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Households' willingness to pay for undergrounding electricity and telecommunications wires

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Abstract Underground telecommunications and low-voltage electricity networks have several advantages over overhead networks including reliability of supply, safety and improved visual amenity. The economic viability of replacing existing overhead networks with new underground networks depends on the value of these benefits to households, but no complete value estimates are available in the literature. This paper represents a contribution towards addressing this research gap. A stated choice survey is used to estimate willingness-to-pay for undergrounding in established residential areas in Canberra. Average willingness-to-pay is at least $6,838 per household and there is significant variation in preferences over the population. The results suggest that benefits would be highest in areas with higher household income and older residents where visual amenity, safety, tree trimming or restrictions on the use of yard space are of concern.

Keywords Stated preference; willingness-to-pay; undergrounding; supply reliability

JEL codes L94; Q51

I Introduction

A number of cities around the world have implemented or are considering programs to replace overhead low-voltage electricity and telecommunications networks with new underground infrastructure.[1] In Australia, only Perth and Darwin have implemented wholesale undergrounding programs, but interest in more widespread undergrounding has been renewed by the recent commencement of the roll-out of the National Broadband Network (NBN) (Bester, 2010; Economic Regulation Authority, 2010; Energy Networks Association Limited, 2010). Most of the households to be connected as part of the first phase of the NBN roll-out in Tasmania will be serviced by overhead cables installed on existing poles. As the roll-out proceeds, consideration needs to be given to whether a better long-term outcome could be achieved by installing NBN cables underground and relocating low-voltage electricity networks at the same time.

Underground networks provide a more secure and reliable service. They reduce the risks of damage from fires, strong winds, storms and other severe weather events, which can cause power outages and risks of electrocution. They lead to more aesthetically pleasing residential areas and savings from lower network energy losses, avoided pole maintenance costs and avoided costs of trimming trees away from power lines.

[1] The New Zealand cities of Auckland and Wellington have implemented undergrounding programs. In the United States, undergrounding is gradually taking place throughout California and in specific locations in Florida, Maryland and Virginia. In the United Kingdom, undergrounding programs are focussed on distribution lines in national parks and areas of outstanding natural beauty.

Based on experience in Perth and South Australia (ETSA Utilities, 2009; Office of Energy, 2008), the cost of undergrounding in established residential areas is at least $10,000 per property ($2009), but could exceed $20,000 per property, depending on soil conditions and existing network arrangements. The savings to electricity and telecommunications businesses in terms of lower energy purchases and network maintenance costs are usually only a small percentage of these costs. The expense of undergrounding must be justified primarily by the benefits to households. The estimated value of household benefits is therefore a key component in the economic evaluation of undergrounding programs.

Here lies a major problem. There appears to be no complete estimate of the benefits to households available in the literature. Supply reliability improvements have been valued using contingent valuation (Carlsson and Martinsson, 2007; Layton and Moeltner, 2005) and choice experiments (Accent, 2008; Beenstock et al., 1998; Carlsson and Martinsson, 2008), but it seems no studies have attempted to value the overall household benefit from undergrounding, including amenity and safety benefits.[2]

As a result, the 1998 Australian Government investigation into the costs and benefits of undergrounding (Commonwealth Department of Communications Information Technology and the Arts, 1998) and the subsequent investigation by the New South Wales economic regulator (Independent Pricing and Regulatory Tribunal, 2002) categorised most household benefits as unquantifiable. This led to the conclusion in both

[2] Several studies have focussed on the impacts of high-voltage transmission wires and towers, but these are of little use in this context because the infrastructure has quite different impacts on households.

reports that widespread undergrounding is not justified on the basis of *quantifiable* costs and benefits. A similar situation has occurred in studies conducted in the United States (InfraSource Technology, 2007).

The absence of household benefit estimates in the literature is not for want of available techniques. Indeed, environmental economists have been estimating household values for the removal of urban disamenities for many years. Most studies have employed the hedonic property price approach or stated preference (SP) techniques such as contingent valuation and choice experiments. McNair (2009) showed how the hedonic property price method (Rosen, 1974) used previously to value the impacts of noise (Nelson, 1982) and poor air quality (Brookshire et al., 1982) can be adapted to estimate the relationship between house prices and underground wires in cities where retrofit undergrounding is yet to take place. The implicit price estimate derived from this approach represents the benefit for the marginal purchaser in the property market.[3] While this estimate is of some use, the key measure of interest in an economic evaluation is the average benefit across the population of households. SP techniques can be used to estimate this value directly, but there appear to be no available studies utilising this approach.

This paper represents a contribution towards addressing this research gap. The main objective is to estimate the value of household benefits from undergrounding in Canberra. To aid the transfer of results to other cities, value estimates are related to the socio-

[3] In principle, the demand curve can be estimated using a second stage of hedonic analysis (Rosen, 1974), but few studies proceed to this stage due to identification problems and costly data requirements.

demographic characteristics of households and to the specific benefits of undergrounding perceived to be most important by households.

II Background

In Canberra, electricity and telecommunications wires have been installed underground in new housing developments since 1990. Approximately 70 per cent of households (about 100,000 households) are situated in older suburbs serviced by overhead networks. These networks are usually reticulated along the rear boundary of properties, reflecting Canberra's original town planning decision to limit the amount of overhead street verge reticulation. Replacing this overhead infrastructure with new underground networks in the street verge would confer several benefits on households.

