Response to DCENR Consultation on the Comparative Merits of Overhead Electricity Transmission Lines Versus Underground Cables

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Introduction

We welcome the opportunity to comment on this issue, which we regard as important for the appropriate regulation of electricity transmission infrastructure in Ireland. In this submission, we outline a method for comparing overhead and underground electricity transmission infrastructure options. This method takes into account both the generalised costs of each option to Irish electricity users and private costs to those in localities through which the infrastructure will run. We provide indicative estimates for some of the key parameters required for assessing the options, but we acknowledge that some important parameters will be specific to local conditions and thus may require further research. We also highlight possible roles for mitigation and compensation arrangements in dealing with any private costs that may arise.

A method for comparing overhead and underground transmission infrastructure options

In general, the best method for assessing competing options for delivering public infrastructure is cost-benefit analysis (CBA). This allows the policymaker to weigh up all the benefits associated with each option and all the costs, including social and private costs. As well as comparing options, CBA would allow consideration of the possibility that all of the options might prove too expensive to justify.

However, given the question posed in this consultation, this submission focuses on the costs rather than the benefits. In effect, we are assuming that the total benefits from reinforcing the transmission system outweigh the total costs of at least one of the options being considered and that the benefits arising from the two options are broadly similar.[2] This approach is sometimes called 'cost-effectiveness analysis'.

To identify the optimal infrastructure choice, one should sum up all the costs associated with each of the options being considered (overhead and underground). Ideally, separate assessments should be made for each alternative route being considered and for each segment of a route over which the infrastructure type could be changed. For example, it might be most efficient to put transmission lines in densely populated urban areas underground, whereas those in sparsely populated areas might be better placed

[1] This consultation response reflects the views of the authors, but it does not necessarily represent the views of the Economic and Social Research Institute.
[2] Such benefits might include, *inter alia*, increased network capacity, greater scope to connect wind power to the system (reducing Ireland's CO_2 emissions) and improved security of supply.

overhead. Costs incurred over time should be expressed in present value terms to facilitate comparison with up-front costs.

The option with the greatest payoff to Irish society will be the one with the **lowest total cost**. If private cost is material for any affected parties, compensation may be used to offset it.

For each option, we suggest that the main components of the total cost will be the following:

Societal costs (borne by electricity users or taxpayers)

- Infrastructure construction costs, including the cost of purchasing rights of way and any costs incurred to mitigate or compensate for local disamenities.
- Infrastructure operating and maintenance (O&M) costs and cost of transmission losses, if these are found to be materially different between the options.

Private costs (borne by those living, working or owning property close to the transmission line)

- Visual, noise and aesthetic effects are the most common disamenities identified in the international literature on proximity to high voltage power lines.
- With regard to underground cables, there are up-front costs from the disruption associated with digging trenches and installing the cables. Particularly in sensitive areas, digging trenches for underground cables may have negative effects on the environment.
- Any health and safety effects, whether actual or perceived, would also fall into this category.
- Mitigation measures, such as planting trees to screen views of pylons, may be used to offset some of these private costs if it is efficient to do so. This would have the effect of reducing the private cost, and thus the total cost, of the relevant option. A cost-benefit analysis should be applied to each available mitigation option to identify whether and where along the route it is efficient.

In the next section, we draw upon previous international research and some simple analysis of Irish data to provide some indications of how the costs of overhead and underground transmission infrastructure are likely to compare under some of these headings.

Indicative estimates of key parameters

We start with societal costs, i.e. those costs borne by electricity users in general. Infrastructure construction and running costs for each option depend upon the voltage being carried, available technology and local conditions. Published estimates vary considerably, but the overall impression is that constructing overhead high voltage transmission infrastructure over flat terrain is significantly less costly than underground cables.

A report commissioned by the European Commission estimates that the capital cost for 400kV underground cables is around ten times that for overhead lines.[3] The exact cost differential will be influenced by factors including density of population, land prices and terrain. Table 1 below provides some European estimates of the relative cost of

[3] ICF Consulting, 2003, p.3.

underground and overhead cables, and Table 4 in the Annex provides additional estimates from the United States.

