Electricity Undergrounding in New South Wales

A Final Report to the Minister for Energy

INDEPENDENT PRICING AND REGULATORY TRIBUNAL
OF NEW SOUTH WALES

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EXECUTIVE SUMMARY

Overhead electricity cables have become a concern for many members of the community in New South Wales. In particular, people are concerned about the potential for overhead lines to be damaged in storms and bushfires, and the impact of power outages resulting from this damage on the customers the lines supply. In addition, many people believe the overhead lines detract from views and streetscapes in cities and neighbourhoods across NSW. These concerns have led to pressure to underground the overhead network.

Electricity distribution businesses around the world are also concerned about the susceptibility of overhead cables to damage, and many are implementing targeted undergrounding programs in areas where the risk of damage is greatest. In Australia, undergrounding programs of varied scope are underway in Perth, Adelaide, Victoria and Queensland. In NSW, undergrounding efforts to date have been the result of local council initiatives and commercial decisions by electricity providers.

The NSW government, together with electricity businesses and interested community groups, is currently exploring the possibility of implementing a much wider undergrounding program. In particular, it is considering undergrounding electricity wires carrying voltages of up to 22 kilovolts (kV) in urban and regional centres.[1] As part of this process, the Minister for Energy asked the Independent Pricing and Regulatory Tribunal (the Tribunal) to assess the costs and benefits to all stakeholders of the proposed program, identify the likely distribution and timing of the benefits, and review the options for funding the program. This Report presents the Tribunal's findings.

Overall, the Tribunal found that the quantified costs are substantially higher than the quantifiable benefits of general widespread undergrounding, and that some benefits, such as improved amenity, are difficult to quantify.

Given the nature of the benefits accruing from undergrounding, the Tribunal recommends that if the program goes ahead, that it be funded through a beneficiary pays approach, in which around 60 per cent of the costs are recovered from property owners through local government charges and the remainder from the state government and the Distribution Network Service Providers (DNSPs), a small proportion of which could be recovered through electricity charges. The Tribunal also recommends that local communities that place a relatively low value on local environment and amenity benefits such as views be able to opt out of the program.

The cost of undergrounding

The costs of undergrounding depend on the voltages of the cables to be undergrounded, the customer density of the areas to be undergrounded, and the approach taken to undergrounding. The costs in this report are broad estimates of the order of the magnitude of these costs. Further work would be required to provide firmer estimates of these costs.

[1] In his Terms of Reference for this review, the Minister for Energy did not define a regional centre. For its analysis, the Tribunal has included centres with populations of 30,000 or more. This is consistent with the definition that the Putting Cables Underground Working Group used.

In its Interim Report, the Tribunal reported the cost range for the project in present value terms. It did so for purposes of comparison with the quantifiable benefits, also reported in present values. This approach has the advantage, in project analysis of this kind, of bringing future outlays and derived benefit values back to a single number for comparative purposes. The Tribunal estimates that the total costs of the proposed project are likely to lie in the range $1.4-$2.4 billion over 40 years in *net present value terms*. This estimate is lower than that reported in the Tribunal's Interim Report. The Tribunal's consultant engaged to estimate the likely costs of undergrounding revised downward its estimates after further analysis.[2] However, *net present values*, which discount costs over time, do not represent the actual project costs, which are equivalent to $2,300-$3,800 per customer (in 2002 dollars). This range broadly corresponds with the average cost of recent undergrounding projects in other Australian capital cities and estimates quoted by submissions to the Tribunal's review.

The Tribunal's total estimated costs include the cost of undergrounding the connection from customer residences to connection points on the network (but excludes costs of undergrounding communication cables, which may be in the order of $2,000 per customer in real terms). The lower end of the range refers to the cost of undergrounding using an 'optimised approach', while the upper bound refers to a 'like-for-like approach', whereby the *existing* network configuration is progressively replaced with an underground replica.

Meritec Limited, the engineering consultancy commissioned by the Tribunal to investigate the costs of undergrounding, strongly recommends using an optimised approach. Such an approach involves reassessing the overall concept of the network and designing a replacement network that takes into account current and future load patterns and the characteristics and cost structures of underground networks, and takes advantage of technological improvements in equipment and cables. This approach would also involve undergrounding sub-transmission assets of up to 132kV, which would enable the sub-transmission system to be restructured, minimise the need for some expensive zone substation facilities and sites, and increase the reliability of supply.[3] Meritec accepts that it is unlikely that an optimally planned network could be implemented in full.

In contrast, the alternative 'like-for-like approach' would involve replacing existing overhead lines with underground lines of a comparable capacity, essentially along the same routes, and retaining the present sub-transmission system. Such an approach is likely to achieve a less efficient result for a higher cost.[4]

While these cost estimates include street lighting costs, they do not include the costs of undergrounding other overhead infrastructure such as communications cables. The Tribunal notes, however, that federal law requires the latter to occur within six months of the undergrounding of the electricity network. Submissions received by the Tribunal suggest that costs related to undergrounding communications infrastructure may be in the order of an additional $2,000 per household in real terms. Some of these costs may be shared with DNSPs, so the total estimate of communications costs cannot be added to the cost of undergrounding electricity cables. In addition, these costs will be offset to some extent by benefits to the telecommunications carriers, such as avoided maintenance costs.

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2 The downward revision was primarily the result of Meritec recognising in its modelling those areas that had already been undergrounded.

3 The lower bound estimate for costs of $1.4 billion in NPV terms includes optimised undergrounding of sub-transmission.

4 The like-for-like costs estimate of up to $2.4 billion in NPV terms does not include undergrounding any sub-transmission assets.

However, in its submission, Optus stated that if it was required to bear the full net costs of undergrounding its overhead infrastructure, the continued operation of its hybrid fibre-optic cable (HFC) network would be unviable.[5]

The benefits of undergrounding

The quantifiable benefits of the proposed undergrounding program are expected to be some $535 to $625 million over 40 years in *net present value terms*, or between $350 and $400 per customer. The value of these benefits is equivalent to around 40 per cent of the costs of the proposed undergrounding program, assuming an optimally planned approach is used. Quantifiable benefits include:

- reduced costs related to motor vehicle accidents that involve collisions with utility poles reducing the severity, not necessarily the number of accidents, valued at between $230 and $260 million over 40 years in *net present value terms*
- improved reliability of energy supply, valued at between $55 and $115 million over 40 years in *net present value terms*
- avoided costs associated with maintaining the overhead network, valued at $105 million over 40 years in *net present value terms*
- reduced losses in DNSP revenues associated with reduced outages as a result of damage to the overhead network and reduced transmission losses, valued at $145 million over 40 years in *net present value terms*.

A range of other benefits from undergrounding are also likely to accrue, but for various reasons these could not be quantified in any absolute sense. Unquantifiable benefits include:

- improved public amenity associated with reducing the visual impact of network infrastructure by removing overhead power lines and replacing them with less obtrusive ‘street furniture’ placed outside residences and commercial operations
- improved vegetation management, particularly if undergrounding is accompanied by enhanced landscape design and management
- improved public and wildlife safety as a result of reduced scope for accidental contact with power lines (including instances where power lines are bought down by severe weather conditions)
- improvements in the safety of workplaces for tradespersons working for various utilities, as well as builders, emergency services workers, volunteers, and others who are potentially exposed to contact with overhead wires
- opportunities to increase efficiency of the network by optimising the layout of underground infrastructure (including but not limited to electricity conduits), and to redesign streetscapes and lighting systems
- potential reduction in the health risks associated with electromagnetic fields.

[5] Optus submission, 12 February 2002, p 3.

Estimating consumers' willingness to pay for undergrounding is the only appropriate method for assessing the extent to which the community values the unquantifiable aspects of undergrounding. This was beyond the scope of the Tribunal's review. Even so, *on average* there is still a sizeable gap between the benefits and costs of undergrounding across the state.

Funding options

In considering who should pay for the proposed undergrounding program, and what are the best means of levying charges, the Tribunal looked at several funding approaches. It concluded that a beneficiary pays approach is more appropriate, but that no single funding mechanism can ensure that all costs are set against the benefits in an equitable way and that market distortions are minimised. The Tribunal recommends a mixed approach, with funding coming mostly from local rates or levies and partly from state contributions and the DNSPs.

Beneficiary pays

Some kind of beneficiary pays approach would be appropriate. However, each of the options the Tribunal has identified is likely to be difficult to implement equitably and without creating distortions. Also, as a large proportion of the key benefits of undergrounding accrue to the local community and the wider public (for example, improved views and streetscapes and avoided accidents) it will not be possible to recover the full costs through a beneficiary pays approach without government involvement. For example, individuals are unlikely to be willing to fund the full cost of improved views that may be enjoyed by the wider community.

There are at least three different options through which the beneficiary pays principle could be applied. The first is to recover costs from individual electricity consumers via electricity charges, as some of the benefits of undergrounding accrue as a result of improved reliability of supply for consumers.[6]

However, the estimated value of these benefits is small, and represents up to 5 per cent of the costs of the program (assuming an optimally planned approach). This means that although funding via electricity charges would be relatively simple to administer, it is likely to be distorting and inequitable. While several submissions endorsed the use of a levy on all electricity account holders, such an approach divorces the funding mechanism (in this case, a single-source levy on electricity consumers) from the allocation of cost recovery on the basis of benefits received. Submissions from people whose electricity cables were already undergrounded expressed the view that they should not be asked to pay again.

Another option is to recover costs from all property owners in a local area where undergrounding will occur via local government rates. This may come closest to aligning benefits with cost recovery, because a significant portion of the benefits of undergrounding are hard-to-quantify amenity benefits, which accrue to a local area and the individuals within it. However, the benefits to individuals will vary widely, depending on the location

6 Communications consumers may also benefit from network undergrounding, but these benefits are likely to be much smaller than those to electricity consumers, given the unused capacity of the existing communications system and the apparently lower impact of undergrounding on communications reliability compared to power reliability.

of their residence in relation to wires and transformers and the impact of this infrastructure on their amenity. In addition, there is likely to be significant differences in individuals' willingness to pay, both within a local government area and between local government areas. Without evidence on how members of local communities value the benefits of undergrounding, it will be difficult to apply the principle that a community should receive the level of undergrounding it is willing to pay for.

A third option is for the state as a whole to pay for urban undergrounding by reimbursing the costs of wires and cable burial out of consolidated revenue and gifting the new assets to the DNSPs, which it currently owns. Although this is administratively simple, it involves undesirable cross subsidisation of urban dwellers by rural residents outside the project area and violates the principle that beneficiary pays in proportion to the benefits they receive. It would also result in some customers paying twice, namely those in new developments where local reticulation systems have been put underground at property owners' expense.

Mixed funding approach

None of the options above meet all the requirements considered desirable in a beneficiary pays approach—that is, no single instrument can ensure all costs are set against the benefits in a way that is equitable, minimises market distortions, and is simple to administer. There are inevitable trade-offs between these requirements.

The Tribunal recommends a combination of these options, which, although not as administratively simple as any single option, comes closest to meeting the equity requirement. The benefits quantified in this report suggest that some 60 per cent of costs would be best recovered through local rates or levies, about 15 per cent would be best funded by the state, about 5 per cent would be best funded by electricity customers and about 20 per cent by DNSPs. This funding share differs from that recommended in the Tribunal's Interim Report due to a revision by Meritec to its projections of estimated total project costs. The revision, which recognises the areas already undergrounded, significantly reduced the estimated total costs of the project, and as a result, narrowed the identifiable funding 'gap' between the quantifiable costs and benefits. This also resulted in a change in the proportionate share of costs to be funded by the beneficiaries of undergrounding.

The proportion to be funded by local government rates could be shared to some extent with the state if the potential to avoid outlays on State Emergency Services activity associated with fires caused by overhead electrical incidents, or storm damage worsened by the collapse of overhead lines, is realised.

The amount funded by local government rates and the state should reflect incremental costs — that is, the full costs of undergrounding the existing networks less the costs associated with replacing the existing overhead network at the end of its economic life. The Tribunal has not quantified replacement costs, as in practice, the overhead network if properly maintained, may never require replacing. However, underground systems are more likely to have a finite life. Prior to finalising funding levels further work will be required to estimate what value (if any) should be assigned to DNSPs to cover any net replacement costs.

While these proportions provide a rough guide for the urban areas *taken as a whole*, two local communities with similar undergrounding costs may value the unquantifiable benefits of undergrounding very differently. Similarly, there may be specific areas where the benefits are closer to the costs. Such differences create problems for an approach to funding under which, in each local government area, the local community is called upon to fund the same dominant proportion of the costs.

It is likely that there is a substantial gap between the value of quantified benefits that accrue on a state-wide basis, or to DNSPs and electricity consumers, and the average cost of undergrounding. Given these circumstances, it will be important that each local community demonstrates a willingness to pay for the difference between the costs allocated to other stakeholders and the total cost. Communities that place a relatively low value on the local benefits of undergrounding should be given the choice of opting out.

The option to opt out was opposed by many at the public forum on undergrounding and in a number of submissions. However, in the absence of willingness to pay data, the Tribunal believes that communities should be able to choose to opt out.

Affordability may be one factor affecting people's willingness to pay for undergrounding. Given the substantial resource cost of undergrounding, and the relatively low level of quantifiable state-wide benefits, affordability especially for lower income families and pensioners is an issue. While opt out is the recommended option, it may be impractical and inequitable for individuals to opt out. Therefore, additional measures such as flexible financing options and targeted assistance on a needs basis should be considered.

1 INTRODUCTION

Overhead electricity cables have become a concern for many members of the NSW community. Some people feel they are unsightly and detract from views or limit streetscape business opportunities. Others are concerned about the potential for overhead cables to be the cause or conduit of damage to property, infrastructure, and even lives, in the event of severe storms or bushfires. They are also concerned about the inconvenience and costs of power outages resulting from storm damage to both the utilities that distribute electricity and the business and residential customers who rely on power supply. In response to these concerns, the NSW government is currently exploring the possibility of undergrounding electricity distribution cables.

1.1 Purpose of this report

To help assess the feasibility of the proposed program, the Minister for Energy has asked the Independent Pricing and Regulatory Tribunal (the Tribunal) to review the costs, benefits and funding of undergrounding.[7] In particular, it was asked to assess:

- the range of possible and expected quantifiable and non-quantifiable benefits from undergrounding, consistent with the proposal
- the costs of undergrounding electricity cables, consistent with the proposal to underground communities of sufficient size
- the likely distribution and timing of benefits to those who would benefit directly and those which accrue to the wider community
- options for funding undergrounding projects
- the impact on customers, including differential impacts across customer groups
- the feasibility of undergrounding electricity cables with communication cables.

The Tribunal has considered submissions made to it (see Appendix 2 for a list of submissions) and information from a number of sources (see Appendix 3 for a detailed list). The Tribunal published its interim report on 8 April 2002. The Tribunal held a public forum on 19 April and received further submissions on its Interim Report.

Overall, the Tribunal found that general, widespread undergrounding is only justified by cost-benefit analysis if the value of hard to quantify benefits such as improved amenity and environmental management is very high. If the program goes ahead, the Tribunal recommends that it be funded through a beneficiary pays approach, in which the majority of the costs are recovered from property owners through local government charges, and the remainder from the state government and DNSPs. The Tribunal also recommends that local communities that place a relatively low value on amenity benefits such as views and other local benefits be able to opt out of the program.

[7] See Appendix 1 for Terms of Reference.

This report discusses the Tribunal's findings and recommendations:

- Chapter 2 examines the costs of the proposed program, drawing on the work undertaken by Meritec, commissioned by the Tribunal.
- Chapter 3 identifies the quantifiable and non-quantifiable benefits of the proposed program.
- Chapter 4 discusses the funding options, focusing on the efficiency and equity of recovering costs in different ways. It also addresses from where funds are to be sourced, and in what proportion relative to the benefits that might accrue to different stakeholders.

1.2 Scope of the proposed undergrounding program

The scope of program being considered is much broader than any other undergrounding effort in NSW to date, and includes:

- All *urban centres* across NSW with a population of 30,000 or greater (see Table 1.1).[8] This accounts for 71 per cent of the NSW population.
- The undergrounding of wires with a voltage of 22kV and under (that is, excluding sub-transmission lines, cables and towers with a higher voltage).
- A proposed roll-out period of 40 years from the date of commencement.

Table 1.1 Urban centres being considered for undergrounding

Urban centre in the project area	Population	% of total NSW
Sydney	3,276,207	54.3
Newcastle	270,324	4.5
Central Coast	227,657	3.8
Wollongong	219,761	3.6
Maitland	50,108	0.8
Wagga Wagga	42,848	0.7
Albury-Wodonga (Albury Part)	41,491	0.7
Gold Coast -Tweed Heads (Tweed Heads Part)	37,775	0.6
Port Macquarie	33,709	0.6
Tamworth	31,865	0.5
Orange	30,705	0.5
Dubbo	30,102	0.5
Total project area	*4,292,552*	*71.1*
Total for NSW	*6,038,696*	*100.0*

Source: 1996 Census, Urban Centres and Localities.

[8] The Terms of Reference for this review do not define an urban centre. The Tribunal has chosen to define an urban centre as one with a population of at least 30,000 as this is consistent with the definition that the Department of Communications Information Technology and the Arts (DCITA) used in its study, *Putting Cables Underground*, 1998.

1.3 Current status of undergrounding in NSW

Distribution network service providers (DNSPs) have undergrounded a large part of the distribution network. (Table 1.2 shows the proportion of both low voltage and high voltage cables that are currently underground.) These programs are usually initiated by the utilities themselves, or by third parties such as local councils and developers.

Local councils generally require DNSPs to underground low and high voltage distribution lines in new urban developments.[9] In these cases, developers of the urban area install the underground cabling. On completion, ownership of these assets passes to the DNSP.

