of these potential

[5] ITC analysis has been used in preparation of Transmission Forecast Statements since 2003, and more recently in the analysis of Gate 3 connections.

termination nodes and the rest of the power system under a range of dispatch scenarios - winter peak, summer peak and summer valley demand scenarios, all studied with generation being removed alternatively in Dublin, Northern Ireland and the South to match generation added in Bellacorick.

Deep reinforcements were identified for all potential termination nodes to ensure that they were technically feasible. Table 4 illustrates the ranking of the options in terms of total investment cost, comprising shallow connection and expected deep reinforcement cost comparisons. For the purpose of this comparison, the shallow connection costs are based on a 400 kV connection.

**Table 4 –Costs Associated with Potential Connection Locations**

| Termination Option | 400 kV Line costs | 400 kV station works costs | Estimated Associated Deep Reinforcement Cost | Total Reinforcement Costs for 400 kV solution | Rank |
|---|---|---|---|---|---|
| Flagford | | | | | 1 |
| Cashla | | | | | 2 |
| Srananagh | | | | | 3 |
| 'Cash-Ford' | | | | | 4 |
| Oldstreet | | | | | 5 |
| Shannonbridge | | | | | 6 |
| Moneypoint | | | | | 7 |
| Kingscourt | | | | | 8 |
| Gorman | | | | | 9 |
| Woodland | | | | | 10 |
| Louth | | | | | 11 |

Legend:

| | |
|---|---|
| | Least preferred |
| | Preferred |
| | Most preferred |

The Cashla and Flagford 220 kV stations were identified from this analysis as the preferred EHV nodes for a connection from Bellacorick based on lowest overall investment costs taking account of shallow connection and deep reinforcement costs. The remaining candidate nodes either had more costly and more numerous associated deep reinforcements, such as the Cash-Ford or Srananagh options, or longer and hence more costly shallow connections, such as the Louth or Woodland options.

The estimated length of the connection to either Flagford or Cashla is assumed to be approximately 130 km, having regard to line routing considerations.

### *4.2 Initial Environmental Review of Connection Options*

A review was undertaken to examine the proposed Gate 3 Bellacorick connection with available EHV nodes within the study area (Srananagh, Flagford and Cashla) in terms of high level environmental constraints, focusing on ecological issues. Sites of European Importance were considered the most significant constraint as any project will have to prove no significant negative impacts on the integrity of any site that may be impacted.

The review was based on EirGrid Strategic Environmental Constraint Mapping and information from the National Parks and Wildlife Service data base (www.npws.ie). Sites of European importance including Special Protection Areas SPA (for wild birds) and Special Conservation Areas SAC (for protected habitats and species) were identified. Sites of national conservation importance were also identified including National Parks and Natural Heritage Areas (NHA).

The review identified that due to the sensitive nature of the ecological environment in the study area and extensive coverage of designated areas of European Importance any proposed new substation in Bellacorick and associated high voltage circuits in this general location will require sensitive siting and routing respectively to avoid potential significant impacts on environmental receptors.

Routing south of Bellacorick is a possible option for all potential connections avoiding in as much as possible impacts on Bellacorick Bog Complex and the Owenduff/Nephin Complex SAC/SPA which includes Ballycroy National Park.

Routing of a high voltage connection between Bellacorick and Srananagh 220 kV station could pose some challenges as the existing 110kV line utilises a corridor which avoids most designated areas, reducing the options available to another high voltage line. Bird flight lines may be a potential issue between River Moy and Lough Conn/Lough Cullin.

In order to reduce the likelihood of potential impacts on bird flight paths between the mouth of the River Moy and Lough Conn Lough Cullin SPA, it is possible that a high voltage connection between Bellacorick and Flagford could be routed south of Lough Conn/Lough Cullin then follow an eastern trajectory roughly following the N 5 to the south of Lough Garra SPA and Callow Bog SAC with sensitive routing to Flagford in order to avoid major impacts on European sites. Further analysis of bird flight paths and movements of water birds in this area will be necessary to aid in identifying an emerging preferred corridor (as part of process of Appropriate Assessment).

In order to reduce the likelihood of impacts on a number of European sites and potential impacts on bird flight paths, it is possible that a high voltage connection between Bellacorick and Cashla could be located to the east of Lough

Carra/Mask and Lough Corrib. Sensitive routing through wetland habitats between Ballinrobe and Headford will be necessary to avoid impacts on a number of European sites and possible movement of water birds between sites. Further analysis of bird flight paths and movements of water birds in this area will be necessary to aid in identifying an emerging preferred corridor (as part of process of Appropriate Assessment).

