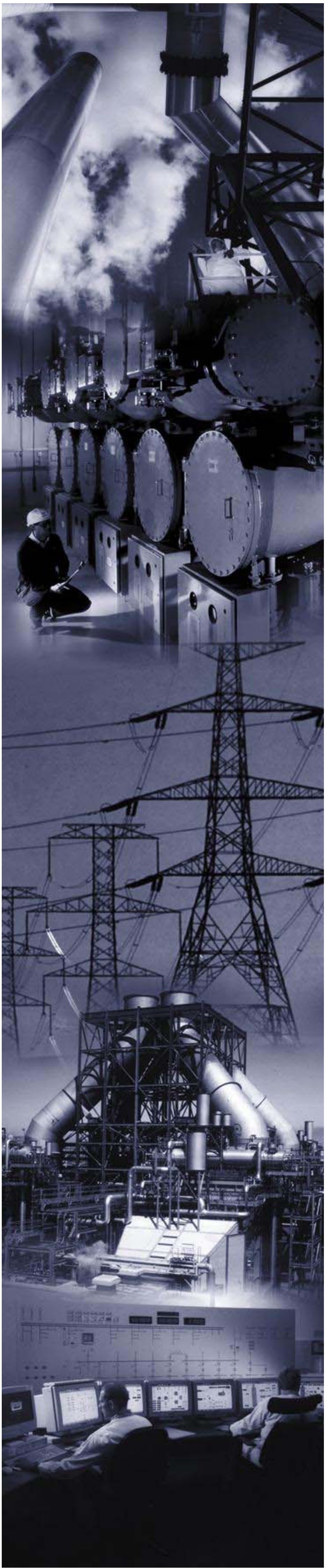

ISLAND OF IRELAND

CAVAN-TYRONE AND MEATH-CAVAN 400KV PROJECTS

PRELIMINARY BRIEFING NOTE

OVERHEAD AND UNDERGROUND ENERGY TRANSMISSION OPTIONS

FEBRUARY 2008

PB POWER

EXECUTIVE SUMMARY

General

1. Two projects have been proposed to develop the electricity transmission infrastructure of the island of Ireland:-

   - EirGrid and Northern Ireland Electricity (NIE) have proposed a new 80km 400kV electricity connection between the Republic of Ireland and Northern Ireland – the Cavan-Tyrone 400kV Project, and
   - EirGrid has proposed a further 60km 400kV development to the transmission network north of Dublin – the Meath-Cavan 400kV Project.

2. This Preliminary Briefing Note summarises in general terms the technical and cost issues associated with implementing these two projects. The note is prepared in advance of the finalisation of the planning applications for each scheme and in advance also of a more detailed report on undergrounding. Accordingly, further detailed information on technical and cost issues will be available in due course.

3. The environmental aspects, including cultural heritage, natural habitat, amenity, and electro magnetic fields (EMFs), are route specific and hence cannot be considered generically in a Preliminary Briefing Document, will be fully discussed in the Environmental Impact Statements (EIS), that will accompany the planning applications and so are not considered further here.

Technical issues

4. There are several technical alternatives by which these two projects could possibly be achieved, the principal technologies being: overhead or underground connections, or a combination of both; and high voltage alternating current (HVAC) or high voltage direct current (HVDC) technology.

5. Overhead line and underground cable alternatives are proven solutions for the transmission of electricity. However, while the HVAC partial undergrounding of the route is a possibility that can be considered, HVAC underground cable has not been used anywhere to date for the route lengths associated with the two projects forming the subject of this Preliminary Briefing Note.

6. Both HVAC and HVDC alternatives are also proven solutions for the transmission of electricity. Though the question of HVDC has been raised for these 2 projects, given the relatively short transmission distances involved, the relatively high cost of additional converter terminals for any future developments of the AC network, and the technical characteristics of AC connections that are not intrinsic to HVDC, HVDC is not considered further in this Preliminary Briefing Note.

Cost issues

7. Preliminary costs have been prepared based on information used for the Beauly-Denny 400kV overhead line in Scotland that is currently being considered by Public Inquiry. These costs have been adapted for the Cavan-Tyrone and Meath-Cavan 400kV projects and show that HVAC overhead line has the lower capital and lifetime costs with capital costs of about £0.7m/km (€0.9m/km).

8. HVAC underground cable would be about 9 times more expensive than an HVAC overhead line implementation.

1. INTRODUCTION

9. Two projects have been proposed to develop the electricity transmission infrastructure of the island of Ireland:-

- EirGrid and Northern Ireland Electricity (NIE) have proposed a new 80km 400kV electricity connection between the Republic of Ireland and Northern Ireland to improve the quality of supply and reliability for both jurisdictions and to support the operation of an efficient All Ireland electricity market – the Cavan-Tyrone 400kV Project, and

- EirGrid has proposed a further 60km 400kV development to the transmission network north of Dublin – Meath-Cavan 400kV Project – to improve the quality of electricity supply to the growing power demand in the North – East region, and to complement the Cavan-Tyrone 400kV Project.

