ATTACHMENT B17.1

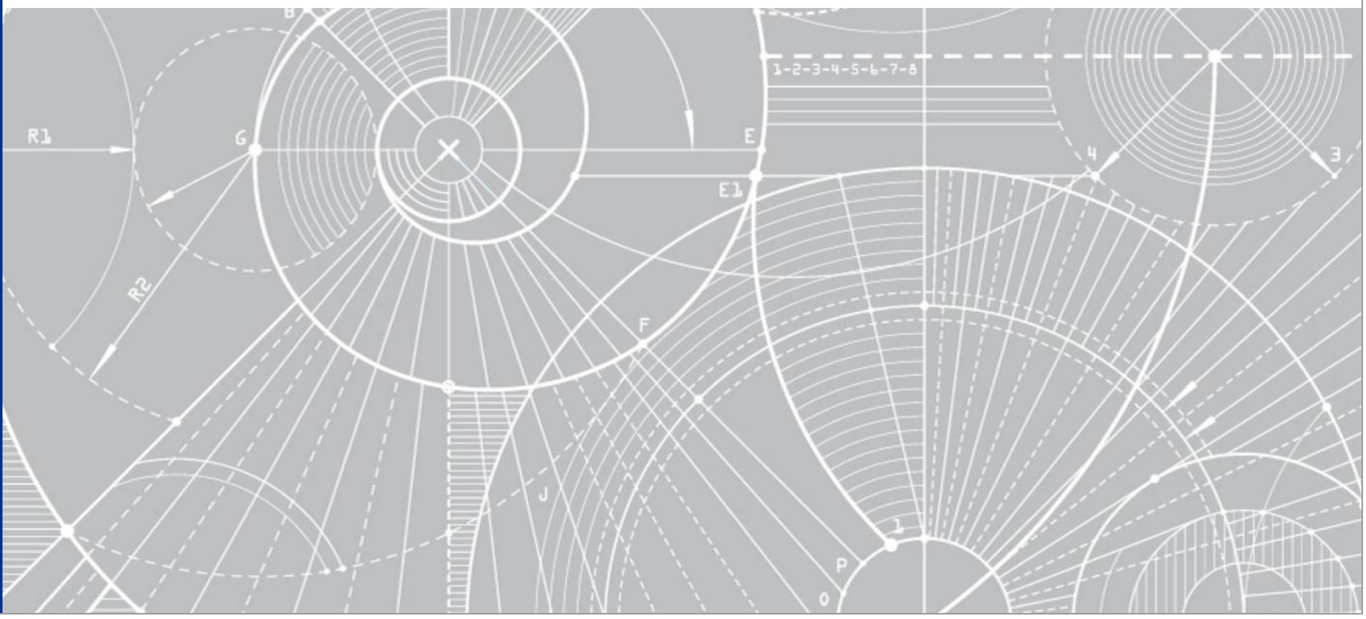
Regulatory Submission Support - Phase 3

ACTEWAGL

CAPEX/OPEX Trade-off Issues

QH10545RP0004 | B

26 May 2014



JACOBS SKM

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Revision	Date	Description	By	Review	Approved
A	11.04.2014	Working draft for client comment	M.Farr/C.Jones	J.Butler	J.Butler
B	26.05.2014	Final. Includes client feedback	M Farr/C Jones	J Butler	J Butler

Contents

Executive summary

Energy at risk modelling (EaR)

- ActewAGL has available to it sophisticated energy at risk modelling to evaluate the full community cost of unreliability, particularly associated with ageing and potentially unreliable critical assets such as power transformers and high voltage switchgear.
- The modelling was applied to determine the optimum timing of the replacement of an ageing 11kV switchboard at Civic zone substation during the 2009-14 regulatory period.
- The model could be applied to similar replacement / refurbishment studies in the future.

Poles

- ActewAGL has been both efficient and prudent in its management of wood pole replacements. ActewAGL has:
  - Developed and implemented strategies to extend the life of wood poles
  - Determined economic strategies for replacing pole top assemblies (verses replacing whole of pole structures)
  - investigated, sourced and implemented innovative pole replacement assets unique in Australia, necessitated as a result of the legacy network that ActewAGL inherited which is dominated by back of block overhead reticulation which prevents heavy vehicle access for poles replacement
- The replacement poles now used by ActewAGL have a demonstrably lower whole of life asset cost, and are safer in the rear of block reticulation situations due the their lighter weight and isolative properties.

Underground cables

- ActewAGL has an aged and growing underground distribution network. 15% of the underground cables have exceeded their average service life and an additional 11% will exceeded their average service life in the next 10 years. These aged cables are failing at an increasing rate.
- To address this trend ActewAGL has been both efficient and prudent in developing an asset management strategy which involves the initiation of a condition monitoring regime of high voltage underground cables and prioritisation of the high voltage underground cable replacement with suspected problems.

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1. Overall impact of an ageing distribution system

1.1 Introduction

A key element of the management of the diverse range of assets on an electricity distribution system is to have a comprehensive asset database with effective condition monitoring capability, and the functionality to accurately model forecast replacement and refurbishment costs.

With the implementation of the RIVA system, ActewAGL now has such a database, and the analytical capability to manage and model forward forecasts of replacement / refurbishment CAPEX, and future trends in OPEX.

In addition to RIVA, ActewAGL also uses a number of sophisticated modelling tools to analyse capital and operating expenditure trends for various asset categories to ensure that total forecast costs (capital and operating) are minimised. This involves consideration of the likely future trend in maintenance costs as the system assets age, and condition deteriorates, together with the risks and costs associated with a certain percentage of in-service asset failures.

This analysis of total asset costs (CAPEX and OPEX) underpins the whole concept of the RIVA system, and is often given the rather simplistic term of "CAPEX/OPEX trade-off"

Over the past 5 years ActewAGL has further developed it's suite of CAPEX/OPEX trade-off tools, and presents the results of some case studies which used these tools to make key investment decisions during the 2009-14 regulatory period. Some of these investment decisions have a flow-on effect into the 2014-19 regulatory periods.

Since the 2009-14 regulatory proposal, ActewAGL has implemented and populated its new RIVA system which offers far more powerful recording, analytical, and forecasting tools than it has had at its disposal in the past. However, RIVA will not replace these CAPEX/OPEX optimisation modelling tools, and ActewAGL continues to develop and enhance the application of such tools for optimisation purposes.