### *4.3 Conclusion of Termination Point Evaluation*

While the initial environmental assessment highlights difficulties facing new transmission infrastructure, particularly near Bellacorick, nothing has been identified that would rule out a connection to either Cashla or Flagford at this stage.

There is therefore very little to distinguish between these two options at this point in time, and hence it is proposed that both are brought forward for further more detailed evaluation in the Stage 1 process.

## 5 Technology and Voltage Options for Connection

### *5.1 Technology and Voltage Options Considered*

Consideration was given to a range of EHV technologies, including HVAC, HVDC, underground and overhead options for the approximate 130 km connection between Bellacorick and Flagford or Cashla. A range of operating voltages was also considered. At present EirGrid operates the transmission system at two distinct EHV levels; 220 kV and 400 kV. The HVAC technologies were therefore examined at these voltages.

In accordance with EirGrid's published policy[6] on the use of underground cables, it was assumed at this stage of the studies that the HVAC solutions would be constructed as overhead lines. It is recognised, however, that the undergrounding option may be re-visited during the route option investigations.

There is no experience of HVDC circuits on the Irish system and, as it is a developing technology in the context of meshed applications, no policy has yet been developed for its use. Nevertheless, both underground and overhead HVDC options were included in the assessment. The HVDC option was assumed to be a 320 kV Voltage Source Convertor (VSC) connection rated to 796 MVA, based on the 2009 TransGrid report, *Investigating the Impact of HVDC Schemes in the Irish Transmission Network*.

[6] http://www.eirgrid.com/media/EirGridPolicy.pdf

From this consideration five scheme options were developed for evaluation. These are:

- Option A – Build a 220 kV station at Bellacorick and a single 220 kV overhead circuit, using a High Tension Low Sag (HTLS) conductor assumed to be GZTACSR, from Bellacorick to the Flagford or Cashla 220 kV stations.
- Option B – Build a 220 kV station at Bellacorick and a 220 kV double circuit, using a standard ACSR conductor, from Bellacorick to the Flagford or Cashla 220 kV stations.
- Option C – Build a single overhead HVDC circuit from Bellacorick to Flagford or Cashla and the associated converter stations.
- Option D - Build a single underground HVDC circuit from Bellacorick to Flagford or Cashla and the associated converter stations.
- Option E - Build a 400 kV station at Bellacorick and a single 400 kV ACSR overhead circuit from Bellacorick to a Flagford or Cashla 400/220 kV station.

The standard summer rating for 220 kV ACSR conductor currently in use by EirGrid is 431 MVA. A single 220 kV line using ACSR would therefore not provide sufficient capacity to accommodate the connection of 476.5 MW at Bellacorick. Although future implementation of technologies or methods, such as use of dynamic line rating, may offer higher rating possibilities for this conductor, it was assumed in these studies that Option A would utilise the higher capacity, but slightly more expensive HTLS conductor, assumed to be GZTACSR commonly referred to as Gap conductor.

## *5.2 Criteria for Assessment of Connection Options*

Each of the options A to E was evaluated based on the following four criteria:

- The ability to meet the need of facilitating the Gate 3 generation expecting to connect at the Bellacorick EHV station. The EHV option must be capable of accommodating 476.5 MW of wind generation.
- The ability to meet strategic development needs. The EHV option should be capable of providing for network extensibility. The development of renewable resources is expected to continue in the vicinity of Bellacorick. The Bellacorick and neighbouring transmission stations may also need reinforcement to ensure long-term security of supply standards in the area. The preferred option should therefore be flexible enough to integrate with a variety of future transmission network developments.
- The EHV option should be cost effective. The combined initial capital and associated lifetime costs should deliver value for money.

- Operability; which addresses the reliability of the connection and how flexible each option is to system operator requirements.

The visual impact of each option has not been addressed in this report.

## *5.3 Assessment of Connection Options*

Table 5 displays comparison of the associated lifetime costs for each of these options. The lifetime costs are derived from the net present value of the initial capital costs and the cost of transmission losses.