Table 1: International estimates of the ratio between the costs of constructing 380/400kV cables underground vs. overhead

	Cost ratio (underground/overhead)	Source
Austria	8	Verbund APG Styria link
Finland - (sea cable)	3.5	Fingrid
France – rural	>10	RTE – Piketty Report
France – urban	10-12	RTE
Italy	8	Terna
Norway	6.5	Statnett
Spain	25	REE
UK	15-25	National Grid

Source: after ICF Consulting, 2003, p.14.

It is worth noting that the estimates of the capital cost ratio for Ireland published by PB Power (a factor of 8.7-8.9) seem consistent with the international experience.[4]

The same report indicates that the cost gap tends to narrow when lifetime costs are taken into account. Overhead lines are susceptible to wind damage and consequently may need more frequent repair. However these repairs can be performed quickly and cheaply. When underground cables are damaged, repairs are far more time consuming. Tol (2007) argues that the value of uninterrupted electricity supply in Ireland is high and rising, while Carlsson and Martinsson (2007) reaffirm that the cost of interruptions rise more than proportionally with the duration of the outage. Table 2 illustrates this trade-off.

Table 2: The rate of outages and average outage durations in 2003 for a sample of Virginia utilities, including the effect of storms

	Outages / Mile / Year	Outage Duration (minutes / year)	Outage Duration (minutes / outage)
Old Dominion Power: Overhead	0.53	113	213
Underground	0.11	795	7,227
Kentucky Utilities: Overhead	0.66	352	533
Underground	0.08	634	7,925
Conectiv Power: Overhead	0.84	293	349
Underground	0.28	317	1,132
Allegheny Power: Overhead	1.1	1,086	987
Underground	0.12	480	4,000
Va Electric Power: Overhead	1.3	132	102
Underground	0.4	116	290

Source: after Johnson, 2006, Fig. 8.

Taking these elements together, it appears than construction and running costs tend to be considerably higher for very high voltage lines when they are installed underground

[4] PB Power, 2008, p.6.

rather than overhead.[5] Unless the likely private costs are very considerable, this implies that overhead infrastructure would be the better choice.

We now turn to private costs. There is a rich literature internationally on the disamenity effects from overhead power lines, but we are not aware of any estimates made in a specifically Irish context. Kroll and Priestley (1991) survey the literature from the 1970s-80s, and Des Rosiers (2002) includes a discussion of more recent work. We focus here on three dimensions relevant to estimating the disamenity value:

1. *Level of disamenity.* There is substantial evidence that households in close proximity to high voltage power lines do suffer some form of disamenity. The most convincing evidence relates house price differences to the presence of nearby high voltage power lines.[6] Disamenity effects seem to decline rapidly as the distance from power lines increases, with little evidence of negative effects beyond about 200m. There may be separate effects arising from having a view of the conductors and proximity *per se*, but these effects seem to operate over a similar distance range. Some authors find that the negative effect on household value is highest immediately after construction of a new power line, but that it declines over time.
2. *Variation by land use category.* Research suggests that the reduction to property prices from proximity to overhead high voltage power lines mainly affects residences rather than unoccupied land.[7] It is important to distinguish between types of land use when assessing the private costs of proximity to a power line.
3. *The effect of density.* The density of affected areas is also important. Any expected loss in value for unoccupied land can simply be multiplied by the quantity of such land along the route. The number of residences within the affected zone can be obtained from geographical databases, and it may either be multiplied by the average disamenity for the zone or calculated separately for varying distances from the power line, depending upon the model used for the disamenity effect.

We have calculated an illustrative estimate of the private disamenity for residences in an average one kilometre stretch of a hypothetical 60km Meath-Cavan transmission line, proxied by the potential reduction in house prices. To calculate this estimate we have assumed that:

- 7.1 houses per kilometre fall within 200m of the new line. We arrive at this rough approximation by assuming that the eventual route of the transmission line will have the same household density as the average for the two counties (see Table 3 below). This is probably higher than the actual figure, because properties tend not to be uniformly distributed across each county and we understand that the proposed routes pass mainly through rural areas. Such areas tend to have lower than average density;
- Average house prices in this zone fall 5-10% due to the relevant disamenity;[8] and

[5] *Ibid.*
[6] These are known as "hedonic" models.
[7] Mitchell and Kinnard, 1996.
[8] We take this figure from Gregory and von Winterfeldt, 1996, p.208.