In established areas where overhead construction already exists, the DNSP or other parties such as local councils may initiate an undergrounding project. Where it initiates the undergrounding project, EnergyAustralia states:

> We initiate undergrounding schemes in areas where supply reliability is below an acceptable standard, for example the Northern Beaches programs over the last 10 years. In these cases we underground the high voltage cables (11,000 volts and higher) as this work provides reliability improvements for many thousands of customers over a large area. Undergrounding low voltage cables only provides supply reliability improvements for customers in the immediate vicinity.[10]

In those cases where a third party initiates the project the DNSP may either share the costs or require the third party to pay. For example, Country Energy states that, in looking at cost sharing schemes with local councils, Country Energy considers the benefits related to reliability, reduced maintenance costs, aesthetics, replacement of inadequate sized or aged conductors.[11]

Table 1.2 Percentage of cables underground in NSW

	Whole of NSW		Urban centres	
	LV mains underground	HV mains underground	LV mains underground	HV mains underground
EnergyAustralia	23	36	25	63
Integral Energy	39	17	39	24
Country Energy	8	1	14	17
Australian Inland Energy	2	<1	-	-

Source: Meritec (2002).
Note:
LV – Low Voltage
HV – High Voltage

9 Country Energy response to stocktake questionnaire, February 2002, p 3.
10 EnergyAustralia response to stocktake questionnaire, February 2002, p 2.
11 Country Energy response to stocktake questionnaire, February 2002, p 12.

2 COSTS

Undergrounding parts of the electricity distribution system is a costly and complex task. This is part of the network that transports electricity from the generator to the consumer. In general, it consists of:

- sub-transmission lines, which deliver high voltage energy (33kV to 132kV) from the transmission system to bulk distribution points
- bulk distribution points, which convert the energy to a lower voltage for local distribution (6.6kV to 22kV)
- primary circuits or 'feeders', which supply power to a well defined geographic area
- local area distribution substations, which convert the energy to low voltage
- low voltage distribution lines, which carry the energy along the street
- customer lead-ins, which deliver the energy from the low voltage distribution lines to the customer’s meter and service entrance.

The part of the electricity distribution network included in the undergrounding program under consideration in NSW is shown in Figure 2.1.

To assist in assessing the likely costs of this program, the Tribunal commissioned Meritec to estimate the likely level of capital expenditure required to implement the program and the possible timing of this expenditure, and to report on other issues associated with the program. Meritec presented its cost estimates in terms of annual expenditures, not as a total program cost, because it believes a total cost to be misleading. It pointed out that ‘such programs are seldom implemented in full because of declining economies, the length of time required and the intervention of other factors’.[12]

However, to enable the costs of the proposed undergrounding program to be compared with the estimated benefits of the program, the Tribunal has aggregated Meritec’s cost estimates for each year of the proposed project. In its Interim Report, the Tribunal reported the cost range for the project in present value terms. It did so for purposes of comparison with the quantifiable benefits, also reported in present values. This approach has the advantage, in project analysis of this kind, of bringing future outlays and derived benefit values back to a single number for comparative purposes. Based on Meritec’s findings, the Tribunal estimates that the total costs of the proposed project are likely to be around $1.4-$2.4 billion over 40 years in *net present value terms.*[13]

The total indicative cost of the program in real terms, (2002 dollars) is $3.6–$5.9 billion. Estimates of total capital costs in real terms are consistent with the way that State Owned Corporations and government report the total cost of major long-term public infrastructure projects.

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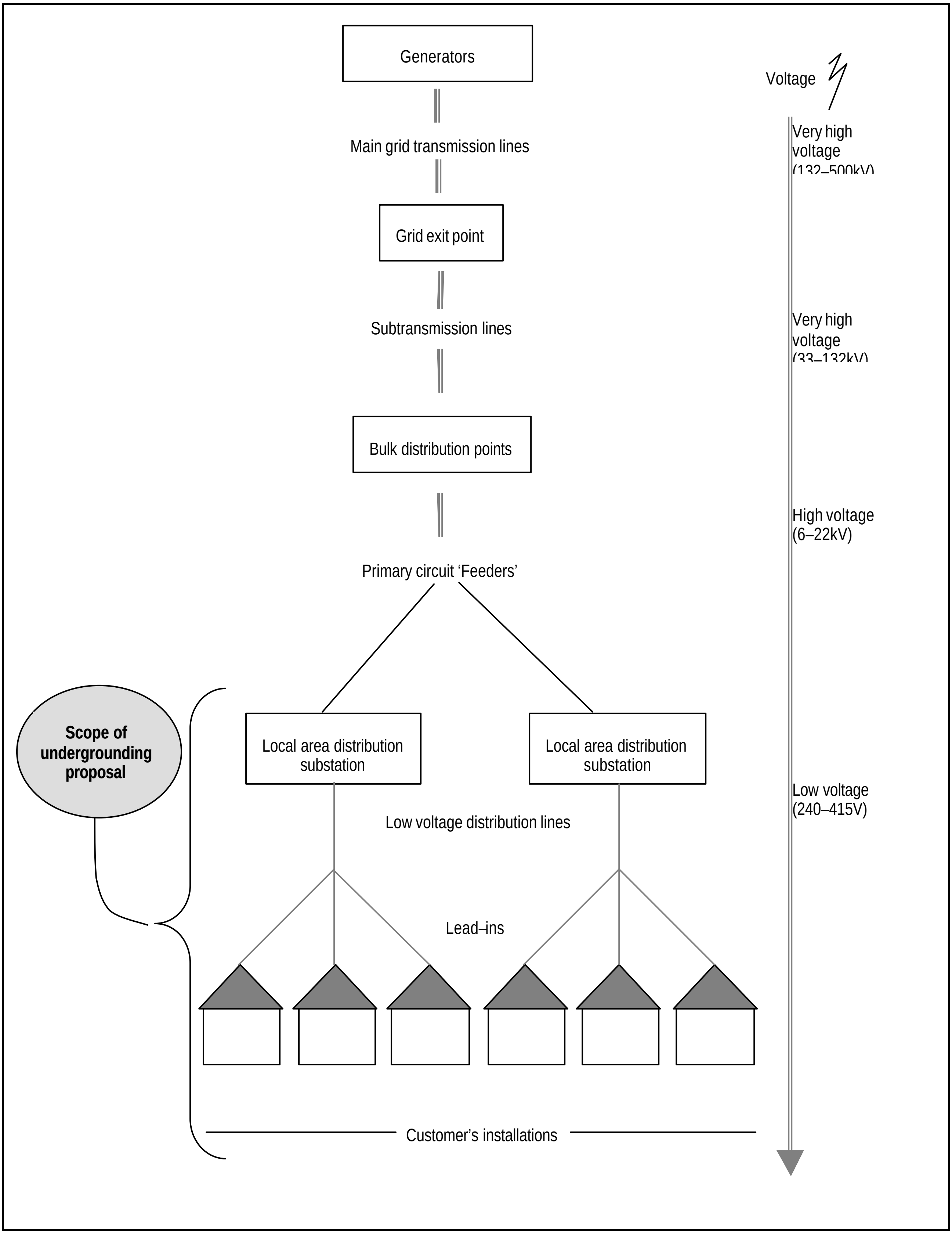
12 Meritec Report, 2002, p 22.

13 The key objective of any investment analysis (of which net present value is a type) is to bring all elements of a business proposal to a common base by discounting all costs and income to a particular point in time. The standard approach to discounting reduces a time stream of costs and income to an equivalent amount of today's dollars. That single amount is known as the present value of the future stream of costs and income. Present value is calculated using the method of compound interest. The rate at which the present value is computed is known as the discount rate. For this review the Tribunal has used a discount rate of 7 per cent real (ie after adjusting for inflation).

These estimates are lower than those indicated in the Interim Report. Following the release of the Tribunal's Interim Report, Meritec reduced its estimate of the total indicative project cost and annual expenditures. The reason for the reduction was the recognition of areas already undergrounded, which were previously included in the total project area for undergrounding. The change has reduced the total area to be undergrounded but has not affected the estimated costs per customer, which are linked to Meritec's estimates of the costs per sq km, not to the total area to be undergrounded.

Figure 2.1 The power supply network



However, *net present values terms* does not represent the estimated project costs in total dollars, which are equivalent to $2,300-$3,800 per customer (in 2002 dollars).[14]

This includes the cost of undergrounding the connection from customer residences to connections points on the network. The lower end of the range refers to the cost of undergrounding using an 'optimised approach', while the upper bound refers to a 'like-for-like approach'. These costs do not include costs of undergrounding communications cables. One estimate of these costs is around $2,000 per customer in real terms.

In its report, Meritec has emphasised the optimally designed approach. The Tribunal notes that this approach is untested and may be proved infeasible in the planning stages especially when environmental considerations are taken into account. However, given the cost and efficiency benefits that Meritec suggests, it provides a lower bound for the range of the costs of undergrounding.

Meritec has indicated that customer density is the primary driver of costs. The 1998 Working Group Report highlighted that costs possibly varied with terrain.[15] While Meritec has not highlighted terrain type as a major cost driver, inevitably terrain may result in different costs within project areas.

Meritec's cost analysis indicates that the investment required to implement the proposed program could be much lower than estimated by the 1998 DCITA report. However, it still represents a significant commitment of resources for the state and a considerable expenditure in the electricity industry for reasons unconnected with the delivery of electricity per se.

This chapter explains these cost estimates in detail, including the methodology Meritec used to develop its cost estimates, the key assumption on which estimates are based, the main cost drivers of the program, the unit costs per sq km and per low voltage customer, and the sensitivity of the estimates to upside risk. It also outlines an indicative program of expenditure and resulting annual costs for the program.

2.1 Meritec's methodology

Meritec's methodology for estimating the likely cost of the undergrounding proposal comprised the following steps:

- reviewing the alternatives for, and selecting a suitable conceptual design for the underground network
- defining a probable coverage in terms of square kilometres for the undergrounding program, taking into account the fact that customer densities, and the economics of undergrounding, fall off as the distance from the centre of urban areas increases
- using actual network data as a reference, extracted from drawings of a sample of a typical urban NSW network to derive:
  - customer densities
  - typical high voltage (HV) and low voltage (LV) mains lengths (at present) per square kilometre (per sq km) of area reticulated

[14] All cost estimates are exclusive of GST.
[15] DCITA, *Putting Cables Underground*, 1998, p 3.

  - the resulting length of LV mains
  - the distance between customers
- using the Meritec Underground Planning Model X-UGPLAN, calibrated for NSW conditions from the sample area data, to estimate the cost of a suitable replacement network
- comparing the quantities of HV and LV mains generated by the model with those in service in the present network
- calibrating the model to ensure that the sample data, and resulting quantities and costs generated by the model, are representative of urban NSW as a whole
- deriving a program for undergrounding in which existing, ageing, overhead mains are replaced when they reach the end of their life.

Meritec's cost estimates for undergrounding parts of the electricity network did not take into account the impact of also undergrounding communication cables.

2.2 Key assumption

One of the key factors that affects the cost of any undergrounding program is the approach taken to undergrounding. One approach, known as a like-for-like approach, is to replace all overhead mains with cables of a comparable or possibly greater capacity, essentially on the same routes, and retain the existing sub-transmission system. This approach would allow for some reconfiguration of the network but would not encompass substantial changes in its form. (This appears to have been the approach taken in the 1998 DCITA report.[16]) The alternative is an optimised approach, which involves reassessing the overall concept of the network and designing an optimised underground system to replace the overhead system.

Meritec reviewed both these alternatives as part of the first step of its methodology. It determined that, for large-scale projects such as the one under consideration, the optimised approach offers significant cost and efficiency benefits and so is more likely to be the approach adopted if the proposal were implemented. It therefore developed its cost estimates based on the assumption that an optimised approach would be used.

An optimised approach effectively takes advantage of the opportunity created by undergrounding to reassess the overall concept of the network, and rationalise the supply arrangements to introduce desirable features and reduce its installed length. (The 1998 DCITA report recognised the potential for savings from this type of approach, although it did not carry this through to its estimates.[17]) For example, an optimised approach enables network planners to:

- take into account current and future load patterns and the characteristics and cost structures of underground networks, to plan and design a replacement network with a high level of optimality
- take advantage of technological improvements in equipment and cables
- develop a program in which parts of the existing ageing overhead network are replaced with underground parts on expiry of their lives, enabling undergrounding to occur at the most efficient time.

16 DCITA, *Putting Cables Underground*, 1998, p 35.

An optimised approach would also involve extending the scope of the proposed program to include the undergrounding of sub-transmission assets of up to 132kV. This would enable the sub-transmission system to be restructured, minimise the need for expensive zone substation facilities and sites and increase the reliability of supply. Meritec's estimates indicate that despite this increased scope, the costs of the proposed program using an optimised approach are around 40 per cent lower than the costs using a like-for-like approach.[18]

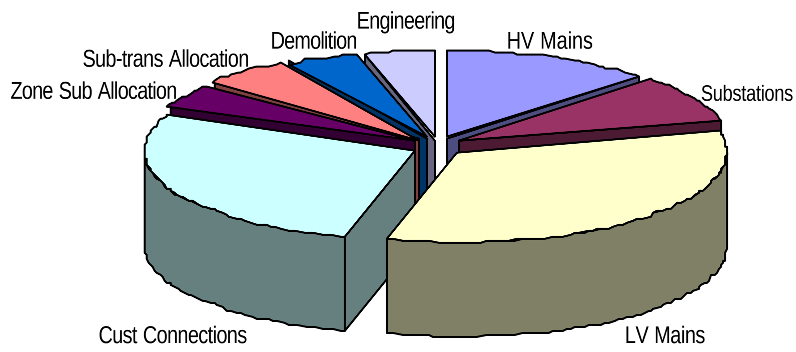
Meritec accepts that it is unlikely than an optimally planned network could be implemented in full. It also acknowledges that no definitive statement can be made about the most appropriate design to adopt for a new underground network without first having made detailed investigations and prepared preliminary designs. Nor has consideration been given to the fact that an optimised electricity network may not be equivalent to an optimised communication carrier network. Therefore, as Meritec points out, the cost estimates it has provided should be considered as indicative only.

2.3 Key cost drivers

The most significant driver of the cost of the proposed undergrounding program is the average distance between customers. This factor determines the length of LV mains and customer connections. The second most significant driver is the length of HV mains, which is determined by the load density and the optimality of the network layout.

Together, these cost drivers account for between 30 per cent and 50 per cent of the total estimated network undergrounding costs. Figure 2.2 shows the breakdown of the estimated cost of a completed, optimally planned, underground network for the project area.

Figure 2.2 Breakdown of the cost of an optimally planned underground network



Source: Meritec 2002, p 16.

17 DCITA, *Putting Cables Underground*, 1998, p 44.
18 Meritec 2002, p 19.

2.4 Unit costs

Meritec estimates that the average cost of the proposed program per sq km undergrounded is $5.9 million. However, as Table 2.1 shows, these unit costs will vary significantly, depending on the customer and load densities of the area to be undergrounded.

Table 2.1 Indicative unit costs for an optimal undergrounding program

Customer density	per square kilometre $m
Lower density: around 1,000 customers per sq km	4.2
High density: around 2,000 customers per sq km	5.2
Higher density: around 3,300 customers per sq km	8.3
Average cost over project area	5.9

Source: Meritec 2002, p 18.
* Note: These estimates cannot be directly compared with estimates from the 1998 Working Group study. This study excluded the cost of the sub-transmission system development, may have been based on present customer load densities not prospective densities, and included communications costs.

These estimates include customer connections, new distribution transformers and substations, HV and LV mains, an apportioned share of the cost of a replacement transmission system (including land and compact substation costs) and the net costs of demolition and engineering. However, they do not include meters, street lighting poles or lanterns or costs related to communications or other utilities (see section 2.5, below).

In addition, the estimate for the lower load density areas is based on the assumption that it will not be practical or economical to underground sparsely populated areas that are not reticulated, and that these areas will be excluded from the proposed undergrounding program.

These unit costs can be used to estimate the undergrounding costs in particular urban areas—core urban, intermediate and fringe—but the appropriate unit rate needs to be used, in line with the *initial* customer and load density of the area (that is, the densities at the time the undergrounding takes place, not those that are expected at the end of the planning period). In addition, the resulting estimate will provide an indicative figure only—to produce a more accurate estimate, an engineering assessment of the factors that will affect the costs of undergrounding will need to be undertaken.

Some of these factors and their impact on costs are discussed in Box 2.1.

Box 2.1 Factors influencing indicative costs of undergrounding in particular areas

The cost of undergrounding across commercial and residential areas of different types will vary, depending on customer and load densities and a range of other factors within the areas concerned. The cost figures in section 2.4 provide a weighted average cost of undergrounding across all regions within the project area. It is not possible to generalise about the specific costs across a particular area without undertaking an engineering assessment of the factors in that area. However, the following points identify some of the factors which affect the way in which the weighted average cost varies across particular areas.

Main Roads

The cost per sq km of undergrounding along main roads as an isolated action will be higher than the average weighted undergrounding cost. While undergrounding along main roads beautifies main thoroughfares and has a positive effect on the appearance of a city, from a technical and economic viewpoint, undergrounding only along main roads is not recommended for several reasons:

- It forces the use of a 'like-for-like' approach which, as already discussed, reduces the overall economy of undergrounding and has other significant disadvantages. For example, it requires the retention of HV mains cables on main roads, which should be avoided as far as possible in the best underground designs.
- It leads to extra costs at the junction of all side streets where the circuits have connections to overhead systems.
- It cuts across the natural design of underground HV networks since they should be built in loops, not in the radial patterns that typify overhead systems.
- It tends to extend and distort zone substation service areas, which is likely to introduce further network distortions rather than removing them and thus reduce network reliability.

Central Business Districts (CBDs) and Regional Centres

The cost of undergrounding CBDs is likely to be at the highest end per sq km and at the lowest end per customer connection. CBDs and regional centres could be large or small in size, and are generally of an expanding nature. Undergrounding such areas should be treated as part of a program for the city or centre as a whole, not in isolation. An optimally planned approach should be adopted in dense load areas of this type to provide an economical network that can be reinforced and extended with the minimum of future disruption or disadvantage.

