Indicative costs for replacing SWER lines

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Department of Primary Industries

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V0_1	Draft	20 August	M Van Doornik
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Executive summary

The Department of Primary Industries (DPI) has engaged PB to provide indicative costs of distributing electricity to areas typically served by Single Wire Earth Return (SWER) using alternative designs to the current bare conductor system.

The alternative electricity distribution designs considered are:

- Bare conductor SWER. This is the standard system implemented around Victoria. This provides a base case for comparison to the alternative options.
- Covered conductor (CCT) SWER. This option involves the use of a single covered, rather than bare, conductor.
- Aerial Bundled Cable (ABC). This option involves the use of a three phase aerial bundled cable (rather than a two wire bundled cable).
- Underground cable. This option involves the use of a three phase cable directly buried in the ground with no extra mechanical protection.
- Remote Area Power Supplies (RAPS). These are generally a combination of renewable power, diesel generator and batteries supplying a single customer.

A number of design assumptions are made relating to a typical SWER system and each of the alternative electricity distribution designs. Costs were obtained from equipment suppliers, public information and PB databases. For each of the pole based options the costs of wood, steel and concrete pole construction are considered.

In preparing the costs of alternatives we focussed our effort on establishing the cost differential between SWER and its alternatives, rather than the absolute cost of SWER.

The costs of the options analysed, along with the advantages and disadvantages are shown in the following summary table. These costs represent the costs per kilometre to install the alternative designs in ideal conditions.

Summary of findings

Option	Cost per km			Advantages	Disadvantages
	Wood Poles	Steel Poles	Concrete Poles		
SWER	**$29,892**	**$32,076**	**$32,244**	Cheap and proven, limited capacity	Poor voltage regulation and exposed conductor

Summary of findings					
CCT	**$65,660**	**$70,106**	**$70,448**	Relatively cheap, higher capacity	Poor voltage regulation
ABC	**$119,703**	**$126,255**	**$126,759**	Good voltage regulation, higher capacity, 3 phase system	Expensive
Under-ground Cable	$168,240	n/a	n/a	More reliable than overhead systems, cheaper to maintain	Very expensive and more difficult to repair
RAPS	$16,700 per kW	n/a	n/a	Relatively environmentally friendly,	Require ongoing maintenance, limited size, effectiveness of renewable energy in Victoria, hazardous material stored on (domestic) sites in remote areas

In a typical situation where conditions are not ideal, the relative cost of the overhead line alternatives will change due to reduced span lengths. To examine the cost differential in a typical situation we developed a scenario involving the construction of a combination of span lengths. The results of this scenario are shown in the table below.

Overhead lines scenario summary

Construction type	Ave span	Max. span	Cost per km		
			Wood Pole	Concrete Pole	Steel Pole
SWER	205	380	$42,348	$46,170	$46,464
CCT	159	180	$69,095	$74,009	$74,387
ABC	115	120	$121,481	$128,267	$128,789

The analysis shows that SWER is the cheapest option followed by CCT, then ABC and finally underground cable. The difference between SWER, CCT and ABC is marginally greater when either concrete or wooden poles are used rather than wooden poles.

1. Introduction

Victoria has an extensive electricity distribution system that includes a proportion of Single Wire Earth Return (SWER). This SWER enables electricity to be distributed to lightly loaded rural areas in a cost efficient manner. The Department of Primary Industries (DPI) has engaged PB to provide indicative costs of distributing electricity to areas typically served by SWER using alternative designs to the current bare conductor system.

1.1 System description

SWER is a single phase electrical power distribution system. It uses an isolation transformer to separate it from the normal three phase distribution system and a single wire to transmit electricity to the customer. The earth is used as the return path to the transformer rather than using a second wire. This design involving a single pole-mounted conductor minimises the cost of electricity distribution.

A disadvantage of SWER is that it requires a good connection to ground, can have poor voltage regulation due to the high impedances of the types of conductors used and earth return path, and the amount of power that can be distributed is limited. Further, when a fault occurs such as when a conductor is broken by a falling tree, the conductor that falls to the ground is likely to remain 'live' for longer than a broken conductor in a typical distribution system that is not of a SWER design[1].

Typical component sizes are:

- 4/3/2.5 ACSR/AC line for highly loaded sections and 3/2.75 SC/GZ for lesser loaded sections and tee-offs.
- Isolation transformer sizes normally range from 25 kVA through to 1125kVA.
- Distribution transformers have typical sizes of 5 kVA up to 25 kVA.