The three case studies presented below are examples of such applications:

- Replacement of critical ageing assets – Civic 11kV zone switchboard
- Wood pole replacement with concrete and fibreglass
- Underground distribution cable replacement

1.2 Asset age and replacement/refurbishment modelling

In its 2009-14 regulatory proposal (section 6.7) ActewAGL provided an overview of the asset age profiling and the CAPEX/OPEX trade-off modelling that had been undertaken to that point in time. The key features and findings at that time were:

- ActewAGL/SKM jointly developed a pole replacement / refurbishment model (the Pole Model)
- Actew/AGL/SKM jointly developed a network asset replacement / refurbishment model (the Network Model)
- The weighted average system age in 2007/8 was 24.88 years
- Age profile forecasting indicated that the weighted average system age would increase to 26.8 years by 2012/13 and 27.5 years by 2013/14.
- The pole replacement/refurbishment model developed by ActewAGL/SKM at the time indicated the necessity for an annual expenditure of between $9.9 million and $10.4 million in order to maintain the pole population in a safe and serviceable condition. Actual expenditure has been within this range.

- The general network replacement/refurbishment model developed by ActewAGL/SKM at the time indicated the necessity for an annual expenditure of between $19.4 million and $10.3 million (declining over time). This excluded pole replacement/refurbishment, and actual expenditure has been generally below this range.
- ActewAGL and SKM jointly developed an “energy at risk” model specifically designed to evaluate the optimum timing for replacement of ageing and potentially unreliable assets. This model was subsequently applied to assessing the costs and benefits of replacing the ageing 11 kV switchboard at Civic zone substation, which was completed in the current regulatory period, and is the case study covered in the following section of this report.

1.3 Trend in ActewAGL system average age

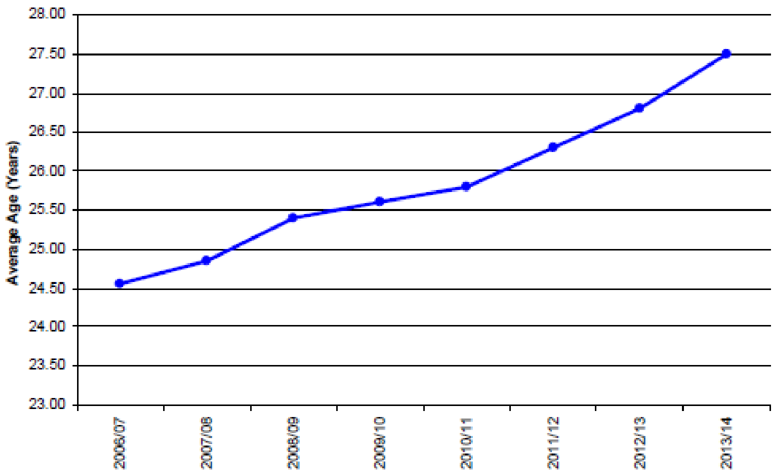
As part of the Network Model, ActewAGL/SKM undertook in 2008 extensive age profiling of ActewAGL Distribution’s network assets on an individual asset category basis. Since the introduction of RIVA, ActewAGL now has a comprehensive “live” database of assets, asset quantities, and asset ages which provide the latest vision of the trends in asset class and overall system age.

Table 1-1 – ActewAGL distribution average asset age by category

Asset category	Weighted average age 2007/08	Weighted average age 2012/13	Average expected life
Sub-transmission overhead lines	28.88	32.9	50
Sub-transmission underground	5.00	11.7	50
Zone substations	26.11	21.8	47
Distribution substation	23.92	24.0	41
Distribution underground	22.57	25.1	50
Distribution poles	31.00	39.9(wood),17.9(conc),13.7(steel), 3.1(f/glass)	45(wood), 80(conc), 60(steel), 70(f/glass)
Distribution overhead lines	22.48	31.0	50
Distribution other	22.29	N/A	31
Total weighted average system age	**24.88**	**26.3**	**-**
Total weighted average system life	**-**		**46**

In 2008 ActewAGL/SKM forecast that the weighted average age of the network would increase from 24.88 years in 2007/08 to approximately 26.8 years in 2012/13, as shown in the following graph:

Figure 1-1 – Forecast weighted average of network



This was based on the assumption that the requested level of replacement/refurbishment CAPEX in the ActewAGL regulatory proposal would be approved, and expended. It should be noted that the average ages and lives shown above are not numerical averages, but are weighted by the replacement cost (RC) value of each asset category.

The latest figures available from RIVA indicate that the weighted average network age in 2012/13 was 26.3 years, indicating a slightly slower rate of ageing than previously indicated. This may be distorted by the fact that the latest RIVA data includes a wider range of assets, including short life assets.

The main conclusion to be drawn from this analysis is that ActewAGL Distribution will need to continue to monitor system ageing and performance over the 2014–19 regulatory period, and will need to analyse asset condition and performance information from RIVA in order to target specific poor performing and high risk assets for replacement/refurbishment.

2. Replacement of critical ageing assets – Civic Z/S case study

2.1 Background

Civic zone substation is located to the North West of Canberra city centre, and supplies predominantly commercial and residential load (including the ANU), and portion of the city. The substation was built in 1986, and had two 55MVA 132/11kV transformers installed, together with 132kV and 11kV switchgear, prior to it being reconstructed in 2013.

2.2 Project scope

Reconstruction of the Civic zone substation was driven in part by the electrical loading exceeding the emergency ratings of the power transformers and associated 11 kV cables, and partly because of the ageing and unreliable nature of sections of the existing 11kV switchgear installed at the time.

The Zone Substation switch-room at the time housed two high voltage (11 kV) switchboards each comprising 13 panels. Both switchboards had been in continuous service since 1965. A detailed condition assessment report showed that the switchboards were in a poor condition, and nearing the end of their useful life.

While the necessity for the augmentation of the capacity of the power transformers and 11 kV cables was quite evident by comparison of the forecast loads with the emergency rating of the equipment, the economic justification and optimum timing for the replacement of the ageing 11 kV switchgear was not quite so obvious.