Shopping Centres

The cost of undergrounding in older shopping centres—generally on main roads—falls within the general case presented in the average cost estimates. Newer centres are likely to be already undergrounded.

Residential Areas

In most residential areas, the cost of undergrounding will fall within the general case presented in the average cost of undergrounding per sq km or per customer.

2.5 Indicative annual costs

Meritec developed an indicative program of expenditure and the resulting expected annual costs, using the weighted average cost of undergrounding per sq km. In doing so, it assumed that successive parts of the existing overhead network would be replaced on the expiry of their lives and that an optimised approach to undergrounding would be used. Table 2.2 below shows this indicative program of expenditures in constant (real) and current (nominal) dollars.

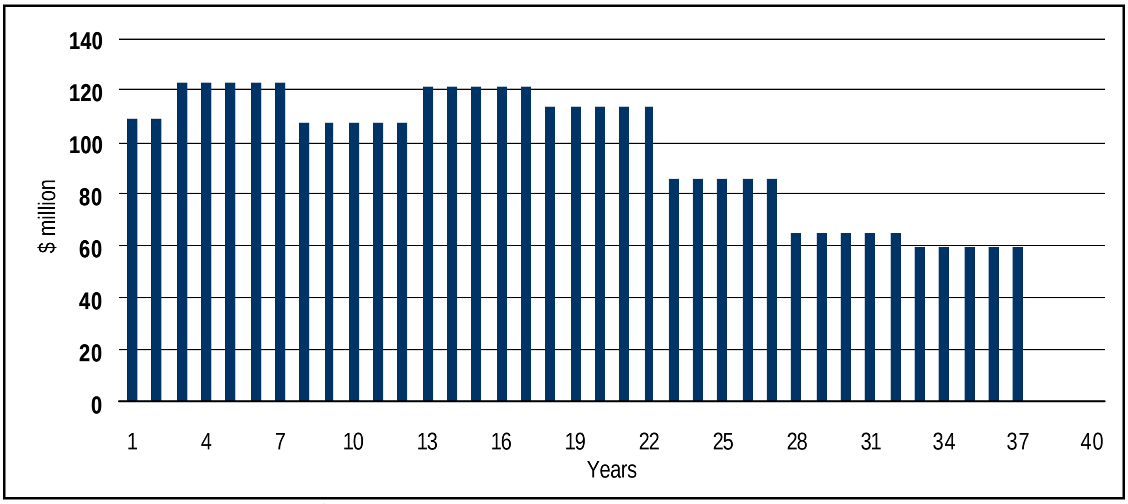
Table 2.2 Indicative program of expenditure for an optimally planned approach

Average per annum cost over a 5 year period	Indicative annual cost in nominal dollars $m	Indicative annual cost in real dollars $m	% cumulative completion of proposed program
2003 – 2007	126	117	14
2008 – 2012	138	113	30
2013 – 2017	160	116	47
2018 – 2022	181	116	63
2023 – 2027	170	97	77
2028 – 2032	146	73	88
2033 – 2037	139	62	97
2038 – 2040	59	60	100

Source: Meritec, 2002.

This program covers the *full* cost of undergrounding, not just the additional cost over that of a technically feasible least-cost overhead network. It includes indicative street lighting costs, but excludes all other costs associated with undergrounding or refurbishing the networks of other utilities. It also includes electricity network capacity augmentation, but excludes the ongoing cost of replacing existing underground cables at the end of their economic lives. These costs do not include communication cable undergrounding costs. Figure 2.3 below shows the capital expenditure component of this program. The replacement of successive parts of the overhead network on the expiry of their lives results in a staged rollout over almost 40 years, with most of the capital expenditure occurring in the first 20 years of the program.

Figure 2.3 Indicative capital expenditure



NB: Calculated in real terms ($2001/2).
Source: Meritec and CIE calculations.

Meritec's 'optimised' cost estimates are lower than those instanced in submissions to the review from utilities involved in smaller scale undergrounding projects. For instance:

- Energex submitted that its Inala pilot program cost $5,480 per household (for a project involving 500 households), and estimates that large-scale projects could be undertaken for around $4,440 per household, with costs for some regions as low as $3,630.[19]
- Country Energy submitted that, for regional centres, the cost of undergrounding is $5,120 per customer, allowing for Country Energy's quantifiable cost savings.[20]
- The Local Government and Shire Associations of NSW quotes an Australian Local Government Association estimate of a cost per property of undergrounding closer to $3,000.[21]
- The Western Australian Office of Energy reports that the average cost per lot for Perth for undergrounding is $4,500. This is above the average cost associated with the pilot study in Perth, where the average costs were closer to $3,700 per connection.[22]

One reason for the difference in cost estimates is scale. The above projects are on a much smaller scale than the program being proposed. Meritec's 'optimally planned network' estimates also assume there are avenues for cost savings and increasing overall network efficiency over a like-for-like approach.

2.5.1 Costs of replacing street lighting

When the low voltage distribution lines and feeders are placed underground, the street lighting system will have to be replaced. The estimated annual costs outlined previously include estimates of costs related to replacing street lighting poles and lanterns[23]. Without differentiating between the lighting needs of different roadways, an indicative cost for street lighting can be obtained by assuming one lantern each 50 metres of roadway at a cost per installation of $1,500. The resulting costs[24] per sq km of urban area would then be as follows:

- Core areas (where customer and load density is around 3,300 customers per sq km): $480,000 per sq km (assuming 16 kilometre of roadway per sq km).
- Intermediate area (where customer and load density is around 2,000 customers per sq km) $360,000 per sq km (assuming 12 kilometre of roadway per sq km).
- Fringe areas (where customer and load density are around 1,000 customers per sq km): Same rate as intermediate areas but applied over a reduced area.

19 Energex submission, 4 February 2002, p 5.
20 Country Energy submission, 5 February 2002, p 1.
21 LGSA of NSW submission, 11 February 2002, p 6.
22 WA Office of Energy, letter to the NSW Ministry of Energy and Utilities, 1 May 2002
23 The average costs cited per sq km in Table 2.1 do not include street lighting costs.
24 Costs are in real terms ($2001/02).

2.6 Costs are indicative only within a wide tolerance

These indicative total costs are accurate *only* within a wide tolerance, because:

- a widespread program of the type proposed will generate a new set of costs
- the way in which the work is programmed and contracted, and the contract incentives offered, will have a significant impact on the costs
- the rate of successful recovery and re-use of overhead equipment will depend on the contract incentives offered
- the recent rationalisation of the cable manufacturing industry may affect cable costs
- central business districts may have special costs
- significant uncertainty will remain in respect of all unit costs until they are confirmed by bidding and contract award
- the principal uncertainly in the cost estimates arises from the variability of equipment unit costs, not the estimates of quantities.

It is not possible to estimate the confidence interval without carrying out further work.

2.7 Cost estimates are lower bound estimates

The undergrounding costs derived by Meritec are also lower bound estimates for a number of important reasons. The cost estimates *exclude* several categories of costs associated with undergrounding including:

- potential for the early retirement of overhead assets and other implementation costs in addition to those considered
- additional vegetation management costs
- intangible costs likely to be borne by the community
- costs borne by communication providers for undergrounding their own infrastructure
- costs associated with redesigning street lighting systems rather than just replacing street lights.

2.7.1 Early asset retirement

The optimised cost estimates allow for the replacement of existing distribution assets as they reach the end of their serviceable life. However, there are several factors which give rise to the potential for existing overhead assets to be retired early (prior to the expiry of their economic life). Writing off such assets increases the cost of undergrounding.

EnergyAustralia submitted that there is a wide variation of equipment ages within a given area. Therefore carrying out an undergrounding program over an extensive area will result in the premature retirement of much of the equipment within the selected area, adding substantially to the real cost of the program.[25] This was supported by Integral Energy who referred to non-homogeneous assets in a given area, resulting in premature asset

25 EnergyAustralia submission, 30 April 2002, p 6.

replacement requiring significant write-off of assets — costs which should be factored into the overall costs of the undergrounding program.[26]

The same cost issues arise for street lighting infrastructure. As was submitted to the review, there is also the cost of decommissioning existing lighting infrastructure prior to expiry of its economic life, claimed to 'waste tens of millions of dollars of assets, with replacement street light standard costs running into several hundred million dollars'.[27] Early write-off of existing lighting infrastructure is not included in the unit cost estimates for undergrounding. SHOROC submitted that all street lighting installed prior to the introduction of the Australian Standard for Street Lighting generally did not meet its requirements. New lighting installations are said to require excavations to make connection to the network and to install a pole for the light. The cost of this is approximately $8,000 up front capital cost to the council per light, plus an additional annual tariff of approximately $90.[28]

2.7.2 Other implementation costs

Additional implementation costs raised in submissions to the review include:

- the costs of potential site rejection as a result of the process of community consultation for the increased number of smaller zone substations which would be required,[29] and the difficulty in acquiring easements for LV cables and substations given perceived concerns in the community[30]
- the possibility that single transformer zone substations may result in an increased risk of failure, which reduces reliability and may require back up supply from adjacent substations via distribution feeders, which would switch capability and cost[31]
- potential co-location problems, due to the complex location of other existing underground utility services, highlighted by Dial Before You Dig.[32]

The NSW Dial Before You Dig Service submitted that the only way to avoid damage to pre-existing pipes and cables when trenching or boring is to follow a series of steps, which are time consuming and ultimately expensive. These include determining existing cable location and orientation, soft digging to positively identify the depth and location of all networks potentially under threat, and strapping or suspending existing networks to avoid damage.[33]

There are also higher maintenance costs for underground systems. These include:

- longer lead times
- higher augmentation costs
- longer repair times
- high replacement costs, given the finite life of underground assets
- the need for critical load monitoring

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26 Integral Energy submission, 26 April 2002, p 3.
27 Mr W RWilliams submission, 14 April 2002, p 4.
28 SHOROC submission, 29 April 2002, p 1.
29 EnergyAustralia submission, 30 April 2002, p 8.
30 Integral Energy submission, 26 April 2002, p 2.
31 Integral Energy submission, 26 April 2002, p 2.
32 LGSA of NSW submission, 23 April 2002, p 5.
33 NSW Dial Before You Dig Service submission, 24 April 2002, p 2.

- back-up design considerations.[34]

Full optimisation will also be constrained by the existence of areas already undergrounded on a like-for-like basis.

For these kinds of reasons, Country Energy submitted that the cost of 'like-for-like' replacement of the network is a 'more practical approach' to assessing the cost of the program.[35]

2.7.3 Vegetation management costs

While improved vegetation management and the opportunity to beautify public areas represents a benefit of undergrounding, there are additional financial costs of achieving these outcomes. As noted by the Local Government and Shires Association of NSW, landscaping, tree planting schemes, replacement of public amenities such as drinking bubblers, bus shelters, and conveniences require design, capital expenditure and long term maintenance — costs which are indirectly part of the undergrounding program.[36]

2.7.4 Costs borne by the community

There are likely to be intangible costs associated with undergrounding that will be borne by households and businesses. One example is the temporary costs of disruption to electricity services. Such costs may be captured in estimates of peoples' willingness to pay for undergrounding, which would factor in the temporary costs of disruption. Another example is costs related to a period of overlap, where both the overhead and underground systems may be paid for simultaneously.

A third example, raised by the Public Interest and Advocacy Centre in its submission, is the scope for services which are co-located with underground electricity to be disrupted when underground electricity services experience faults:

> Where several providers share an underground conduit the likelihood of disruption to services aside from electricity would be increased…Such disruptions will impose costs on households and businesses in addition to any contribution to the capital funding for an undergrounding project.[37]

The Tribunal notes that whether above or under ground, the scope for disruptions to electricity services still exists, albeit more frequently with overhead systems.

34 Mr W R Williams submission, 14 April 2002, p 2.
35 Country Energy submission, 26 April 2002, p 3.
36 LGSA of NSW submission, 23 April 2002, p 4.
37 PIAC submission, 7 February 2002, p 4.

2.7.5 Avoided replacement costs

Meritec have assumed that the cost of replacing the present overhead network at the end of its life with another overhead network is the principal avoided cost of undergrounding. It states that this could be around one half of the cost of building an optimally planned underground replacement network.[38]

However, these costs are only avoided if overhead networks have a finite life and would otherwise need replacing if they were not undergrounded. As was submitted to the review, in reality, overhead construction properly maintained in accordance with Overhead Line Construction Regulations, has an infinite life. The very nature of overhead construction requires an ongoing unit replacement approach to keep the construction in sound condition, which is what makes the maintenance costs of overhead systems relatively greater than underground systems. This is as opposed to underground systems, which do have a finite life of 50 years or less, and require total asset replacement from time to time.[39]

In practice, it is likely that there will be some avoided replacement of overhead networks, as well as some replacement of underground networks over the course of the proposed undergrounding program. While the replacement cost of underground systems is greater than that of overhead systems, it is not possible to estimate at this early state what the *net* effect of asset replacement will be on the cost of the program.

The Tribunal has not quantified replacement costs. Prior to finalising funding levels, further work will be required to estimate what value (if any) should be assigned to DNSPs to cover any net replacement costs.

2.7.6 Costs borne by communications providers

Communications carriers have been identified as potential beneficiaries of undergrounding and also as the bearers of significant costs. Under clause 51(1) of Schedule 3 of the *Communications Act 1997*, they are required to remove their overhead cables no more than six months after the final power cable in an area is removed (although the Act does not specify who should bear the cost of this).

The undergrounding costs of a particular communications provider will vary, depending on how much of its network needs to be undergrounded, the costs attributable to undergrounding, and the possibility of sharing those costs with other utilities. However shared, both Optus and Telstra are likely to face significant costs.

In its submission to the Tribunal, Optus estimated its total costs as being around $2,000 per household, or $90 per underground metre in real terms. Around 10 per cent of these costs relates to removing its overhead network, while around 90 per cent relates to building the underground network.[40] Given that Telstra and Optus have separate networks, the cost per household of undergrounding communications cables will be even greater in some areas when it includes *both* the Telstra and Optus networks.

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38 Meritec 2002, p 26.

39 Mr W R Williams submission, 14 April 2002, p 2.

40 Optus submission, 12 February 2002, p 19.

A pilot study carried out by Energex indicates that the estimated cost per household of undergrounding broadband cables in Brisbane is around $1,200.[41]

Telstra have noted that it is also important to consider that opportunities for cost savings may exist where there is a coordinated approach to undergrounding electricity and carrier cables, such as centralised project management and trenching costs.[42] Undergrounding costs are said to only be minimised when utilities consult and cooperate in infrastructure undergrounding programs. If communications carriers are treated separately, this reduction of cost will be at risk, cause inefficient undergrounding, and lead to other adverse impacts such as an increase in public inconvenience.[43]

An important impact on the undergrounding costs of communications cables is the approach taken to electricity undergrounding. For instance, the cost of an optimised undergrounding system for electricity cables does not take into consideration an optimised carrier network. Telstra note that some of the reduction in cost from an optimised electricity network may result in higher costs for the carrier network, such as through more trenching and cable plant in order to meet carrier performance requirements and limits.[44] This was supported by Optus who note that efficiencies gained from an optimised electricity network may result in greater costs from additional trenching because telecommunications networks follow different paths to optimised electricity networks.[45]

Certainly some of the communication undergrounding costs could probably be shared between communications providers and DNSPs, and adding communication costs to the estimates for undergrounding electricity is likely to result in double counting to some degree.

Some of the costs to communications providers would be offset by the benefits they receive from undergrounding. These include avoided maintenance costs, and possibly improvements to the reliability of their service, although the carriers regard any reliability gains as marginal.

In terms of quantifying part of these benefits, Optus submitted that the current cost of maintaining its overhead network in NSW is approx $5 million per annum. The key components of this cost are rental of overhead poles ($4.25 million), and repair costs and associated labour costs ($0.9 million).[46] Optus has estimated that the total cost of undergrounding their infrastructure in *net present value terms* is $760 million, and states that carrying this cost alone would make the continued operation of its Hybrid Fibre-Optic Cable (HFC) unviable.[47]

41 Ministry of Energy and Utilities, Research Report, *Undergrounding Electricity Cables*, 10 January 2002, p 21.
42 Telstra submission, 26 April 2002, p 4.
43 Telstra submission, 26 April 2002, p 2.
44 Telstra submission, 26 April 2002, p 2.
45 Optus submission, 19 April 2002, p 1.
46 Optus submission, 12 February 2002, p 19.
47 Optus submission, 12 February 2002, p 2.

2.8 Competition impacts

Because undergrounding will result in significant costs and benefits to various businesses, the Tribunal has considered its likely effect on the degree of competition in the markets in which these businesses operate, particularly the electricity and communications markets. The likely impact of undergrounding on how level the 'playing field' is, and the desirability or feasibility of adopting measures to reduce this impact, would need to be considered by government in any final decision to implement the proposed undergrounding program.

The Allen Consulting Group in its report to the Working Group, *Putting Cables Underground*, found that any decision to underground electricity and communications cables may cause distortions in both electricity and communications markets, as well as imposing costs on users of those services. Increases in electricity charges to fund undergrounding could have adverse downstream effects, for example on industrial users of electricity.[48] One of the objections to the use of electricity tariffs as the principal funding instrument is the distorting effect this could have on electricity use. Any substantial price increase could influence competition between electricity, gas and other energy forms, and could affect the competitive ability of electricity intensive industries.

2.8.1 Likely impact of undergrounding on competition in the communications industry

Undergrounding could affect competition in the communications sector for several reasons, including the different costs of undergrounding to different carriers; the possible creation of barriers to entry; and the differential impact of different funding options. Adopting a strict 'beneficiary pays' approach, whereby communications carriers contribute to the costs of undergrounding in proportion to their avoided maintenance costs, may have a limited impact on competition. If communications carriers are expected to fund the relocation of their cables, and pass those costs on to consumers through higher prices or bear the cost themselves by accepting reduced profits, there is likely to be an impact on competition.[49]

Entry barriers and underground access

As the historical incumbent, Telstra has had an advantage in providing broadband services in many areas, as it was able to leverage off its existing fixed local network. In contrast, Optus has had to make substantial investments in infrastructure. According to the Productivity Commission, Telstra's past domination of the market could provide it with residual market power that it could use to deter efficient entry.[50] As noted by the ACCC in its submission to the *Communications Competition Regulation* report, 'economies of scale and density, together with the sunk nature of the customer access infrastructure, constitute significant barriers to entry in the customer access market'.[51]

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48 Economic Sub-Committee 1998, p 25.