- The average house price is equal to the arithmetic average of 2006 house prices in Meath (€336,959) and Cavan (€262,954) from ESRI-Permanent TSB House Price Index data.[9]

Table 3: Approximate density of properties within 200m of a 1km strip of land in Meath-Cavan

	Households	Area (ha)	Area (km^2)	Households /km^2	Households/400m strip 1 km long
Meath County	53,694	193,188	1,932	27.8	11.1
Cavan County	21,864	233,454	2,335	9.4	3.7
Both	75,558	426,642	4,266	17.7	**7.1**

Source: estimate by the authors based on CSO 2006 Census data.

Based on these assumptions, **the private cost per km of an overhead transmission line in Meath-Cavan would be approximately €106,000 - €212,000, based on a house price reduction of 5% to 10% for those within 200m of the line.**

Note that this estimate is only an illustration; ideally the analysis should be carried out using a precise map of the proposed routes to identify the number of affected properties and an estimate of disamenity effects deemed appropriate for local conditions. However, given the conservative nature of our assumptions, it is likely that more precise figures would turn out lower than the ones we have estimated. On the other hand, we have not included the effect of option value: installing overhead transmission lines should reduce the value of potential houses too, and should thus reduce the price of undeveloped land.[10]

We do not have the data to estimate the private costs associated with disruption and environmental effects from the underground option. However, in principle, these should be netted off against the expected cost of the overhead option when making the comparison.

Conclusions

Our analysis suggests that overhead infrastructure would give rise to a significantly lower cost to energy users than underground cables, even after deduction of private costs. On the basis of the PB Power estimates, which seem consistent with published international experience, the underground option would cost about €7 million per kilometre more than the overhead option.[11] This compares with a private cost difference of only €106,000-212,000 per kilometre, estimated using conservative assumptions.

[9] Permanent TSB-ESRI House Price Index, Quarter 4, 2006.
[10] However, as noted earlier, some international research (footnote 7 above) has found that the effect of power lines on the price of unoccupied land was not significant.
[11] PB Power, 2008, p.6.

References

Carlsson, F. and P. Martinsson 2007, "Willingness to Pay among Swedish Households to Avoid Power Outages: A Random Parameter Tobit Model Approach", *Energy Journal 28 (1),* 75-89.

Des Rosiers, F., 2002, " Power lines, visual encumbrance and house values: A microspatial approach to impact measurement", *The Journal of Real Estate Research 23,* May/June, 275-302.

Gregory, R. and D. von Winterfeldt, 1996, "The Effects of Electromagnetic Fields from Transmission Lines on Public Fears and Property Values", *Journal of Environmental Management* 48, 201–214.

ICF Consulting, 2003, *Overview of the Potential for Undergrounding the Electricity Networks in Europe*, prepared for the DG TREN/European Commission, Study Contract No 2002/009/C2, 28 February.

Johnson, B.W., 2006, *A study on the costs and benefits of undergrounding overhead power lines*. Edison Electric Institute, Washington, DC.

Joint Legislative Audit and Review Commission, 2006, Report to the Governor and the General Assembly of Virginia, *Evaluation of Underground Electric Transmission Lines in Virginia*, House Document No. 87.

Kroll, C.A. and T. Priestley, 1991, *The Effects of Overhead Transmission Lines on Property Values: A Review and Analysis of the Literature*, Edison Electric Institute, Washington, DC.

Mitchell, P.S., and W.N. Kinnard Jr., 1996, "Statistical Analysis of High-Voltage Overhead Transmission Line Construction on the Value of Vacant Land" *Valuation* June, 23-29.