10. Overall these two proposed projects comprise 140km of 400kV circuit, with a required transmission capacity of 1500MW. Associated with this would be two proposed new 400kV substation sites at Turleenen and Kingscourt, and modifications to a third at Woodland.

11. There are several technical alternatives by which these two projects may be achieved, the principal ones being:-

- overhead or underground connections, or a combination of both, and

- high voltage alternating current (HVAC) or high voltage direct current (HVDC) technology.

12. The electricity companies, EirGrid and NIE, have an obligation to ensure a cost effective and economically viable solution is found for implementing the two projects having due regard to technical issues and the impact of the proposal on the environment.

13. A clear understanding of the balance between the technical, environmental and cost issues will allow an informed decision on which of the alternatives to adopt.

14. This document has been commissioned jointly by EirGrid and NIE to provide early identification of some of the issues that will face decision-makers tasked with deciding upon this balance. It is an Preliminary Briefing Note – drawing on PB Power's [1] recent experiences with other utilities where these issues have been considered, and the results of the earlier analyses have been applied to the proposed Cavan-Tyrone and Meath-Cavan 400kV projects.

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[1] PB Power is an independent consultant on electricity generation, transmission and distribution infrastructure to governments, electricity utilities, developers, lenders, consumers, contractors and stakeholders around the world.

15. EirGrid and NIE have already commissioned a more in-depth assessment from PB Power to assess the technical and cost issues specifically pertaining to the Cavan-Tyrone and the Meath-Cavan 400kV projects, and this has yet to be completed.

16. In the meantime, this Preliminary Briefing Note is structured as follows:-

- Section 1 - This Introduction,
- Section 2 - Background – the options and present practice,
- Section 3 - Technical issues associated with overhead line and with the options for underground cable,
- Section 4 - Costs – Indicative costs for the alternatives,
- Section 5 - Conclusions, and
- Section 6 - Explanation of Acronyms.

17. The information set out below is based upon a desk-top analysis of the aforementioned issues and provides a generic comparison of technologies. Its focus is on technical and cost issues.

18. The environmental aspects, including cultural heritage, natural habitat, amenity, and electro magnetic fields (EMFs), are route specific and hence cannot be considered generically in a Preliminary Briefing Document, will be fully discussed in the Environmental Impact Statements (EIS), that will accompany the planning applications and so are not considered further here.

2. BACKGROUND – THE OPTIONS AND PRESENT PRACTICE

19. Two principal sets of alternatives present themselves for implementing the proposed projects to the transmission networks:-

- Firstly, electrical energy may be transmitted either above ground on overhead lines supported by pylons, or by underground cable, and
- Secondly, the energy may be transmitted either by alternating current (AC), or by direct current (DC). In all cases high voltage (HV) is employed because of the overwhelming efficiency benefits that result from this approach.

20. The transmission of electrical energy worldwide is primarily based on high voltage alternating current (HVAC) overhead line technology. UCTE [2] reports that some 99.1% of the extra high voltage electricity (EHV) [3] transmission network is of HVAC overhead line construction, with the remaining 0.9% being underground cable [4]. CIGRE [5], focusing on a number of large power transmission systems throughout the world, reports comparable statistics and states that some 99.5% of the EHV transmission network is of HVAC overhead line construction, with the remaining 0.5% being underground cable, mainly found in urban areas [6].

21. High Voltage Direct current (HVDC) provides an alternative to HVAC transmission in some specific situations, particularly when electrical energy has to be transported between two points which are many hundreds of kilometres (kms) apart, or where a very long stretch of water has to be crossed.

22. Though the question of HVDC has been raised for these 2 projects, given the relatively short transmission distances involved, the relatively high cost of additional converter terminals for any future developments of the AC network, and the technical characteristics of AC connections that are not intrinsic to HVDC, HVDC is not considered further in this Preliminary Briefing Note.

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[2] The Union for the Co-ordination of Transmission of electricity (UCTE) is an association of 33 transmission system operators in 23 continental European countries.

[3] Defined as service voltages above 300kV for the purposes of this Preliminary Briefing Note.

[4] UCTE Statistical Year Book 2006.

[5] The International Council on Large Electric Systems (CIGRE) is one of the leading worldwide organisatons addressing technical, economic, environmental, organisational and regulatory aspects on power systems.