49 Recent developments in the pay-TV market and any implications they might have for competition are currently being considered by the ACCC.

50 Productivity Commission 2001, *Telecommunications Competition Regulation*, Report Number 16, p 37.

51 Productivity Commission 2001, *Telecommunications Competition Regulation*, Report Number 16, p 109.

Undergrounding may affect competition in the communications sector. If one carrier's costs of undergrounding its broadband cable services is too burdensome, it could exit the broadband market with a substantial reduction in competition, including any flow on effects of this to other interconnected communications services markets (eg, telephony, mobile phone services).

If a 'carrier pays' approach to undergrounding communications is adopted, the cost of undergrounding plus the additional cost of any council levies on communications infrastructure will ultimately be passed on to consumers in the form of higher prices for communications services, to the extent that the market will bear this. In the short term, however, there may be significant strategic advantage in absorbing any such cost if it leads ultimately to enhanced market share through the exit of a competitor. A balance should be borne in mind between achieving one community desire for an improved aesthetic environment and achieving another community desire of maximising consumer welfare through competitive prices for communications services.

3 BENEFITS

The benefits of undergrounding, which may accrue to the wider community, are those comprising of the external costs of overhead networks. These costs (or negative externalities) can be seen as a by-product of having power supplied by overhead electricity cables. They include, for example, actual or perceived impacts on the visual amenity of local environments, motor vehicle accidents that involve collisions with electricity poles, and the costs to consumers of power outages that result from storm damage to overhead cables. External costs are much less tangible than the avoided costs which accrue to DNSPs, and the value of avoiding many of them by placing overhead infrastructure underground cannot be quantified in any absolute sense.

The high capital cost and complexities of undergrounding, however, mean that it is important to quantify any benefits likely to result from the proposed program for NSW to the greatest extent possible, in order to assess the merits of the program. The Tribunal commissioned the Centre for International Economics (CIE) to assist it with this task. Based on CIE's assessment, the Tribunal estimates the value of the quantifiable benefits of the proposed program to range between around $535 and $625 million over 40 years in *net present value terms*, or $350-$400 per connection or lead in. This is equivalent to around 40 per cent of the estimated cost of the proposed undergrounding program, assuming an optimally planned approach is used.[52]

The quantified benefits include:

- reduced costs related to motor vehicle accidents that involve collisions with utility poles
- improved reliability of energy supply to customers
- avoided costs associated with maintaining the overhead network
- reduced losses in DNSP revenues associated with reduced outages as a result of damage to the overhead network, and reduced energy losses.

Additional, unquantifiable benefits include:

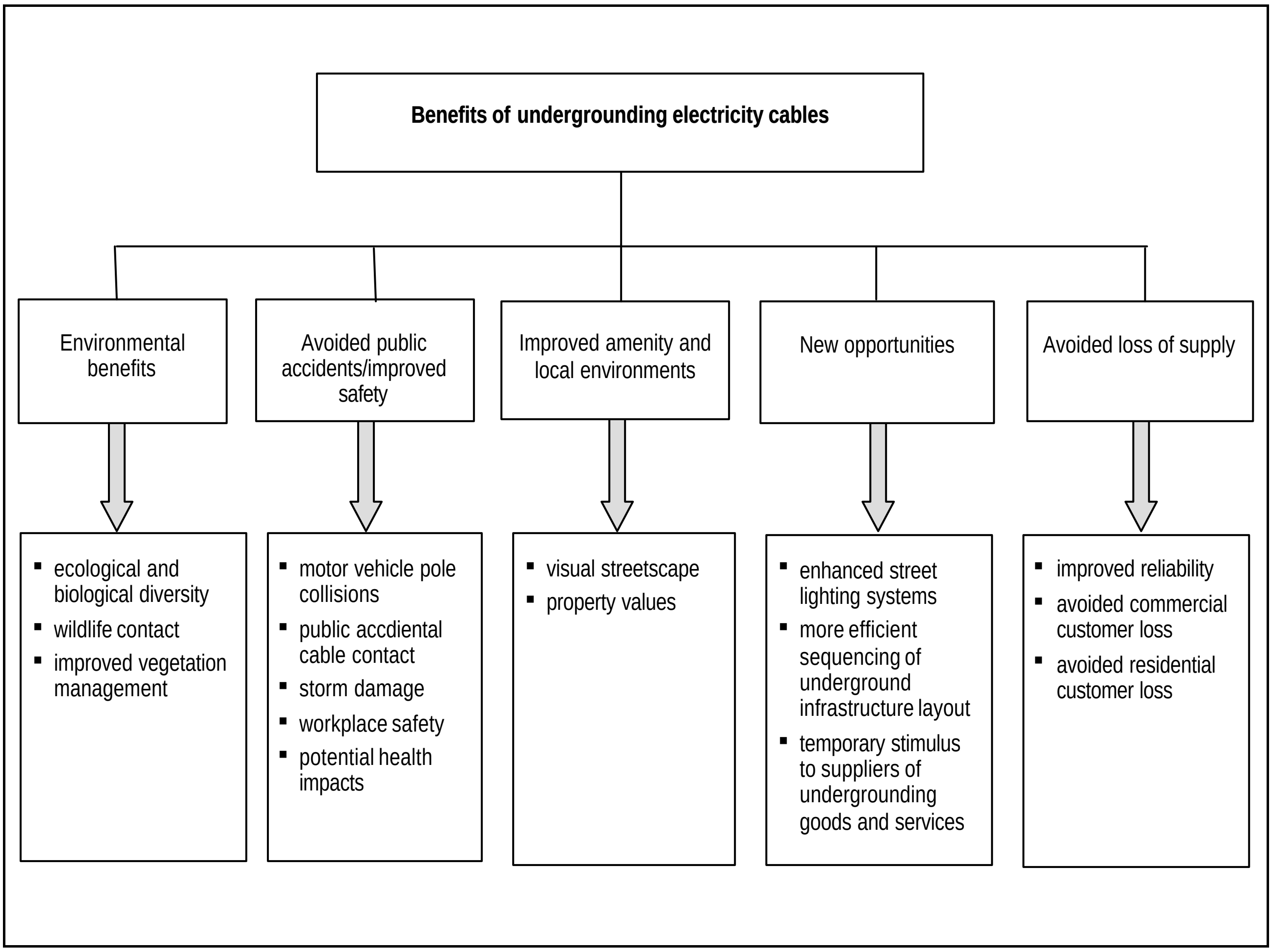
- improved public amenity associated with reducing the visual impact of network infrastructure by removing overhead power lines and replacing them with less obtrusive 'street furniture' placed outside residences and commercial operations
- improved vegetation management, particularly if undergrounding is accompanied by enhanced landscape design and management
- improved public and wildlife safety as a result of reduced scope for accidental contact with power lines (including instances where power lines are brought down by severe weather conditions)
- improvements in the safety of workplaces for tradespersons working for various utilities, as well as builders, emergency services workers, volunteers, and others who are potentially exposed to contact with overhead wires

[52] If like-for-like cost estimates are used, benefits will fall to or around 26-30 per cent of the costs.

- opportunities to increase efficiency of the network by optimising the layout of underground infrastructure (including but not limited to electricity conduits), and to redesign streetscapes and lighting systems
- potential reduction in the health risks associated with electromagnetic fields.

Quantifiable and unquantifiable benefits are discussed in more detail in sections 3.1 and 3.2. An overview of the estimated value of these benefits is provided in section 3.3. Detail of calculations and additional analysis may be found in Appendices 4 to 9.

Figure 3.1 Benefits of undergrounding electricity cables



Box 3.1 Placing a value on avoided external costs

Estimating the value of benefits related to reducing the externalities, or external costs, borne by individuals, local communities and the wider public is a complex task. In principle, these costs can be measured by estimating consumers' willingness to pay for undergrounding. However, this willingness to pay will vary between individuals, between communities, and between jurisdictions. For instance, the willingness to pay for undergrounding in NSW may be different to that in Queensland, where the risk of severe weather and storms creating power outages is greater.

To estimate the willingness of NSW residents to pay for undergrounding involves consideration of a range of quality attributes associated with electricity supply that may affect people's willingness to pay. These issues include the frequency and duration of outages, voltage quality, safety, time taken to connect to electricity supply, fault rectification service, and customer service attributes.

In addition, there are significant bias risks associated with estimating willingness to pay for undergrounding, which has the characteristics of a public good—that is, the consumption of an improved outlook by one person does not diminish its consumption by another. This leaves scope for people to 'free ride' on any payments by others to underground cables, reducing the amount they declare they are willing to pay for something they might in fact want.

NSW Treasury has commissioned a wider study to estimate NSW residents' willingness to pay for quality in relation to electricity supply, one attribute of which is likely to be undergrounding.

3.1 Quantifiable benefits

The Tribunal has quantified the value of four benefits associated with undergrounding: the avoided costs associated with motor vehicle accidents, improved reliability of energy supply to customers, avoided costs associated with maintaining the overhead network, and reduced revenues losses.

3.1.1 Avoided costs associated with motor vehicle accidents

The proposed undergrounding program has the potential to avoid costs associated with off-road motor vehicle accidents. In most cases it is not likely to reduce the number of off-road accidents, however, the removal of road-side poles currently housing overhead cabling is likely to reduce the severity of any accidents which do occur.[53] This represents an important social and economic benefit, particularly given there are no offsetting risks of vehicle accidents with underground cables.

The avoided costs due to a reduction in accidents that are serious or fatal are expected to save the NSW community approximately $48-$53 million each year, once implementation of the proposed program is complete. Although the full roll-out is expected to take close to 40 years, a steadily increasing proportion of these savings could be expected to accrue until that time. The CIE estimates the value of these avoided costs over the roll-out period to be between $230 and $260 million, in *net present value terms*. Avoided costs would be greater if more poles were removed more quickly, as the total annual benefits expected to be derived do not accrue in full until the program is complete. This reduces the value of the total benefits *in today's dollar terms.*

53 In its submission to the Tribunal, the Motorcycle Council of NSW noted that crash barriers on the roadside present a more serious danger to motorcyclists than power poles. As motorcycles are smaller than passenger cars, there is a greater chance that a motorcyclist will pass between power poles without collision (Motorcycle Council of NSW Incorporated, 2002, p 1).

Of course, the human costs associated with motor vehicle accidents go far beyond those that are capable of being quantified. A reduction in accidents would benefit the community in ways that are not accounted for in CIE's analysis, for instance by reducing emotional distress suffered by individuals involved in accidents, their family and their friends. SHOROC submitted that the cost in terms of post traumatic stress disorder (both in dollar terms for treatment and in reduced productivity) is a matter which needs particular consideration.[54]

3.1.2 Improved reliability of electricity supply

Undergrounding electricity cables has the potential to increase the reliability of electricity supply, therefore it can reduce costs related to the unreliability of supply. These costs include direct financial costs and inconvenience borne by customers when power outages occur. Submissions to the review emphasised the increasing importance of reliability as more and more people choose to work or study from home, utilising essential access to internet and other computer services.[55]

The Tribunal has estimated the value of improved reliability benefits to customers by calculating the costs of outages to customers, and the likely improvement in reliability due to undergrounding. Reliability is expected to improve by between 20 and 45 per cent, leading to cost savings over the project period of $55-$115 million in *net present value terms*, which will accrue to customers as a consequence of reliability improvements from undergrounding.

These estimates are derived from survey responses from non-residential customers who estimated the cost of a power outage occurring, without warning, at the worse possible time (time of day, day of the week and month). This approach is intended to capture the costs of food spoilage and other business losses.

Other aspects of improved reliability cannot be quantified, but have been raised by Sydney Cables Down Under to include:

- potentially preventing undesirable disruptions to lift services, particularly for the elderly and less mobile
- in extreme cases such as natural disasters, enhanced reliability of water supply and sanitation services.[56]

3.1.3 Avoided maintenance costs

Undergrounding parts of the distribution system can provide benefits to DNSPs by way of reduced operating and maintenance costs. As well as improving the reliability of supply, undergrounding can reduce costs related to repairing damage to the distribution system by external factors such as storms.

54 SHOROC submission, 29 April 2002, p 2.
55 Warringah Council submission, 26 April 2002, p 1.
56 Sydney Cables Down Under submission, 22 April 2002, p 3.

It can also reduce other types of maintenance costs, including vegetation management and preventive maintenance costs. In addition, as Manly Council points out, some avoided maintenance costs can also have additional environmental benefits.

> Another cost which could be avoided both in actual cost terms and environmental terms is the need to treat power poles (timber) with potent pesticides, so as to avoid insect attack. This is frequently done adjacent to kerbs, which in turn carry water to our stormwater disposal system, and is potentially harmful.[57]

The Tribunal estimates the broad value for avoided maintenance costs to be around $105 million (in *net present value terms* over the entire project period), including both fault and emergency maintenance costs.

Other utilities such as communications carriers are also likely to benefit from avoided maintenance costs. For example, in its submission, Optus stated that the current costs of maintaining its overhead network are $5 million per annum and that these costs would not be incurred if the network were to be undergrounded.[58] However, in the absence of sufficient data from all other utilities, the Tribunal has not estimated the avoided maintenance costs benefits likely to accrue to other utilities.

Local councils also incur costs for the backlog of tree lopping and removal. The Local Government and Shires Association of NSW estimates these costs to be up to twice as much as those estimated for utilities.[59] As stated by SHOROC:

> The cost of tree lopping to the Energy Authorities and to local councils over a period of 40 years must be enormous…This real cost is quite separate and distinct from the amenity cost associated with the mutilation of trees.[60]

The extent to which these costs would be *avoided* in the event of undergrounding depends on the additional vegetation management costs required to achieve the desired level of aesthetic improvement in streetscapes, which is made possible by undergrounding.

3.1.4 Reduction in lost revenue to DNSPs

DNSPs are expected to recoup revenue which is currently lost as:

- reliability improvements reduce outages to customers (and thereby increase revenue to utilities)
- energy losses are minimised.

With respect to the latter, as current passes through the conductors in electricity lines, they heat up due to the resistance of the conductor. This heating effect consumes energy, which cannot be delivered elsewhere and therefore constitutes a 'loss'. Meritec has advised the Tribunal that, in the proposed undergrounding program area, these energy losses are currently around 5.5 per cent of electrical energy supplied into the system, and that these losses will be reduced to 4 per cent after completion of the undergrounding project.[61]

57 Manly Council submission, 4 February 2002 p 3.
58 Optus submission, 12 February 2002, p 7.
59 LGSA of NSW submission, 23 April 2002, p 6.
60 SHOROC submission, 29 April 2002, p 4.
61 Meritec acknowledge that the calculations it used to estimate these losses are complex and cannot be done with any level of certainty.

Avoided energy losses could also result in reduced greenhouse gas emissions. However, these reductions would need to be offset against any increase in greenhouse gas emissions associated with the manufacture and installation of the underground network components. As these emissions cannot be estimated and the costs of emissions are not known, the impacts on greenhouse gas emissions from undergrounding have not been quantified.

Energy loss gains from underground conversion is said to be dependent on load densities in specific network segments, particularly in the design and spare capacity of networks. These make the order of accuracy in any calculation of energy gains low, and gains could be offset by the amortised cost components of larger conductors required for the same load in any given underground conversion.[62]

To estimate the value of energy losses which may be recouped in the event of undergrounding, peak load losses are assumed to be reduced from 5.5 per cent to 4 per cent. Meritec compared energy losses per unit area for underground and overhead systems to derive expected revenue savings for DNSPs in the event of undergrounding of $145 million in *net present value terms* over 40 years.[63] These gains are higher than those estimated in the Interim Report, which were based on analysis in the 1998 DCITA study.[64] Unlike the 1998 study, the reduced energy losses estimated by Meritec assumes an optimal design. This reduces the distance of power transfer through the network. Were an optimised approach not be used, reduced energy losses would be reduced considerably.

The potential recapture of some of this lost revenue may be displaced by the reduction in rental income which is currently obtained from communications carriers for the use of above ground poles.

3.2 Unquantifiable benefits

The Tribunal has identified five further potential benefits of undergrounding which, for a range of reasons, it has not been able to quantify. These include:

- improved public amenity related to reducing the visual impact of the overhead network
- improved public safety as a result of reduced scope for accidental contact with power lines and a potential reduction in health risks
- opportunities to increase network efficiency and redesign lighting and streetscapes that arise as a result of undergrounding
- improved environmental qualities.

62 Mr W R Williams submission, 14 April 2002, p 4.

63 This represents an upper bound estimate based on a fully optimised approach. However, as stated elsewhere in this report, full optimisation is unlikely to occur in practice due to various constraints, including areas already undergrounded on a like-for-like basis.

64 In 1998 Sinclair Knight Merz found there would be no net gain from reduced transmission losses resulting from putting cables underground.

3.2.1 Improved public amenity

Improved public amenity as a result of reducing the visual impact of the overhead network—such as improved views and streetscapes—is an important benefit of undergrounding to the community. The Tribunal received many submissions commenting on the positive landscape and amenity benefits that undergrounding brings. For example:

> Undergrounding means that the environment and the street-scape will be vastly improved. Ugly poles with their tangled web of wires, cables, boxes and transformers will disappear. Trees will look like trees again instead of mutilated stumps.[65]

> The issue of public benefit in terms of view are particularly relevant in [areas] … which [have] … harbour and ocean views. It is regrettable that the height of the electricity infrastructure network in many instances is roughly equivalent to the window heights and viewing areas of adjoining properties.[66]

Placing a value on these benefits is not straightforward. People's preferences for out-of-sight cables and concern about aesthetics differ. In addition, undergrounding would be implemented gradually over 40 years, and people's preference (and willingness to pay) may change over time. Moreover, the proposed program does not involve removing all aboveground infrastructure. Only those poles that are not light-only poles, that are technically and practically removable, and are in urban areas and localities with a population of 30,000 or greater may be removed. Some of the amenity benefits associated with undergrounding will also be offset to some extent by the replacement of overhead infrastructure with various elements of 'street furniture' required to support the underground system (see Box 3.2).