[1] This is due to the high impedances which result in low currents that makes fault clearing times longer. Also, protection is normally based on over current protection since it can be difficult to detect ground faults due to the normal earth return path.

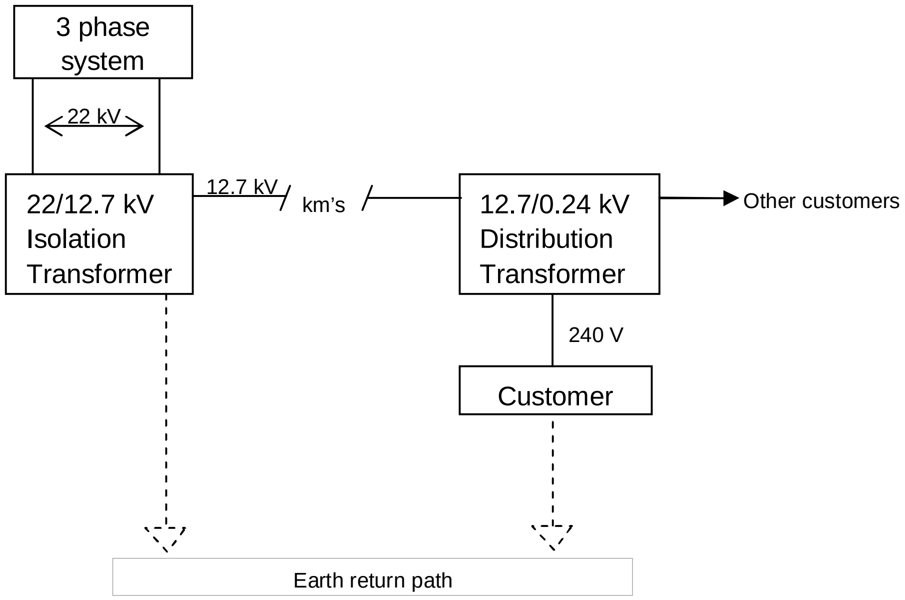

Figure 1.1 Representation of a SWER system

1.2 Methodology

PB has been asked to develop costs for, and provide a comparison between, SWER and alternative electricity distribution designs.

PB has developed the costs for each system from high level designs that were prepared to a level of detail sufficient to capture the system components that contribute significantly to the cost. These costs were compiled and compared to unit costs from other sources. Costs were obtained from vendors, from the Rawlinsons Australian Construction Handbook and from PB's internal database.

In preparing the costs of alternatives we focussed our effort on establishing the cost differential between SWER and its alternatives, rather than the absolute cost of SWER.

A number of assumptions are made to provide a clear basis for comparison between options. These assumptions ensure that the same criteria are applied to each option and, where relevant, Australian Standards have been incorporated. Any issues relating to the feasibility of the options are discussed in the relevant sections.

The following sections define the options PB considered, the scenarios in which they are considered and the overall assumptions.

1.2.1 Replacement options

The DPI has requested the costs of four specific options. The capacity of each option has been designed to be as similar to SWER as possible to make sure it is a 'like for like' comparison. These options have been defined as:

- Bare conductor SWER. This is the standard system implemented around Victoria and is costed using the same method and information that is used to cost the alternative options. This provides a base case for comparison to the alternative options.

- Covered conductor SWER. This option involves the use of a single covered, rather than bare, conductor.
- Aerial Bundled Cable (ABC). This option involves the use of a three phase aerial bundled cable (rather than a two wire bundled cable). The bundled cable design incorporates a cable comprising three single phase cables twisted around a catenary wire.
- Underground cable. This option involves the use of a three phase cable directly buried in the ground with no extra mechanical protection. (Although it is likely to be technically feasible to use a single phase cable with an earth return path similar to the functioning of SWER, to the best of PB's knowledge this has not been implemented in practice and therefore we have selected a three phase cable for this option.)
- Remote Area Power Supplies (RAPS). These are generally a combination of renewable power, diesel generator and batteries sized to supply power to a single customer. The RAPS systems are installed at the customers' location and are not connected to the electricity grid.

1.2.2 Terrain

Two terrain scenarios are considered. These are:

Flat terrain – low cost environment

This scenario comprises flat land without any major obstacles to overhead line or underground cable routes. It is also assumed that there is easy access throughout the route for machinery required for construction. Further, it is assumed that there are very minor underground obstacles (such as rocks) for the buried cable.