PB Power, 2008, *Island of Ireland, Cavan-Tyrone and Meath-Cavan 400kV projects, Preliminary Briefing Note, Overhead and Underground Energy Transmission Options,* February.

Tol, R.S.J. (2007), "The Value of Lost Load" in F. O'Leary, M. Bazilian, M. Howley and B. O Gallachoir (eds) *Security of Supply in Ireland – 2007 Report*, Sustainable Energy Ireland, Cork.

Annex

Table 4: Ratios of Underground to Overhead Costs—Transmission at Above 230 kV

Ratios for Transmission at Above 230 kV			
Kilovolt (kV) Level	Other Cost Notes / Assumptions	Information Source	Cost Ratios, Underground to Overhead
220 to 362	Single value of 13, with range from 5.1 to 22.1	CIGRE, as cited by the Commission of the European Communities (CEC)	13
275	Double circuit	SHETL, cited by Highland Council	12 to 15
345	SCFF single circuit compared to H-frame	Institute for Sustainable Energy	8.8
	XLPE single circuit compared to H-frame	Institute for Sustainable Energy	7.1
	Ratio given as part of discussion of proposed 345 kV line	American Transmission Co. staff	7.0
	HPFF single circuit compared to H-frame	Institute for Sustainable Energy	6.2
	SCFF single circuit compared to steel pole	Institute for Sustainable Energy	3.6 to 4.6
	Bethel-Norwalk, 2 miles of XLPE	Northeast Utilities	3.2 to 3.8
	XLPE single circuit compared to OH steel pole	Institute for Sustainable Energy	2.9 to 3.8
	HPFF single circuit compared to OH steel pole	Institute for Sustainable Energy	2.5 to 3.3
	Bethel-Norwalk, 10 miles of HPFF	Northeast Utilities	2.5 to 2.9
380 / 400	Not stated	REE, Spain, cited by ICF	25
	Not stated	National Grid, UK, cited by ICF	15 to 25
	400 kV double circuit line	SHETL, cited by Highland Council	14 to 25
	Not stated	RTE France, cited by ICF	10 to 20
	Not stated	UK Regulator OFGEM, cited by ICF	14
	Capital cost, 1 km 400 kV double circuit fluid-filled	The Highland Council	12
	400 kV	ICF Consulting	10
	Capital cost, 5 km 400 kV double circuit fluid-filled	The Highland Council	9.5
	Life cycle cost, 5 km 400 kV fluid-filled	The Highland Council	9.1 to 9.3
	Capital cost, 10 km 400 kV double circuit fluid-filled	The Highland Council	8.9
	Capital cost, 1 km of 400 kV double circuit XLPE	The Highland Council	8.9
	Not stated	APG, Austria, cited by ICF	8
	Not stated	Terna, Italy, cited by ICF	8
	400 kV	Europowercab, cited by CEC	7.5
	400 kV, installed cost	Harry Orton	5 to 10
	Not stated	GRTN, cited by ICF	5 to 8
	Not stated	Fingrid, cited by ICF	5 to 8
	Life cycle cost, 5 km line, 400 kV, XLPE versus OH	The Highland Council	7.2 to 7.6
	Not stated	Statnett, Norway, cited by ICF	6.5
	Capital cost, 5 km, 400 kV, double circuit XLPE	The Highland Council	6.4
	380 kV, lifetime cost	ICF report on Italian regulated tariff	5.9
	Capital cost, 10 km, 400 kV double circuit, XLPE	The Highland Council	5.8
	Estimate for 400 kV project	ICF report, Beauly Scotland line	5
	400 kV project in Denmark	ICF Consulting	4.5
500	Range of ratios given in EIS for four 500 kV projects	U.S. DOE EIS documents	10 to 16
363 to 764	Single value of 20, with range from 14.6 to 33.3	CIGRE, as cited by the Commission of the European Communities (CEC)	20

Note: Information sorted from high to low by kV level first, and then by the cost ratio. Where the kV level or the cost ratio is expressed as a range, the mid-point of the range is used in sorting from high to low.

Source: JLARC staff compilation.

Source: Joint Legislative Audit and Review Commission, 2006, Table 6.