REVIEW OF PROPOSED 132KV CONNECTION FROM VINEYARD TO ROUSE HILL

Vineyard to Rouse Hill Electricity Upgrade
Review of proposed 132kV Connection

Report for the Department of Planning

NSW GOVERNMENT
Department of Planning

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EXECUTIVE SUMMARY

Introduction

A section of an existing Integral Energy (IE) 132kV overhead line is proposed to be replaced between Vineyard and Rouse Hill. On 9 May 2006, Burns and Roe Worley (BRW) were asked by the Department of Planning (DP) to undertake an independent review of the pricing and technical information provided by Integral Energy for planning purposes[1]. BRW's initial findings were requested by 12 May 2006 with an Interim Report by 16 May 2006[2] due to the urgency of this matter.

As requested by the DP, BRW's technical analysis was to focus on the following two options:

- Option D: Two single circuit 132 kV overhead lines (OHL) using steel pole construction with a single high temperature Invar cored conductor per phase.
- Option E: Two 132 kV underground cable circuits using twin 1600 mm^2 XLPE insulated cables per phase.

Each of the overhead line and underground cable circuits are required to have a capacity rating of 500 MVA.

Given the tight program, BRW was requested to initially focus only on the high cost items in its Interim Report. This updated report includes the results of further investigations and inquiries for consideration by the DP.

Methodology

The BRW review is based on the following approach:

- Comparison of IE's ($2004) budget prices for the overhead line and cable options against the BRW pricing model which has been developed using historical data for similar projects.
- Review of overhead line and cable supply costs to ascertain the likely impact of recent movements in raw material prices, particularly copper and aluminium. BRW has also obtained quotations from suppliers for the key equipment items for comparison with the original IE prices.
- Rating calculations for the overhead line and cable options based on the technical information obtained by BRW.

Key Findings

Initial key findings were supplied to the DP on 9 May 2006 in accordance with the program[3]. Some of the key findings have been adjusted due to changes in component prices and some additional issues have been identified and included in this updated report.

The key findings that have a significant impact on the project are as follows:

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[1] See DP's required workscope in Section 1 of the Report

[2] It was subsequently agreed to postpone this one day to 17 May 2006

[3] See Appendix 4.1 for Initial Key Findings

1. The BRW $2006 price estimate for Option D (overhead line with high temperature conductor), which includes a recent supplier quotation for the Invar conductor, is 5% higher than the IE $2004 estimate. This difference is not considered to be material.
2. The BRW $2006 price estimate for Option E (twin 1600 mm^2 cables), which includes consideration of two recent cable supplier quotations, is 24% lower than the IE $2004 estimate. This large difference is unexplained and additional information should be sought for some of IE's key construction cost allowances.
3. The cable supplier quotations received indicate that the price of the underground cable option varies significantly with any material price changes. The cable prices received are substantially higher than that included in the IE price estimate, but they reflect substantially higher base metal costs. However, the long term LME copper price charts indicate that the long term trend (beyond 3 months) on copper prices appears to be heading in a downwards direction, which indicates that the price difference between the options identified by BRW would not be expected to increase materially from a raw materials perspective within a reasonable time frame. The current high global manufacturing levels for cables and other electrical equipment may also be a factor in the current higher component prices.
4. Based on BRW calculations, the continuous current rating of the 28.5mm diameter invar cored conductor overhead line proposed by IE is considered to be less than 400 MVA, compared with the required 500 MVA rating, as achieved by the Option E underground cable circuits. The Invar conductor quotation included in the BRW estimate is for a larger conductor (35.1mm diameter), as offered by the manufacturer to achieve the required 500 MVA rating.
5. Also, relatively higher resistive losses are anticipated for the overhead lines option than for the underground cables option, giving the overhead lines option a higher greenhouse gas impact and an higher operating cost[4] than for the underground cable. However, although these losses are approximately eight times greater for the overheadline, they are not material compared to the energy transported or the capital cost difference[5].
6. Recent research papers have been published on causal links between high voltage (HV) overhead lines and cancer. These should be reviewed and integrated as appropriate into the planning decision.
7. The present 30 metres wide easement is suitable for the overhead line installation (Option D). Should the underground cable option be implemented the required easement could be reduced in width to approximately 10 metres, which would release approximately 17 hectares of land for sale or other use.

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[4] Rough estimates indicate higher costs of losses for Option D (OHL) amounting to typically $10,000/year compared with Option E (Cable) – based on a 100 MVA average circuit loading and $40/MWHr wholesale energy costs.

[5] A whole of life costing could be employed but this would require an annual loading profile. However, such analysis is difficult to justify because the difference in the "value" of annual operating losses is two to three orders of magnitude below the difference in the capital cost of the two options, depending on the loading of the circuits and the value assigned to carbon dioxide emissions.

Capital Cost Comparisons

A summary level comparison of the IE and BRW capital cost estimates is given in the Table 1 below. The initial BRW estimates shown have been revised following receipt of supplier quotations for the invar cored high temperature conductor and XLPE insulated cable:

Table 1: Capital Cost Comparisons for OHL and Cable

Item	IE Estimate ($2004)	BRW Estimate ($2006)	
		With 2004 Materials Prices	With 2006 Supplier Quotations
Option D (OHL)	$17,444,504	$19,030776	$18,377,775
Option E (Cable)	$72,837,576	$49,164,048	$58,498,985
Difference (E – D)	$55,393,072	$30,133,272	$40,121,210

The above capital costs do not include the value of the 17 hectares of easement that would be freed for Option E, so reducing the cost difference between the two options.

Commentary

The following additional comments are offered on the review findings:

1. The impact of the overhead line on property prices ($2004) has been identified in the IE report[6] as being negative with an approximate value of (-)$3.4 Million, whilst for the cable there is a positive benefit of (+)$25.5 Million. Inclusion of this impact would reduce the difference in costs between the two options to less than $10.2 million for the above BRW $2006 revised capital cost estimates. Recent land value increases would further reduce the difference as would a decrease in copper prices as anticipated by longer term LME price forecasts.

2. The IE estimates include a 5% of capital costs loading for project management. This treatment may be reasonable in costing a project in isolation; however, it distorts the comparison when applied to two options with significantly different capital costs that have similar project management requirements. It is also noted that IE has used a 15% contingency allowance, which seems excessive for a project of this nature. BRW has applied a fixed project management fee for the budget price estimates and a contingency figure of 10% to cover such issues as latent conditions and tender prices volatility.

3. As expected, annual operation and maintenance (O&M) costs for both options are significantly less than their respective capital costs. O&M costs over the life of the assets could be incorporated (together with operating energy losses) into a “whole-of-life” assessment using net present value (NPV) analysis to fully measure their impact. However, as the capital costs are at least two orders of magnitude greater than annual O&M costs and annual loading estimates and conductor performance data are required to calculate the losses accurately, a “whole-of-life” assessment has not been carried out.

[6] This shadow pricing of the impact of the respective technologies on property prices has not been reviewed by BRW.

4. It is noted that the annual maintenance costs quoted in the IE report are approximately $12,000 more for the cable. This would seem to be due to weekly inspections of the cable compared to annual inspection for the overhead line. Such an inspection interval seems excessive.

5. Public concerns relating to the Electro-Magnetic Field (EMF) issue have the potential to cause longer delays in the approval and construction of overhead lines than for underground cables. Whilst such potential delays increase costs, these have not been quantified in the costing of the overhead line.

6. The visual impact of the overhead lines also has the potential to delay their installation. This is especially so during the approvals process and possibly during the construction phase. This is less likely to be the case with underground cable. However, as with the EMF issue, the cost impact of these potential delays and additional administrative effort required, has not been factored into the analysis for this report.

7. Potential uses of the 10-metre wide cable easement include recreational purposes such as bicycle paths and walkways. The 30-metre wide overhead line easement could have similar uses. The easement could also be incorporated as part of a road reservation, subject to overhead line visibility considerations and appropriate design provisions to protect the line or cable against damage, particularly by vehicles or other development works within the same corridor.

Summary and Recommendations

The capital costs of the two options, particularly that of the underground cable, is significantly dependent on the cost of raw materials, particularly copper and to a lesser extent, aluminium and nickel. World copper prices have risen significantly over the last two years though there is some indication that they may now fall. The volatility of raw material prices has a material effect on the analysis and it is recommended that this be taken into account in the decision making process of which option to proceed with.

Notwithstanding this price volatility, based on the information received and the technical analyses carried out, the capital cost differential between the overhead line and underground cable options is considered to be materially lower than that indicated in the IE reports for the reasons given. BRW also found that the conductor specified for the line would not provide the required 500 MVA capacity and so substituted one that would in its analysis. It is recommended that BRW meets with IE to help resolve the differences in the technical cost and performance estimates.

It is possible that the overhead line option will take longer than anticipated to put in place due to the perceived greater impact of an overhead line compared to an underground cable. No attempt has been made to quantify the cost of any delay in the line’s approval and construction compared to that of the cable that may result from this perception. It is recommended that this matter be given further consideration.

Table of Contents

1 INTRODUCTION & SCOPE OF WORKS

Burns and Roe Worley (BRW) has been engaged by the Department of Planning (DP) to review the budget prices submitted by Integral Energy Ltd (IE) and its consultants for the proposed Vineyard to Rouse Hill Electricity Upgrade.