Hilly terrain – high cost environment

This scenario comprises hilly and rocky terrain which will create obstacles to overhead lines and underground cables. The terrain will force the different design options considered to take different routes according to physical properties. The terrain is assumed to have difficult access for machinery required for construction.

In this report PB has only included a qualitative assessment of the additional costs associated with hilly terrain.

1.2.3 Assumptions

PB has made assumptions based on knowledge from line design experience and publicly available sources. These assumptions cover the typical topology of the SWER system including line lengths and loads. A detailed list of the general assumptions made by PB is included in section 2.3 and assumptions specific to each option are discussed as part of that specific case.

2. Cost components

In this section we outline the technical considerations, provide detail of the typical components of SWER and alternative designs (including component costs), and detail the assumptions made for each of the alternatives.

2.1 Technical considerations

2.1.1 Calculations

To determine the costs of the SWER and the proposed alternatives, it is necessary to calculate some technical aspects. In particular the calculation of the span length for overhead lines is important as this length has the greatest affect on the cost.

We have not calculated the voltage drop or the impact on voltage of voltage correction equipment although we have included some discussion of this aspect of line design in the discussion of the options.

2.1.2 Span length

The distance between two poles (span length) for any particular conductor is limited by the physical characteristics of the conductor, including mass and the maximum working tension (how tightly the conductor can be pulled). The conductor forms a catenary between the two poles that is approximately parabolic in shape. The lowest point of the conductor (bottom of the parabola) must comply with the minimum clearances from ground as set out in Australian Standards.

Two notable effects are that a heavier conductor will have a shorter maximum span length (if other constraints such as pole height remain constant), and when traversing an inclined route the span length is required to be shorter in order to maintain the required clearance from ground.

2.2 Typical components

A 12.5m wooden pole rated to 8kN is representative of the type used in rural Victoria. Concrete poles and steel poles have been considered to demonstrate a comparison in costs even though they are not widely used in rural areas.

The following conductors have been costed. The conductors are standard products with a capacity the most similar to current typical Victorian SWER designs.

Table 1 Conductors (excluding installation)

Conductor prices		
Item description	Abbreviated code	Cost ($AUD) per metre
Aluminium clad steel reinforced	ASCR	$ 7.50
Galvanised steel	SC/GZ	$ 2.50
Covered conductor	CCT	$ 12.50
Aerial Bundled Cable	ABC	$ 27.50
Underground cable	35mm2 Al	$ 32.40

Pole costs are shown in the following table. The costs presented have been built up from 'first principles' and have been compared to other compiled costs to verify the accuracy of the "built up" costs. We have considered three general pole types. These are:

- Intermediate pole. This type of pole is used where the conductor travels in a straight line. It only has a single insulator on the top of the pole to which the conductor is connected. The pole is not designed to withstand any significant tensions.
- Strain pole. This type of pole is used where the conductor changes direction. The conductor is attached to the pole using a strain assembly. The pole will normally be under significant tension in one direction and a stay is used to counteract this tension.
- ABC poles. The use of covered conductors and ABC requires specialised attachments which connect the catenary wire to the post and protect the cable insulation from rubbing against the pole. These attachments are used for both intermediate and strain poles.

Table 2 Pole Costs (excluding installation)

Typical pole costs			
	Wood Pole	Concrete Pole	Steel Pole
Item description		Cost ($AUD)	
SWER Intermediate Pole	**$ 750**	**$ 1,400**	**$ 1,450**
SWER Strain Pole	**$ 1,100**	**$ 1,750**	**$ 1,800**
CCT Intermediate Pole	**$ 770**	**$ 1,420**	**$ 1,470**
CCT Strain Pole	**$ 1,210**	**$ 1,860**	**$ 1,910**
ABC Intermediate Pole	**$ 940**	**$ 1,590**	**$ 1,640**
ABC Intermediate Pole	**$ 1,385**	**$ 2,035**	**$ 2,085**

2.3 Assumptions

A number of assumptions have been made in this comparison. These assumptions are necessary to simplify the calculations and to ensure that costs are comparable. The assumptions are based on both our electricity design experience and from publicly available sources. These assumptions cover the typical topology of the SWER system including line lengths and loads.