2.3 Energy at risk modelling (EaR)

ActewAGL and SKM jointly developed a sophisticated energy-at-risk (EaR) model which compared the annualised cost of all maintenance costs, capital costs, and energy at risk costs, to determine the optimum timing for the replacement of the switchgear. The Civic EaR model is based on similar models used by Victorian DNSP's to optimise the timing of augmentation projects, but is more sophisticated in terms of modelling failure rates of plant and equipment nearing the end of its technical life.

Key features of the EaR model for Civic zone substation were:

- It modelled the specific load duration curves (Summer and Winter) for Civic zone substation,
- The Value of Customer Reliability (VCR) was adapted from CRA report of 2002, escalated to 2007
- The model calculated the magnitude and value (at VCR) of energy at risk in Summer and Winter over the period 2007/8 to 2017/18
- Different values of VCR (from $13,416 to $63,994 per MWhr) were applied for different categories of customer load (e.g. residential, commercial, agricultural, and industrial)
- The model used internationally available statistics for the probability of failure, and equipment damage,
- The model took account of load able to be switched away from Civic in the event of a catastrophic fault (3 stages of load transfer and restoration after a fault)

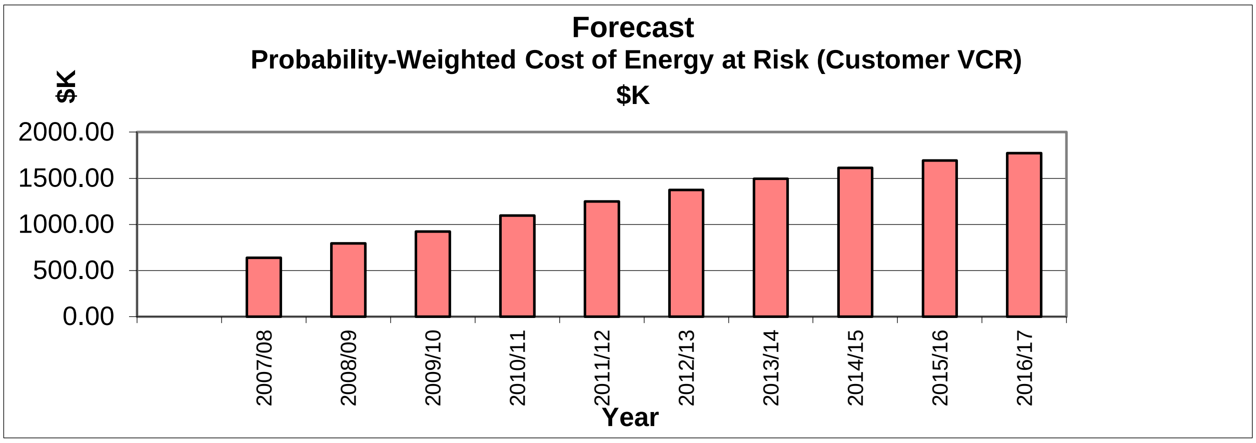
2.4 NPV analysis and outcome

An NPV analysis of four options was conducted:

- Option 1 – A “do nothing” option where the ageing switchboard is replaced on failure
- Option 2 – Replacement of the ageing switchboard I 2013/14 (a slightly deferred date)
- Option 3 – Refurbish the ageing switchboard (and relays) in 2011/12, and defer replacement for 10 years
- Option 4 – Replacement of the ageing switchboard in 2011/12 (earliest possible date)

The probability weighted cost of energy at risk is shown in Figure 2-1 below, and this combined with the NPV analysis of the capital and operating costs of the four options clearly indicated the economic justification for replacement of the ageing Civic switchboard in the 2009-14 regulatory period (options 2 and 4).

Figure 2-1 – Forecast probability-weighted cost of energy at risk



The switchboard was subsequently replaced in 2013

3. Wood pole replacement with concrete and fibreglass – case study

3.1 Overview

ActewAGL has been both efficient and prudent in its management of wood pole replacements. With the aged nature of the wood pole assets, ActewAGL has developed and implemented strategies to extend the life of wood poles, determined economic strategies for replacing pole top assemblies (verses replacing whole of pole structures), and investigated, sourced and implemented innovative pole replacement assets unique in Australia. The latter was the result of the legacy network that ActewAGL inherited which is dominated by back of block overhead reticulation which prevents heavy vehicle access for poles replacement.

The replacement poles now used by ActewAGL have a demonstrably lower whole of life asset cost, and are safer in the rear of block reticulation situations due the their lighter weight and insulative properties.

3.2 Introduction

Poles are a key element in ActewAGLs distribution network supporting electrical current carrying equipment above ground level and is predominantly used in ActewAGLs HV and LV networks. It is a critical component in the performance, reliability and safety of an overhead network. The poles in ActewAGL's network also supports other utility infrastructure including Government owned streetlights and communication infrastructure for Telstra and TransACT, placing a further importance on the need for safe and reliability of these components. Poles generally contribute around 20-30% to the total capital cost of an overhead line on a per km basis.

The basic pole material in use in ActewAGL is natural round timber (wood), Creosote treated (wood), Tanalith treated (wood), concrete, stobie, steel or fibreglass. Natural round timber poles were not originally treated with preservatives and they did not have the sapwood removed. Creosote poles were purchased already pressure treated with creosote preservative. Tanalith poles were purchased already pressure treated with a Copper Chromium Arsenic (CCA) preservative.

In 2013, 63% of the pole population was wood. Of the 63% wood poles, 38% are reinforced. However, the percentage of wooden pole population is slowly reducing over time as they are gradually replaced by concrete or fibreglass poles. Between 2008 and 2013, the population of wooden poles declined by 5,500, from 39,000 to 33,480.