The project involves the replacement of the existing 8.5kM overhead line. Twelve options were originally considered in the Integral Energy report. BRW has been asked to review the two main options:

a) Option D: Two single circuit 22 metre high overhead line circuits utilising 132 kV 28.5 mm diameter invar cored conductors

b) Option E: Two 132 kV 1600 mm^2 XLPE underground cable circuits, with each circuit having 2 cables per phase in a trefoil configuration.

The scope of the study required by the DP is as follows:

- "A critical review of the costs (capital, operating, social and environmental externalities) of the proposal, focusing on options D (aboveground) and E (underground), and taking both Integral Energy's and Maunsell's estimates into account. This review should examine the variables used in IE's and Maunsell's estimates, but also identify any other variables (or omissions) that should have been considered.
- For any disagreements or omissions, we would like to get your indicative alternative estimates."

This scope has been divided into the following activities as part of the BRW methodology:

1) Review the budget construction prices for both options to ascertain if they are reasonable and accurate, using historical data for similar installations and supplier quotations.
2) Confirm that the equipments are suitable for the stated design ratings.
3) Review the maintenance costs to ascertain if they are reasonable.
4) Review the stated circuit losses to confirm that they are reasonable.
5) Advise on any other areas where costs need to be introduced, including the possible reuse of land released by a reduction in easement width.

Due to the limited time available it has not been possible to complete a detailed evaluation of the works. The analysis is limited to a desktop study based on the documents provided by the DP and the use of BRW's pricing model. BRW have also sought quotations from suppliers for the key equipment items for comparison with the original IE prices.

2 METHODOLOGY

2.1 Approach and Methodology

BRW's review has been based on the following approach:

1. Comparison of IE's budget prices for the overhead line and cable options with the BRW pricing model, which has been developed using historical data from similar projects.
2. Obtaining current quotations from suppliers for the overhead line conductor and cables and using these new figures in the pricing models.
3. Calculation of the overhead line and cable losses using their respective technical specifications and projected loadings over the life of the two options.
4. A NPV analysis (if warranted) to calculate the total present day cost of the two options given the costs over their respective lives.
5. Provide the DP with regular updates on progress and factor DP's comments on the Interim Report into the Final Report.

The methodology involves only desktop analysis. No inspection of the proposed route has been carried out and no contact has been made with IE or its consultants. Due to data availability limitations, items 3 and 4 have not been fully completed.

2.2 Documents Reviewed

This report is based on the following documents provided by the DP and sourced by BRW from the Integral Energy website.

- Volume1, Volume 2 & Volume 3 of Integral Energy 'Vineyard to Rouse Hill Electricity Upgrade Environmental Assessment' report.
- Maunsell Independent Report to Examine Upgrade Cost Options for Vineyard to Rouse Hill Electricity Upgrade.

BRW has also sourced documents from cable and conductor suppliers as provided in the Appendices.

3 STUDY RESULTS

This section reviews the construction, material and maintenance costs, the equipment ratings and losses, EMF and easement usage.

3.1 Review of IE Overhead Line and Underground Cable Cost Estimates

BRW has reviewed the key pricing elements from the documents provided and compared them with historical data. The detailed BRW estimates are detailed in Appendices 4.2 to 4.5.

The key findings from this review are as outlined below.

3.1.1 Option D: 132 kV Overhead Line (OHL)

BRW has reviewed the IE supply & construction costs against the detailed estimates shown in Appendix 4.3 and the results are summarised in Table 3.1 below. These estimates were prepared prior to the receipt of any supplier quotations for the specified invar cored high temperature conductor.

Table 3.1: Comparison of IE and BRW Estimates for the OHL

Item	Integral Energy Estimate $2004	BRW Estimate $2006 (Using 2004 Material Prices)	Difference
Design, Administration	$538,875	$699,000	+29%
Materials	$10,716,825	$11,007,585	+2.7%
Construction	$3,137,264	$4,595,028	+46%
IE Project Management	$827,595	$940,000	+13%
Contingency Figure	$2,158,945	$1,724,160	-25%
Easements	$65,000	$65,000	0%
TOTAL	$17,444,504	$19,030,779	+ 9%

BRW comments are as follows:

a) There is a 29% difference between the Integral Energy estimate for the Design & Administration and the BRW estimate. This is probably due to the BRW pricing structure being based on the works for the two lines being done independently. If they are run in parallel then this percentage difference may reduce. It should also be noted that parallel construction may not be possible as the existing 132 kV line has to remain in-service to provide supply until at least one new line is commissioned in the same easement.

b) IE has adopted a fixed percentage of cost for project management and contingency figures of 5% and 15% respectively. BRW has applied a fixed project management cost and applied a 10% contingency which is normal for a project of this type.

c) There is a 46% difference between the two construction cost estimates. BRW's estimates are based on its experience on previous projects of a similar nature, for which a detailed breakdown is shown in Appendix 4.3.

d) The BRW prices use up-to-date information installation costs whilst the Integral Energy figure uses information from 2004 when they were prepared.

e) There is a 9% difference between the figures which is within the expected accuracy range for a budget price check undertaken in the absence of detailed topographical and soil survey data.

f) No allowance has been made for potential delays to the overhead line project due to concerns over EMF and visual amenity. These could lengthen the approvals process and possibly the construction period and also increase administration costs.

3.1.2 Option E: 132 kV Underground Cable

BRW has reviewed the IE supply & construction costs against the detailed estimates shown in Appendix 4.3. The results are summarised in Table 3.2 below. These estimates were prepared prior to the receipt of any supplier quotations for the specified 1600mm^2 XLPE cable.

Table 3.2: Comparison of IE and BRW estimates for the underground cable

Item	Integral Energy Estimate $2004	BRW Estimate $2006 (Using 2004 Material Prices)	Difference
Design, Administration	$1,587,660	$787,000	- 101%
Materials	$36,630,294	$34,130,975	- 7%
Construction	$22,065,753	$8,795,705	-150%
IE Project Management	$3,466,313	$940,000	-268%
Contingency Figure	$9,042,556	$4,465,368	-102%
Easements	$45,000	$45,000	0%
TOTAL	$72,837,576	$49,164,048	-48%

BRW comments are as follows:

a) The IE design & administration figure estimate is double the BRW estimate.

b) There is a large difference between the two construction costs. The main reasons for this are as follows:

   a. IE has estimated a cost of $17 million for the trenching works whilst BRW has estimated a cost of $4.4 million. BRW's figures are based on cubic metres of material excavated, installed and removed in accordance with industry standards.

   b. IE has shown a figure of $5 million for cable laying and installation with BRW estimating the cost to be $2.53 million.

c) IE has adopted a fixed percentage of cost for project management and contingency figures of 5% and 15% respectively. This further increases the costs for a higher capital cost project. BRW has applied a fixed project management cost and applied a 10% contingency which is normal for a project of this type.

d) The BRW prices use up-to-date installation costs whilst the IE prices use information from 2004 when they were calculated.

e) Overall there is a 48% difference between the two total figures which seems excessive.

3.1.3 Construction Costs Summary

BRW has reviewed the overhead line figures and it would seem that there is only a 9% difference between the BRW and IE estimates. This is considered reasonable for a budget estimate.

When the cable costs are reviewed there is a (-)48% difference between BRW's and Integral Energy's estimates This is mainly due to differences in the overall construction costs. BRW recommends that a further breakdown is requested for the 'external construction contractor' and the 'Integral Energy Construction' costs items as they both seem excessive.

BRW has also used a fixed project management figure and reduced the contingency to 10% which is industry standard for a project of this nature.

3.1.4 Comparison of BRW Cost Estimates

Table 3.3 below summarises the BRW estimates for the two options prepared prior to the receipt of any supplier quotations for the specified invar cored high temperature conductor and 1600mm^2 XLPE cable.

Table 3.3: BRW $2006 estimates for the OHL and the underground cable (using 2004 Material Prices).

Item	Option D (OHL)	Option E (Cable)	Price Difference
Design, Administration	$699,000	$787,000	+12.5%
Materials	$11,007,585	$34,130,975	+200%
Construction	$4,595,028	$8,795,705	+91%
IE Project Management	$940,000	$940,000	0%
Contingency Figure	$1,724,160	$4,465,368	+258%
Easements	$65,000	$45,000	-31%
TOTAL	$19,030,776	$49,164,048	+158%

BRW comments are as follows:

a) The materials costs are 200% higher for the cable than the overhead line. This is due to the higher manufacturing costs of the cable due to the additional insulation layers and armouring, the use of copper instead of lower-cost aluminium, and the need for high-cost joints every 500 metres in the cable.

b) The construction costs are 91% higher for the cable, due to the excavation and reinstatement costs of the trench verses simple foundations for the overhead line.

c) When the overall costs are compared cable option is approximately 2.6 times the cost of the overhead line. This compares with the IE budget estimate in which the cable option is approximately 4.2 times the cost of the overhead line.

3.2 Revised BRW Cost Estimates Using Recent Supplier Quotations

3.2.1 Raw Material Cost Movements

Since the IE estimates were prepared in November 2004 a number of major raw material costs have increased substantially. The London Metal Exchange (LME) & Nymex websites indicate the increases shown in Table 3.4 below:

Table 3.4: Summary of commodity price increases

Item	Increases in Materials Costs
Steel	+ 0%
Aluminium	+ 30%
Nickel	+ 30%
Copper	+ 113%

The sizes of these increases in raw material costs can be expected to have a significant effect on the equipment supply prices, the estimated magnitude of which is indicated in table 3.5 below:

Table 3.5: Summary of effects of commodity price increases have on equipment

Item	Increase in Cost of OHL Structures	Increase in Cost of Invar Conductor	Increase in Cable Supply Cost
100% Steel Price Uplift	+ 20%	+ 12%	-
100% Aluminium Price Uplift	-	+ 80%	-
100% Nickel Price Uplift	-	+ 8%	-
100% Copper Price Uplift	-	-	+ 30%

Based on the above analysis, the expected price increases applied to the BRW estimates are indicated in Table 3.6 below:

Table 3.6: Estimated impact of materials price rises on the budget price estimates.