2.3.1 General

- Costs of isolation and distribution transformers are ignored as transformer costs will be similar for each scenario and are not likely to be a significant factor in cost differential between options.
- All values used are in real 2009 dollars ($AUD). Where necessary costs were escalated using CPI.
- There is no consideration given to possible future effects of the change in foreign exchange rates or changes in commodities prices.
- All costs are exclusive of GST.
- The cost for each option has been based on a new installation. There is no consideration given to re-use or decommissioning of existing infrastructure.
- The length of an average SWER line route is 10 km.
- The alternate arrangements use standard equipment that is as similar as possible (but not identical) to the capacity of the SWER system.

2.3.2 Overhead conductors

- Actual line length is assumed to be the same as the span length as the additional line due to the catenary effect is negligible.
- 20% of poles are strain poles for all overhead line systems.
- Cost of installation of conductor is equal to the cost of the conductor.
- All pole have the same installation cost.
- All pole costs include delivery to the centre of Melbourne.
- Wind loads are ignored.
- Voltage correction/regulation equipment is not considered.

2.3.3 Underground conductors

- De-rating of the cable capacity due to ground conditions and cable configurations is not considered.
- The route taken is exactly the same as for the overhead line on flat terrain, but is different in hilly terrain due the ground contours.
- Trenches are no deeper than 1m.
- Land is required to be cleared 10m wide for vehicle access.
- Cable joints are included in labour cost.

3. Options

This section uses the information presented in Section 2 to calculate the costs of the individual options based on the average route length of 10 km. The results are then shown on a per kilometre basis. The standard bare conductor SWER system has been used as the basis for comparison of all the options.

Flat terrain with light bush is a typical ideal terrain for SWER. This has been selected to demonstrate the comparative costs with all systems in their best possible configuration using the maximum span length.

SWER is known to have voltage regulation problems due to the high impedance of the steel conductor and earth return path. To correct this voltage regulators are used. A voltage regulator that can be controlled locally by inbuilt electronics and can correct for +/-10% changes in the voltage will cost approximately $18k per single phase unit. These have not been included in this study as many SWER lines do not require a voltage regulator and the need for a voltage regulator is based on individual system characteristics and studies.

3.1 SWER

The cost of SWER is shown below in Table 3 as a baseline cost for comparison of the alternative options.

Flat terrain

Two conductor types are used in a typical SWER system. ACSR is used where a higher capacity is required and SC/GZ is used where there is low loading and for most tee-offs. Specific assumptions made relating to SWER are:

- The cost of the system is based on a 50% split between ASCR/AC and SC/GZ to account for the mix between high and low capacity sections
- Maximum span length is 380m for both ASCR/AC and SC/GZ

Table 3 shows the costs of a basic SWER system for flat terrain.

Table 3 SWER costs

SWER summary and costs								
Item description	**Unit**	**Amount**	**Cost**					
			Wood Pole		**Concrete Pole**		**Steel Pole**	
Length of conductor	m	10,000	$	50,000	$	50,000	$	50,000
Number of intermediate poles	ea	22	$	16,500	$	30,800	$	31,900
Number of strain poles	ea	6	$	6,600	$	10,500	$	10,800
Stringing conductor	m	10,000	$	50,000	$	50,000	$	50,000
Pole installation (total)	lot	n/a	$	118,000	$	118,000	$	118,000

SWER summary and costs								
Clearing land (10m wide through light bush)	m	$0.80	$	8,000	$	8,000	$	8,000
Project management and design (20%)	lot	n/a	$	49,820	$	53,460	$	53,740
Subtotal (for 10,000m)			$	298,920	$	320,760	$	322,440
TOTAL PER KM			**$**	**29,892**	**$**	**32,076**	**$**	**32,244**

It is important to note that this is the cost for the ideal conditions for SWER as the cost assumes that all spans are the maximum length. The cost is therefore not typical of the cost of a 10 km section of SWER. However, we have presented costs in this way to show a direct comparison between SWER and other options in ideal conditions. A scenario showing the typical cost of a section of line is shown in Section 3.4.

Hilly terrain

The cost in this scenario is extremely dependant upon the actual contours of the terrain. Economies can be achieved through certain strategies such as spanning from the summit of one hill to another. Alternatively, extra poles may be required when going up or down a large hill to maintain the required clearance from the ground.

Due to the number of possible variations and without a specific route profile, too many assumptions are required to make a meaningful quantitative analysis. Due to this PB will only qualitatively discuss this terrain profile and its effect on the cost of each option.