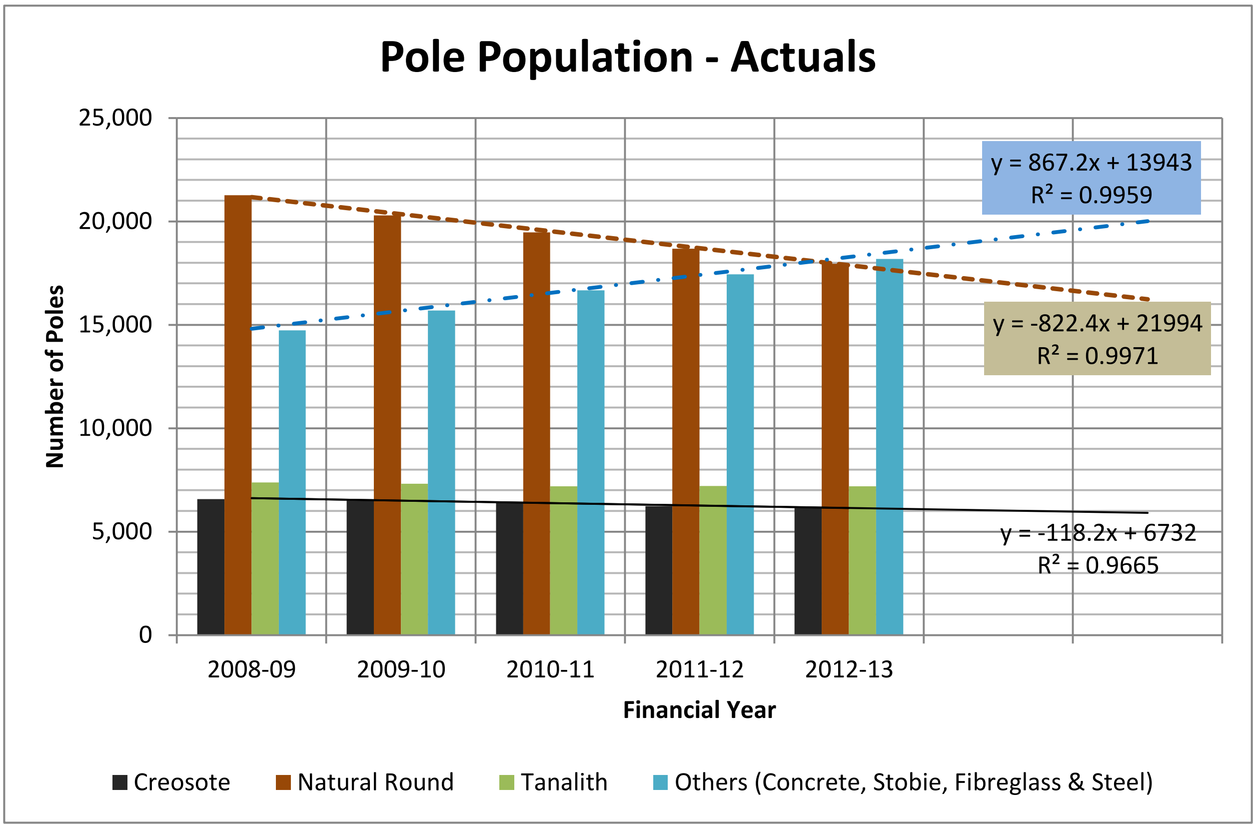
3.3 Asset age

ActewAGL have an aged population of timber poles as evidenced in Table 3-1 and Figure 3-1 below.

Table 3-1 : Average Pole Age

Pole Type	Average Age of Pole	Number of Poles
Concrete	16	10266
Creosote	40	6097
Fibreglass	3	2030
Natural Round Timber	57	17612
Steel	15	5919
Stobie	65	359
Tanalith	27	7191

Figure 3-1 – Pole population actuals



As the average service life for a timber pole is 45 years, ActewAGL is facing a bow wave of poles reaching the end of their serviceable life.

To address this challenge, ActewAGL have actively looked at options for life extension for condemned timber poles, and have an extensive pole nailing regime. It is worth noting that 38% of all timber poles in service are now reinforced, and that over the last four years, on average 60% of the poles that were condemned have been reinforced and remain in the network. This ratio is forecast to increase modestly during the next regulatory period.

3.4 Review of pole material

As well as investigating options for pole life extension, in the late 1980's ActewAGL commenced a series of major reviews of the type of poles being used for pole replacements. Whilst the average life for a timber pole is 45 years, ActweAGL wanted to ensure that the replacement pole was the optimal asset for the network, and provided a greater asset life. Other key considerations in the selection of pole type were:

- The capital cost of the replacement pole
- Reduced ongoing OPEX requirements
- Constructability
- Safety

3.4.1 CAPEX considerations

In the 1980's steel distribution poles could be purchased and installed more economically than timber poles. Accordingly (and for other reasons listed below) steel poles became the standard asset for pole replacements in back of block situations.

With the significant increases in commodity prices which were experienced in the early 21st century, the cost of steel poles increased significantly.