Box 3.2 Street furniture required to support underground system

The proposed undergrounding program will involve replacing some overhead infrastructure with 'street furniture' that is required to support the underground electricity network. This includes:

- ground mounted substations (also known as padmounts or kiosks), which occur outside one in every 100 lots and have dimensions of around 2 metres square by 1.8 metres high
- high voltage switching cubicles, which are placed on one in three substations, and are approximately 1 metre square by 1.5 metre high
- service pillars, which occur around one in four lots and are 0.3 metres square by 0.5 metres high.

Street furniture required to support underground communication cables includes major connection cubicles, which occur outside one in every 400 lots, and are around 0.5 metres square by 1.8 metres high, pedestals, required outside around one in every thirty lots, and are around 0.3 metres square by 1 metre high, and mobile phone antennas, which are not particularly frequent, and are currently on poles but should be able to be relocated to light poles.

As well as partly offsetting the improved amenity benefits of undergrounding, the location of substations in particular will create additional problems. In new developments, the location of substations is considered at the planning stage, but with retrofits there is no obvious location for such infrastructure. If agreement cannot be reached with council and adjoining landholders for placement on footpaths or parks, for instance, easements may be required on private land, which will involve negotiations and possibly compensation.

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65 Penrith City Council submission, 11 February 2002, p 3.

66 Manly Council submission, 4 February 2002, p 3.

3.2.2 Improved environment

Undergrounding electricity cables is likely to have several important impacts on improving the flora and fauna of local areas. As was raised in submissions to the review:

> The additions to the urban forest, which will be possible when the overhead cables are removed, will add great value to the urban environment. Additional wildlife habitat will be created on streets and front gardens … Wildlife movement corridors will be enhanced, and additional greenhouse gas reduction capacity will result from the increase in the mass of the urban forest. Plantings of trees of a wider selection, not restricted to small trees and shrubs that can be accommodated under the wires, will enhance species diversity.[67]

> If the overhead network was underground, more trees could be planted in many of these areas which contributes to reduction in greenhouse gases.[68]

The Ku-ring-gai Bat Conservation Society also noted that each year, the majority of infant flying-foxes rehabilitated by wildlife care groups in urban areas were orphaned by the electrocution of their mothers.[69]

> Overhead electricity supply contributes to the decline in the grey-headed flying-fox population, impacting on a named threatened species and on the ecological functions (pollination and seed disposal) which it performs.[70]

Undergrounding would therefore reduce the safety risks to bats and other wildlife that may come into contact with overhead lines and has direct benefits for improving wildlife safety and enhancing biological diversity.

Not all environmental concerns associated with overhead cables will be addressed by the proposed scheme. For instance, the scope of the undergrounding proposal is also limited to voltages up to 22kV. As noted by EnergyAustralia:

> Suburban streets and the communities that decide to be part of an undergrounding scheme will expect these [transmission and sub transmission networks] overhead wires to be removed…as the poles are higher and…more visible and require greater vegetation management.[71]

3.2.3 Improved public and workplace safety

Undergrounding electricity cables could significantly reduce the risks to workers and the wider public associated with accidental or inappropriate contact with aboveground cables. The potential change in risk to electrical workers from undergrounding is probably minimal, given they receive extensive electrical safety training, and wherever cables are located, injuries should be minimised. However, in the last three years, up to two non-electrical workers or members of the general public have been killed every year as a result of contact with overhead electricity cables.[72]

67 LGSA of NSW submission, 11 February 2002, p 11.
68 Mosman Council submission, 29 April 2002, p 2.
69 Ku-ring-gai Bat Conservation Society Inc submission, 8 February 2002, p 1.
70 Ku-ring-gai Bat Conservation Society Inc submission, 8 February 2002, p 2.
71 EnergyAustralia submission 2002, p 5.
72 Data does not distinguish between accidents with high voltage and low voltage lines.

A number of submissions mentioned other risks which can be reduced as a result of undergrounding. These include falls in damage repairs and hazards to life when oversized trucks hit wires, such as garbage trucks emptying wheelie bins, and trucks delivering materials and construction equipment. Crane safety would also be enhanced, and it would no longer be necessary to shield overhead cables at worksites, or use alternative methods of materials handling because of the constraints imposed by overhead wiring.[73]

The scope for reducing electrocutions and other electrical accidents as a result of undergrounding depends on the proposed roll-out of the undergrounding proposal, whether overhead cables are removed from the street level to residences in all instances, and whether the replacement underground cables are buried deep enough to keep them 'out of harms way'. Given these uncertainties, potential avoided costs from electrocutions with overhead lines have not been estimated.

3.2.4 New opportunities

In addition to minimising or eliminating the external effects of power poles, undergrounding also provides new opportunities by enhancing efficiency and reducing costs not directly related to power provision.

- Existing undergrounding projects have been accompanied by a redesign of street lighting systems, providing better, more efficient lighting than existing systems designed around the need to provide conduits of power supply. AEEMA noted that the new luminaries in Anzac Parade, Canberra produce twice the light levels of the originals, consume 40 per cent less energy, have a maintenance free operating life of 15 years, with estimated labour savings in lamp replacement of $1,200 to $2,000 per luminaire.[74] There may also be opportunities to match the type of street lighting to particular areas such as with federation lighting.[75] Clearly there are additional costs associated with light redesign. However, the opportunity to improve lighting systems is greatly facilitated by undergrounding.
- Undergrounding cables provides the opportunity to more efficiently plan and map public easements containing a wide range of underground utilities, including water and gas services. AEEMA noted that this can lead to the development of protocols for the sequenced lay out of underground infrastructure, providing benefits and cost savings to both utilities and contractors accessing public underground space.[76] The LGSA of NSW also identified that the undergrounding of power cables gives rise to a broad-scale opportunity to rationalise the distribution of utility services. Streets in major centres contain numerous pipes, ducts, cables and conduits for the various utility providers, all in separate trenches, crowding the sub-surface area. A more efficient and functional system for utility reticulation is desirable.[77]
- Undergrounding provides an opportunity for communications carriers to relocate their cables in a coordinated way, minimising the costs to carriers. Communications carriers currently have a substantial amount of their broadband (internet and pay TV) and telephony network on overhead poles, and are required by the *Telecommunication Act 1997* to underground these cables within six months of the undergrounding of

73 LGSA of NSW submission, 11 February 2002, p 9.
74 AEEMA submission, 5 February 2002, p 10.
75 Mr R D Dunstan submission, 20 April 2002, p 2.
76 AEEMA submission, 5 February 2002, p 16.
77 LGSA of NSW submission, 11 February 2002, p 6.

power cables. In past undergrounding projects, relocation of underground cables has occurred in an uncoordinated way increasing overall costs to carriers.

- New opportunities arising during the construction phase may also be apparent. Sydney Cables Downunder highlights benefits likely to flow to the construction industry, cabling manufacturing, aluminium refining, plastics and plastics compounding industries, transformer, electrical component and switchgear manufacturers, and tourism in NSW.[78] However most economic activity generated by the process of undergrounding will be transferred from other areas, with little net impact.

3.2.5 Reduced health risks

Some submissions to the Tribunal suggested that the proposed underground project will generate beneficial health outcomes for the community. This is due to the perception that when power lines are underground, the electromagnetic field, a by-product of electricity generation, will be reduced compared to the strength of the field present with similar voltage overhead lines. As discussed in Appendix 9, the strength of the field around power lines depends on the materials and approach used to underground, as well as proximity to ground level. As was submitted to the review, field-reducing techniques would need to be factored into the undergrounding process if undergrounding is to reduce electromagnetic field exposure among the community.[79]

The available evidence on the dangers associated with electromagnetic fields around overhead and underground cables is mixed, particularly for lower voltages. However, the Tribunal acknowledges that even perceived health effects can have a negative impact on, for example, confidence and property prices.

3.3 Overview of the value of benefits

The range of potential benefits from undergrounding cables across NSW urban centres are illustrated in Figure 3.1. The benefits the Tribunal has quantified are itemised in Table 3.2.[80]

Table 3.2 Summary of quantifiable benefits

Item	Present value over project span
Reduction in motor vehicle accident costs	$230-$260 million
Improvements in reliability of supply	$55-$115 million
Reduction in maintenance costs	$105 million
Reduction in revenue losses	$145 million
TOTAL	$535-$625 million
Benefits per lead in	$350-$400
Benefits as a proportion of optimised system costs	40 per cent

Source: CIE.

78 SCDU submission, 4 February 2002.
79 EMRAA submission, 26 April 2002, p 6.
80 Using a discount rate of 7 per cent.

Undergrounding may not be the only means of achieving these benefits—for example, benefits might also be obtained through more ‘careful driving’ campaigns, expenditure on improving parklands or other aspects of streetscapes to ‘improve the view’, or technological developments which improve the reliability of existing overhead networks. As was submitted to the review:

> …spending thousands of millions of dollars on undergrounding would seem necessarily to preclude expenditure on alternatives…the community ultimately will gain greater utility from allocating these resources to, say, health or education.[81]

The value of benefits of undergrounding to the community will be affected by the option chosen for funding the program, which will determine who pays, the basis on which they pay, and why. For instance, the value placed by consumers on a relatively cable-free environment will be affected by any personal contributions they might be asked to make to the capital costs. These issues are discussed in Chapter 4.

81 PIAC submission, 7 February 2002, p 2.

4 FUNDING OPTIONS

The importance and complexity of funding issues was demonstrated by the considerable discussion on the topic at the public forum held by the Tribunal in April 2002. Like the submissions received prior to the public forum, participants presented various views and options, ranging from utilities charges and levies, local government rates and levies, and state government contributions. There is no general consensus on the most appropriate mechanism.

In considering the options for funding the proposed undergrounding project, the Tribunal examined two key questions: Who should pay for the proposed program—impactors or beneficiaries? And, what are the best means of levying charges? It concluded that a beneficiary pays approach is more appropriate, but that no single payment option can ensure that all costs are set against the benefits in an equitable way and that market distortions are minimised. The Tribunal therefore recommends using a combination of payment options, so that most of the costs of undergrounding are recovered through local rates or levies and some are recovered through contributions from the state and the DNSPs, some part of which could be borne by electricity customers. The Tribunal also recommends that, given the size of the contribution required from local communities, those that place a relatively low value on the unquantified benefits, such as amenity, should be able to opt out of the program.

4.1 Impactor pays or beneficiary pays?

As Chapter 3 discussed, the benefits of the proposed undergrounding program by way of avoided external costs—such as improved public amenity and reduced motor vehicle accident costs—are to some extent ‘public goods’, in that consumption of an improved outlook by one person does not diminish its consumption by another. This suggests that undergrounding costs will not be recoverable without some government involvement. The incentives for individuals to fund improved views or safer driving conditions that will be shared by the local community and possibly the wider public are limited. Some individuals will object to paying for the value *they* receive from the program when others receive similar benefits for nothing.

In comparable situations, where expenditure is required to avoid external costs related to the delivery of a service, an ‘impactor pays’ (or ‘polluter pays’) approach is often used to fund that expenditure. The Tribunal received several submissions that supported this approach for funding undergrounding—either with DNSPs paying (with no recourse to increase charges), or the current generation of electricity users paying through higher prices, or some combination.[82]

However, the Tribunal believes that an ‘impactor pays’ approach is not appropriate for several reasons. First, the external costs of the overhead network are to a large degree the legacy of historical rather than current decisions by electricity providers. There is no proposal to compensate those who are currently disadvantaged by this legacy. Rather, undergrounding is a direct means of reducing the externalities themselves. It can be argued that when distribution infrastructure is ready for replacement and DNSPs elect to continue to use poles and wires when an underground option is available, they are electing to impose

82 LGSA of NSW submission, 11 February 2002, p 5; Mr G Moore submission, 1 February 2002, p 3; SCDU submission, 4 February 2002, p 14; Mr G Carrard submission, 11 April 2002, p 1.

continued externalities and thus an 'impactor pays' approach is appropriate. However, in practice, undergrounding cannot occur only in response to replacement needs or opportunities. It must inevitably involve the premature replacement of some assets when whole local networks are replaced with underground infrastructure, and ideally should incorporate network optimisation principles.

Second, electricity DNSPs have long-standing property rights to use overhead distribution systems, and an impactor pays approach to fund retrospective undergrounding would reverse these implicit property rights. This reversal has already occurred in new developments, where undergrounding is mandatory, but in this situation the additional costs of avoiding the impacts of overhead systems are borne exclusively by property purchasers who bear it as property owners, not as electricity consumers — arguably a case of beneficiary pays. Not all beneficiaries pay, only new property owners.

The Tribunal agrees with the finding in the DCITA 1998 report that beneficiaries should, desirably, pay in proportion to the benefits they receive. This would see the DNSPs fund the undergrounding program to the extent that they derive benefits from it.

4.2 Identifying beneficiaries for funding purposes

For some of the benefits of the proposed undergrounding program, both the source of the benefit and its beneficiaries are readily identifiable. These include those benefits that are clearly private as opposed to public goods, such as reduced maintenance and repair costs that will accrue to DNSPs, and increased quality in the form of improved reliability of supply to customers.[83]

At a broader level, however, classes of beneficiaries are easily defined but the benefits themselves are more diffuse and cannot be linked so readily to individuals, households, or businesses in a defined area, or apportioned to them. For example, amenity benefits related to improved views will accrue to individual property owners in the local areas where undergrounding has occurred, while those related to improved streetscapes will accrue to the local community in general. In addition, enjoyment of improved streetscapes will extend to visitors to the locality, while benefits in the form of reduced risk of collision with poles will accrue to all those who drive through it, not just those who live there.

This diffusion of benefits means that there are at least three different levels at which the beneficiary pays principle can be applied in recovering contributions to the cost of undergrounding:

- at the individual household, residence, business or building level — all as electricity consumers
- at the community level, either at the local community level or at the state-wide level
- at the service provider level.

83 Improved quality in the form of reliability also has certain 'public goods' characteristics. For instance, non-rivalness, non-excludability and non-optionality (ie improved reliability from undergrounding, say high voltage cables), is delivered to all who are served by that system. Care needs to be taken in identifying the beneficiaries of greater reliability from partial undergrounding. They may include consumers who remain connected by poles and wires but who benefit from burial of high voltage distribution components, for instance.

Table 4.1 sets out the major benefits and the level at which the greater part of each benefit will accrue.

Table 4.1 Benefits and beneficiaries from undergrounding

Benefit type	Beneficiaries						
	Utilities		Consumers		Communities		
	DNSPs	Telcos	Of local electricity	Of local communications	Local residents	Local property owners	Wider community
Avoided maintenance and repair costs	✓	✓					
Improved electricity service reliability			✓				✓
Improved views					✓	✓	
Streetscape improvement					✓	✓	
Avoided vehicle accident costs							✓
Reduced accidental cable contact					✓		✓
Reduced storm damage[84]	✓		✓	✓			✓
Reduce wildlife electrocutions	✓				✓		✓
Efficient sequencing of u/g infrastructure	✓	✓					
Reduced transmission losses	✓						✓

Note:
1. u/g refers to underground.
Source: CIE.

As Table 4.1 shows, communications carriers can also be seen as beneficiaries, as the proposed undergrounding program will force them to underground their own overhead networks within 6 months of electricity undergrounding. As a result, they will receive benefits, such as reduced recurrent costs associated with overhead infrastructure (eg, pole rental payments to electricity businesses). On the other hand, they will also incur the costs of rolling out a new underground cable network and probably writing off recently strung cable, which will have to be met. The inclusion of communications consumers in a beneficiary pays approach will be problematic if the costs of undergrounding greatly outweigh the benefits, as they are expected to do.

84 Undergrounding Telco cables is not expected to generate benefits from reduced storm damage, given that the design of the PSTN is different to that of DNSPs and a loss of power does not imply a loss of telecommunications service. Moreover, storms generally result in higher faults due to water problems in existing underground cables (Telstra submission, 26 April 2002, p 5).

Box 4.1 Beneficiaries of undergrounding communications

To be consistent with the 'beneficiary pays' principle, communications carriers would be expected to contribute in proportion to any net savings in maintenance costs or other benefits they obtain as a result of undergrounding their network. However, the extent of the benefits they are likely to receive is open to question.

Australian Electrical & Electronic Manufacturers Association (AEEMA) noted the undergrounding program would provide incentives for carriers to install a broadband fibre optic network to replace the existing copper wire network in areas where open access broadband local access networks do not exist, which would provide future benefits to the communications sector.[85] However, Telstra put the view that investments in additional broadband infrastructure could be premature, as the full capacity of the existing copper wire network has not yet been fully explored or exploited. Optus indicated that it would receive benefits only in the form of avoided maintenance and rental costs. In addition, it claimed that any savings it makes on pole rental would be offset by it having to pay local council levies for the right to pass cables under councils' streets.

The costs of providing future broadband capacity may be reduced as the result of any joint undergrounding; however, it is not clear that a demand exists or can be forecast for the services it could provide. Unless other significant benefits to the carriers arise, there would be a large shortfall between the costs of undergrounding and any savings it allowed. Who would pay for the shortfall?

Telstra argued in its submission that the beneficiaries of undergrounding its network, not Telstra, should bear the costs of any undergrounding.[86] Moreover, funding options for undergrounding cables should account for the relocation costs of communications cables and reimbursement of those costs. However it did not say who it believes these beneficiaries are.

Optus stated that if the undergrounding program proceeds, and Optus was required to carry this cost it would make the continued operation of its Hybrid Fibre Optic Cable unviable.[87] It also argued that requiring electricity and communications carriers to fund relocating their cables would result in significant distortions by 'undermining investment incentives and pushing up the prices of electricity and communications services'.[88] In its view, this would impact most heavily on low-income consumers, who are the least able to afford increases in electricity and communications charges.