3.2 Covered conductor SWER

The option shows the cost of a SWER system design that utilises a covered conductor (CCT). A covered conductor insulates the conductor from external contact from items such as branches and birds. This option is a SWER design and therefore involves the use of an earth return. The option will have similar voltage regulation issues to those of a standard SWER system.

The conductor selected by PB comprises a heavy duty outer sheath which can remain in contact with objects such as vegetation for extended periods of time. The connection to the pole does not expose the cable and specialised connectors are used to pierce the insulation for any tee-offs, such as for distribution transformers. This design minimises the amount of exposed conductor and will therefore reduce the risk of fire compared to exposed conductor SWER. If the conductor covering is worn or broken, then the risk of a fault will increase depending on the amount of conductor exposed and the type of object that may come into contact with the exposed conductor.

Flat terrain

We have selected a covered conductor that is currently commercially available. This covered conductor is an aluminium alloy that has a higher capacity than standard SWER but a lower breaking tension. Combined with the extra weight of the insulation the maximum span length is significantly reduced compared to uncovered SWER. Specific assumptions made for this option are:

- Maximum span length is 180m for CCT

It can be seen from Table 4, that the reduced span length results in twice the number of poles. This adds significantly to the cost.

A second conductor could be used for the earth return to improve the voltage regulation and protection issues however, this would further increase the cost of the option.

Table 4 Covered conductor SWER costs

CCT summary and costs								
Item description	**Unit**	**Amount**	**Cost**					
			Wood Pole		**Concrete Pole**		**Steel Pole**	
Length of conductor	m	10,000	$	125,000	$	125,000	$	125,000
Number of intermediate poles	ea	45	$	34,650	$	63,900	$	66,150
Number of strain poles	ea	12	$	14,520	$	22,320	$	22,920
Stringing conductor	m	10,000	$	125,000	$	125,000	$	125,000
Pole installation (total)	lot	n/a	$	240,000	$	240,000	$	240,000
Clearing land (10m wide through light bush)	m	$0.80	$	8,000	$	8,000	$	8,000
Project management and design (20%)	lot	n/a	$	109,434	$	116,844	$	117,414
Subtotal (for 10,000m)			$	656,604	$	701,064	$	704,484
TOTAL PER KM			**$**	**65,660**	**$**	**70,106**	**$**	**70,448**

Hilly terrain

The cost in this scenario is extremely dependant upon the actual contours of the terrain the same as for bare conductor SWER. However, the catenary between poles will be much more pronounced than for SWER and this will limit the maximum span due to clearance from the ground as required by Australian Standards. Due to this the actual route will probably be forced to follow the contours of the land more closely than for SWER resulting in the use of more poles.

3.3 Aerial bundled cable

The cost of Aerial Bundled Cable (ABC) is shown in this section. There is no specific cable currently available from an Australian supplier for two-phase HV ABC, so we have selected three-phase ABC. It should be noted that this is also an upgrade rather than a ‘like for like’ replacement. The three phase system will not experience the same voltage regulation or protection issues that are seen with single wire systems.

ABC is connected to the pole top in a different manner to the options already considered. The catenary wire is used to string the cable between the poles and takes all the tension. The ABC is hung on the catenary wire and is not placed under any tension. This design means that the ABC requires extra connections at the pole top to hold the cable as it passes the pole.

The ABC comprises a heavy duty outer sheath which can remain in contact with objects such as vegetation for extended periods of time.

Flat terrain

ABC is also an aluminium alloy conductor and it has a higher capacity than standard SWER. The catenary wire is also an aluminium alloy (although a SC/GZ conductor is available for larger cables) and this has a lower breaking tension. Combined with the extra weight of the extra cables and insulation the maximum span length is significantly reduced compared to SWER and CCT. Specific assumptions made that concern SWER are:

- Maximum span length is 120m for ABC

Table 5 shows that the ABC cable is much more expensive than either SWER or CCT and the shorter span length means more poles are required and this further increases the costs. It is important to note that the poles top connections are more complicated than for SWER and this also makes each pole slightly more expensive.

Hilly terrain

This will have the same effect as for CCT, however, it would be expected to be more pronounced and the route would probably be required to follow the contours of the terrain quite closely. This would mean more conductor and poles would be needed and the actual line length will become much greater than the route length.