The appearance of residential areas would be improved by the removal of visible poles and wires. Trees would be allowed to grow to a more natural shape and, in some instances, views from residential properties may become less polluted. In Canberra, households are responsible for keeping trees clear of power lines on their property. If wires were placed underground, households would save on fees paid to tree surgeons and time and safety costs associated with undertaking trimming themselves.

Underground networks are less exposed to risks of damage from fires, strong winds, storms and other severe weather events. This leads to safety benefits from reduced risks of electrocution from fallen wires and supply reliability benefits from reduced frequency of electricity and telecommunications outages.

Most households in areas with overhead wires are connected to the network by an overhead service line from a nearby pole. Restrictions are imposed on the use of yard space beneath these service lines. In some instances, the positioning of service lines prevents the installation of swimming pools or garden sheds. Undergrounding would lead to the removal of these restrictions.

Finally, undergrounding would remove the need for network operators to access residential properties to conduct inspections or maintenance on the network. This access can be inconvenient for households, for example where arrangements need to be made with regard to pets kept in back yards.

A slightly different set of household benefits would apply in cities where existing overhead infrastructure is located in the street verge. It is not clear how the overall value of household benefits would differ. On one hand, the value of amenity improvements may be higher because streetscapes are affected; and there may be additional benefits from reduced incidence of motor vehicle accidents. On the other hand, the value of relaxing restrictions on use of yard space may be lower because construction of pools and sheds is less likely in front yards; and benefits associated with tree trimming requirements and network operator access are less relevant to households where tree trimming is undertaken by local councils and network maintenance is conducted in the street verge.

III The survey approach

The household benefits of undergrounding in Canberra are valued using stated preference data collected from an online survey. A draft questionnaire was developed in consultation with the local electricity network operator, ActewAGL Distribution, and tested using in-depth interviews with 11 participants. Information from the interviews was used to improve layout and functionality and to clarify background information in the questionnaire. Responses to the draft questionnaire were used to revise the design of the stated preference component. Households were recruited to the main survey by telephone using random sampling from directory listings for Canberra suburbs serviced by overhead wires. Screening questions were used to ensure that participating households were owner-occupiers of stand-alone houses serviced by overhead wires. Email invitations were sent to the 2,485 households that agreed to participate. 1,744 respondents completed the online questionnaire.

Three parts of the questionnaire are of particular interest. The first is a question about the specific benefits from undergrounding. Respondents were asked to select two of the following specific benefits in response to the question, '*What would be the two most significant benefits to your household from undergrounding?*'

- Improved appearance and unobstructed views
- Fewer power cuts
- Better safety, particularly during storms and bushfires
- Reduced tree trimming requirements and associated costs
- Fewer restrictions on use of yard space (eg for construction of a garage or swimming pool)
- Less need for ActewAGL to access your backyard
- Other (please specify below)

In the analysis herein, responses to this question are related to stated preferences, providing an indication of the relative value of the specific benefits.

The key part of the questionnaire in terms of valuation of overall household benefits is the stated preference component. Our approach is a hybrid of stated choice experiment (CE) (Louviere *et al.*, 2000) and dichotomous-choice contingent valuation (DCCV) (Carson and Mitchell, 1989) methods. Both methods use 'choice tasks' in which respondents are presented with one or more scenarios with specified cost and asked to state which scenario he/she prefers. Our survey is similar to a DCCV survey in that each choice task presents two scenarios – the current service scenario and an undergrounding scenario – where the price of the undergrounding scenario varies over choice tasks. The survey also has characteristics of a CE survey. The scenarios are described by multiple service attributes and the levels assigned to the attributes vary over choice tasks providing the variation necessary for estimation. Respondents' choices reveal their willingness to pay (WTP) for each service attribute and for undergrounding overall. Some 1,163 households responded to a single choice task (the *SB* format) and 292 households responded to a sequence of four choice tasks (the repeated binary, *RB*, format).[4] Data from questions subsequent to the first in the *RB* format were excluded from the analysis in this paper due to concerns over the response bias caused by information observed in previous choice tasks. For more detail the reader is referred to McNair *et al.* (2010). A further 82 choice observations were excluded from our models where respondents took less than five minutes to complete the survey. It was judged that these responses were

[4] A third format comprised a sequence of four choices between the current service and two undergrounding options. Data from this format is not analysed in this paper.

given without consideration (possibly randomly) solely as a means of qualifying for the prize draw participation incentive. The final data set comprised 1,373 binary choice observations.

Sixteen choice tasks were designed (an example is presented in Figure 1). The survey instrument was programmed to cycle through the choice tasks, ensuring approximately equal representation across choice observations. The scenarios were described in terms of the number and duration of planned and unplanned power cuts. Undergrounding scenarios included a one-off household contribution. Respondents were instructed that their contribution would be payable either up-front with a three per cent discount or in instalments for up to five years at an interest rate of 6.5 per cent. The levels assigned to the attributes are presented in Table 1. Of the specific benefits of undergrounding, only supply reliability could be included as a variable in the choice tasks. The other benefits of undergrounding are effectively embodied in the alternative label. To ensure the prominence of supply reliability benefits in choice tasks did not cause a disproportionate focus on this benefit, each choice task page included a reminder of the two most important benefits and the most important disadvantage of undergrounding selected by the respondent in earlier questions.[5]

[5] In the question about disadvantages of undergrounding, respondents were asked "*Other than cost, what would be the most significant disadvantage to your household?*" The options provided were: 'power cuts may be longer', 'inconvenience during undergrounding works', 'service pillar in front of property', and 'other (please specify below)'.