4.3 Funding options to match benefits and beneficiaries

If a beneficiary pays approach is adopted as an underlying principle for funding the proposed undergrounding program, a range of funding options could potentially be used to recover the costs of the program. Ideally, these funding options should be selected using the following principles, which are widely accepted as desirable in a beneficiary pays approach:

- all costs should be considered and set against the benefits
- the community should receive the level of undergrounding for which it is willing to pay
- relative prices should not be distorted
- up and downstream effects should be minimised
- non-distortional taxes and subsidies should be used
- undergrounding should not create barriers to entry or hinder competition

85 AEEMA submission, 5 February 2002, p 5.
86 Telstra submission, 1 February 2002, p 3.
87 Optus submission, 12 February 2002, p 2.
88 Optus submission, 12 February 2002, p 4.

- transactions and compliance costs should be kept to a minimum
- payment for undergrounding should not be used as a redistributive mechanism
- subject to these other principles, the option should be realistic and maximise outcomes.

The Tribunal considered four funding options to be the most likely possibilities, and has assessed each of these options using the principles outlined above. These include:

- utilities charges and levies
- local government rates or levies
- a state government subsidy funded from consolidated revenue, implying adjustments across the range of state taxing and charging instruments (including payroll tax, land tax, gaming taxes etc) or a reduction in other services
- some combination of the above.

Box 4.2 Possible funding options

The ACG report (1997) listed a wide range of funding options as possibilities for recovering the costs of undergrounding electricity and communications infrastructure in NSW, including:

- a 2 cent levy on local telephone calls
- a 5 per cent levy on the aerial based revenues of communications carriers over a period of 20 years
- a flat charge per pole for connecting cables aerially to council poles, levied by local councils on electricity and/or communications utilities—depending on how it is passed on this could either be translated into a flat charge or a per–unit charge
- a general and proportional increase in local council rates (equivalent to a reduction in the allocation of funding for other projects) or a lump sum increase in council rates, or some combination of the two
- a targeted increase in council rates (eg rate increases only for those households in streets which have underground utility distribution)
- a Commonwealth or state government subsidy funded from general revenue — the subsidy may or may not be conditional on funding from other sources
- using the proceeds from the sale of specific government assets (eg the partial privatisation of Telstra)—this is akin to funding the undergrounding project from general government revenue
- a mandatory contribution from electricity and/or communications utilities; and/or
- any combination of the above.

4.4 Funding via utility charges and levies

Two types of utility charges could potentially be used to recover the costs of the undergrounding program. These are electricity charges and communications charges.

Electricity charges

DNSP charges and levies as a funding mechanism are relevant to a beneficiaries pay approach only to the extent that customers benefit from undergrounding by way of improved reliability of supply. These gains, represent some 10-20 per cent of the total quantified benefits of undergrounding, which is equivalent to 5 per cent of undergrounding costs, and are expected largely to accrue to commercial and industrial users.

Integral Energy submitted that to use electricity charges to recoup more than this proportion of the costs would be to 'effectively entrench a cross-subsidy between communities' by requiring customers living in an area who do not place a high value on undergrounding, as well as those already living in undergrounded areas, to contribute to undergrounding programs. It would also require the vast majority of electricity consumers to contribute now, to a program what will not realise benefits in their local area for another 20 to 40 years, and would distort electricity prices over this timeframe.[89]

There are various ways in which electricity charges could be imposed. A network-wide consumption charge, or per unit levy, could be imposed on commercial and industrial users, but this would fail to deal with the widely differing circumstances of different users in terms of the relative benefit they receive from improved reliability of supply. Thus, this kind of levy will be distorting (in that it most affects the most price-responsive consumers), as well as 'horizontally inequitable' since even consumers who consumer similar amounts will experience different outcomes, depending on how important reliability of supply is to them.

An electricity surcharge could be imposed incrementally, as customers in different areas are connected to the newly undergrounded system. However this would mean that differential electricity prices would emerge, and the differentials could be quite substantial. In its submission to the Tribunal, Energex pointed out the difficulties under present regulatory arrangements of creating different localised tariff zones.[90]

A lump sum levy could be imposed selectively, as customers are connected to the undergrounded network. Lump sum charging has the benefit of not influencing electricity consumption decisions (except in extreme cases where it is so large that it causes some to disconnect), but it doesn't take into account the different value consumers might place on improved reliability of supply. In addition, as the Public Interest Advocacy Centre pointed out in its submission, it could bear disproportionately on lower income households.[91]

One way a lump sum levy could be imposed is as an up front capital contribution direct from electricity consumers to DNSPs. This would allow the charge to be differentiated so as to reflect cost differentials in different areas. However, the benefits consumers receive may or may not be correlated with this. The capital contribution approach also raises the wider issue of implications for future electricity prices.

Despite the inefficiencies associated with this funding mechanism, several submissions to the review supported the use of funding undergrounding via an additional line item on energy accounts.[92]

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89 Integral Energy submission, 26 April 2002, p 5.

90 Energex submission, 4 February 2002, p 6.

91 PIAC submission, 7 February 2002, p 8.

92 SCDU submission, 22 April 2002, p 5, Pittwater Council submission, 24 April 2002, p 1, Mosman Council submission, 29 April 2002, p 3.

For instance, the LGSA stated the levy should be linked to 'service provision and the level of usage' of electricity.[93] Blacktown Council suggested that such a levy be amortised over a period of time rather than being imposed as a single lump sum so as to avoid hardship.[94] However, these proposals divorce the funding mechanism (in this case a single source levy on electricity consumers) from the allocation of cost recovery in proportion to, or on the basis of, benefits received.

The possibility of (partial) cost recovery through electricity charges is inextricably linked to issues of ownership of new trenches, bore holes, ducts etc. For instance, which of the newly created assets would be on the books of the DNSPs, and which would reside with local councils? This issue—which is discussed further in Box 4.3—raises a related question of financing arrangements, which is beyond the scope of this review. However, a number of submissions have raised the possibility of the creation of a new infrastructure entity to variously build, own, operate and maintain the multi-functional underground network. Others would become the purchasers of its capacity.

Box 4.3 Asset ownership issues and the regulatory asset base

Under current arrangements, when local electricity reticulation assets are provided to connect new developments to the system, developers reimburse DNSPs for the cost of the works and pass those costs on to the residents and businesses that acquire the new premises. The assets themselves are typically transferred to DNSP ownership. These assets are then maintained by the DNSPs and the costs of maintenance are provided for in electricity network tariffs, regulated by the Tribunal. As the DNSPs did not fund the assets they are not included in the regulatory asset base. This means these assets are not factored into calculations of depreciation and required rate of return requirements when establishing the revenue requirements of the DNSPs.

A similar approach would be appropriate if an up front capital levy on consumers in districts due for undergrounding was considered the best funding option. Such an approach would ensure that the capital costs of undergrounding are not over-recovered by also being incorporated in electricity charges when they have already been addressed via a capital contribution by consumers.

If retrospective undergrounding was funded exclusively through electricity charges and paid for by consumers via periodic charges, an ownership issue would not arise with respect to the distribution assets themselves. The trenching or bore holes would be part of these assets. Whether local councils own the space below the streets through which the trenching would pass, and are thus entitled to charge for its use, is a separate issue.

Where some significant part of the cost of retrospective undergrounding is funded by entities other than the DNSPs then the appropriate treatment of capital contributions and gifted assets is again relevant.

If electricity charges were used to recover costs, or a proportion of them, they would need to be modified to reflect any forgone depreciation and rate of return on the overhead assets no longer in use plus the anticipated cost saving to the utilities discussed above. This modification is common to any funding method.

93 LGSA of NSW submission, 11 February 2002, p 12.

94 Blacktown City Council submission, 6 February 2002, p 8.

The DCITA 1998 report was critical of the use of electricity consumption charges as a payment instrument for these reasons. It noted that levies that influence per unit charges have the capacity to alter the relative profitability of industrial users in an arbitrary way. In addition, as large industrial users often take power directly from the high voltage transmission network or from the sub-transmission system which is not under consideration for undergrounding, extending a per unit levy to them would be horizontally inequitable and have the potential to reduce their competitiveness and to distort the allocation of resources within the economy. The Tribunal does not support a per unit levy on electricity prices to fund the entire retrospective undergrounding program.

Communications charges

Communications charges could be used to recover part of the total cost of undergrounding communication assets. On the evidence currently available, however, the benefits that will accrue to current communications consumers per se are likely to be relatively small, given the unused capacity of the system and the apparently lower impact of undergrounding on communications reliability compared to power reliability. If utility charges are to play a part in funding cost recovery, additional communication charges do not appear to be warranted as part of a beneficiary pays approach. However, any net avoided cost that the affected carrier might enjoy could be asked for as a contribution from the carrier, as this would leave it no worse off.

Nevertheless, there will be significant communications undergrounding costs and the chosen funding mechanism must cover them. If these costs of putting cables underground are not to be picked up by consumers of cable products, they will have to be part of a broader tax or charge.

If a beneficiary pays approach is put aside, it might be argued that the legislated requirement for communication lines to follow electricity lines underground is just another cost of doing business and that the potential for this cost was recognised when the initial investment was made. However, Telstra notes that the vast majority of its Public Switched Telecommunication Network and HFC aerial network was installed prior to 1997, when there was no legislative framework that considered the undergrounding of telecommunications cables.[95]

4.4.1 Local government rates or levies

Local government rates or levies could be used to recover the costs of the proposed undergrounding program because a significant proportion of the benefits come from unquantifiable local benefits, such as improved public amenity and streetscapes, local environment and improved local vegetation management. These benefits will accrue largely to individuals within a local area and the local community. The benefits to individuals may vary widely, depending on the location of people's residence in relation to wires and transformers and the impact of this infrastructure on their views, for instance. The main payment vehicles are local government rates or special rates.

95 Telstra submission, 26 April 2002, p 3.

Funding or part funding at this level can notionally be separated into private contributions for private amenity gains (improved views), and public funding for local public benefits (improved street lighting opportunities, improved streetscapes and footpath space etc). Practically, however, these will be inseparable. The options for local government are restricted to local rates or levies, a reduction in other local government services, or some combination of these. Further consideration needs to be given as to how undergrounding (which is likely to be undertaken by DNSPs) could be funded through local rates or levies given that rate pegging applies in NSW.

A special levy per property (or rateable unit) could be imposed for the period necessary to undertake the undergrounding works in a local government area. Local councils would need to decide how to treat unconnected properties, parkland etc. If the levy was set as a percentage of rates, it would fall most heavily on the owners of the highest valued parcels of land. A flat levy would result in all owners paying the same amount.

The size of the levy or rate adjustment could be set so that it also recovers the cost of burying communications cables. However, given the fact that broadband cabling currently only serves a minority of premises, this may not be equitable.

Local government has already voiced its opposition to being given responsibility for funding. For example:

> Penrith City Council is opposed to any program that would impose costs on local government or impose responsibilities or obligations on local government for the management of the program (this should be an issue for the electricity distributors).[96]

However, local government rates and levies is probably the pricing instrument that comes closest to aligning benefits with cost recovery. Most benefits appear to occur at the local level, given the large gap between costs of undergrounding and the quantifiable non-local benefits.

One important obstacle to the use of council rates as a funding mechanism is that there is likely to be significant differences in peoples' willingness to pay for undergrounding, both within a local government area and *between* local government areas. Without an accurate understanding of how the members of an individual community value the benefits of undergrounding, it will be difficult to ensure that the community receives the level of underground cables that it is willing to pay for. In addition, it may be difficult to obtain this understanding. Individual members of any municipality or city council area may tend to understate the value to them of undergrounding if faced with the prospect of having to pay in proportion to benefits they receive.

4.4.2 State government contribution

The state as a whole could pay for urban undergrounding by reimbursing the costs of wires and cable burial out of consolidated revenue and gifting the new assets to the distribution companies, which it currently owns. Some of the benefits of undergrounding can be seen as accruing to the state in general, particularly reduced costs of motor vehicle accidents. The Tribunal has estimated the value of these benefits as round \$230 to \$260 million over 40 years in *present value terms*, which represents 15 per cent of the costs of the proposed undergrounding program.

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96 Penrith City Council submission, 11 February 2002, p 5.

A state government contribution would be administratively simple, but it would involve undesirable cross subsidisation of urban dwellers by rural residents outside the proposed program area, and would not involve beneficiaries paying in proportion to the benefits they receive. As was submitted to the review, the majority of the state's own-source taxation revenue is derived from taxes that are fundamentally city-centric, being heavily related to either land values or population.[97]

Furthermore, some avoided accident cost benefits could probably be realised through a highly selective replacement of the network with undergrounding or relocation in key black spot areas if such areas can be convincingly identified. The consequence of this approach, however, would be that an optimised undergrounding approach could not be adopted and many of the other benefits of the proposed program would not materialise or would be significantly reduced.

The available quantitative evidence suggests that *on a strict beneficiary pays basis at least*, the role for direct state funding is likely to be modest. However, the state may take the view that undergrounding needs to take place on a wider level than it would if it were left to individual communities to determine and fund, with only small state contributions. Unquantified state-wide benefits would include the potential to avoid outlays on State Emergency Services activity associated with fires caused by overhead electrical incidents, or storm damage worsened by the collapse of overhead lines, the intangible associated environmental damage that is avoidable, and other similar benefits. But unless state-wide benefits substantially outweigh the strictly local benefits associated with undergrounding, there will be a risk of significant cross subsidisation of some communities by others if the state funding component is large.

4.4.3 Combination of funding options

The Tribunal's view is that no single funding option meets all of the requirements considered desirable in a beneficiary pays approach. The use of any of the options it assessed would involve trade-offs between, for example, meeting equity and minimal distortion requirements and achieving administrative simplicity. A state contribution would meet the latter requirement, but not the former. Electricity charges would also be relatively simple to administer but are likely to be distorting and inequitable. If a net benefit is to be demonstrated, a large proportion of the costs of undergrounding need to be offset by hard-to-quantify amenity benefits and other gains that are largely local in nature. Local rates or levies may come closest to aligning largely local benefits with cost recovery, but there will be inevitable mismatches between individual benefits received and individual cost burdens.

The Tribunal recommends the use of a mixed funding approach. Although this would come at a cost to simplicity, it would come closest to meeting the other requirements of a beneficiary pays approach. As an illustration, the estimated value of the benefits quantified in this report suggest that the costs of undergrounding could be recovered in the following way – local government levies (60 per cent), state government (15 per cent), electricity consumers (5 per cent) and DNSPs (20per cent).

This funding share differs from that recommended in the Tribunal's Interim Report due to a revision by Meritec to its projections of estimated total project costs. The revision, which recognises the areas already undergrounded, significantly reduced the estimated total costs

97 The Vaucluse Progress Association submission, 21 April 2002, p 2.

of the project, and as a result, narrowed the identifiable funding 'gap' between the quantifiable costs and benefits. This also resulted in a change in the proportionate share of costs to be funded by the beneficiaries of undergrounding.

Further work may need to be done to establish which customers benefit from reliability gains and how their electricity charges might best be varied to reflect any such gains. The proportion to be funded by local government rates could be shared to some extent with the state if the potential to avoid outlays on State Emergency Services activity associated with fires caused by overhead electrical incidents, or storm damage worsened by the collapse of overhead lines etc is realised.

The amount funded by local government rates and the state should reflect incremental costs —that is, the full costs of undergrounding the existing networks less the costs associated with replacing the existing overhead network at the end of its economic life. The Tribunal has not quantified replacement costs as in practice the overhead network if properly maintained may never require replacing. However, underground systems are more likely to have a finite life. Prior to finalising funding levels, further work will be required to estimate what value (if any) should be assigned to DNSPs to cover any net replacement costs. Any change in the share of DNSP costs could be offset by a corresponding change in the local government funding level.

The use of a combination of payment instruments was support by some submissions to the Tribunal. Energex, for example, commented that:

> …the most successful undergrounding programs to date in Australia have been funded from a combination of state government/utility sources and local government … Under these arrangements, ETSA Utilities pays two thirds of the costs of undergrounding, the relevant local council pays one third and the undergrounding investment is rolled into ETSA Utilities' asset base'.[98]

DCITA 1998 report also recommended that avoided costs of undergrounding be funded by utilities and the cost shortfall be funded by property owners and state (and possibly Commonwealth) governments. That report did not consider in detail how these cost shares would be resolved.

However, while these proportions provide a rough guide for the urban areas *taken as a whole*, two local communities with similar undergrounding costs may value the amenity benefits of undergrounding very differently. Similarly, there may be specific areas where the benefits are closer to the costs. Such differences create problems for an approach to funding under which, in each local government area, the local community is called upon to fund the same dominant proportion of the costs.

It is likely that there is a substantial gap between the value of benefits that accrue on a state-wide basis, or to DNSPs and electricity consumers, and the average cost of undergrounding. Given these circumstances, it will be important that each local community demonstrates a willingness to pay for the difference between the costs allocated to other stakeholders and the total estimated cost. This would mean that communities that place a relatively low value on the local benefits of undergrounding should be given the choice of opting out.

98 Energex submission, 4 February 2002, p 5.

4.4.4 Affordability issues

It is recognised that affordability can be one factor affecting people's willingness to pay for undergrounding. Affordability concerns were expressed by local councils who supported that any levy be amortised over a period of time rather than being imposed as a single lump sum so as to avoid hardship.[99]

Other local councils agreed that given the substantial resource cost of undergrounding, and the relatively low level of quantifiable state-wide benefits, affordability is an important driver of the 'opt out' model.

> No community should be forced into an undergrounding of electricity cables program if it does not identify it as being a major priority, and it has a detrimental effect on existing programs.[100]

The option to opt out was opposed by many at the public forum on undergrounding and in a number of submissions. However, in the absence of willingness to pay data, the Tribunal believes that communities should be able to choose to opt out.