Table 5 Aerial bundled cable costs

CCT summary and costs					
Item description	**Unit**	**Amount**	**Cost**		
			Wood Pole	**Concrete Pole**	**Steel Pole**
Length of conductor	m	10,000	$ 275,000	$ 275,000	$ 275,000
Number of intermediate poles	ea	67	$ 62,980	$ 106,530	$ 109,880
Number of strain poles	ea	17	$ 23,545	$ 34,595	$ 35,445
Stringing conductor	m	10,000	$ 275,000	$ 275,000	$ 275,000
Pole installation (total)	lot	n/a	$ 353,000	$ 353,000	$ 353,000
Clearing land (10m wide through light bush)	m	$0.80	$ 8,000	$ 8,000	$ 8,000
Project management and design (20%)	lot	n/a	$ 199,505	$ 210,425	$ 211,265
Subtotal (for 10,000m)			$ 1,197,030	$ 1,262,550	$ 1,267,590
TOTAL PER KM			**$ 119,703**	**$ 126,255**	**$ 126,759**

3.4 Overhead lines scenario

The analysis in Sections 3.1 to 3.3 above has assumed ideal conditions for all conductors. However, in practice the average length of an overhead line span is shorter that the maximum span. The average span is shorter than the maximum span because a typical line comprises many spans that are shorter than the maximum. These spans are shorter because the terrain and other obstacles such as roads, limit both the number of feasible pole sites and the necessary line clearances.

To calculate the potential cost of a line with a shorter average span we developed a hypothetical scenario where a combination of different span lengths is adopted for each conductor type. This hypothetical scenario is intended to model the typical cost of an average kilometre of line, rather than ideal costs presented in Sections 3.1 to 3.3 above. This scenario includes a number of spans at the maximum SWER length of 380 metres, a number of spans at 180 metres and other shorter spans. Where a particular construction type is not capable of reaching the span lengths adopted in our scenario, we added spans at the maximum span length for that construction type.

The results of this scenario modelling are shown in Table 6. As expected, the average cost per kilometre increases for every construction type due to the additional number of poles required. However, the construction types with shorter maximum spans (such as ABC) increase less (proportionally) than the construction types with longer maximum spans.

Table 6 Overhead lines scenario summary

Overhead lines scenario summary								
Construction type	Ave span	Max. span	Cost per km					
			Wood Pole		Concrete Pole		Steel Pole	
SWER	205	380	$	42,348	$	46,170	$	46,464
CCT	159	180	$	69,095	$	74,009	$	74,387
ABC	115	120	$	121,481	$	128,267	$	128,789

3.5 Underground cable

The cost of underground cable is presented in this section. We have selected a three-phase cable to give a direct comparison to the ABC option presented in section 3.3 (and because two-phase HV cable is not common). This option is an upgrade to the SWER system rather than a 'like for like' replacement.

Flat terrain

Table 7 shows that underground cable is much more expensive than any of the other options. This is mainly attributable to the cost of the cable, however, installation is also much more expensive as a trench must be dug the complete length of the route. Higher voltage cables also require a specialised technician to make the joints in the cable which further increases the cost of installation and maintenance.

Table 7 Underground cable summary

Underground cable summary and costs				
Item description	Unit	Amount	Cost	
Length of conductor	m	10,000	$	324,000
Trenching	m	10,000	$	520,000
Clearing land (10m wide through light bush)	m	10,000	$	8,000
Labour (laying cable and jointing)	m	10,000	$	550,000
Project management and design (20%)	lot	n/a	$	280,400
Subtotal (for 10,000m)			$	1,682,400

Underground cable summary and costs		
TOTAL PER KM	**$**	**168,240**

Hilly terrain

Installation of underground cable in hilly and rocky terrain is much more expensive than the other options examined. There are several reasons for this:

- The cable will be required to follow the contours of the land whereas the overhead lines are able to span across valleys. This increases the length of the cable required to be purchased and installed.
- The cost of installation will be higher due to objects in the ground such as rock. These objects would have to be either removed or cut through to complete the installation. Trenching could be up to 3 times more expensive.
- Some obstacles such as valleys or cliffs cannot be traversed by cable resulting in a need to change (increase) the route.

This highlights that, although using underground cable in some areas may be very advantageous, it is not necessarily beneficial when the route involves long stretches through difficult terrain.