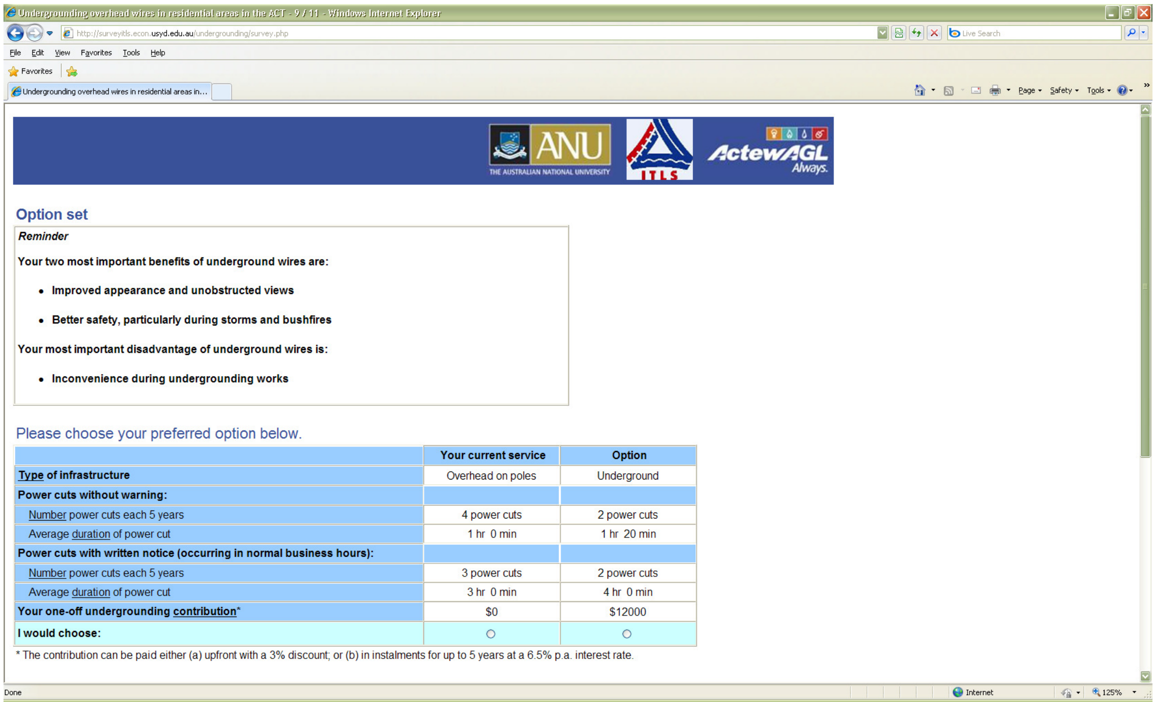
Table 1: Attributes and levels

Attribute	Levels	
	Current service (overhead) alternative	Undergrounding alternatives
Your one-off undergrounding contribution (AUD 2009)	0	1,000, 1,100, 2,000, 2,100, 2,800, 3,000, 3,900, 4,000, 6,000, 6,200, 8,000, 8,200, 11,800, 12,000, 15,900, 16,000
Power cuts without warning:		
Number of power cuts each five years	Set by respondent	Proportions of status quo level: 0.25, 0.5, 0.75, 1 [a,b]
Average duration of power cuts	Set by respondent	Proportions of status quo level: 0.33, 0.66, 1.33, 1.66 [a]
Power cuts with written notice (occurring in normal business hours):		
Number of power cuts each five years	Set by respondent	Proportions of status quo level: 0.2, 0.4, 0.6, 0.8 [a,b]
Average duration of power cuts	Set by respondent	Proportions of status quo level: 0.33, 0.66, 1.33, 1.66 [a]

[a] Rounded to the nearest integer; [b] Absolute levels (0, 1 and 2) were assigned where respondents chose very low status quo levels (1 or less).

The final part of the questionnaire comprised questions about the socio-demographic characteristics of the respondent and their household. In particular, questions related to the age, gender and education of the respondent, the number of persons in the household, the suburb location of the household and annual household income.

Figure 1: Example of a choice task



Option set

Reminder

Your two most important benefits of underground wires are:

- Improved appearance and unobstructed views
- Better safety, particularly during storms and bushfires

Your most important disadvantage of underground wires is:

- Inconvenience during undergrounding works

Please choose your preferred option below.

	Your current service	Option
Type of infrastructure	Overhead on poles	Underground
Power cuts without warning:		
Number power cuts each 5 years	4 power cuts	2 power cuts
Average duration of power cut	1 hr 0 min	1 hr 20 min
Power cuts with written notice (occurring in normal business hours):		
Number power cuts each 5 years	3 power cuts	2 power cuts
Average duration of power cut	3 hr 0 min	4 hr 0 min
Your one-off undergrounding contribution*	$0	$12000
I would choose:	○	○

* The contribution can be paid either (a) upfront with a 3% discount; or (b) in instalments for up to 5 years at a 6.5% p.a. interest rate.