Some submissions to the review criticised the 'opt out' option for funding on the basis of unfairly disadvantaging lower income groups who might otherwise be willing to pay, or because of the impact on the cost and ease of undergrounding broadly in lines with an optimised approach (see below).[101] If an 'opt out' option were to be overlooked or modified, alternative means of funding the residual proportion, where willingness to pay is absent, would have to met. Questions raised in submissions as to whether concessions would be available to pensioners, or whether the government would pay the share for public housing are cases in point.[102]

Given the substantial resource cost of undergrounding, and the relatively low level of quantifiable state-wide benefits, affordability especially for lower income families and pensioners is an issue. While opt out is one possible option, it may be impractical and inequitable for individuals to opt out. Therefore, additional measures such as flexible financing options and possibly targeted subsidies should be considered.

4.4.5 Feasibility considerations

There are several factors which may impinge on the feasibility of implementing a mixed funding model which distributes the incidence of costs in line with the benefits received by different stakeholder groups.

Firstly, a mixed funding model which allows for 'opting out' may impact on the feasibility of implementing a fully optimised system as envisaged and broadly costed by Meritec.

> Whilst it is important that any process adopted allows sections of the communities who do not want or cannot afford undergrounding to opt out of the program, Meritec's proposed optimisation would not allow this to occur.[103]

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99 Bankstown City Council submission, 26 April 2002, p 6.

100 Penrith City Council submission, 29 April 2002, p 2.

101 Mr R Garner submission, 17 April 2002, p 1; Mr R D Dunstan submission, 22 April 2002, p 1; Mr M E J Parker submission, 22 April 2002, p 9; Bankstown Council submission, 26 April 2002, p 7.

102 Bankstown City Council submission, 26 April 2002, p 6.

103 EnergyAustralia submission, p 6.

Secondly, there may be difficulty in using local council rates to fund the larger share of costs to be borne by the community given existing rate pegging. The Local Government and Shires Association of NSW have submitted that local councils in NSW have been faced with rate pegging since 1977. This means that local councils cannot increase their total rate collections by more than the percentage announced by the Minister for Local Government, which has seen rate increases pegged between 2.7 and 3.3 per cent for the past three years.[104] Using council rates as part of a funding mechanism may require the resolution of some practical administrative issues, including consideration by the government of the approval process for additional rate increases in excess of those allowed for under the existing rate pegging regime. Sections 495, 503 and 506 of the *Local Government Act 1993* represent possible ways by which undergrounding funding may be raised via local government rates.

104 LGSA of NSW submission, 23 April 2002, p 8.

APPENDIX 1 TERMS OF REFERENCE

This review is to be conducted by the Independent Pricing and Regulatory Tribunal (IPART) under section 9 of the *Independent Pricing and Regulatory Tribunal Act, 1992.* The review is to identify the costs, benefits and funding options for undergrounding electricity cables in NSW. In considering these matters, the Tribunal shall have regard to:

1. The level of capital expenditure required for putting electricity distribution cables underground in NSW urban areas (including Sydney and regional centres).
2. The feasibility of undergrounding electricity cables with other utility services including telecommunications, and any economy of scale that can be achieved.
3. A comparison of the costs associated with maintaining the current network compared to undergrounding.
4. The types of costs which are avoided as a result of undergrounding.
5. The distribution and timing of benefits to those who benefit including an appraisal of the overall public benefit to the wider community.
6. Options for funding undergrounding projects having regard to:
   - improvement to the urban environment and public amenity
   - reliability of electricity supply
   - types of undergrounding projects including main roads, CBD/regional centres, shopping centres and residential streets
   - impact on electricity pricing
   - those who benefit and those who pay.
7. The impact on customers and in particular any differential impact on rural or urban customers, pensioners and low income households.

In conducting this review, IPART is requested to:

- provide an interim report to the Minister for Energy in March 2002
- undertake consultation including a public workshop in April 2002
- provide a final report by 10 May 2002.

APPENDIX 2 LIST OF SUBMISSIONS

Organisations

Australian Electrical and Electronic Manufacturers' Association Limited (AEEMA)
Bay Precinct (North Sydney Council)
Bankstown City Council
Blacktown City Council
Blue Mountains City Council
Cable and Wireless Optus Limited
Country Energy
Datasonics
Electromagnetic Radiation Alliance of Australia (EMRAA)
EMR Association of Australia Inc
Energex
EnergyAustralia
Heritage Office NSW
Integral Energy
Hornsby Shire Council
Kogarah Council
Ku-ring-gai Bat Conservation Society Inc.
Ku-ring-gai Council
Lake Macquarie Council
Lane Cove Council
Local Government & Shires Associations (LGSA)
Manly Council
Mosman Council
Motorcycle Council of New South Wales Incorporated
NECA
North Sydney Council
Penrith City Council
Pittwater Council
Public Interest Advocacy Centre
Rockdale City Council
SHOROC (regional organisation of Councils)
Sydney Cables Downunder
Sydney One Call Service

Telstra Corporation
The Council of the Shire of Hornsby
The KBA Consulting Group Pty Limited
UEA (AR Drilling Pty Ltd)
Vaucluse Progress Association
Warringah Council

Individuals

Dr Sydney Baggs
Mr Lex Bewley
Mr Greg Bleazard
Mr George Carrard
Mr Rob Downing
Mr James Dunbar
Mr Ronald D Dunstan
Mr John Egger
Mr Leigh Fitton
Mr Roy Garner
Mr Adam Johnston
Ms Marlene Jones
Ms Kim Margin
Ms Clover Moore MP
Mr Gary Moore
Mr Michael E J Parker
Mr Andrew Partos
Mr Terry Perram
Mr Don Phillips
Mr Allen Viney
Mr W R Williams
Mr William Michael Woods

APPENDIX 3 KEY SOURCES FOR THIS REPORT

To assist in undertaking this review, the Tribunal commissioned Meritec Limited of Auckland New Zealand to prepare estimates of the costs of the proposed undergrounding program. To complete this task, Meritec reviewed:

- the level of capital expenditure required for putting electricity cables underground in NSW urban areas (including Sydney and regional centres) for main roads, CBD / regional centres, shopping centres and residential streets
- the possible timing of such expenditure
- the feasibility of undergrounding electricity cables with other utility services including telecommunications, and any economies that can be achieved
- the costs associated with maintaining the current network compared to undergrounding
- the types of costs which are avoided as a result of undergrounding.

Other key sources of information used in this review include:

- the 1998 *Putting Cables Underground* Working Group Report and its supplementary reports, including those by The Allen Consulting Group, Sinclair Knight Merz, Khan and Conlon and the Bureau of Transport Economics
- the January 2002 *Research Report: Undergrounding Electricity Cables* prepared by the Ministry of Energy and Utilities
- data submitted by distribution network service providers (DNSPs) operating in the project area in response to a survey undertaken by the Tribunal
- submissions received by the Tribunal
- DNSPs responses to the Ministry of Energy and Utilities (MEU) stocktake questionnaire
- Australian Bureau of Statistics data on population and households
- Road Transport Authority accident data and estimates.

APPENDIX 4 QUANTIFYING AVOIDED NETWORK MAINTENANCE COSTS

The maintenance cost faced by utility companies depends on a number of factors, including:

- the age profile of the infrastructure
- the rate of deterioration
- history of maintenance and rehabilitation
- network management practices
- available technology.

In its submission to the Tribunal, Integral Energy noted that

> …the avoided costs associated with repairs and maintenance will depend on the type of undergrounding technique used (eg ducting). Higher capital costs up front may result in reduced operating costs in the future. It is also important to note that while undergrounding will result in assets with longer lives and possibly requiring fewer inspections, the unit cost of repairs and inspections will increase significantly.[105]

Country Energy stated in its submission that

> …many of the network avoided costs are variable, based on the location, varying age, rate of deterioration, and maintenance and rehabilitation history of the assets.[106]

To calculate a broad estimate of the possible avoided maintenance costs from replacing overhead cables with an underground system, the Tribunal obtained information from NSW DNSPs. The information was provided in various forms (see Table A4.1). The Tribunal multiplied those cost savings presented as a unit of route length by the route length estimated to be in the project area. This resulted in estimated avoided maintenance costs of $105 million in *net present value terms* over the entire project period, including both fault and emergency maintenance costs.

Table A4.1 Avoided maintenance cost in project area

Utility	Estimation method
Country Energy	Provided a forecast of the annual cost savings per km of route length
EnergyAustralia	Provided a total cost savings based on the estimated benefits (per km) from the 1998 Working group report and the length of the network to be undergrounded in the proposal: • vegetation management, pole inspection/treatment and repairs and maintenance for low and high voltage lines.
Integral Energy	Provided, for both underground and above ground systems (feeders and low voltage distribution lines), average estimates per 100 km of route length for: • planned and routine maintenance costs • tree trimming costs and • fault and emergency costs.

105 Intergal Energy submission, 14 February 2002, p 7.
106 Country Energy submission, 5 February 2002, p 7.

APPENDIX 5 VALUING AVOIDED ENERGY LOSSES

In its final report *Putting Cables Underground*, the Working Group estimated 'that a reduction in losses as a result of putting the lines underground would be of the order of 20 kilowatt hours per kilometre per day for the high and low voltage lines. This represents approximately 0.3 kilowatt hours per day for a typical domestic electricity customer (that is, a 3kVA domestic installation)'.[107] The report goes on to say that:

> …this figure is only an indication that there will be reduced electrical loss when overhead cables are replaced underground. The working group has been advised that it should not be used to calculate losses for any particular scheme to put cable underground as the local parameters will vary to a large degree.[108]

Sinclair Knight Merz also reported that for a particular arrangement the losses will be considerably lower than can be tolerated on an overhead conductor. However, it considers:

> …that there would be no net gain from reduced transmission losses resulting from putting cables underground because, although underground cables would be likely to be thicker than overhead cables and therefore have less electrical resistance, the capacity of substations will be larger and they will be further apart thus increasing the length of LV cable connected to each substation and therefore increasing overall resistance.[109]

However, Meritec put the view that the redevelopment of the network implicit in an undergrounding program that is optimally planned could be expected to reduce electrical losses for several reasons:

- it will reduce the distance of power transfer through the network
- it will raise the capacity of some or all of the network elements and thus reduce average current densities, resulting in reduced losses, at least initially
- losses on underground distribution networks are generally lower anyway, even when they reach their planned loads, because of the larger size of conductors used and the operation of many parts of the HV network in closed rings.[110]

Meritec acknowledges that the calculations are complex and cannot be done with any level of certainty. However, it suggests that losses before the proposed undergrounding are 5.5 per cent of electrical energy supplied into the system and after completion of the undergrounding project these losses will be reduced to 4 per cent.

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107 DCITA, *Putting Cables Underground*, 1998, p 74.
108 DCITA, *Putting Cables Underground*, 1998, p 74.
109 Sinclair Knight Merz, 1998, p 45.
110 Meritec Report, 2002, p 28.

APPENDIX 6 ESTIMATING AVOIDED COSTS RELATED TO MOTOR VEHICLE ACCIDENTS

The potential avoided costs associated with motor vehicle accidents as a result of underground cabling depends on:

- the extent to which poles can be removed from areas where there is a risk of collision
- and in the event of pole removal, the extent to which injuries and fatalities caused by off-road accidents are reduced, taking into account that some of these injuries are caused by collisions with road-side objects other than electricity poles, such as trees, fences and the like
- the timing and distribution of the undergrounding project across NSW.

In estimating the value of these avoided costs, the CIE made several assumptions regarding the likelihood and extent of avoided costs in the event of utility pole removal:

- utility poles, excluding light-only poles, are all assumed to be removed as part of the undergrounding roll-out within the project area, with poles housing telecommunication and other non-electricity infrastructure undergrounded at the same time as electricity poles (without a lag, given no data is available on accidents by pole type), excluding light only poles
- the removal of utility poles is assumed to eliminate the costs associated with minor and major injuries, fatalities and property damage associated with utility pole collisions
- the average number of collisions with trees and fences is assumed to increase by 20 per cent as vehicles collide with non-pole objects off the road, increasing the cost of those accidents[111]
- the cost of accidents with roadside objects other than poles is assumed to be the average cost of major injury, minor injury and property damage estimates in today's dollar terms[112] — that is, accidents with non-pole objects on the road side are assumed to result in no fatalities
- the number of pole accidents impacted by undergrounding is weighted according to the distribution of poles in the project area (60 per cent of poles in NSW)
- total savings are weighted in accordance with the roll-out profile of undergrounding.

Cost data was then calculated based on the following:

- accidents costs are an average of costs calculated by Andreassen (2001), and CIE estimates based on updated BTE 1998 costings, plus accounting for additional accidents expected with non-pole roadside objects
- RTA 2001 estimates were used to identify the frequency and severity of utility pole accidents in NSW
- the current distribution of minor and major accidents associated with pole collisions is similar to that in 1997, when accident data distinguished between minor and major accident severity

111 Broadly consistent with the assumption in DCITA 1998 that only 80 per cent of pole damage is 'avoidable' in the event of pole removal.

112 BTE 1998.

- no provision can be made for the fact that vehicle accidents are typically concentrated in particular 'hot spots', rather than evenly spread across all poles in the project area.

The DCITA 1998 study assumed that only 90 per cent of non-lighting only poles could be removed, given the existence of practical or technical difficulties associated with pole removal. This assumption has been used to generate the lower bound estimate of expected annual savings to be accrued as a result of reduced motor vehicle accident costs. The upper bound estimate assumes that all non-lighting only poles can be removed.

APPENDIX 7 VALUING IMPROVED RELIABILITY BENEFITS

To estimate the value of improved reliability of supply benefits—or avoided loss-of-supply costs—the Tribunal calculated the cost of outages to consumers and the likely improvement in reliability of supply as a result of undergrounding.

The DCITA 1998 study reported that the costs associated with outages depend on a number of factors including the type of customer affected; the outage frequency and duration; the magnitude of the load interrupted; and the time of day and week outages occur. In 1997 Monash University's Centre for Electrical Power Engineering conducted a survey to determine the cost of outages for customers. Residential customers were asked to choose from as many of the described actions as they felt was necessary to reduce the effect of the outage to their satisfaction. Non-residential customers were surveyed using the direct cost estimation approach. Respondents were given the scenario of a power outage occurring, without warning, at the worse possible time (time of day, day of the week and month) and asked to estimate the losses to their company arising from outages of various durations.

The responses were normalised using total annual electricity energy consumption to provide a cost per kilowatt hour (kWh) of annual usage. To calculate the 'cost per unit of energy not supplied'—the value of lost load (VoLL)—the outage costs associated with the specific outage duration were divided by the energy that would have been supplied given the outage duration (Kahn and Conlon 1997). The results are presented in Table A7.1 below.

Table A7.1 Value of lost load - Australia

Outage Duration	Value of lost load ($/KWh not supplied)			
	Residential	Commercial	Agricultural	Industrial
2 seconds	-	45,534	-	7,902
1 minute	-	1,318	3,684	276
20 minutes	-	152	266	24
1 hour	-	88	123	18
2 hours	-	36	75	7.70
4 hours	1.75	32	113	7.95
8 hours	2.18	51	93	10.27
1 day	3.35	23	88	5.24
2 days	3.87	-	-	-

Source: Kahn and Conlon (1997).

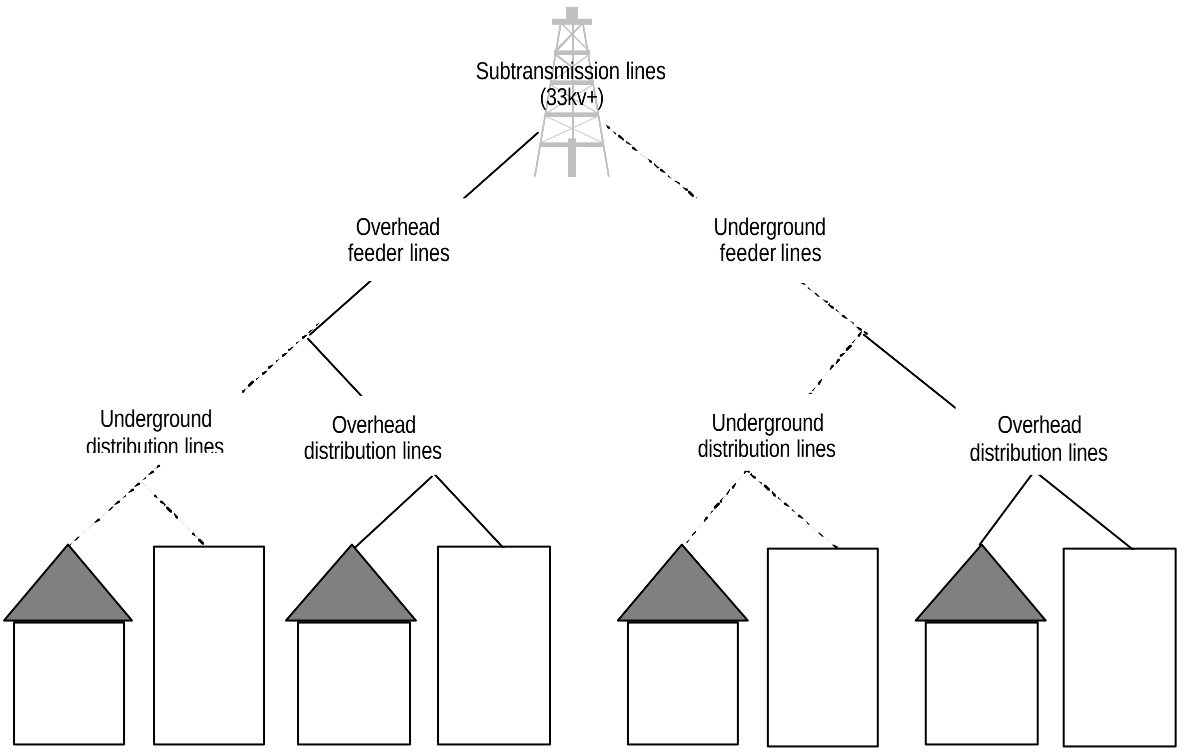
The results indicate that there is a wide diversity of values for each kWh of electricity not supplied, with the value depending on both the duration of the outage and the customer type. The results can be used to derive costs per outage. For example a commercial customer with a 20kW of load during a 2-second outage would incur losses of $45,534 x 20 x 2 / 3600 (number of seconds in an hour) = $505. Similarly a residential property which would have demanded 1kW of load during an 8 hour outage would face a cost of $2.18 x 1 x 8 =$17.44.[113] These figures show that the cost of outages are far greater for non-residential customers and therefore the majority of benefits are likely to accrue to this sector if reliability is enhanced by undergrounding.