Other issues

Other relevant issues that affect underground cables include:

- The thermal properties of cables have been purposefully ignored (as stated in the assumptions). In practice the thermal properties of the ground and the effect on cables can make a big difference to the required cable size and therefore cost.
- The cost of maintenance or repair of a cable is generally much greater than an overhead line as the cable needs to be dug up.
- The time taken to repair cable faults is generally greater than overhead lines as locating faults is more difficult and repairs are generally more complex than repairs to overhead systems.
- Cables are less susceptible to external damage from events including lightning, impact from tree branches and bushfires.

3.6 Remote area power supplies

The costs of Remote Area Power Supplies (RAPS) are discussed in this section.

These systems are normally a combination of a solar energy (although other renewable source are also used such as wind or mini-hydro), a battery system and a diesel generator. Depending on the system set-up the generator can be used either as a main power source or infrequently as a back up. The difference is the additional cost of fuel consumption or capital cost of the additional renewable energy equipment.

RAPS systems of up to 10 kW are normally sized to suit the load of a single customer such as a remote domestic house or farm. When installing a RAPS system it is usual to consider the energy efficiency of the house and improve energy uses including using gas cooking, solar hot water systems or wood fire heating to reduce the reliance on electricity.

There are issues with these systems that lead to ongoing operational costs. These can include:

- Maintenance is required for all main components
- Fuel transport and storage
- Environmental conditions have a major impact on efficiency and performance of the renewable energy sources and may even rule out certain options
- Inefficient renewable energy sources can lead to reliance on the diesel generator and increased operational expenses due to diesel fuel consumption
- Smaller systems typically have higher fuel consumption per kW than larger systems
- The batteries need to be maintained and periodically replaced

A risk associated with RAPS is the storage of flammable and hazardous materials, such as diesel and acid, on remote sites. These materials may pose a fire hazard.

Table 8 shows a summary of the capital cost of installation of a selection of systems. This table does not include the operational costs which include the diesel fuel for the generator.

Table 8 Remote area power supplies summary

RAPS summary and costs	
Item description	**Cost/kW**
Solar Photovoltaic and diesel generator (average of 1 kW to 5 kW systems)	$22,000
Mini hydro and diesel generator (1.8 kW system case study)	$10,000
Wind turbine and diesel generator (average of 1 kW to 5 kW systems)	$18,000
Average cost per kilowatt	**$16,700**

4. Summary of options

Table 9 shows the relative costs of each option that has been reviewed by PB.

Table 9 Summary of flat terrain options

Summary of findings					
Option	Cost per km			Advantages	Disadvantages
	Wood Poles	Steel Poles	Concrete Poles		
SWER	**$29,892**	**$32,076**	**$32,244**	Cheap and proven, limited capacity	Poor voltage regulation and exposed conductor
CCT	**$65,660**	**$70,106**	**$70,448**	Relatively cheap, higher capacity	Poor voltage regulation
ABC	**$119,703**	**$126,255**	**$126,759**	Good voltage regulation, higher capacity, 3 phase system	Expensive
Under-ground Cable	$168,240	n/a	n/a	More reliable than overhead systems, cheaper to maintain	Very expensive and more difficult to repair
RAPS	$16,700 per kW	n/a	n/a	Relatively environmentally friendly,	Require ongoing maintenance, limited size, effectiveness of renewable energy in Victoria, hazardous material stored on (domestic) sites in remote areas

This shows that SWER is the cheapest option followed by CCT, then ABC and finally underground cable. The difference between SWER, CCT and ABC is marginally greater when either concrete or wooden poles are used rather than wooden poles.

Hilly terrain

Hilly terrain is likely to have the effect of increasing the difference between the costs of the different options. The more closely the conductor must follow the contours of the land, the greater the length of conductor required and the greater the installation costs.

4.1.1 RAPS option comparison

It is difficult to compare RAPS to a distribution line as there are many factors that affect its viability. For example, a relatively high density of customers will increase the cost of using RAPS as each customer will have a RAPS system. Conversely, a low customer density combined with a long distance from established electricity distribution infrastructure will make the use of RAPS more attractive. It is necessary to consider RAPS on a case by case basis to make a valid comparison.

A more meaningful method of comparing the cost of RAPS might be to calculate the NPV of a RAPS system over a long-term and then calculate the length of a dedicated SWER line with an equivalent NPV.

This would provide the “break even” point between RAPS and SWER. We have not undertaken this analysis as the calculation is beyond the scope of this report on indicative costs.