IV The model

Respondents' choices were modelled with a standard binary logit model based on random utility theory (McFadden, 1974).[6] The utility, U, derived by a respondent from an alternative is a function of the attributes of the alternative, choice invariant characteristics

[6] Analysis is restricted to the standard binary logit model because models estimating heterogeneity in taste (RPL models), scale (scaled multinomial logit model) or both (generalised mixed logit model) across individuals are problematic when estimated on data with a single choice observation per respondent. Although these models can disentangle the Gumbel error distribution and the random parameter distributions when estimated on repeated choice data (Fosgerau and Nielsen, 2006), further work is required to establish whether this is true of models estimated on single binary choice data. Rose et al. (2009) found statistically insignificant random parameter estimates where data consisted of single choice observations per respondent in their study of the impact of the number of choice tasks per respondent.

(such as characteristics of the respondent) and a random element, ε. In any given choice task, respondents are assumed to choose the alternative that yields the highest utility. The outcome is an index of the observed choice, y. The utility that respondent i derives from alternative j in choice task t is $U_{ijt} = \alpha_{ij} + \beta'\mathbf{x}_{itj} + \varepsilon_{itj}$ where $\mathbf{x}_{itj}$ is a vector of observed variables, α_{ij} is the coefficient on a constant specific to undergrounding options, and β is a vector of coefficients to be estimated. The assumption that ε is independently and identically distributed according to the extreme value type I function gives the logit model form. In the models herein, all choice tasks comprise two alternatives and all observed variables are defined in such a way that $\mathbf{x}_{it} = 0$ in the current service alternative (j=1). This allows the choice probability function for respondent i in choice task t to be written:

$$\pi_{\text{it}} = \Pr\left(y_{it} = 1 \mid x_{it}, z_i\right) = \frac{\exp(\alpha_i + \beta' x_{it})}{1 + \exp(\alpha_i + \beta' x_{it})} \qquad (1)$$

where

α_i $= \alpha + \delta'\mathbf{z}_i$

δ = a vector of coefficients to be estimated

$\mathbf{z}_i$ = a vector of respondent characteristics (two separate vectors are considered: socio-demographic characteristics and the specific benefits identified as most significant by each respondent)

Household benefits are measured as the truncated expected willingness-to-pay (WTP) of the representative household - a Hicksian compensating measure of welfare change. It is calculated analytically as the area under the choice probability function truncated at the maximum cost level used in the survey ($16,000) with supply reliability variables set at their population means:[7]

$$E(WTP) = \int_0^{x_{\max}^{\cos t}} \overline{\pi}_{it} dx^{\cos t} = \int_0^{x_{\max}^{\cos t}} \frac{\exp(\overline{W}_{it})}{1+\exp(\overline{W}_{it})} dx^{\cos t} \qquad (2)$$

where

$$\overline{W}_{it} = \alpha_i + \beta' \overline{x} + \beta^{\cos t} x_{it}^{\cos t}$$

$\overline{x}$ = a vector of the means of supply reliability variables

Truncation at the maximum cost level used in the survey is typical in analysis of DCCV data. It accords with standard statistical practice of not extrapolating beyond the range of the data, and has desirable properties including consistency with theoretical constraints, statistical efficiency, and ability to be aggregated (Duffield and Patterson, 1991). However, it is important to note the implications of the approach. The effect in this case is to assign a WTP estimate of $16,000 to all respondents whose WTP is $16,000 *or more*. This results in an underestimate of the true mean WTP, but to an unknown extent.

Confidence intervals are generated using a bootstrapping procedure with 1,000 random draws from normal distributions for relevant parameters, with moments set at their coefficient point estimates and standard errors (Krinsky and Robb, 1986).

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[7] This is a measure of ‘total WTP’ in contrast to attribute-specific marginal WTP. The analytical calculation of the integral in Small and Rosen’s (1981) equation 5.5 is required as the log transformation on cost in our models prevents the use of the well-known explicit evaluation (Small and Rosen’s equation 5.9).

V Results

The estimation results are presented in Table 2. Model 1 includes the undergrounding-specific constant, the natural logarithm of the household contribution and the change in the various power supply reliability attributes between the current service and undergrounding alternatives. The log transformation of the cost variable is utilised because it results in a better model fit. The choice probability curve derived from Model 1, with supply reliability variables set at their population means, is presented in Figure 2. It shows that there is significant heterogeneity in WTP for undergrounding across the population. Approximately one quarter of households are not willing to pay $1,000 towards undergrounding in their suburb, while another quarter are willing to pay $16,000 or more. The truncated mean WTP is $6,838 with a 95 per cent confidence interval of $5,444 to $8,253. This is a conservative estimate of mean WTP since approximately one quarter of households have been assigned a WTP of $16,000 in the calculation when in fact their valuation may be higher. The true mean WTP is higher than $6,838, but to an unknown extent.[8] The median WTP, which may be important from a political perspective, is approximately $4,000.