Item	Original Price	With Material Uplift	% Increase
Option D (OHL)	$19,030,776	$19,737,231	+ 3.7%
Option E (Cable)	$49,164,048	$59,233,804	+ 20%

These figures show that significant materials price movements such as have occurred over the past year and a half can be expected to materially impact on the comparative prices for the 132kV line replacement options under review. BRW has therefore sought current quotations for the underground cable and invar cored conductor.

3.2.2 Supplier Quotations

The quotations received from suppliers in response to the inquiries issued by BRW are shown in Table 3.7 below. The price and technical details are shown in Appendix 4.7.

Table 3.7: Supplier CIF Price Quotations

Item	Supplier Quote ($/m)	Adjusted Price ($/m)
Prysmian Cable Quote	$341/m	$374/m
Olex Cable Quote	$484/m	$458/m
J-Power Invar Conductor	$35/m (3,000Yen/m)	-

Only a single quotation has been received for the Invar conductor, from a Japanese supplier. This is based on the 35.1mm diameter conductor, which the supplier nominated to achieve the required 132kV line rating, as discussed further in the following Section 3.4.1.

The pricing assumptions used for the two cable supplier quotations are based on substantially different raw copper prices, due to the downward movement by approximately 17% over the past few weeks. This indicates the current volatility of the materials market. The LME website (on 28 June 2006) indicated a 3 month seller rate of $9400/tonne. For comparative price purposes, BRW have adjusted the Olex quotation to reflect a copper price of $9166/tonne, as quoted by Prysmian.

It should also be noted that Prysmian has offered a cable with a corrugated aluminium sheath, as there is a longer lead time at present for lead alloy sheathed cable, as specified, but has indicated that the lead alloy sheath cable is approx 10% more expensive to manufacture. BRW has therefore applied this increase to derive the adjusted price given in Table 3.7.

The least cost supplier quotations received have been used to adjust the BRW cost estimates for the overhead line and underground cable options, as shown in Appendices 4.4 and 4.5. The revised estimates are summarised in the following Tables 3.8:

Table 3.8: Comparison of BRW Estimates

Item	BRW $2006 Estimate (with 2004 Material Prices)	BRW $2006 Estimate (with Supplier Quotations)	Difference	% Differenc e
Option D : OHL	$19,030,779	$18,377,775	-$653,000	-3%
Option E : Cable	$49,164,048	$58,498,985	+$9,334,937	+18%

A comparison between the revised BRW estimates and the IE estimates is given by the following Table 3.9:

Table 3.9: Comparison of IE $2004 and BRW $2006 Revised estimates

Item	Integral Energy $2004Estimate	BRW $2006 Estimate (with Supplier Quotations)	Difference	% Differenc e
Option D : OHL	$17,444,504	$18,377,775	+ $933,271	+5.3 %
Option E : Cable	$72,837,576	$58,498,985	-$14,338,591	-24 %
Option E – Option D	$55,393,072	$40,121,210	-$15,271862	-38 %

BRW comments are as follows:

a) Inclusion of the Prysmian cable quotation in the BRW estimates increases the cable option price by 18%, which is comparable to the increase predicted based on the raw material price movements – ie. an approximate doubling of the copper price. Inclusion of the higher Olex cable price would result in a larger increase. This reinforces the need for obtaining more than one quotation (where possible) for all high value components.

b) When the J-Power Invar Conductor quotation is applied to BRW's original pricing model the BRW OHL option price estimate decreases by 3% compared to the original IE obtained quotation, despite the conductor now being larger and the recent material price increases.

c) The price for the cable option is considerably more sensitive to variations in metal prices than for the OHL option, which is of particular concern considering the current high volatility of the raw material markets. The long term LME copper price charts indicate that the long term trend (beyond 3 months) on copper prices appear to be heading in a downwards direction. This indicates that the price difference identified by BRW for the cable option would not be expected to increase materially from a raw materials perspective within a reasonable time frame and should in fact fall if copper prices continue to decline.

d) It is clear from Table 3.9 that even when the 2006 material price movements are considered, the BRW estimates show a 38% lower difference between the OHL and cable options than the IE estimates.

3.3 Use of Easements

The present easement is 30 metres wide which is suitable for the OHL installation (Option D). Should the cable option be taken, BRW estimates that the required easement could be reduced in width to approximately 10 metres which would release approximately 17 hectares of land for sale.

Potential use of the 10-metre wide cable easement includes recreational use such as bicycle paths and walkways. The same types of use could be made of the 30-metre wide OHL easement.

The easement could also be incorporated as part of a road reservation, subject to OHL visibility considerations and appropriate design provisions to protect the line or cable against damage, particularly by vehicles or other development works within the same corridor.

3.4 Equipment Ratings & Losses

3.4.1 Option D: OHL Conductor Rating

The reviewed documents indicate that the conductor proposed by IE for the OHL is 28.5mm 58ZTACIR/AS high temperature Invar cored conductor. This is a special conductor with a high temperature rating to allow greater current flow and hence greater MVA capacity at a given voltage than for normally used line conductors of a similar size. It has not been widely used in Australia and at the time of preparing this report update, BRW has been able to obtain only limited design and rating information from overseas suppliers.

This lack of definitive information affects the determination of the OHL losses. As a result, it has not been able to compare the dollar value of the losses or their effect on greenhouse emissions for the OHL compared to the cable.

However, following consideration of catalogue details received with the J-Power quotation for Invar cored conductor produced under the Japanese Standard JCS405 and comparison of the results of BRW calculations against those for Australian standard ACSR conductors, BRW is concerned that:

1. The stated 28.5mm diameter high temperature Invar cored conductor rating will be limited to less than 400MVA, which does not meet the required 500MVA rating, as provided for by the selected underground cable size. This has been confirmed by the J-Power quotation, which offered a larger conductor size of 35.1mm diameter to achieve the specified rating under typical Australian ambient conditions.

2. The resistive losses (MW) for the Invar cored conductor operating at the maximum rating temperature (210 ^{o}C) are considered to be significantly higher than those for the selected underground cable size. More data is required to quantify this including IE's anticipated loading over the asset's life and the resistance of the conductor as a function of operating temperature.

3.4.2 Option E: Cable Rating

The rating calculation for cable shown in Table 3.10 below is based on typical ground and laying conditions within Australia.

Table 3.10: Cable rating calculation

Item	Design Value	Derating Factor
Cable Size	1600 mm^2	-
Nominal Cable Rating	1260 A	-
Ambient air Derating Factor	40 ^{o}C	1
Ground Temp Derating Factor	25^{o}C	1
Depth of burial Derating Factor	1.25m	0.96
Thermal resistivity Derating Factor	1.2 K.m/W	1
Group rating factor	0.60m	0.91
	Cable Rating	1,100.74 A
	MVA Rating	251.36 MVA

Table 3.10 shows that each cable is rated for 251 MVA, thus giving each independent circuit a rating of 502 MVA which meets the required rating of 500 MVA.

This calculation does not take into account any overload or cyclic ratings that may be applied dependant on the load curve of the system involved.

3.5 Operation and Maintenance

The annual cost of maintenance is a very small fraction of the capital costs. In keeping with the focus of this interim report on high cost items, the NPV of maintenance has not been calculated. A NPV analysis could be carried out, if required by the DP, but more information as indicated above, would be required.

However, it is noted that the annual maintenance costs quoted in the IE report are approximately $12,000 higher for the cable than the OHL. This would seem to be due to weekly inspections of the cable compared to annual inspection for the OHL. Such an inspection program seems excessive given that a far more strategic cable, namely the 180 km Murraylink high voltage DC cable between Victoria and South Australia, is only inspected monthly

3.6 Social and Environmental Factors

3.6.1 EMF

The initial IE reports were prepared in November 2004. Since that date further EMF studies have been published and BRW considers that this new information should also be taken into account. The following papers published in the British Medical Journal are specifically referenced:

- *Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study* **:** *Author Gerald Draper, Tim Vincent, Mary E Kroll, and John Swanson, June 2005*
- *Childhood cancer and power lines: What do the data mean? : Author Nick Day, Tim Eden, Patricia McKinney, Eve Roman, and Jill Simpson, Sept 2005*

Copies of the reports can be found in Appendix 4.6. The first paper concludes that:

"There is an association between childhood leukaemia and proximity of home address at birth to high voltage power lines, and the apparent risk extends to a greater distance than would have been expected from previous studies. About 4% of children in England and Wales live within 600m of high voltage lines at birth. If the association is causal, about 1% of childhood leukaemia in England and Wales would be attributable to these lines, though this estimate has considerable statistical uncertainty. There is no accepted biological mechanism to explain the epidemiological results; indeed, the relation may be due to chance or confounding."

Whilst EMF may be concluded by some to be more perception than reality, it has the significant potential to delay OHL projects, especially when there are potential alternatives such as underground cable.