**Table 5: Cost Comparison of Technology Options**

| | 220 kV Single Circuit | 220 kV Double Circuit | 400 kV Single Circuit | HVDC Overhead | HVDC Under-ground |
|---|---|---|---|---|---|
| Circuit Costs | Most preferred | Preferred | Preferred | Most preferred | Least preferred |
| Station Costs | Most preferred | Most preferred | Most preferred | Least preferred | Least preferred |
| Present Value of Initial Investment Cost | Most preferred | Preferred | Preferred | Least preferred | Least preferred |
| Present Value of Lifetime Losses Cost | Least preferred | Preferred | Most preferred | Least preferred | Least preferred |
| Present Value of Total Lifetime Cost | Most preferred | Most preferred | Most preferred | Least preferred | Least preferred |
| Circuit Capacity – Summer Rating | Preferred | Preferred | Most preferred | Preferred | Preferred |
| Cost of Capacity (€M/MVA) | Most preferred | Most preferred | Most preferred | Least preferred | Least preferred |

Legend:

| | |
|---|---|
| | Least preferred |
| | Preferred |
| | Most preferred |

The final row of Table 5 provides an indication of the cost of the potential capacity provided by each option. To realise this potential, another circuit to Bellacorick is required to avoid the loss of an unacceptably high infeed.

All technology / voltage options have adequate capacity to connect the 476.5 MW of Gate 3 generation at Bellacorick. In all cases, to provide additional capacity for further generation development in north west Mayo, a second EHV circuit will be required.

### 5.3.1 Option A - Single 220 kV Gap Overhead Line

This option consists of a new single 220 kV Gap transmission line, and new 220 kV works at the Bellacorick and the Flagford or Cashla 220 kV stations. This provides the required capacity for Gate 3. The addition of a second 220 kV circuit would provide overall transmission capacity at Bellacorick of 790 MVA, which is just 320 MW over Gate 3 needs. Thus, it has much lower future potential than the other options.

### 5.3.2 Option B – Double Circuit 220 kV Overhead Line

This option consists of a new double circuit 220 kV transmission line, new 220 kV works at the Bellacorick and the Flagford or Cashla 220 kV stations. This provides the required capacity for Gate 3. The risk of the loss of both circuits simultaneously is less than the risk of losing a single circuit, making this option somewhat more reliable than the single circuit options. However, for the avoidance of doubt, the remaining risk of a double circuit outage is still deemed ‘a credible contingency’ and therefore another separate circuit would be required to increase the capacity at Bellacorick beyond the Gate 3 requirements. This option can be adapted to facilitate additional capacity at Bellacorick – a second double circuit could provide up to 1,500 MVA of capacity if the marginally more expensive Gap conductor is used on both double circuits. This would represent an additional 1,000 MW over Gate 3 needs.

### 5.3.3 Option C – Single 400 kV Overhead Line

This option consists of a new single 400 kV transmission line between Bellacorick and Flagford or Cashla, new 400 kV works at the terminal stations at each end. This provides the required capacity for Gate 3. A strong benefit of this option is that it facilitates large amounts of future generation development in north west Mayo – the construction of a second 400 kV circuit in the longer term would provide 1,500 MW capacity at Bellacorick, an additional 1,000 MW over Gate 3 needs.

### 5.3.4 Option D and E – Single HVDC Circuit (Overhead and Underground)

These options consist of a new HVDC transmission circuit from Bellacorick to Flagford or Cashla and converter stations at either end of the circuit. Both options will provide sufficient capacity for the immediate needs to connect the Bellacorick subgroup. A second HVDC circuit from Bellacorick to the EHV network will provide a moderate increase in generation capability at Bellacorick. However, further development of these options to meet future needs along the route of either circuit would be very limited by the technical difficulties relating to multi-terminal HVDC circuits and by the very high costs of integration with the HVAC network at new intermediate points.

## 5.4 Comparison of Connection Options

Table 6 provides a visual comparison of the five options against the selection criteria. Lighter blue indicates that the option performs better against the criterion and is most preferred, whereas darker blue shading indicates a poorer performance.