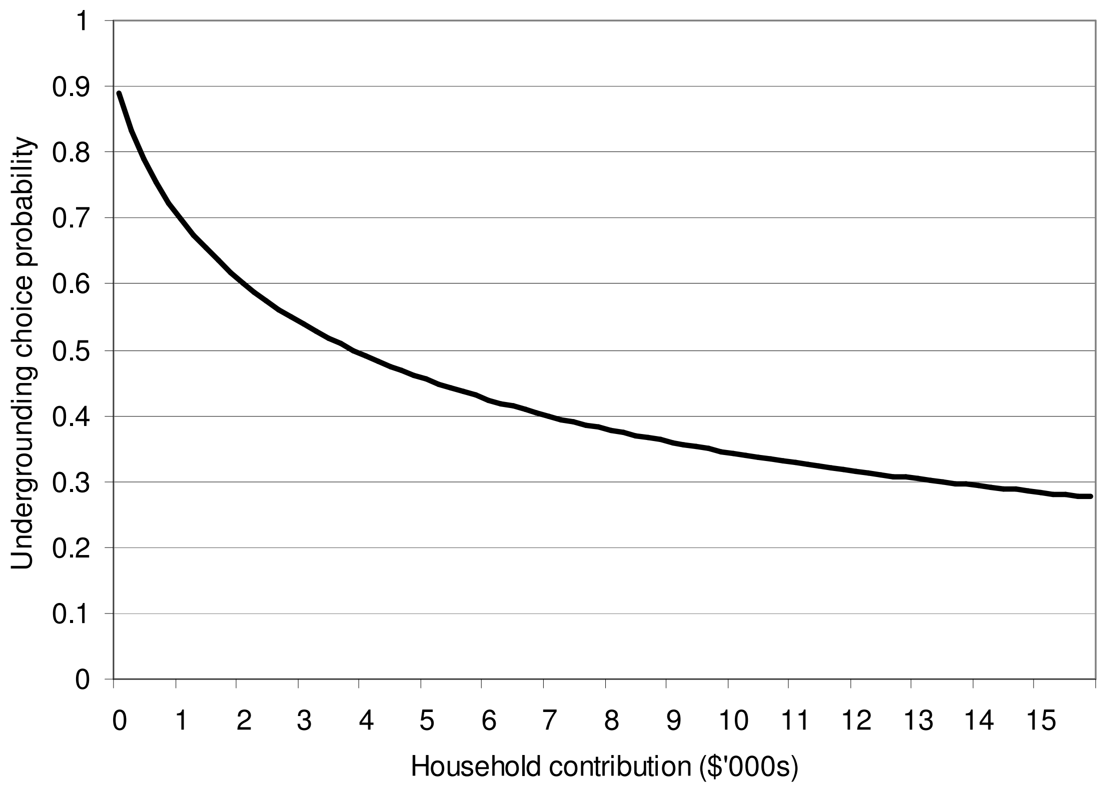
[8] A higher maximum cost level (or 'choke price') in the choice tasks would be required to resolve this uncertainty. The maximum level used in this survey, $16,000, was determined based on evidence of household WTP from pre-testing interviews. The proportion of respondents stating a willingness to pay this amount in the main survey was higher than anticipated. There is some debate as to how best to select this 'choke price' level given evidence suggesting that it affects stated preferences (Cooper and Loomis, 1992; Mørkbak *et al.*, 2010).

Table 2: Models of household choice between network scenarios

Variable	Model 1		Model 2		Model 3	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Undergrounding-specific constant	0.7476 ***	0.1335	0.6333***	0.1650	0.3212*	0.1831
Log of household contribution ($'000s)	-0.6944 ***	0.0706	-0.7407***	0.0728	-0.7363***	0.0740
Change in number of power cuts without warning each 5 years	-0.0691 *	0.0383	-0.0652*	0.0390	-0.0525	0.0397
Change in average duration of power cuts without warning each 5 years	-0.0016	0.0017	-0.0021	0.0017	-0.0017	0.0018
Change in number of power cuts with notice each 5 years	-0.1050 *	0.0538	-0.0921*	0.0542	-0.0973*	0.0520
Change in average duration of power cuts with notice each 5 years	-0.0004	0.0006	-0.0003	0.0006	-0.0005	0.0006
Interactions with undergrounding-specific constant:						
Age: 18-29			-0.0513	0.2648		
Age: 30-39			-0.2302	0.1456		
Age: 50-64			0.0905	0.1072		
Age: 65 and over			0.3145**	0.1452		
Household income: $18,199 or less			-1.4401***	0.5076		
Household income: $18,200 - $51,999			-0.1429	0.1864		
Household income: $52,000 - $88,399			0.0036	0.1480		
Household income: $88,400 - $129,999			0.3162**	0.1422		
Household income: $130,000 - $181,999			0.5444***	0.1564		
Household income: $182,000 or more			0.9787***	0.1970		
Benefits: Appearance and power cuts					1.0026***	0.3644
Benefits: Appearance and safety					0.9145***	0.1874
Benefits: Appearance and tree trimming					0.8710***	0.1928
Benefits: Appearance and yard space					0.9053***	0.2536
Benefits: Appearance and DNSP access					0.1898	0.3285
Benefits: Appearance and other					-0.0408	0.5292
Benefits: Power cuts and safety					-0.3641	0.2749
Benefits: Power cuts and tree trimming					-0.0938	0.4558
Benefits: Power cuts and yard space					-0.4181	1.2326
Benefits: Power cuts and DNSP access					-1.1155	1.0959
Benefits: Power cuts and other					-0.4081	1.1816
Benefits: Safety and tree trimming					0.7558***	0.2029
Benefits: Safety and yard space					0.8063***	0.2963
Benefits: Safety and other					-0.8147	0.5604
Benefits: Tree trimming and yard pace					0.8859***	0.2886
Benefits: Tree trimming and DNSP access					-0.4708	0.3084
Benefits: Tree trimming and other					-0.3658	0.6606
Benefits: Yard space and DNSP access					0.1058	0.4361
Benefits: Yard space and other					-0.5495	1.2186
Benefits: DNSP access and other					-1.5290**	0.7446
Model fit:						
Observations	1373		1373		1373	
Log-likelihood	891		867		844	
Information criterion AIC	1795		1765		1741	

*, ** and *** indicate statistical significance at the 0.1, 0.05 and 0.01 levels, respectively.