[6] Statistics of AC Underground Cables in Power Networks, Cigre 338, December 2007.

3. OVERHEAD OR UNDERGROUND

3.1 General

23. Both overhead line and underground cable alternatives are proven solutions for the transmission of electricity. Overhead line transmission is most common, primarily because it has been considered to represent the best balance from an economic, technical and environmental perspective and facilitates a reliable approach to establishing, running, and maintaining an electrical transmission grid. Underground cable technology, however, plays an important role, particularly:-

- in urban and congested areas, for example, the 20km 400kV HVAC Elstree – St Johns Wood circuit in the London area,
- where a marine crossing cannot be spanned by an EHV overhead line, for example:-

  a. the 62km 500MW HVDC Moyle under-sea crossing between Scotland and Northern Ireland, and

  b. the 2.8km 220kV sub-sea crossing across the Shannon Estuary at Tarbert, Co. Kerry.

24. Underground cables have also been used over short distances on grounds of amenity, for example:-

- the undergrounding of about 5.7km of part of the 75km 400kV HVAC Second Yorkshire Line between Newby and Nunthorpe in England, and
- the undergrounding of 1.8km of the two 220kV circuits from Turlough Hill Pumped Storage station to the transmission system in Co. Wicklow.

3.2 Technical

25. The main technical differences between overhead lines and underground cables are summarised in the table below. Note that cross-linked polyethylene (XLPE) cable designs are now replacing the previously dominant fluid-filled designs, which are becoming obsolete.

Issue	Notes
Reliability and availability	Whilst the persistent fault rates for overhead line and underground cable are of the same order, the mean repair times of cables are much higher than those for overhead lines, resulting in higher average unavailabilities of cable circuits, length for length. *Implication:* higher generator constraint costs, reduced system security, and lower quality of supply with underground cables.
Power	In AC systems, the average currents flowing in cables tend to

Issue	Notes
losses	be higher than in overhead lines as a result of cable charging currents, however, generally cable losses are still lower than overhead line losses because of their lower resistances. *Implication*: Lower running costs with underground cable (if the circuits are heavily loaded).
Service Experience	103,552km of EHV overhead line are in service in continental Europe[4] compared with 907km of underground cable. HVAC underground cable has not been used to date for long distance HVAC transmission. The longest application of a 500kV HVAC XLPE cable interconnection is in Japan where it is used for the supply of the metropolitan area of Tokyo. The circuit has a length of 40km and is constructed in a high cost cable tunnel to provide ready access for fault repairs. The longest HVDC cable application rated above 1500MW is the Cross Channel Link, comprising 4x500MW links each with a total land and sea route length of 71km. *Implication*: While overhead line is well established, increasing experience is being gained in underground cable and both technologies are considered proven. However, a long underground cable route for the projects forming the subject of this Preliminary Briefing Note (140km total) would be the first of its kind in the world and an undertaking of considerable cost.
Reactive power	The capacitance added to the system by underground cable is considerably higher than that from overhead line. This capacitance requires extra compensation at terminating substations and probably the introduction of at least two additional compensation substations along the route, one on the Cavan-Tyrone section of the route and the other on the Meath-Cavan section of the route. *Implication*: Additional costs for compensating equipment. Additional land-take at the terminating substations and for intermediate substations.
Overvoltages	The capacitance added to the system by underground cable also has the effect of lowering the frequencies at which the system resonates. Without more costly designs, equipment damage can result, particularly if there are high levels of underground cable and low short circuit levels. *Implication*: Additional costs and land-take for filter equipment for underground cable. There may be restrictions to system operation flexibilities (for example charging end restrictions), with knock-on implications for system security / quality of supply.

4. COSTS

26. The following tables provide a comparison of costs between overhead and undergrounding for the Cavan-Tyrone and Meath-Cavan 400kV projects.

27. The costs are indicative figures only but are robust for comparative purposes. They are based on those used for the Beauly-Denny 400kV overhead line in Scotland that is currently being considered by Public Inquiry. Since the development of the cost estimates for that project there have been substantial market and commodity price pressures on transmission equipment prices. Given the different technologies employed in transmission projects, and overhead and underground cable, the effect on prices can be different but is generally in the upwards direction. The costs presented are thus provisional but provide a reasonable indication of the cost ratios between the various options.