Figure 3-2 – Steel pole annual average unit cost

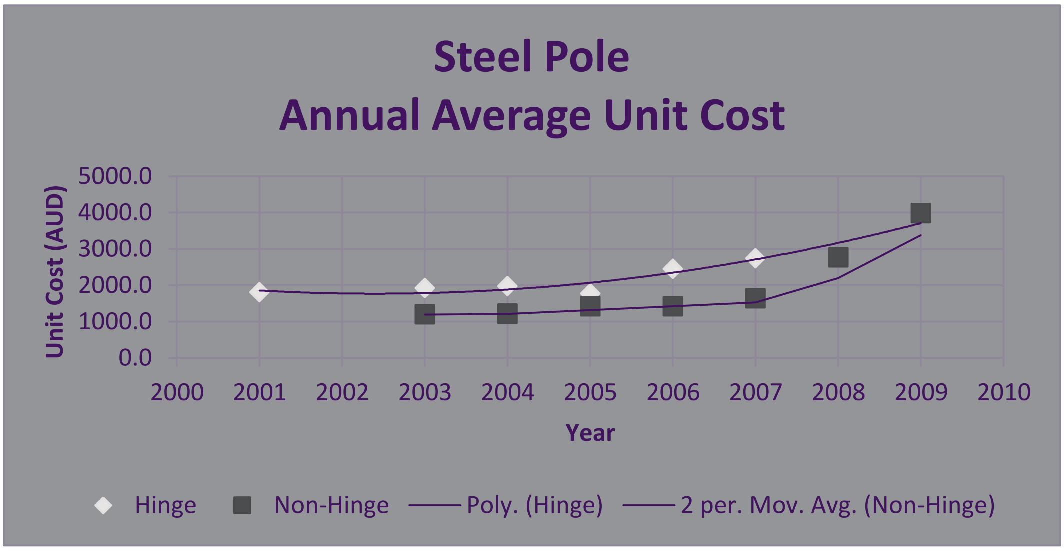
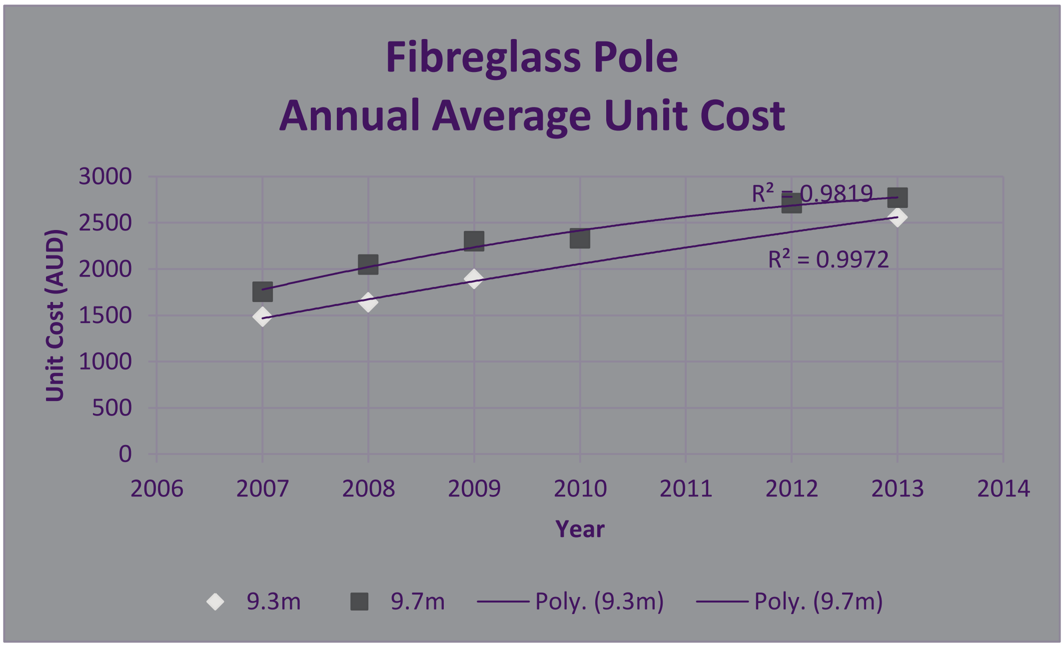


Figure 3-3 – Fiberglass pole annual average unit cost



ActewAGL continued reviewing appropriate replacement poles and commenced investigating the use of fibreglass poles which, whilst manufactured in Canada, were a more capital competitive alternative to steel poles. Fibreglass poles have been used exclusively for back of block pole replacements since 2008.

Since ActewAGL commenced purchasing and installing fibreglass poles in the ACT, a fibreglass pole manufacturing plant has been established in NSW and is now one of the sources of fibre glass poles for ActewAGL. This has realised further cost savings to ActewAGL, eliminating the off shore transportation costs and import duties.

Average service life is a consideration in determining whole of life replacement cost for poles. Timber poles have the shortest average service life[1] as evidenced in Table 3-2 below.

Table 3-2 - Average asset service life

Pole type	Average service life (approx.)
Timber	45 years
Reinforced Timber (Staked)	55 years
Steel	50 years
Fibreglass	At least 60 years
Concrete	At least 80 Years

3.4.2 OPEX considerations

Timber poles require inspection at and below ground level every 4.5 years. This involves excavation the soil from around the pole base, inspecting the integrity of the timber for rot, termite activity and the effects of moisture on the poles.

Whilst steel poles also require below ground inspections every 4.5 years, they are not susceptible to termite attack or timber rot. Additionally the steel poles have an outer galvanised coating providing protection against the rusting effects of water. The timber poles do not have an outer protective layer against the effects of water. As such steel poles provide a longer asset life, reducing the annualised replacement cost

In the late 1980's ActewAGL started to move away from wood pole to steel replacement poles for back of block reticulation and concrete pole replacements where there is heavy vehicle access. In 2008, ActewAGL moved fully to the use of fibreglass poles in lieu of steel poles for back of block distribution.

Fibreglass and concrete poles do not require below surface pole inspections as neither are susceptible to rot, termite infestation nor rust. As such the annual OPEX requirement for below ground inspections was eliminated, realising OPEX savings that compound annually, as the timber pole population is progressively replaced with fibreglass and concrete poles.

3.4.2.1 Financial effect of CAPEX and OPEX considerations

Based on the financial assumptions shown in Table 3-3 below, ActewAGL has determined that over the extended asset life of 55 years achievable by reinforcing a timber pole at the end of its service life, the whole of life economic cost for timber poles is $28,049 compared with $14,992 for concrete poles

[1] As used in regulatory asset valuations for the AER

Table 3-3 - Whole of life cost for timber and concrete poles

	Timber poles	Concrete poles
Asset life	Reinforce @ 45 years; replace pole at 55 years.	80 years
Installation cost	$10,500	$12,660
Inspection cost	$348	$150
Inspection frequency	4.5 years	4.5 years
Assumed annual inflation rate	3%	3%
Whole of asset life at 45 years	$25,127.	$14,505.
Whole of asset life at 55 years (not including the cost of pole replacement	$28,049.	$14,992.

3.4.3 Constructability

ActewAGL's low voltage network is dominated by back of block overhead reticulation. Heavy vehicle access is not available to transport in and construct new timber poles.

Replacement poles must be carried to the back of the block and installed manually. The steel poles selected by ActewAGL were or multi part assemblies, allowing the base to be installed separately. The remainder of the pole was then assembled in sections.

All of the fibreglass poles used are similarly supplied in sections allowing the base to be installed prior to assembly of the top section. Pole top assemblies are fitted once the pole has been fully assembled.

The old, condemned pole is cut into manageable sections and removed from the back of the block.

There is no differing constructability issues between wood poles and concrete poles where there is heavy vehicle access.

3.4.4 Safety

Especially for poles at the rear of blocks, the safety afforded by the fibreglass poles is a significant consideration. Fibreglass poles are electrical insulators. As such, when compared with steel and concrete poles, they eliminate the potential for step and touch voltage rises at the pole base in the event of a fault.