Such delays can substantially add to the approvals and construction phases with resultant increases in the cost for the OHL. Such potential increases have not been quantified in the costing of the OHL.

3.6.2 Visual Amenity

The OHL will have a very significantly higher visual impact than the underground cable with consequential reduction in amenity. This has been addressed in the IE reports by applying a "shadow price" in the form of an impact on property prices.

Notwithstanding this treatment, experience has shown that the approvals process can be considerably longer for OHLs compared to underground cables.

The potential delays from public concerns with EMF and loss of visual amenity from OHLs could be addressed by a NPV analysis, if required by the DP.

4 APPENDICES

4.1 Initial Key Findings

The Initial Key Findings, as supplied to the DP on 9 May 2006.

4.2 Calc C3049-1: Vineyard to Rouse Hill Cable Installation Cost

BRW cost estimate for the supply and installation of the underground cable circuits, assuming no increase in material costs.

4.3 Calc C3049-2: Vineyard to Rouse Hill OHL Installation Cost

BRW cost estimate for the supply and installation of the overhead line circuits, assuming no increase in material costs.

4.4 Calc C3049-3: Vineyard to Rouse Hill Cable Installation Cost (with 2006 Supplier Quotations)

BRW cost estimate for the supply and installation of the underground cable circuits, using 2006 Supplier Quotations.

4.5 Calc C3049-4: Vineyard to Rouse Hill OHL Installation Cost (with 2006 Supplier Quotations)

BRW cost estimate for the supply and installation of the overhead line circuits, using 2006 Supplier Quotations.

4.6 Recent Papers on EMF

1 – *Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study* **:** *Author* Gerald Draper, Tim Vincent, Mary E Kroll, and John Swanson, June 2005.

2 – *Childhood cancer and power lines: What do the data mean? : Author* Nick Day, Tim Eden, Patricia McKinney, Eve Roman, and Jill Simpson, Sept 2005.

4.7 Supplier Quotations

2006 Supplier Quotations from Olex and Prysmian (cable) and J-Power (Invar cored conductor).

APPENDIX 4.1

PRELIMINARY FINDINGS

Introduction

A section of an existing 132kV Integral Energy (IE) overhead line is to be replaced between Vineyard and Rouse Hill. Burns and Roe Worley (BRW) has been asked by the Department Infrastructure, Planning & Natural Resources (DIPNR) to review the pricing and technical information provided by IE. Our key findings to date for the two options identified by DIPNR are given below. These are very much preliminary as we source additional information critical to the analysis.

Option D: 132 kV Overhead Line (OHL)

We have reviewed the IE supply & construction costs against the BRW model, the significant items are shown below.

Item	Integral Energy Estimate	BRW Estimate	Price Difference
Design, Administration (excluding IE 5% project management uplift)	$418,875	TBA	TBA
Materials	$10,716,825	TBA	TBA
Construction	$3,257,264	TBA	TBA
TOTAL	$17,444,504	TBA	TBA

We are still finalising the review of the OHL price against the BRW model, but initial estimates confirm that the material and construction prices shown are within reason.

Option E: 132 kV Underground Cable

We have reviewed the IE supply & construction costs against the BRW model, the significant items are shown below.

Item	Integral Energy Estimate	BRW Estimate	Price Difference
Design, Administration (excluding IE 5% project management uplift)	$401,250	$587,000	- 30%
Materials	$36,630,294	$33,797,440	+ 8 %
Construction	$23,223,920	$8,831,905	+ 162%
TOTAL	$72,837,576	$49,776,276	+46%

- It should be noted that the design & administration costs shown above do not include the IE project management and design uplift ($3,466,313). These are not included in the BRW model as it assumes that all works will be done by a single external contractor who would also do the work. If they are included the project management total would increase significantly.
- It is obvious that there is a large variation between the two construction costs. These are mainly due to the difference in excavation costs for the trench (IE $17,000,000, BRW 4,000,000) and the cable and jointing costs (IE 5,037,510, BRW 2,345,640).

Uplift in Material Costs

Since the IE quotation was done in November 2004, base material costs have increased substantially. A key example is the copper price; in Olex's a figure of $4,300 per tonne is assumed, the LME figure is presently running over twice this amount.

We have therefore gone out to obtain new quotations for the key equipment on this project in an effort to firm up the budget estimates. We would advise at this stage that the cable option is likely to suffer most from the price increases.

Use of Easements

The present easement is 30 metres wide which is suitable for the OHL installation. Should the cable option be taken we estimate that the required easement could be reduced significantly in width and also be used for other purposes.

We are reviewing this issue and will advise in due course.

Equipment Ratings & Losses

We are presently reviewing the sizes of the OHL conductor and cable and will advise if they are suitable in due course. This may have an affect on the costs and electrical losses. Any effect on the electrical losses will impact the carbon dioxide emissions attributed to them.

Operation and Maintenance

This is not a high order cost compared to the capital costs. However, the significantly higher cost assumed by Integral for the cable maintenance is being reviewed.

EMF

There has been some recent movement in this area that may be relevant to the analysis. BRW is in the process of confirming recent advice on this matter.

END

APPENDIX 4.2

CABLE SUPPLY & INSTALLATION PRICING CALCULATION

Project : Vineyard To Rouse Hill 132kV Cable Circuit No1
Title : Double Width Trench with 2 cables per phase using 2004 metal prices
Job Number : C3049
Calculation Number : C3049-1
Revision Number : 0
Author : S. Brooks

INFORMATION

Cable Voltage =	132 kV
Cable Size =	1600 M²
Route Length =	8690 M
Length Per Cable Section =	500 M
Cables Per Phase =	2
Trench Depth =	1.3
Trench Width =	1.7
Depth of Stabilised Backfill =	0.5
Total Cable Length =	52140 M
Volume of Trench =	19205 M³
Number of Joint Pits =	16
Number of Joints =	99
Number of Link Pits =	8
Number of Terminations =	12

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**DESIGN AND PLANNING**				
1.1	Project Quality Health & Safety Plans	Each	1	$ 1,500.00	$ 1,500.00
1.2	Construction Management	Each	1	$ 94,000.00	$ 94,000.00
1.3	Traffic Management & Control	Each	1	$ 100,000.00	$ 100,000.00
1.4	Route Survey	Each	1	$ 48,000.00	$ 48,000.00
1.5	Work Permits, planning & easements	Each	1	$ 150,000.00	$ 150,000.00
2	**MATERIALS**				
2.1	Supply Cable	Per Metre	52140 M	$ 292.62	$ 15,257,206.80
2.2	Supply Cable Joints	Each	99	$ 10,251.00	$ 1,014,849.00
2.3	Supply Cable Termination & Structures	Each	12	$ 12,000.00	$ 144,000.00
2.4	Supply Link Pits	Each	8	$ 8,333.00	$ 66,664.00
2.5	Supply Joint Pits	Each	16	$ 35,000.00	$ 560,000.00
2.6	Supply Fibre Optic Cable	Per Metre	8690	$ 2.62	$ 22,767.80
3	**EXCAVATION**				
3.1	Machine Excavation of Cable Trench in greenfield area	Per M³	19205 M³	$ 70.00	$ 1,344,350.00
3.2	Roadcrossings & modifications	Each	15	$ 15,000.00	$ 225,000.00
4	**CABLE INSTALLATION**				
4.1	Install Cable, including equipment hire	Per Metre	52140 M	$ 13.00	$ 677,820.00
4.2	Install Joint	Each	99	$ 5,000.00	$ 495,000.00
4.3	Install Cable Termination & Structure	Each	12	$ 8,000.00	$ 96,000.00
5	**REINSTATEMENT**				
5.1	Supply and Install Stabilised Backfill	Per M³	7387 M³	$ 65.00	$ 480,122.50
5.2	Supply & Install Warning Tape	Per Metre	17380 M	$ 5.00	$ 86,900.00
5.3	Supply & Install Protective Tiles	Per Metre	17380 M	$ 12.00	$ 208,560.00
5.4	Install Joint Pit	Each	16	$ 20,000.00	$ 320,000.00
5.5	Install Link Pit	Each	8	$ 2,500.00	$ 20,000.00
5.6	Reinstate Excavated Material	Per M³	11819 M³	$ 20.00	$ 236,370.00
5.7	Remove Excess Spoil	Per M³	7387 M³	$ 20.00	$ 147,730.00
6	**TESTING**				
6.1	Test Cable	Per cable	6	$ 10,000.00	$ 60,000.00
7	**Integral Energy Project Management**	Each	1	$ 470,000.00	$ 470,000.00
				TOTAL	$ 22,326,840.10
				CONTINGENCY (10%)	$ 2,232,684.01
				REVISED TOTAL	$ 24,559,524.11
				TOTAL FOR 2 CIRCUITS	$ 49,119,048.22
				GRAND TOTAL WITH EASEMENT COSTS	$ 49,164,048.22

APPENDIX 4.3

OHL SUPPLY & INSTALLATION PRICING CALCULATION

Project : Vineyard To Rouse Hill 132kV OHL Circuit No1
Title : Single Circuit Steel Pole with Invar Conductor, OH earth wire and fibre optic cable using 2004 metal prices
Job Number : C3049
Calculation Number : C3049-2
Revision Number : 0
Author : S. Brooks

INFORMATION

OHL Voltage =	132 kV
OHL Conductor Size =	28.5mm
Route Length =	8500 M
No of Conductors Per Phase =	1
No Of Earthwires Per Circuit =	1
Distance Between Towers =	190 M
Number of Termination Structures =	2
Number of Overhead Structures =	44
Total Conductor Length =	25500 M
Total Earthwire Length =	8500 M