**Table 6: Comparison of Technology Options against Criteria**

| Criteria | 220 kV Single Circuit | 220 kV Double Circuit | 400 kV Single Circuit | HVDC Over-head | HVDC Under-ground |
|---|---|---|---|---|---|
| Facilitate Gate 3 Connections at Bellacorick | | | | | |
| Maximise Future Extensibility | | | | | |
| Minimise Lifetime Cost | | | | | |
| Maintain System Operability | | | | | |

Legend:

| | |
|---|---|
| | Least preferred |
| | Preferred |
| | Most preferred |

The following points provide an explanation for the scoring:

- Option A has the least overall lifetime cost, largely because of its low initial capital costs. However, it is also the least efficient option as it incurs the highest transmission losses of the HVAC options. It presents no particular operational difficulties.
- Option B proved to be relatively efficient from a transmission losses perspective; only the 400 kV single circuit option performed better. The expected lifetime cost of this option was ranked third - marginally higher than the 400 kV single circuit option.
- Option C is the most efficient option, incurring the least transmission losses, despite the need for 400/220 kV transformation at Flagford or Cashla. The calculated lifetime cost of the project is the second lowest of the technically feasible options. The cost per MVA circuit capacity is the lowest of all the options.
- Both Options D and E would incur initial investment and lifetime costs significantly in excess of the other options, because of the need to build very expensive convertor stations at each termination point to integrate the HVDC circuit with the existing HVAC system. Both options have the

potential to introduce operational complexity in the control systems without offering any technical advantages over the HVAC solutions.

Based on this comparison the 220 kV double circuit option and the 400 kV single circuit option were considered the best of the five technology options evaluated.

Of these two options, the double circuit 220 kV solution integrates better initially than the 400 kV option as it will connect into an existing 220 kV station at the same voltage. The 400 kV circuit will also connect into a 220 kV station and, while technically feasible, it will not be fully integrated with the rest of the 400 kV network until such time as this is extended to the new 400 kV termination point at Flagford or Cashla. However, even as currently proposed, a single 400 kV circuit solution is significantly more efficient (i.e. incurs lower transmission losses) than the double circuit 220 kV option and has a marginally lower overall lifetime cost. Building this circuit at 400 kV conforms to the strategy for new development outlined in Grid**25**.

### *5.5 Preferred Connection Options*

The conclusion of the evaluation of the connection technology options is that a 400 kV single circuit provides the best economic option from a long-term perspective and is thus the preferred technology and voltage solution for the high capacity connection of the Bellacorick subgroup.

# 6 Scope of Work

The scope for Stage 1 is to investigate the preferred option, a 400 kV connection, which essentially provides for two route possibilities. One of these routes is to be selected and progressed for planning permission and project agreement.

The preferred connection option consists of the following transmission plant:

- A new 400 kV line from Bellacorick to Flagford or Cashla. The line must be rated to at least the equivalent of a 2 x 600 $mm^2$ bundled ACSR conductor operated at 80°C;
- New 400/110 kV station at Bellacorick, consisting of:
    - One 400 kV line to transformer bay (for circuit to Flagford);
    - One 400/110 kV 500 MVA transformer;
    - Double 110 kV busbar[7];
    - One 110 kV transformer bay (for 400/110 kV 500 MVA transformer);
    - One 110 kV line bay (for circuit to existing Bellacorick 110 kV station);
    - Two 110 kV couplers;
    - Room for future 400 kV line and busbars etc.
- Connection to existing Bellacorick station:
    - One 110 kV line bay in the existing Bellacorick 110 kV station (for the circuit to the new 400/110 kV station at Bellacorick - including busbar extension if required);
    - One 110 kV circuit rated at least equivalent to 430$mm^2$ ACSR at 80°C from new Bellacorick 400/110 kV station to existing Bellacorick 110 kV station (circuit length dependant on location of new Bellacorick 400/110 kV station - current assumption is that the new station will be next to the existing station);
    - One 110 kV coupler in the existing Bellacorick 110 kV station.
- At Flagford or Cashla 220/110 kV station:
    - One 400 kV line to transformer bay;
    - One 400/220 kV 500 MVA transformer;
    - One 220 kV transformer bay - including busbar extension if required).

[8] There may be a requirement for a ring busbar configuration based on the recommendation of an EirGrid policy document on busbar configuration.

While a single 400 kV overhead line is the preferred connection method, it is understood that as part of the Stage 1 process, there may be other (non-technical or commercial) influencing factors such as environmental constraints, which may require other options (previously presented in this report), to be revisited.

Further consideration may also have to be given to the possible requirement for reactive compensation devices and harmonic filters or series reactors due to the use of 400 kV technology at the Bellacorick EHV station. The detailed design stage will conclude on these aspects of the project at a later stage.

# 7 Financial Considerations

The total initial proposed development costs for a 400 kV circuit from Bellacorick to either Flagford or Cashla and associated station works is estimated to be in the order of €240 million. The final project cost will be subject to issues such as substation works and station site acquisition, and will be better estimated following completion of Stage 1.