They are also considerably lighter than timber and steel poles.

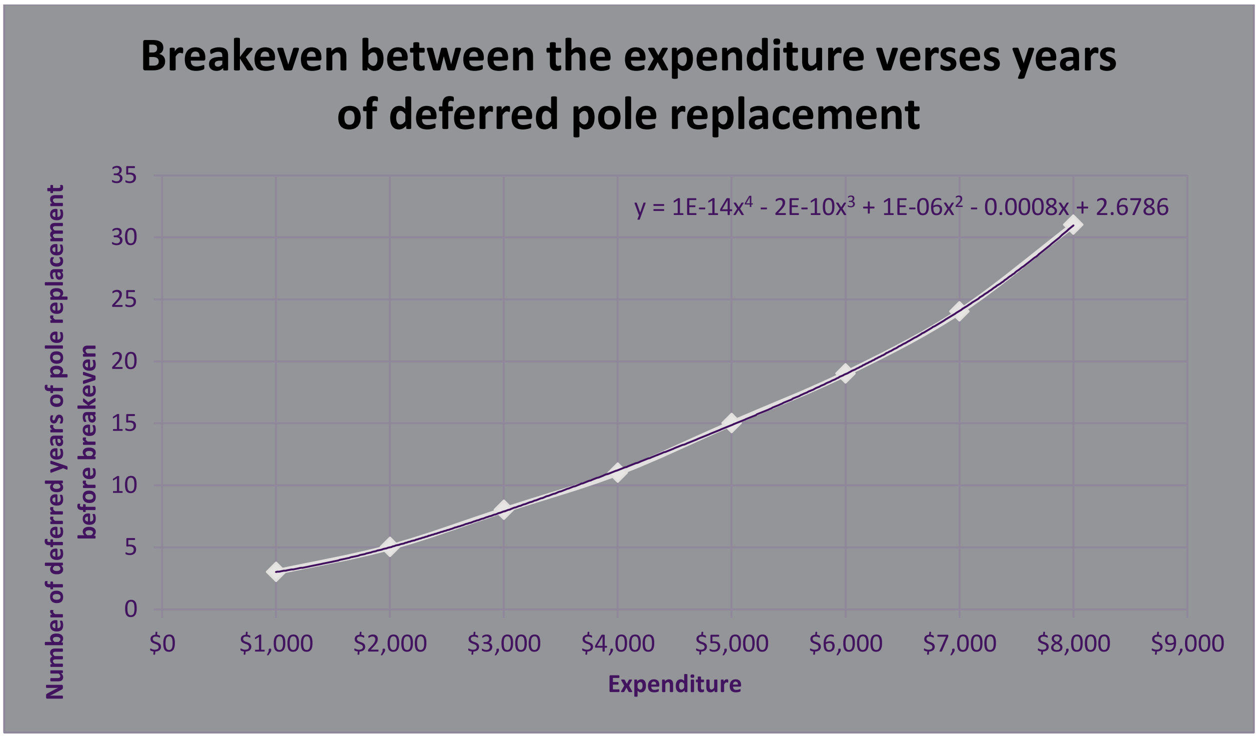
3.5 Pole top hardware

3.5.1 Crossarm replacement (pole top upgrade)

Some pole top hardware requires the renewal during its service life. With the renewal of the pole top hardware on suitable poles, it is typically expected to maximise the pole serviceable life. A deteriorated crossarm which is unlikely to survive until the next inspection are identified during the pole inspection or the aerial pole top inspection. Where the pole remains in good condition and also meets other criterion (such as the good accessibility, no black king bolt installed or split pole head), the deteriorated crossarm is scheduled for replacement under the unplanned crossarm replacement program.

Without analysing the past expenditure on a specific pole, the chart below shows the number of years the repair solution/expenditure on the pole should defer an end of life pole replacement before it breakeven. For example, for a $5,000 crossarm replacement job would take approximately 15 years to breakeven (defer the end of life pole replacement by at least 15 years).

Figure 3-4 - Breakeven analysis between an expenditure on an asset verse the years of deferred pole replacement



This breakeven analysis is based on:

- Pole replacement is inevitable
- Pole replacement cost of $12,600
- Wood pole inspection every three years at $236
- 7.7% discounted rate and 3% inflation

4. Underground distribution cable replacement – case study

4.1 Overview

ActewAGL has an aged and growing underground distribution network. 15% of the underground cables have exceeded their average service life and an additional 11% will exceeded their average service life in the next 10 years. These aged cables are failing at an increasing rate.

To address this trend ActewAGL has been both efficient and prudent in developing an asset management strategy. The strategy involves the initiation of a condition monitoring regime of high voltage underground cables and prioritisation of the high voltage underground cable replacement with suspected problems.

Three (3) critical HV feeders will be condition monitored between FY14/15 to FY15/16 increasing to condition monitoring of 5 critical HV feeders from FY16/17 and onwards.

It is estimated that 700metres of cable section will be identified for replacement in FY14/15 from the condition monitoring, and 4.5km of cable section will be identified for replacement from FY15/16 and onwards.

This initiative will reduce the highest risk of asset failure.

4.2 Introduction

All new sub-division developments in the Australian Capital Territory (ACT) are reticulated with an underground distribution network since the 1980s. The underground cable asset is managed and categorised by the voltage level, insulation type and the type of cable construction

Most of ActewAGL's high voltage cables are three core cables. The cable conductor material is either stranded aluminium or copper for HV and LV mains power cable and copper for LV service cable.

Consac cables were installed in ActewAGL from 1960s to mid-1970s and polymeric cables have been used in the industry since the 1980s. Table 4-1 below details to total lengths of underground cable in the ActewAGL distribution network.

Table 4-1 - Cable Population

Cable type by voltage	Length in service	Average service lift
HV UG cables	1460km	50 years
LV UG cables	1236km	50 years
Service UG cables	1898km	50 years

4.3 Asset age

ActewAGL maintains and operates approximately 1,460 kms of high voltage (11kV and 22kV) cable. Of this length, 15% is older than 50 years and 12 % is older than 60 years.