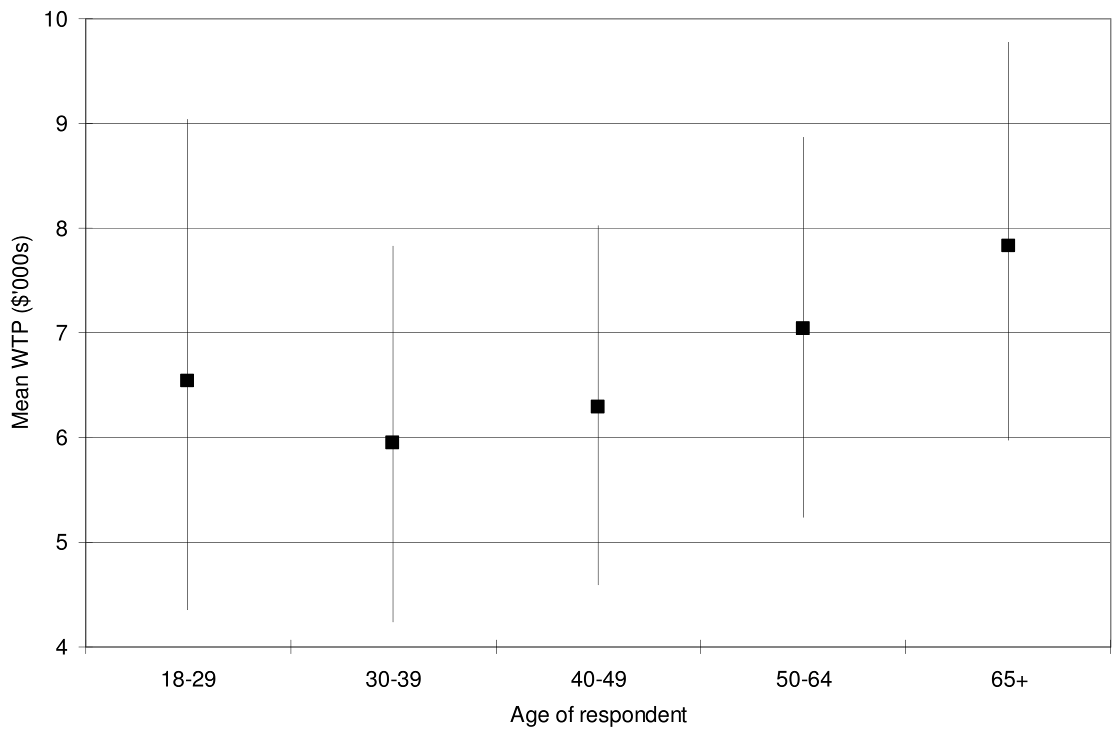
Figure 2: Estimated undergrounding choice probability curve



Model 2 incorporates effects-coded variables for household income and the age of the respondent.[9] Other socio-demographic characteristics, namely gender, education and household size were found to be statistically insignificant and omitted from the final model. Of the coefficient estimates on the age variables, the estimate for respondents over 65 years old is highest, indicating a stronger preference for undergrounding among that group (holding constant other variables, including income). Figure 3 confirms the point estimate of mean WTP is highest when evaluated for this age group.

[9] The variables are effects coded such that: each of the four age variables included in the model take the value -1 when age is 40-49; and, each of the six income variables included in the model take the value -1 when income is not provided.

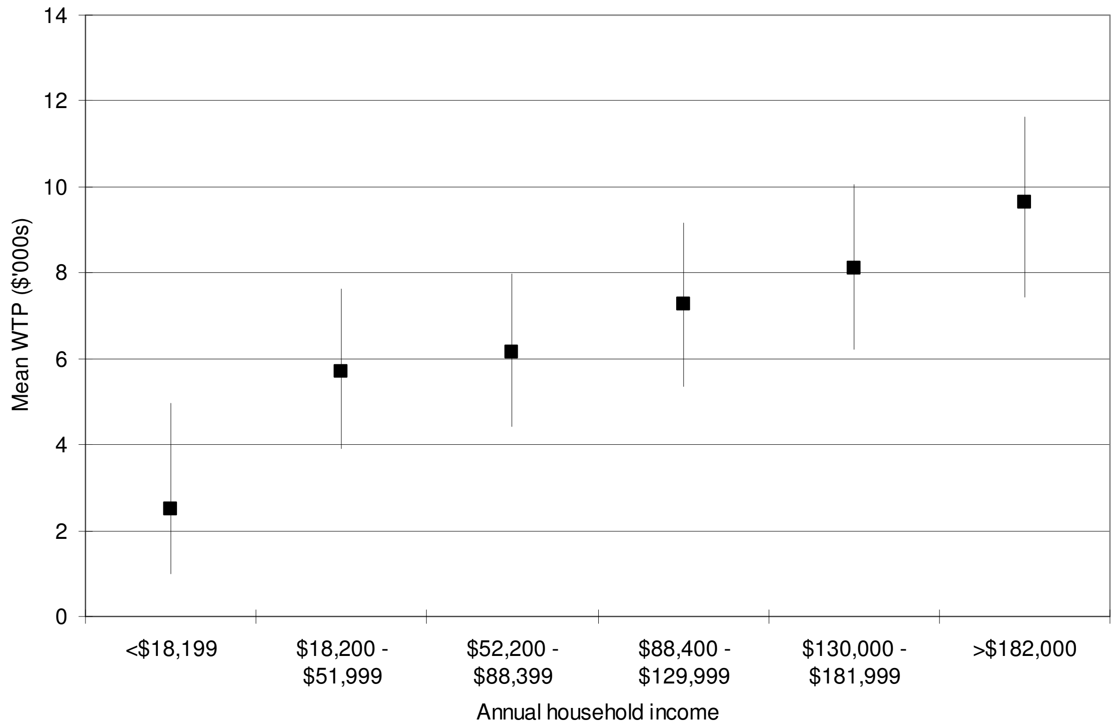
Figure 3: Willingness-to-pay by age (with 95 per cent confidence intervals)