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**DESIGN AND PLANNING**				
1.1	Project Quality Health & Safety Plans	Each	1	$ 1,500.00	$ 1,500.00
1.2	Construction Management	Each	1	$ 150,000.00	$ 150,000.00
1.3	Traffic Management & Control	Each	1	$ -	$ -
1.4	Route Survey	Each	1	$ 48,000.00	$ 48,000.00
1.5	Work Permits, planning & easements	Each	1	$ 150,000.00	$ 150,000.00
2	**MATERIALS**				
2.1	Supply Conductor	Per Metre	25500 M	$ 46.64	$ 1,189,320.00
2.2	Supply Earthwire	Per Metre	8500 M	$ 2.92	$ 24,820.00
2.3	Supply Structures	Each	46	$ 76,320.00	$ 3,490,635.79
2.4	Supply Insulators	Each	46	$ 12,190.00	$ 557,532.11
2.5	Supply Fibre Optic Cable	Per Metre	8500 M	$ 28.41	$ 241,485.00
3	**EXCAVATION**				
3.1	Machine Excavation of Tower Foundations	Each	46	$ 12,000.00	$ 548,842.11
3.2	Roadcrossings & modifications	Each	15	$ 15,000.00	$ 225,000.00
4	**OHL INSTALLATION**				
4.1	Supply New Foundation	Each	46	$ 6,784.00	$ 310,278.74
4.2	Install Pole & Fittings	Each	46	$ 8,000.00	$ 365,894.74
4.3	Install Conductor Incl Equipment Hire	Each	25500 M	$ 25.00	$ 637,500.00
5	**MISCELLANEOUS**				
5.7	Interfacing Works	Each	1	$ 200,000.00	$ 200,000.00
6	**TESTING**				
6.1	Test OHL	Per OHL	1	$ 10,000.00	$ 10,000.00
7	**Integral Energy Project Management**	Each	1	$ 470,000.00	$ 470,000.00
				TOTAL	$ 8,620,808.47
				CONTINGENCY (10%)	$ 862,080.85
				REVISED TOTAL	$ 9,482,889.32
				TOTAL FOR TWO CIRCUITS	$18,965,779
				GRAND TOTAL WITH EASEMENT COSTS	$19,030,779

APPENDIX 4.4

CABLE SUPPLY & INSTALLATION PRICING CALCULATION

Project : Vineyard To Rouse Hill 132kV Cable Circuit No1
Title : Double Width Trench with 2 cables per phase using 2006 metal prices
Job Number : C3049
Calculation Number : C3049-3
Revision Number : 0
Author : S. Brooks

INFORMATION

Cable Voltage =	132 kV
Cable Size =	1600 M²
Route Length =	8690 M
Length Per Cable Section =	500 M
Cables Per Phase =	2
Trench Depth =	1.3
Trench Width =	1.7
Depth of Stabilised Backfill =	0.5
Total Cable Length =	52140 M
Volume of Trench =	19205 M³
Number of Joint Pits =	16
Number of Joints =	99
Number of Link Pits =	8
Number of Terminations =	12

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**DESIGN AND PLANNING**				
1.1	Project Quality Health & Safety Plans	Each	1	$ 1,500.00	$ 1,500.00
1.2	Construction Management	Each	1	$ 94,000.00	$ 94,000.00
1.3	Traffic Management & Control	Each	1	$ 100,000.00	$ 100,000.00
1.4	Route Survey	Each	1	$ 48,000.00	$ 48,000.00
1.5	Work Permits, planning & easements	Each	1	$ 150,000.00	$ 150,000.00
2	**MATERIALS**				
2.1	Supply Cable	Per Metre	52140 M	$ 374.00	$ 19,500,360.00
2.2	Supply Cable Joints	Each	99	$ 10,251.00	$ 1,014,849.00
2.3	Supply Cable Termination & Structures	Each	12	$ 12,000.00	$ 144,000.00
2.4	Supply Link Pits	Each	8	$ 8,333.00	$ 66,664.00
2.5	Supply Joint Pits	Each	16	$ 35,000.00	$ 560,000.00
2.6	Supply Fibre Optic Cable	Per Metre	8690	$ 2.62	$ 22,767.80
3	**EXCAVATION**				
3.1	Machine Excavation of Cable Trench in greenfield area	Per M³	19205 M³	$ 70.00	$ 1,344,350.00
3.2	Roadcrossings & modifications	Each	15	$ 15,000.00	$ 225,000.00
4	**CABLE INSTALLATION**				
4.1	Install Cable, including equipment hire	Per Metre	52140 M	$ 13.00	$ 677,820.00
4.2	Install Joint	Each	99	$ 5,000.00	$ 495,000.00
4.3	Install Cable Termination & Structure	Each	12	$ 8,000.00	$ 96,000.00
5	**REINSTATEMENT**				
5.1	Supply and Install Stabilised Backfill	Per M³	7387 M³	$ 65.00	$ 480,122.50
5.2	Supply & Install Warning Tape	Per Metre	17380 M	$ 5.00	$ 86,900.00
5.3	Supply & Install Protective Tiles	Per Metre	17380 M	$ 12.00	$ 208,560.00
5.4	Install Joint Pit	Each	16	$ 20,000.00	$ 320,000.00
5.5	Install Link Pit	Each	8	$ 2,500.00	$ 20,000.00
5.6	Reinstate Excavated Material	Per M³	11819 M³	$ 20.00	$ 236,370.00
5.7	Remove Excess Spoil	Per M³	7387 M³	$ 20.00	$ 147,730.00
6	**TESTING**				
6.1	Test Cable	Per cable	6	$ 10,000.00	$ 60,000.00
7	**Integral Energy Project Management**	Each	1	$ 470,000.00	$ 470,000.00
				TOTAL	$ 26,569,993.30
				CONTINGENCY (10%)	$ 2,656,999.33
				REVISED TOTAL	$ 29,226,992.63
				TOTAL FOR 2 CIRCUITS	$ 58,453,985.26
				GRAND TOTAL WITH EASEMENT COSTS	$ 58,498,985.26

APPENDIX 4.5

OHL SUPPLY & INSTALLATION PRICING CALCULATION

Project : Vineyard To Rouse Hill 132kV OHL Circuit No1
Title : Single Circuit Steel Pole with Invar Conductor, OH earth wire and fibre optic cable using 2006 metal prices
Job Number : C3049
Calculation Number : C3049-4
Revision Number : 0
Author : S. Brooks

INFORMATION

OHL Voltage =	132 kV
OHL Conductor Size =	35.1mm
Route Length =	8500 M
No of Conductors Per Phase =	1
No Of Earthwires Per Circuit =	1
Distance Between Towers =	190 M
Number of Termination Structures =	2
Number of Overhead Structures =	44
Total Conductor Length =	25500 M
Total Earthwire Length =	8500 M

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE		AMOUNT
1	**DESIGN AND PLANNING**					
1.1	Project Quality Health & Safety Plans	Each	1	$	1,500.00	$1,500
1.2	Construction Management	Each	1	$	150,000.00	$150,000
1.3	Traffic Management & Control	Each	1	$	-	$0
1.4	Route Survey	Each	1	$	48,000.00	$48,000
1.5	Work Permits, planning & easements	Each	1	$	150,000.00	$150,000
2	**MATERIALS**					
2.1	Supply Conductor	Per Metre	25500 M	$	35.00	$892,500
2.2	Supply Earthwire	Per Metre	8500 M	$	2.92	$24,820
2.3	Supply Structures	Each	46	$	76,320.00	$3,490,636
2.4	Supply Insulators	Each	46	$	12,190.00	$557,532
2.5	Supply Fibre Optic Cable	Per Metre	8500 M	$	28.41	$241,485
3	**EXCAVATION**					
3.1	Machine Excavation of Tower Foundations	Each	46	$	12,000.00	$548,842
3.2	Roadcrossings & modifications	Each	15	$	15,000.00	$225,000
4	**OHL INSTALLATION**					
4.1	Supply New Foundation	Each	46	$	6,784.00	$310,279
4.2	Install Pole & Fittings	Each	46	$	8,000.00	$365,895
4.3	Install Conductor Incl Equipment Hire	Each	25500 M	$	25.00	$637,500
5	**MISCELLANEOUS**					
5.7	Interfacing Works	Each	1	$	200,000.00	$200,000
6	**TESTING**					
6.1	Test OHL	Per OHL	1	$	10,000.00	$10,000
7	**Integral Energy Project Management**	Each	1	$	470,000.00	$470,000
				TOTAL		$8,323,988
				CONTINGENCY (10%)		$832,399
				REVISED TOTAL		$9,156,387
				TOTAL FOR TWO CIRCUITS		$18,312,775
				GRAND TOTAL WITH EASEMENT COSTS		$18,377,775

APPENDIX 4.6

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Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study

Gerald Draper, Tim Vincent, Mary E Kroll and John Swanson

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Papers

Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study

Gerald Draper, Tim Vincent, Mary E Kroll, John Swanson

Abstract

Objective To determine whether there is an association between distance of home address at birth from high voltage power lines and the incidence of leukaemia and other cancers in children in England and Wales.
Design Case-control study.
Setting Cancer registry and National Grid records.
Subjects Records of 29 081 children with cancer, including 9700 with leukaemia. Children were aged 0-14 years and born in England and Wales, 1962-95. Controls were individually matched for sex, approximate date of birth, and birth registration district. No active participation was required.
Main outcome measures Distance from home address at birth to the nearest high voltage overhead power line in existence at the time.
Results Compared with those who lived > 600 m from a line at birth, children who lived within 200 m had a relative risk of leukaemia of 1.69 (95% confidence interval 1.13 to 2.53); those born between 200 and 600 m had a relative risk of 1.23 (1.02 to 1.49). There was a significant ($P < 0.01$) trend in risk in relation to the reciprocal of distance from the line. No excess risk in relation to proximity to lines was found for other childhood cancers.
Conclusions There is an association between childhood leukaemia and proximity of home address at birth to high voltage power lines, and the apparent risk extends to a greater distance than would have been expected from previous studies. About 4% of children in England and Wales live within 600 m of high voltage lines at birth. If the association is causal, about 1% of childhood leukaemia in England and Wales would be attributable to these lines, though this estimate has considerable statistical uncertainty. There is no accepted biological mechanism to explain the epidemiological results; indeed, the relation may be due to chance or confounding.