113 DCITA, *Putting Cables Underground*, 1998, p 62.

A7.1 Reliability of supply: overhead versus underground systems

System reliability is the sum of component failure rates plus exposure factors such as motor vehicle pole accidents, dig-ins, tree contact and climatic factors. As underground networks are less exposed to these factors than overhead systems, they are likely to be more reliable. However, it is important to recognise that different undergrounding options result in different reliability gains. Figure A7.1 shows the ranges of combinations of overhead and underground systems across parts of the electricity supply system.

Figure A7.1 Combinations of overhead and underground systems



Most parts of metropolitan Sydney are serviced by hybrid systems rather than fully overhead or underground systems. Integral Energy report that high voltage distribution lines contribute approximately 70 per cent of their unplanned lost customer minutes.[114] It also notes that:

> Undergrounding a particular part of an overhead system will not necessarily lead to an immediate improvement in the reliability of the supply for customers. Reliability improvement will only occur over a number of years, as larger and larger sections of the distribution system a placed underground.[115]

114 Integral Energy submission, 14 February 2002, p 4.
115 Integral Energy submission, 14 February 2002, p 3.

Even when the same components of the supply network are undergrounded they may result in different reliability gains depending on the design and construction of the undergrounded network. Meritec (2002) report that the reliability of underground systems may be poorer than those of overhead systems if they are not planned, designed and constructed well.

A7.1.1 Measuring reliability

Reliability of supply can be measured in a number of ways. The most widely used standardised measures of reliability are the:

- system average interruption duration index (SAIDI)—the total number of minutes, on average, a customer is without electricity in a year
- customer average interruption duration index (CAIDI)—average duration of each interruption
- system average interruption frequency index (SAIFI)—the average number of times a customers' supply is interrupted per year
- customer average interruption frequency index (CAIFI)—the average number of interruptions per affected customer per year
- average number of interruptions per kilometre of circuit
- average duration of interruptions per kilometre of circuit.

The Ministry of Energy and Utilities collects this information annually from NSW utilities to monitor their service performance. These measures are required for underground *and* overhead networks of the 22KV and under component of the distribution network (the scope of the NSW proposal) to compare the relative reliability of the two systems. In their reports to the 1998 Working Group, both Sinclair Knight Merz (1998) and Max Garner & Associates (1998) noted the paucity of published data comparing the reliability of underground and overhead systems. This is due in part to the fact that there are very few utilities with sufficient proportions of underground network.[116] However, both reports were able to identify some data—presented in Table A7.2—that supports the contention that underground systems are significantly more reliable than overhead systems.

According to Sinclair Knight Merz, the information in this table indicates underground networks outperform overhead networks by at least 1 to 3 in terms of frequency of interruptions.[117] It is important to note that this comparison is derived from an average of NSW utilities, which operate in different environments, and a combination of voltage levels. Furthermore, low and high voltages as presented in this table are not defined. This is important, since the *duration* of any outage has the most significant impact on its cost.

116 Max Garner & Associates 1998, p 23.
117 Sinclair Knight Merz, 1998 p 17.

Table A7.2 Interruptions per 100 km of circuit in 1996

Utility	Voltage	Overhead	Underground
Integral Energy - 3 year average, 1994/95 to 1996/97	HV	30.27	2.79
Integral Energy - 3 year average, 1994/95 to 1996/97	LV	7.44	7.66
EnergyAustralia	HV	13	4
CitiPower	HV	14	1
Mercury Energy	HV	30.5	7.14
Survey of Australian Utilities	HV and LV	23.6	5.6
France	LV	12.29	7.55
Finland	LV	8.0	4.0

Source: Max Garner & Associates (1998) and Sinclair Knight Merz (1998).

To gain more information on the relative reliability of underground and overhead feeder and low voltage distribution systems, the Tribunal surveyed the DNSPs in NSW. Ideally, it required reliability measures for an all-underground system of feeder and low voltage distribution lines and an all-overhead system (shown in Figure A7.1). However, the DNSPs were not able to exclude hybrid systems when providing data on the number of interruptions and had insufficient data to provide all measures of reliability. Table A7.3 presents the results from the survey. Country Energy was the only DNSP that was able to provide information on the duration of outages for both underground and overhead feeder line systems. Meritec (2002) notes that:

> When considering the resulting benefits, however, account must be taken of the improvements in the performance of all types of networks through feeder automation (the installation of automatic devices to restore supply after a fault on the network), improvements in distribution management and changes in the method of compiling statistics on reliability.[118]

Table A7.3 Reliability for underground and overhead networks in urban NSW

Source	SAIDI		SAIFI		Interruptions per kilometre	
	O/H	U/G	O/H	U/G	O/H	U/G
Country Energy	90	70	1.02	0.80	-	-
EnergyAustralia	-	-	-	-	13	4
Integral Energy	-	-	-	-	23.3	1.2
Meritec	55	30	-	-	-	-

Source: Country Energy, EnergyAstralia, Integral Energy and Meritec (2002).

The range of reliability estimates is given by comparing the gains in reliability in the event of undergrounding indicated by Meritec and Country Energy with respect to the total number of minutes, on average, a customer is without electricity in a year (SAIDI).

118 Meritec Report, 2002, p 28.

A7.1.2 Estimated benefits

Reduced costs for customers

Having established the relative differences in reliability, CIE calculated the average cost for customers using the VoLL results from the Monash study. When the Tribunal surveyed the DNSPs it also asked for the lost load across their networks for the project area. Only the total lost load across the DNSPs' networks could be provided. Therefore the Tribunal estimated the share of lost load occurring in the proposed project area using the proportion of customers in the project area. The proportion of lost load attributable to severe weather conditions—approximated using information from the DNSPs—was multiplied by the value of lost load calculated in the Monash study to provide a base case of customer loss from outages. The assumed reliability improvement of 22-45 per cent was then applied to this base case. Over the project period, a total cost savings to customers of $57-$116 million in *net present value terms* is estimated as a consequence of reliability improvements from undergrounding (see Table A7.4).

Table A7.4 Annual reduced costs for customers from improved reliability

	Unit	NPV over 40 years
Per customer lead-in	$	$35-$75
Total value of lost load	$m	$55-$115

NB: Total savings expected at the end of the roll out period.
Source: CIE calculations.

APPENDIX 8 ASSESSING PUBLIC SAFETY BENEFITS

The 1998 DCITA study found insufficient evidence to suggest network safety would be improved as a result of undergrounding, making it inappropriate to speculate on reduced electrical worker accidents as a result of undergrounding. However, overhead electricity cables pose risks to non-electrical workers and the general public. Data collected by the Electrical Regulators Authorities Council (ERAC 1999, 2000, 2001) shows that over the last three years, all recorded electrical fatalities in NSW as a result of overhead power lines occurred among non-electrical workers and the general public (Table A8.1). There were no recorded fatalities among electrical workers as a result of overhead power lines during this time. Data does not distinguish between accidents with high voltage and low voltage lines.

Undergrounding electricity cables could significantly reduce the dangers that exist for the public as a result of accident or misinformation about the dangers of cable contact. The Tribunal received several submissions commenting these dangers—for example:

> It is plainly obvious that bare overhead high voltage cabling is dangerous...overhead cables that require only a small mistake to kill someone. Raise a ladder, use a cherry picker, fly a kite and so on.[119]

Parker (2002) identifies several areas were safety would be enhanced in the event of undergrounding, including bridge construction, building construction, and motor vehicle accident sites where accidents bring live wires down.

There is clearly scope for reducing public safety risks as a result of undergrounding. There are no recorded fatal electrocutions associated with the underground service over the past three years for which data is available, although the proportion of households currently connected by undergrounded cables is low. Nationally, an estimated 10 per cent of household connections are underground (DCITA 1998), although EnergyAustralia report that 23 per cent of customers in the NSW project area are supplied by underground cables, as are 48 per cent of Integral Energy customers in the project area. However the absence of fatality recordings does not mean that the risks to the public from underground cables cannot be serious, given scope for accidental digging of underground lines.

Table A8.1 Fatal electrocutions associated with overhead power lines in NSW

Year	Number	% of total NSW electrocutions	Occupation
2000/01	1	11	Non-electrical worker
1999/00	2	22	General public
1998/99	1	11	General public

Source: ERAC (1999, 2000, and 2001).

119 Mr M E J Parker submission, 4 February 2002, p 4.

Other health and safety risks which would be at least partly reduced by undergrounding were highlighted in submissions to the review. The LGSA of NSW instanced falls in damage repairs and hazards to life when oversized trucks hit wires, such as garbage trucks emptying wheelie bins, and trucks delivering materials and construction equipment. Crane safety would also be enhanced, and it would no longer be necessary to shield overhead cables at worksites, or use alternative methods of materials handling because of the constraints imposed by overhead wiring.[120]

The scope for a reduction in electrocutions and other electrical accidents as a result of undergrounding depends on the proposed roll-out of the undergrounding proposal, whether overhead cables are removed from the street level to residences in all instances, and the depth of underground cables needed to keep lines 'out of harms way'. Given these uncertainties, potential avoided costs from electrocutions with overhead lines have not been estimated.

120 LGSA of NSW submission, 11 February 2002, p 9.

APPENDIX 9 ASSESSING POTENTIAL HEALTH BENEFITS

There is mixed evidence about the potential health benefits associated with undergrounding electricity cables. These potential benefits are the result of reducing the risks posed by electromagnetic fields around overhead cables. There is a perception that when power lines are underground, the electromagnetic fields—a by-product of electricity generation—will be reduced compared to the strength of the electromagnetic filed present with similar voltage overhead lines. In his submission to the Tribunal, Dr Baggs noted that research on electromagnetic radiation (EMR) shows a deleterious effect (particularly in the ELF band) to biological cells. His concern is such that he recommends that:

> All electricity cables should … be located in service corridors, away from public access, and well signposted with warnings about overexposure being a health hazard.[121]

There is evidence that electric fields can be easily shielded by undergrounding, but the same cannot be said of magnetic fields, which can pass through both the earth and buildings (Preston 1989). Data from the United States suggests magnetic fields are present, but substantially reduced by underground cabling. Overhead cabling was found to emit 30-30 mG more than underground cabling at a distance of 50 feet from the line (Table A9.1).[122] This is consistent with Bonwick reported in DCITA 1998. Bonwick found that, for comparable 220kV overhead and underground lines, the magnetic field of an underground 3 phase cable was reduced by 60 per cent for a single circuit and 15.8 per cent for a double circuit when compared to the overhead equivalent.[123] The strength of magnetic fields also depends on the materials and approach used to underground, and it is also possible to construct underground power lines to reduce magnetic fields. By placing conductors in a helical formation, the magnetic field falls exponentially with distance. Placing such power cables further underground can reduce fields to negligible levels (Swanson 1996).

More important than the level of EMF is the link between any EMF and health outcomes. Despite extensive research efforts, studies on the health affects of overhead cabling fail to demonstrate a *causal* relationship between undergrounding and improved health outcomes. The electric and magnetic field (EMF) created during electricity generation is generally classified into the extremely low frequency (ELF) range (see discussion below). Much research has been conducted into whether this EMF-ELF radiation can be linked to negative health outcomes. A report in the United States by the National Institute of Environmental Health Sciences (NIEHS 1999) surveyed the extensive literature in the area and concluded that scientific evidence suggesting that ELF-EMF exposure causes any health risk is weak.

The strongest evidence for health risks came from epidemiological studies of human populations finding an association between exposure to EMF-ELF and incidence of two forms of cancer - childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. In general, epidemiological studies demonstrate a fairly consistent pattern of small increased risk with increasing exposure. However, this evidence is still considered to be 'weak' because the results could not be replicated under laboratory conditions.

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121 Dr S Baggs submission, 1 February 2002, p 1.

122 It is noted that this research is related to high voltage transmission lines.

123 DCITA, *Putting Cables Underground*, 1998, p 55.

Virtually all laboratory evidence in animals and humans fails to support a causal relationship between exposure to ELF-EMF and disease status (NIEHS 1999). However, the latest fact sheet from the World Health Organisation (WHO) on electromagnetic fields and public health notes that, in addition to aesthetics and public sensibilities, 'siting decisions should also consider ways to reduce peoples' exposure' (WHO 2001, p 4).

Table A9.1 Burying lines and EMF

		Distance to proposed centreline								
		300 feet	200 feet	100 feet	50 feet	0 feet	50 feet	100 feet	200 feet	300 feet
Calculated magnetic fields (mG) for OVERHEAD transmission line designs										
	Unit									
Single circuit 230 kV 1-string long span	mG	1.7	3.8	13.4	38.5	108.1	45.3	14.9	4.0	1.8
Single circuit 230kV braced 1-string long-span	mG	1.5	3.4	12.0	34.4	100.1	40.6	13.4	3.6	1.6
Single circuit 230 kV low profile/ braced post	mG	1.2	2.8	10.6	36.0	170.0	38.2	11.2	2.9	1.3
Double circuit 230/69 kV 1-string long-span	mG	1.1	2.6	10.8	34.7	74.3	14.9	4.0	1.3	0.7
Double circuit 230/69 kV braced 1-string long-span	mG	1.0	2.4	9.8	30.8	65.1	13.8	4.6	1.5	0.7
Calculated magnetic fields (mG) for UNDERGROUND transmission line designs										
	Unit									
69 kV 1 cable per phase SCFF or XLPE	mG			0.5	2.0	107.0	2.0	0.5		
230 kV 2 cables per phase SCFF or XLPE	mG			1.0	3.9	186.0	3.9	1.0		
230 kV 3 cables per phase SCFF or XLPE	mG			1.0	4.0	153.0	4.0	1.0		
230 kV 2 cables per phase HPFF with 2 pipes	mG				0.1	5.2	0.1			
Higher average mG for overhead 230kV over underground 230kV	*mG*	*+1.5*	*+3.3*	*+11.0*	*+33.6*	*+11.3*	*+38.7*	*+12.2*	*+3.5*	*+1.6*

Source: Table 4–1 and Table 4–2 of Final Environmental Impact Statement, Arrowhead – Weston Electric Transmission Line Project – Volume 1, Public Service Commission of Wisconsin, October 2000.

Extremely low frequency fields

The section below is based on information provided to the Tribunal by the Ministry of Energy and Utilities' Technical Reference Group on Undergrounding Electricity Cables.[124]

Extremely low frequency electric and magnetic fields (EMFs) are produced from electricity supply equipment.

The strength of an electric field is related to the relevant operating voltage. The voltage does not vary significantly throughout the day for a given item of equipment. The strength of a magnetic field is related to the current passing through the supply equipment. Because the current varies over time in a day, so does the strength of the magnetic field. The strength of

124 This Group has been established to report on the practical issues associated with undergrounding electricity cables.

both electric and magnetic field strengths decrease rapidly with distance from the supply equipment.

Electric fields are shielded effectively, and reduced to a negligible amount, by objects such as soil and buildings etc. The electric field from an underground cable is also effectively shielded if the cable is made with a concentric metallic sheath or screen, which is common practice. Electric fields from ground-mounted substations are also effectively shielded by the commonly used metallic enclosures.

Research indicates that as most underground cables contain some form of outer electrical sheath, this virtually eliminates any external electric field. Even those cables without such a sheath do not give rise to a field above ground because the ground itself is a good screen for electric fields.[125]

Magnetic field strength is also related to the geometry of the current carrying conductors. The closer the conductors, particularly if they are arranged in a triangular (trefoil) configuration, the lower will be the resultant magnetic field strength. Magnetic fields are not as easily shielded as electric fields, however good equipment design and installation can reduce magnetic field strengths to the required levels.

Overhead and underground cabling

When comparing extremely low frequency EMF's arising from overhead and underground systems, it is normal to compare field strengths one metre above ground level, directly below an overhead line or directly above the equivalent underground cable buried at one metre depth.

For overhead networks, the low voltage mains are typically 6-7 metres above ground level. The high voltage conductors are typically 8-9 metres above ground level in urban areas. Low and high voltage underground cables are typically multi-core cables. That is, the respective phase conductors are bound together in a common sheath or jacket. The resultant magnetic field strengths are very low because the conductors are so close together.

The electric fields emitted from both low and high voltage underground cables, measured above ground, are negligible because of the shielding effect of the soil. The electric fields from high voltage underground cables are further shielded because multi-core cables are either individually or collectively screened.

In some circumstances, individual, single core cables are used. However these cables are generally installed in relatively close proximity to one another, compared with their overhead equivalent. They are often laid in a bundled or trefoil arrangement, particularly if installed in conduits, as if they were a multi-core cable. This provides the arrangement for the minimum resultant magnetic fields.

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125 Clause 4.2 of *Electric Power Transmission and the Environment: Fields, Noise and Interference.* Working Group 36.01 (Corona and Field Effects) of the International Conference on Large High Voltage Electric Systems (CIGRE).

In limited situations, such as the main (or 'trunk') sections of high voltage lines from zone substations, the single core cables may be spaced slightly apart to reduce mutual heating. In these situations only, will the resultant magnetic field measured 1 metre above the ground, be comparable with an equivalent overhead line.

Other supply equipment

Magnetic fields emitted from ground-mounted substations will be higher than for equivalent pole-mounted substations (located 6 metres above ground) due to their proximity. The selection of substation locations will need to be given due consideration to ensure that magnetic field strengths experienced in occupied areas are minimised.