Turning to the household income variables, the coefficient estimates are negative for lower income levels and positive for higher income levels, suggesting a positive relationship between income and WTP for undergrounding. Figure 4 confirms there is a strong relationship. The point estimate of mean WTP is less than $3,000 for the lowest income bracket. It rises with each successive income bracket to more than $9,000 for the highest bracket.

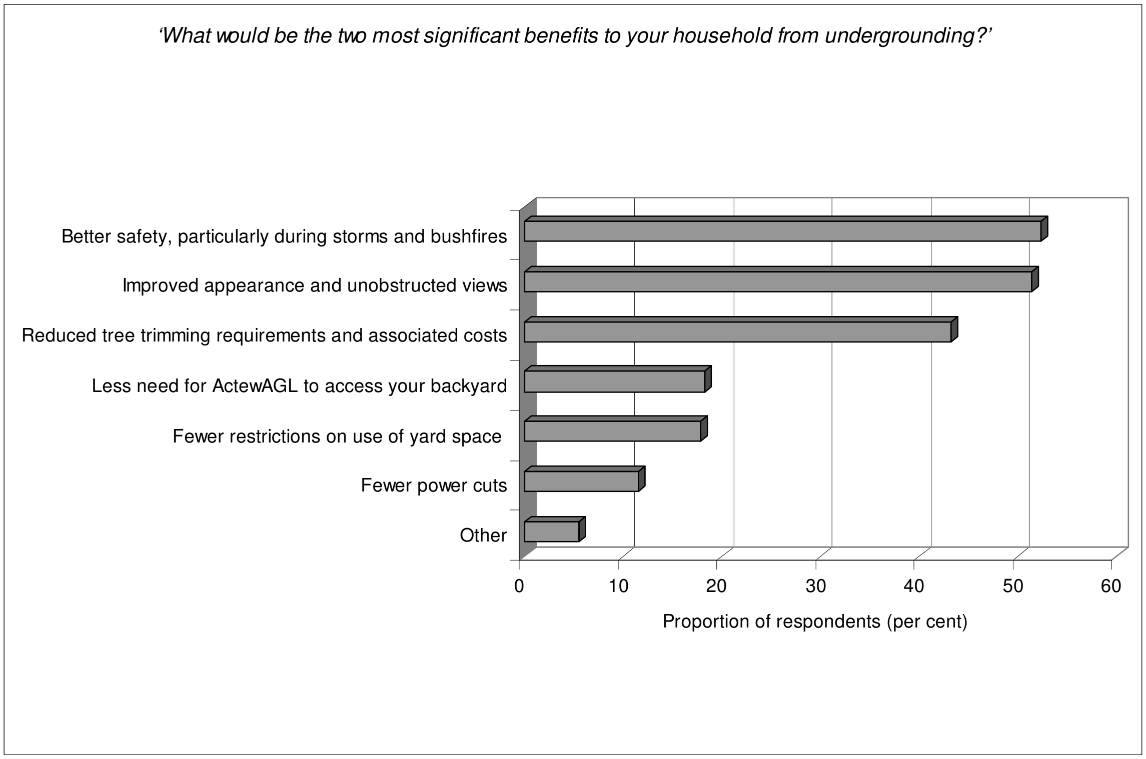
Response shares for the qualitative question about specific benefits are presented in Figure 5. Consistent with prior expectations, more than half of respondents indicated that improved appearance would be one of the two most significant benefits of undergrounding for their household. A similar proportion of respondents indicated that improved safety was a significant benefit, while just 12 per cent of respondents viewed a reduction in the frequency of power cuts as one of the most significant benefits to their household.

Figure 4: Willingness-to-pay by household income (with 95 per cent confidence intervals)



Model 3 includes effects-coded variables for the pairs of specific benefits chosen by the respondent in the qualitative question. The purpose of the model is to reveal whether there is a relationship between WTP and the specific benefits viewed as most significant by the respondent. While the simple response shares discussed above are useful information, they can be misleading. A specific benefit may be viewed as one of the most significant by a large number of respondents that place a low value on undergrounding. Conversely, a specific benefit may be significant to a small group of respondents that place a high value on undergrounding.