Introduction

The electric power system produces extremely low frequency electric and magnetic fields. Since 1979 there has been concern that these fields may be associated with cancer.[1] Concern has concentrated on magnetic rather than electric fields and on childhood leukaemia in particular. A pooled analysis of nine studies that met specified quality criteria found that children living in homes with 24 hour average fields of ≥0.4 μT have twice the risk of leukaemia.[2] In 2001 the International Agency for Research on Cancer classified extremely low frequency magnetic fields as "possibly carcinogenic" on the basis of "limited" epidemiological evidence and "inadequate" evidence from animals.

Magnetic fields in homes arise mainly from low voltage distribution wiring, house wiring, and domestic appliances. Only a small fraction of homes are close to high voltage overhead power lines (transmission lines), but in these homes the power line is likely to be the main source of magnetic field.

We investigated whether proximity of home address at birth to transmission lines in England and Wales is associated with increased risks of childhood cancer. It is not known which period of life, if any, is relevant to induction of cancer by magnetic fields. Previous research has considered address at diagnosis or throughout some specified period. Over half (55%) of cases of childhood leukaemia and 43% of other cancers in childhood occur by the age of 5 years.

Methods

Cases and controls

Children aged 0-14 years with cancer (malignant neoplasms and tumours of the central nervous system and brain) in England, Scotland, and Wales, ascertained through several sources including the National Cancer Registration System and the UK Children's Cancer Study Group, are included in the National Registry of Childhood Tumours at the Childhood Cancer Research Group.

We identified nearly 33 000 cases of childhood cancer in children born in England and Wales, 1962-95, and diagnosed in England, Wales, or Scotland over the same period. We obtained birth information for just over 31 000 cases, 1700 having been excluded because the child was adopted or the birth record could not be traced. For each case we selected from birth registers a control matched for sex, date of birth (within six months), and birth registration district. Registration districts vary greatly in size and are frequently redefined; there are currently about 400. We attempted to find the postcode and approximate grid reference of the address at birth for all cases and controls, but this was not always possible. The final dataset comprised 29 081 matched case-control pairs (9700 for leukaemia) that we could map with respect to transmission lines.

Calculation of distance from power lines

We looked at overhead power lines forming the National Grid in England and Wales—that is, all 275 and 400 kV overhead lines (the highest voltages used) plus a small fraction of 132 kV lines, about 7000 km altogether. We obtained the grid references of all 21 800 pylons concerned from the records of National Grid Transco. Using the postcode at birth we identified subjects living within 1 km of a transmission line. For 93% of these addresses we

Table 1 Distance of address at birth from nearest National Grid line for cases and controls in each diagnostic group, and estimated relative risk (RR)

	Leukaemia			CNS/brain tumours			Other diagnoses		
Distance to line (metres)	Cases	Controls	RR	Cases	Controls	RR	Cases	Controls	RR
0-49	5	3	1.67	3	7	0.44	7	6	1.17
50-99	19	11	1.79	4	6	0.69	15	16	0.91
100-199	40	25	1.64	26	32	0.82	37	45	0.81
200-299	44	39	1.16	38	28	1.35	66	76	0.87
300-399	61	54	1.15	35	30	1.19	79	65	1.21
400-499	78	65	1.23	40	42	0.96	80	97	0.82
500-599	75	56	1.36	54	41	1.33	86	85	1.01
≥600 (reference group)	9378	9447	1.00	6405	6419	1.00	12 406	12 386	1.00
Total	9700	9700		6605	6605		12 776	12 776	

CNS=central nervous system.

obtained, from the Ordnance Survey product AddressPoint, a 0.1 m grid reference and hence calculated the shortest distance to any of the transmission lines that had existed in the year of birth, re-creating previous locations of lines when necessary and possible. For calculated distances less than 50 m, we took the average of the nearest and furthest points of the building from the line, using large scale maps. We aimed to obtain a complete set of accurate distances for all subjects within 600 m of a line, a distance chosen to be well beyond that at which the magnetic field from the line is thought to be important.

Statistical analysis

We used conditional logistic regression on the matched case-control pairs to calculate relative risks and χ^2 values.

Results

Table 1 shows the distribution of distances from the nearest line for cases, subdivided into leukaemia, central nervous system/brain, and "other," and for matched controls. Most (97%) of these distances were ≥600 m. The relative risk is an estimate of the incidence compared with that at distances ≥600 m. For leukaemia, at each distance category <600 m the relative risks are greater than 1.0; there is some evidence that the risk varies according to distance from the line, though there is no smooth trend. For the other diagnoses, our data suggest no increased risk.

In general, emanations from a line source are expected to reduce in strength as the reciprocal of distance, but the magnetic field from a power line generally falls as the inverse square of distance, or sometimes the inverse cube.[3] For each diagnostic group, we tested whether the risk is some function of distance (d) from the nearest line (table 2), using three models: that the risk depends on the rank of the distance band, the reciprocal of the distance ($1/d$), or the inverse square ($1/d^2$). There were no significant results for central nervous system/brain tumours or for "other tumours." For leukaemia, the results of two of the trend analyses were significant ($P<0.01$); these analyses suggest the risk might depend either on the rank of the distance category or on the reciprocal of distance. The latter seems more plausible. We therefore retabulated the results for leukaemia at intervals corresponding to roughly equal intervals of $1/d$ (table 3). This change in the grouping of the data does not change the pattern of relative risk estimates shown in table 1 or the significance of the test for trend with $1/d$. For simplicity we also analysed risk of leukaemia in bands 0-199 m and 200-599 m. The risks relative to ≥600 m were 1.69 and 1.23; the trend with $1/d$ was significant ($P<0.01$).

We examined the possibility that the relation between distance and risk of leukaemia is a consequence of a relation between distance and socioeconomic status. We used the Carstairs deprivation index to allocate a measure of socioeconomic status to the census ward in which each child was living at birth.[4] The results in table 4 confirm the previously reported association between affluence and risk of childhood leukaemia (P for trend <0.01).[5] Adjustment for socioeconomic status had no effect on the relative risks for distance (table 3).

Power lines produce small air ions through a process known as "corona." Fews et al suggest that this could lead to health

Table 2 Tests of hypotheses relating trends in relative risks to alternative measures of proximity to nearest line (based on the eight distance categories* in table 1). Figures are χ^2 for trend (with 1 df) and P value

	Leukaemia	CNS/brain tumours	Other diagnoses
Ranked distances	8.76, P=0.003	0.01, P=0.924	0.64, P=0.424
Reciprocal of distance ($1/d$)	6.72, P=0.0095	1.09, P=0.296	0.12, P=0.733
Reciprocal of square of distance ($1/d^2$)	1.47, P=0.225	1.83, P=0.177	0.03, P=0.873

*Distance (d) for each case is taken as midpoint of limits of band within which it lies (as specified in table 1).

Table 3 Relative risk (RR) estimates for leukaemia using revised distance categories (see text)

Distance, d (metres)	$1/d$	RR (95% CI)	RR* (95% CI)
0-49	0.040	1.67 (0.40 to 6.97)	1.65 (0.39 to 6.89)
50-69	0.017	1.51 (0.48 to 4.79)	1.53 (0.48 to 4.83)
70-99	0.012	2.02 (0.76 to 5.39)	2.00 (0.75 to 5.32)
100-199	0.007	1.64 (1.00 to 2.71)	1.64 (0.99 to 2.70)
0-199	0.010	1.69 (1.13 to 2.53)	1.68 (1.12 to 2.52)
200-599	0.003	1.23 (1.02 to 1.49)	1.22 (1.01 to 1.47)
≥600 (reference group)	0.000	1.00	1.00

*Adjusted for socioeconomic status.

Table 4 Relative risks for categories of socioeconomic status

Socioeconomic status	Leukaemia	CNS/brain tumours	Other diagnoses
1 (most affluent)	1.00	1.00	1.00
2	0.96	0.97	1.04
3	0.94	0.93	0.99
4	0.90	0.97	0.95
5 (most deprived)	0.88	0.92	0.98
χ^2 for trend	6.79, P=0.009	1.38, P=0.240	1.07, P=0.302

effects when winds blow the ions away from the line.[6] We have made an initial test of this hypothesis using a simple model suggested by Preece et al (personal communication), assuming the prevailing wind is from the south west. The case-control ratio was no greater downwind than upwind of power lines, so, using this admittedly oversimplified approach, we have no evidence to support this hypothesis.