Table 4-2 - Cable age

Age group (years in service)	Length (km)	% of network
1 - 10	317	22
11 - 20	113	8
21 - 30	244	17
31 - 40	359	25
41 - 50	158	11
51 - 60	49	3
61 - 70	70	5
Over 70	105	7
Unknown	22	2

High voltage underground cables are considered to have an average service life of 50 years for HV and LV cables. As such 15% ActewAGL's HV cable is older than its considered service life, and a further 11% will exceed its service life in the next 10 years. This statistic is reflected in the graph of cable failure rates below.

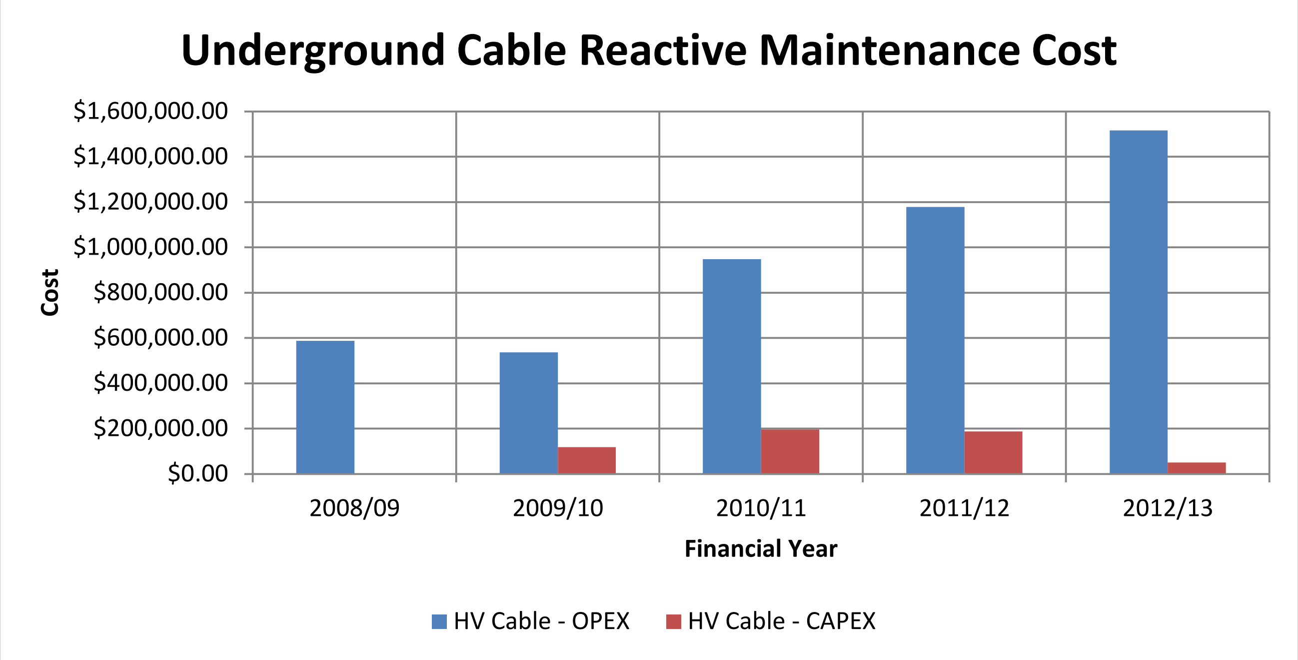
4.4 Asset performance

It has been ActewAGL's practice in the past, to run the underground cables to failure. Cable repairs have generally been limited to the removal of faulted sections. Over the previous 5 years, reactive repairs and replacements have been increasing, see Figure 4-1.

Most repair work has been on the cable joint or termination, and an increasing number of underground cables are reaching the end of their life. This was especially observed in Griffith and Kingston where the steel armour tape and the lead metallic sheath of the cable showed signs of corrosion during cable repairs. These cables were installed in 1943.

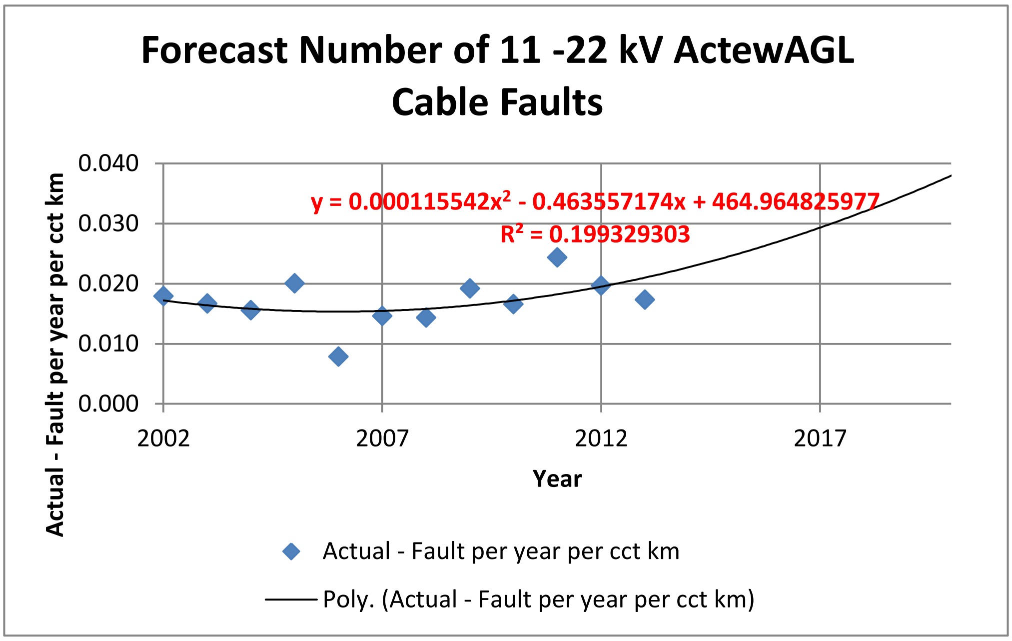
Once the metallic sheath is compromised, moisture ingress into the cable will eventually lead to failure.