Figure 5: Specific benefits of undergrounding



Despite the large number of additional variables, the AIC model fit criterion is improved relative to Model 1, indicating a significant relationship between WTP for undergrounding and responses to the qualitative question about specific benefits. Estimates of mean WTP evaluated at each of the pairings of specific benefits are presented in Table 3. Although only 18 per cent of respondents indicated that fewer restrictions on use of yard space would be one of the most significant benefits, these respondents tended to place a higher-than-average value on undergrounding. Respondents indicating reduced need for network operator access to their yard, or some other (respondent-specified) benefit as one of the most significant benefits, tended to place a lower-than-average value on undergrounding.[10] All pairings of specific benefits from improved appearance, safety, tree trimming or use of yard space were associated with higher levels of WTP for undergrounding.

Table 3: Willingness-to-pay by pairings of specific benefits (AUD 2009)

	Appearance	Power cuts	Safety	Tree trimming	Yard space	DNSP access
Power cuts	8,469 [38] (5,350 - 11,529)					
Safety	8,172 [274] (5,995 - 10,378)	4,024 [86] (2,322 - 6,248)				
Tree trimming	8,016 [237] (5,818 - 10,243)	4,839 [22] (2,285 - 8,289)	7,602 [190] (5,388 - 9,906)			
Yard space	8,134 [92] (5,598 - 10,737)	4,473 [3] (502 - 12,224)	7,779 [59] (5,132 - 10,565)	8,062 [63] (5,398 - 10,826)		
DNSP access	5,674 [47] (3,293 - 8,547)	2,862 [6] (333 - 9,105)	4,289 [87] (2,506 - 6,570)	3,755 [68] (2,062 - 6,030)	5,435 [25] (2,730 - 8,895)	
Other	5,024 [17] (2,142 - 9,022)	4,456 [3] (555 - 11,979)	3,060 [22] (1,072 - 6,424)	4,187 [13] (1,344 - 8,806)	4,154 [3] (457 - 11,771)	1,897 [17] (418 - 5,253)

Note: 95 per cent confidence intervals in parentheses; number of choice observations in square brackets.

The few respondents who viewed a reduction in the frequency of power cuts as one of the most significant benefits from undergrounding exhibited below-average WTP for undergrounding. This result is consistent with the lack of statistical significance for coefficient estimates on the supply reliability attributes included in the choice tasks. Evidence from pre-testing interviews suggests this lack of WTP is due to the relatively high level of reliability of electricity supply from the current overhead service in Canberra.

[10] Some of the respondents selecting 'other' used the text field to indicate that they did not see any benefit in undergrounding or that only one specific benefit was important to them. Others used the field to express the view that the benefits are insufficient to justify the cost of undergrounding.

VI Conclusion

The evidence reported here suggests the value of household benefits from undergrounding electricity and telecommunications wires in Canberra would be at least $6,838 per property on average. This is a conservative estimate of average WTP calculated by assigning a WTP level of $16,000 to households indicating they would be WTP $16,000 *or more* for undergrounding in their suburb. There is significant heterogeneity in benefits across households with approximately one quarter of households falling into this category and another quarter of households not willing to pay $1,000 for undergrounding in their suburb. An undergrounding program would receive majority support across all areas currently serviced by overhead wires if the household contribution were $4,000 or less.

When compared to preferences revealed in the recent hedonic price study conducted in three Canberra suburbs (McNair, 2009), the preferences stated in this survey are broadly consistent. The key finding from the hedonic price study was that 31 per cent of households in the sample paid an estimated property price premium of approximately $11,700 for houses serviced by underground wires. In this study, an estimated 32 per cent of households across all suburbs with overhead wires would be willing to pay that amount or more for undergrounding in their suburb.

The key question from an economic evaluation perspective is whether the household benefit estimate exceeds the difference between the capital cost of undergrounding and the present value of ongoing cost savings to network businesses (including the avoided cost of an overhead roll-out of NBN infrastructure if applicable). This seems most plausible where capital costs are similar to those experienced in Perth of approximately $10,000 per property (Office of Energy, 2008). If capital costs exceed $20,000 per property as they have in South Australia (ETSA Utilities, 2009), then the economic viability of widespread undergrounding would depend on the avoided costs of an overhead NBN roll-out and wider community benefits.[11] Where widespread undergrounding is not justified, there may be merit in programs targeting particular areas where the costs and benefits are favourable. Evidence from this study suggests benefits would be highest in areas with higher household income and older residents where improved appearance, safety, tree trimming or restrictions on the use of yard space are of concern.[12]

Care should be taken when transferring this benefit estimate to other cities. In Canberra, most overhead electricity and telecommunications networks are reticulated along the rear boundary of properties rather than the much more common street verge reticulation. Electricity supply is relatively reliable and households are responsible for keeping trees clear of power lines. The value of amenity and supply reliability benefits may be higher in other cities, while the value of relaxing tree trimming requirements and restrictions on the use of yard space may be lower. Despite these limitations, the estimate derived from this study provides valuable information to policy-makers considering the economic

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[11] This study estimates the benefit to households from undergrounding in their own suburb. There may be further benefits to households from undergrounding in neighbouring suburbs and other parts of the city.

[12] This conclusion is drawn based on the economic efficiency criterion. The main role of distributional (equity) considerations will be in determining funding arrangements for undergrounding programs, but they may also affect decisions about where undergrounding should take place.

merits of undergrounding programs where little or no information was previously available.

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