Discussion

To date this is the largest study of childhood cancer and power lines, with roughly twice the number of children living close to power lines than in the next largest study.[7] We found that the relative risk of leukaemia was 1.69 (95% confidence interval 1.13 to 2.53) for children whose home address at birth was within 200 m of a high voltage power line compared with those more than 600 m from the nearest line. For 200-600 m the relative risk was 1.23 (1.02 to 1.49). The finding that the increased leukaemia risk apparently extends so far from the line is surprising in view of the very low level of magnetic field that could be produced by power lines at these distances.

Possible explanations for findings

There is no obvious source of bias in the choice of cases or controls. The study is based on records of childhood cancer in England and Wales over most of the period that the National Grid has existed. Registration for childhood cancer is nearly complete, and it seems improbable that the likelihood of registration is related to proximity of birth address to transmission lines. Controls were selected from registers compiled through the legally required process of birth registration. No participation by cases or controls was required. We calculated distances without knowing case-control status, and we were able to include 88% of the eligible cases, each with a matched control.

Populations near power lines may have different characteristics from the rest of the population. In our control data there is a slight tendency in urban areas for greater affluence (measured by the Carstairs index) closer to lines, though in rural areas there is no clear trend. There is known to be a positive association between affluence and rates of childhood leukaemia. However, adjustment for socioeconomic status of the census ward of birth address did not explain our finding. Population mixing has been associated with childhood leukaemia,[8] but in our cases individual mobility, measured by changes of postcode between birth and diagnosis, was no more common for those whose home at birth was closer to the lines. Other characteristics of the population (for instance parity, which has sometimes been found to be associated with childhood leukaemia[9]) may vary with proximity to power lines, but we do not have the data to determine whether these explain our result.

The results are highly significant but could nevertheless be due to chance—for example, if the leukaemia controls are not sufficiently representative of the relevant population. Some support for this explanation can be derived from the different distance distributions observed for the leukaemia and non-leukaemia controls in table 1. Comparison of the leukaemia cases with the latter still suggests that there is an increased risk for leukaemia but it is much lower than that found using the matched controls. We emphasise, however, that the use of the matched controls is the most appropriate approach.

Six of the studies included in the pooled analysis referred to above[2] contain, or have been extended to include, analyses of proximity to power lines.[7 10-14] Of these, one, a previous UK study,[10] with 1582 cases of leukaemia diagnosed during 1992-6 (most of which will be contained within our 9700), found a relative risk of 1.42 (0.85 to 2.37) for acute lymphocytic leukaemia within 400 m for 275 and 400 kV lines; this supports our results. Studies in Canada[11] and Sweden[7] also found increased risks for childhood leukaemia (Canada: relative risk 1.8 (0.7 to 4.7) for residence within 100 m of transmission lines of 50 kV or more, and 1.3 within 50 m; Sweden: 2.9 (1.0 to 7.3) for residence ≤ 50 m versus 101-300 m from 220 and 400 kV power lines, with no increase for other childhood cancers). Studies from Denmark,[12] Norway,[13] and the United States[14] found relative risks below 1.0 but were based on smaller numbers. None of these estimates relates to distances as great as ours; some used a reference category that is within the distance where we found an increased risk.

Our study concerned home address at birth, whereas much previous magnetic field epidemiology has concerned address at other times. Half of the children with leukaemia in this study had the same address at diagnosis as at birth; we have no corresponding information for the control group.

The most obvious explanation of the association with distance from a line is that it is indeed a consequence of exposure to magnetic fields. For magnetic fields in the home the pooled analysis by Ahlbom et al found a relative risk of 2.00 (1.27 to 3.13) for exposures ≥ 0.4 μT versus < 0.1 μT; the risks for fields < 0.4 μT were near the no effect level.[2] Another pooled analysis, including additional studies, found a similar result with a threshold of 0.3 μT.[15] For the power lines we investigated, the magnetic field falls to 0.4 μT at an average of about 60 m from the line (based on calculations using one year of recorded loads for a sample of 42 lines). Our increased risk seems to extend to at least 200 m, and at that distance typical calculated fields from power lines are < 0.1 μT, and often < 0.01 μT—that is, less than the average fields in homes from other sources. Thus our results do not seem to be compatible with the existing data on the relation between magnetic fields and risk. The estimated relative risk was more closely related to the reciprocal of the distance from the line than to the square of the reciprocal of the distance.

Conclusions

While few children in England and Wales live close to high voltage power lines at birth, there is a slight tendency for the birth addresses of children with leukaemia to be closer to these lines than those of matched controls. An association between childhood leukaemia and power lines has been reported in several studies, but it is nevertheless surprising to find the effect extending so far from the lines. We have no satisfactory explanation for our results in terms of causation by magnetic fields or association with other factors. Neither the association reported here nor previous findings relating to level of exposure to magnetic fields are supported by convincing laboratory data or any accepted biological mechanism.

Assuming that the higher risk in the vicinity of high voltage lines is indeed a consequence of proximity to the lines we can estimate the attributable annual number of cases of childhood

What is already known on this topic

Power frequency magnetic fields, produced by the electric power system, are "possibly carcinogenic"

A pooled analysis of case-control studies found that children living in homes with high magnetic fields (>0.4 μT) had twice the risk of childhood leukaemia

High voltage power lines are one source of these fields

What this study adds

A UK study of 29 000 cases of childhood cancer, including 9700 cases of leukaemia, found a raised risk of childhood leukaemia in children who lived within 200 m of high voltage lines at birth compared with those who lived beyond 600m (relative risk 1.7)

There was also a slightly increased risk for those living 200-600 m from the lines at birth (relative risk 1.2, P for trend <0.01); as this is further than can readily be explained by magnetic fields it may be due to other aetiological factors associated with power lines

leukaemia in England and Wales. The annual incidence of childhood leukaemia in England and Wales is about 42 per million; the excess relative risks at distances of 0-199 m and 200-599 m are about 0.69 and 0.23, respectively, giving excess rates of 28 and 10 per million. (These two estimates allow for the fact that the incidence for England and Wales is itself partly based on cases occurring in the vicinity of power lines.) We estimate that of the 9.7 million children in the population (2003 estimate), at birth about 80 000 would have lived within 199 m of a line and 320 000 between 200 and 599 m. Thus, of the 400-420 cases of childhood leukaemia occurring annually, about five would be associated with high voltage power lines, though this estimate is imprecise. We emphasise again the uncertainty about whether this statistical association represents a causal relation.

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Contributors: GD was responsible for overall direction of the study and publication. GD and JS had the initial idea and designed the study. TV and MEK collected information on cases and controls and carried out the statistical analysis. JS assessed exposures. GD and JS are guarantors

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Competing interests: JS is employed by National Grid Transco and worked on this project with their permission. A written contract exists between the Childhood Cancer Research Group and National Grid Transco specifying that the Childhood Cancer Research Group has complete control over the conduct, interpretation, and publication of this study; this paper has not been approved by anyone in National Grid Transco other than JS in his capacity as author and does not necessarily represent National Grid Transco's views.

Ethical approval: The Childhood Cancer Research Group has local ethics committee approval and, through membership of the UK Association of Cancer Registries, has approval from the Patient Information Advisory Group with respect to cancer registration function.

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Science commentary: Power to confuse

Geoff Watts

Ever since Nancy Wertheimer of the University of Colorado reported her 1979 findings of an excess of cancer in children living near overhead power lines, seldom has a year passed without a flurry of public debate over the safety or otherwise of these ugly (the one thing all parties agree on) but essential installations.

Much of the argument has been about the very existence of the alleged hazard. As recently as last month, the organisers of the 15 year UK childhood cancer study declared that "perceived risk factors such as living near sources of electromagnetic fields . . . are not principal causes, if at all, of leukaemia in children." But a clutch of studies reporting a positive association—of which this week's by Draper and colleagues is the most recent[1]—has encouraged researchers to continue investigating possible mechanisms.

Electrical and magnetic fields can induce currents that might alter the voltages across cell membranes. Magnetic fields might cause the movement of ferromagnetic particles within cells. They might also influence free radicals: atoms with unpaired electrons that are highly reactive and play a part in all sorts of biochemical processes. Low frequency electromagnetic fields have been said to alter the progress of cells through the cell cycle and reduce the effectiveness of the immune system. Power lines might even deflect and concentrate cosmic rays on people living within their vicinity. Evidence to support these and other ideas, however, is at best thin and at worst non-existent.

One of the more recent attempts at identifying a mechanism sidesteps the need to invoke direct effects. For the past 10 years or so, Bristol University physicist Dennis Henshaw has been working on the influence of powerful electric fields on the deposition of airborne particles. The relevance of this to power lines entered public consciousness in 1999 with the publication of two papers by Henshaw and colleagues.[2 3] High energy power systems, they pointed out, cause some breakdown in the surrounding air molecules and so generate positive or negative ions. The systems are designed to minimise this effect, but it does still occur—and any aerosol pollutants that pass through these ion clouds can acquire an electrical charge.