Table 4-1: Cost Comparators for Transmission of 1500MW over a distance of 80km (Cavan-Tyrone 400kV Project)

	AC	AD	AE	AF	AG	AH	AI	AJ
7	**Technology**	**Capital Cost**		**Capitalised Cost**		**Capital Cost Ratio (relative to AC Overhead Line)**	**Capital Cost Per Kilometre**	
8		**£m**	**€m**	**£m**	**€m**		**£m/km**	**€m/km**
9	HVAC 400kV Overhead Line	56	73	61	80	1.0	0.7	0.9
10	HVAC 400kV Underground Cable	490	637	497	646	8.7	6.1	8.0

Table 4-2: Cost Comparators for Transmission of 1500MW over a distance of 60km (Meath-Cavan 400kV Project)

	AC	AD	AE	AF	AG	AH	AI	AJ
20	**Technology**	**Capital Cost**		**Capitalised Cost**		**Capital Cost Ratio (relative to AC Overhead Line)**	**Capital Cost Per Kilometre**	
21		**£m**	**€m**	**£m**	**€m**		**£m/km**	**€m/km**
22	HVAC 400kV Overhead Line	42	55	46	60	1.0	0.7	0.9
23	HVAC 400kV Underground Cable	370	481	375	488	8.8	6.2	8.0

28. The capital costs are inclusive of typical project management, equipment supply (including reactive compensation, intermediate substation reactive compensation compounds and other equipment costs), transport, civil works, erection, and commissioning and land purchase/wayleaves. The capital costs exclude common substation costs.

29. The tables also include the capitalised costs, which is the sum of the capital cost and the net present value of the power loss, maintenance and operation costs, and the end of life disposal costs, assuming a 40 year life.

30. The cable costs assume they are to be directly buried rather than laid in ducts or tunnels. Current practice in the Republic of Ireland is that HV cable is laid in ducts regardless of whether the cable is laid along a public road or across private land.

31. Based on cost information used for Beauly-Denny but adapted for the Cavan-Tyrone and Meath-Cavan 400kV projects, HVAC overhead line has the lowest capital and lifetime costs estimates with capital costs of about £0.7m/km (€0.9m/km).

32. HVAC undergrounding would have estimated capital costs of about £6m/km (€8m/km) based on a 100% cable implementation of the projects, some 9 times more expensive than an HVAC overhead line based implementation.

33. There can be considerable variation in cost ratios, for example, where issues such as inclines are to be traversed, tunnelling is necessary or the underground cable route is longer than that of the overhead line in interconnecting two locations, ratios of up to 20 times (and above) for HVAC implementations have been reported.

34. Further work to be undertaken will include detailed consideration of costs for the two projects taking into account:-

- chosen overhead line route and equipment design,
- comparative length and terrain of the alternative underground cable route, and
- load to be transmitted.

35. This work will assist in arriving at more detailed cost estimates which will be furnished in the planning applications

5. CONCLUSIONS

36. The principal technical alternatives by which the Cavan-Tyrone and Meath-Cavan 400kV projects could be implemented are: overhead or underground connections, or a combination of both; and HVAC or HVDC technology.

37. While EHV overhead line is well established, increasing experience is being gained in underground cable and both technologies are considered proven. However, while the HVAC partial undergrounding of the route is a possibility that can be considered, HVAC underground cable has not been used anywhere to date for route lengths associated with the two projects forming the subject of this Preliminary Briefing Note.

38. Both HVAC and HVDC alternatives are also proven solutions for the transmission of electricity. Though the question of HVDC has been raised for these 2 projects, given the relatively short transmission distances involved, the relatively high cost of additional converter terminals for any future developments of the AC network, and the technical characteristics of AC connections that are not intrinsic to HVDC, HVDC is not considered further in this Preliminary Briefing Note.

39. The HVAC undergrounding capital and capitalised costs for the two projects are likely to be about 9 times greater than the alternative HVAC overhead line. Further work to be undertaken will include detailed consideration of unit costs and the ,

- chosen overhead line route and equipment design,
- comparative length and terrain of the alternative underground cable route, and
- load to be transmitted.

40. There can be considerable variation in cost ratios. The lower cost ratios tend to include operating costs in addition to capital costs and assume reasonable terrain such as agricultural land with cable solutions implemented by direct burying. Where issues such as inclines are to be traversed, tunnelling is necessary or the underground cable route is longer than that of the overhead line in interconnecting two locations, although not discussed here the ratio can increase considerably to 20 times and more.

41. In summary, it can be seen that for this application underground cable implementations are a substantially more expensive alternative to HVAC overhead lines.

6. ACRONYMS

AC	Alternating current
DC	Direct current
EHV	Service voltages above 300kV
EIS	Environmental Impact Statement
HV, HVAC	High voltage, high voltage alternating current
HV, HVDC	High voltage, high voltage direct current
kV	Kilovolt (1000 volts)
MW	Megawatt (1,000,000 Watts)
NIE	Northern Ireland Electricity
XLPE	Cross-linked polyethylene (modern AC transmission cable design replacing fluid-filled designs)