Figure 4-1 - Historical underground cable maintenance cost



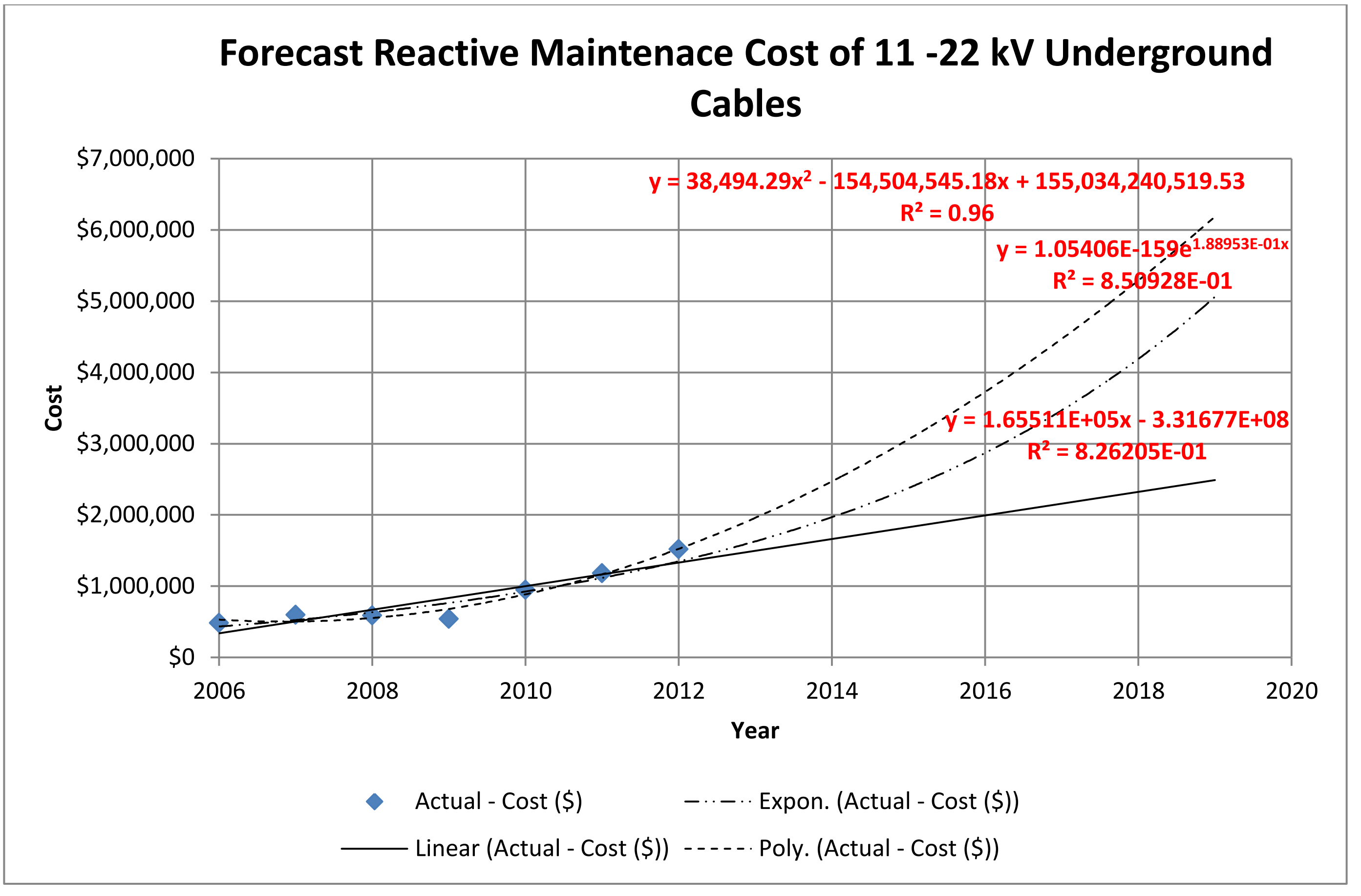
It can be seen that the HV cable fault rate is trending upwards. By 2020, we may expect up to 64 high voltage cable faults in that year (Figure 4-2). If this remains as the status quo, there is a risk of expenditure on possible cable repairs of up to $7.1 million in 2020, see Figure 4-3, with essentially no reduction in the future risk of cable failure.

Figure 4-2 - Forecast number of high voltage cable fault



In the past 5 years, reactive repairs and replacements have been increasing, see **Error! Reference source not found.**. Most repair work is on the cable joint or termination, and an increasing number of underground cables are reaching the end of their life. This was observed in Griffith and Kingston where the steel armour tape and the lead metallic sheath of the cable showed signs of corrosion during cable repairs. These cables were installed in 1943. Once the metallic sheath is compromised, moisture ingress into the cable will eventually lead to failure.

Figure 4-3 - Forecast reactive maintenance cost



4.5 Asset replacement strategy

4.5.1 Immediate response

To address the increasing number of cable failures, in June 2013, ActewAGL examined the route cause of the cable failures and determined that the failures were occurring predominantly at cable joints. ActewAGL decided to commence strategic feeder replacement and a desk top investigation was undertaken of three critical feeders, namely the Yamba, Belmore and ANU back up feeders. It was decided to augment the Yamba feeder.

The Yamba feeder is fully underground and supplies the Canberra Hospital from the Woden substation. The feeder is 48 years old and contains 27 joints and is 3.7 kms in length and recorded 8 cable failures in the period 2002 – 2012. An additional 2 cable failures occurred in 2013. On average it takes 2.5 days to repair a cable failure after the fault location is identified.

The feeder was replaced in full in 2013/14.

4.5.2 Longer term strategy

ActweAGL considered 3 options to address the declining performance of the underground network. They were:

1) Maintain the status quo and accept the rising cost.
2) Replace all underground paper insulated cables over 60 years old and XLPE cables over 50 years old.
   - If this strategy is adopted, over 175km will be due for replacement
   - The estimated cost is 175,000m x $250/m = **$43,750,000 +/- 30%** capital expenditure over the next 5 years.
3) Initiate condition monitoring of underground cables and prioritise sections of the underground cable replacement with suspected problems.
   - Condition monitoring of 3 HV critical and feeders between FY14/15 to FY15/16 and increase to condition monitoring of 5 HV critical and feeders from FY16/17 and onwards.
   - Estimate of 700metres cable section replacement in FY14/15 identified from condition monitoring. Then 4.5km of cable section replacement from FY15/16 and onwards.

Option three has been accepted and is to begin implementation during the 2014/15 financial year