If particles with a charge are inhaled, more of them will stick to the lining of the respiratory system. The data are limited, but one study that used a model of the human airway suggests that deposition could be increased by a factor of around three. A 2004 report by the (then) National Radiological Protection Board conceded the plausibility of the mechanism and suggested some further experiments.[4] Draper and colleagues refer to the Henshaw hypothesis but add that more work will be necessary to rule it in or out.[1]

Like the fluoridation of drinking water and the genetic modification of crops, the debate over power lines seems destined to be with us for a while yet. So, in these risk averse times, and before activists begin blowing up pylons, a bit of perspective might help. In 2002, according to the Child Accident Prevention Trust, more than 36 000 children were hurt in road accidents and around 200 were killed. Another 32 died in house fires. Draper and colleagues reckon that five cases annually of childhood leukaemia may be associated with power lines.

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***Childhood cancer and power lines: What do the data mean? : Author* Nick Day, Tim Eden, Patricia McKinney, Eve Roman, and Jill Simpson, Sept 2005**

Paper Summary

"Editor—Draper et al used distance of mother's home from high voltage overhead transmission lines (predominantly 275 kV and 400 kV) at the time of her child's birth as a proxy for her child's subsequent exposure to power-frequency magnetic fields (reviewed by Ahlbom et al).[1 2] As they acknowledge, this is a crude estimate since, in contrast to other reports,[2] no household measurements were taken, no data on more prevalent low voltage distribution sources were collected, no information from other time points in the child's life was obtained, variations during the 33 years period studied were not considered, and no validatory home visits were carried out. A recent report into residential exposures to magnetic fields in the United Kingdom estimated that proximity to high voltage lines, 275 kV and above, explained only 9% of those with measurements ≥0.2 microtesla (µT).[3]"

APPENDIX 4.7

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OLEX Contact: DAVID MITCHELL

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1. Charges will be applied to individual orders less than $500 excl GST (branch delivery) and $1000 excl GST (site delivery).
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Customer: Burns & Roe Worley XSDdim 23/05/2006
Reference: VC650646 Item 1

DESCRIPTION: 1 Conductor 1600 mm2 Milliken Sector Plain Annealed Copper, Semiconductive Conductor Screen (0.0 mm nom wall), 76/132 kV Superclean XLPE Insulated (18 mm min av wall), Semiconductive XLPE Insulation Screen (1.0 mm min av wall), Waterblocking Screen Taped, Lead Sheathed (2.4 mm min av wall), Copper Wire Screened (area 174 mm2 min suitable for 25 kA for 1 sec fault level), PVC (5V-90) Sheathed (1.6 mm min av wall), HD PE Sheathed (2.5 mm min av wall), Graphite Coated, EHV cable to AS/NZS 1429.2.

Ident Number: 5699,029996,58,2666 Marketing Code: not available

Colour Code:

Insulation	Natural
Sheath	Black

Physical Properties:

Cable dimensions :

Overall cable diameter:	114.3 mm nom ± 1.7 mm
Diameter over lead sheath :	100.0 mm
Conductor Diameter :	49.7 mm
Net mass of cable:	30790 kg/km

Recommended minimum internal bending radius :

Pulling In :	2900 mm
Set in Position :	1700 mm

Recommended maximum safe pulling/working tension :

Conductors :	20.0 kN

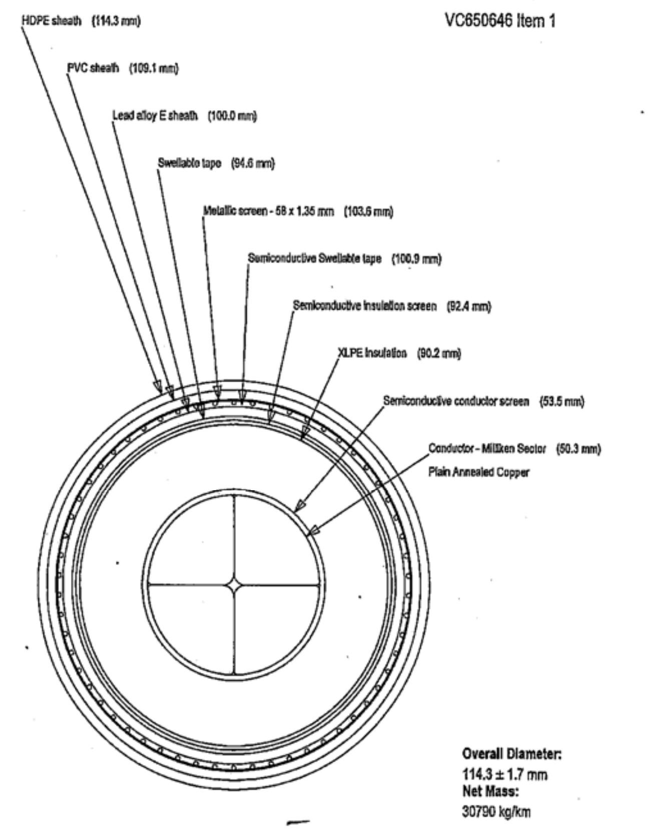
Electrical Properties:

Maximum conductor resistance =	0.0113 ohm/km
Minimum insulation resistance =	9080 megohm.km
Capacitance of main conductor =	0.24 µF/km

Despatch Parameters:

Lengths	9 x 500 m
Internal drum size	3700 mm x 2600 mm B x 2000 mm
Overall drum size	3700 mm x 2220 mm (Steel Drum)
Gross mass per drum	16922 kg
Minimum barrel diameter	2500 mm

Subject to change without notice



<u>DESCRIPTION:</u> 1 Conductor 1600 mm2 Milliken Sector Plain Annealed Copper, Semiconductive Conductor Screen (0.0 mm nom wall), 76/132 kV Superclean XLPE Insulated (18 mm min av wall), Semiconductive XLPE Insulation Screen (1.0 mm min av wall), Waterblocking Screen Taped, Lead Sheathed (2.4 mm min av wall), Copper Wire Screened (area 174 mm2 min suitable for 2.5 kA for 1 sec fault level), PVC (5V-90) Sheathed (1.6 mm min av wall), HD PE Sheathed (2.5 mm min av wall), Graphite Coated, EHV cable to AS/NZS 1429.2.

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Olex Australia Pty Limited
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Prepared: CAU	23 May 06
Approved:	Scale: 1.0 x full size
IDENT:	5699,029996,58,2666

PRYSMIAN CABLES & SYSTEMS

Customer: **Burns and Roe Worley**

Project: **132kV project - Vineyard to Rouse Hill Upgrade**

Strategic Metals: **Copper 6,710.50 US$ / tonne: Aluminium 2,397.50 US$ / tonne**

Currency: **Australian Dollars**

Item	Description	Copper (kg/km)	Aluminium (kg/km)	Quantity	Unit Price A$	Budgetary Price (A$)
1.1	132kV 1,600mm² XLPE cable	14,200.00	2,350.00	104.00 km	341.00 per m	35,464,000.00
1.2	132kV Straight through Joint	NA	NA	99 pcs	8,520.00 per pc	843,480.00
1.3	132kV Termination	NA	NA	12 pcs	13,320.00 per pc	159,840.00
1.4	Joint Link Boxes (with bonding cable)	NA	NA	33 pcs	10,120.00 per pc	333,960.00
1.5	Term Link Boxes (with bonding cable)	NA	NA	12 pcs	2,730.00 per pc	32,760.00
					Total A$:	36,834,040.00

Notes:

The budgetary prices are delivered to site, quoted in Australian Dollars but are NOT FIRM
The prices are inclusive of all import duties and taxes payable in Australia but are exclusive of GST

METAL CLAUSE:
Our budgetary prices of cables and conductors are linked to the LME settlement (London Metal Exchange) quotations for metal ingots according to above mentioned rates. Should there occur a change in our purchasing price of metals, the cable price will be revised according to the metal contents of offered cables and conductors on the basis of the rates on the next working day of the LME following the Contract.

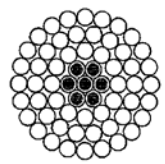
Terms of payment: to be agreed separately

Delivery date: to be agreed separately

J-Power Systems Corp.
Joint Venture Company of Hitachi Cable and Sumitomo Electric

Ref No. JTD 80-1038
June 23, 2006

Proposal of Invar Core Conductor (ZTACIR/AS 650mm^2)

Description		Unit	ZTACIR/AS 650mm^2
Construction		Nos/mm	54/3.9-ZTAL*1 7/3.9- IR/AS*2
Nominal Diameter		mm	35.1
Ultimate tensile strength (UTS)		kN	Min. 173.6
Cross Sectional Area	Al	mm^2	645.3
	AC-Invar		83.65
	Total		729.0
Nominal Weight		kg/km	2387
DC Resistance at 20 degC		ohm/km	0.0444
Modulus of elasticity	Conductor	GPa	72.2
	Core	GPa	152.0
Co-efficient of linear expansion	Conductor	/degC	18.3 $\times 10^{-6}$
	Core	/degC	3.7 $\times 10^{-6}$
Allowable continuous operation Temp.		℃	210
Sag at allowable continuous operation Temp. *A		m	6.85 (at 210℃)
Current capacity *B		A	2212 (at 210℃)
Cross sectional view		-	

Notes *1 ZTAL: Super Thermal-resistant aluminum alloy
*2 IR/AS: Aluminum-clad invar steel alloy

*A: Calculation Conditions for Sag
Everyday working tension: 34.72kN(20% UTS of Conductor)
Temp.at Everyday working tension: 15℃
Span length: 220m

*B: Calculation Conditions for Current Capacity
Ambient temp.:35℃
Wind velocity:0.6m/s
Wind direction: Transverse to Line
Solar radiation 0.1 w/cm^2
Absorptivity: 0.5