Jemena Electricity Networks (Vic) Ltd

2016-20 Electricity Distribution Price Review Regulatory Proposal

Attachment 7-11

Nuttall Consulting - Independent analysis of replacement expenditure

Public

30 April 2015

Nuttall Consulting

Regulation and business strategy

AER repex modelling

Category Analysis RIN calibration

A report to the JEN

Confidential final

7 April 2015

This report includes an addendum prepared on 27 April 2015.

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Executive Summary

Introduction

Nuttall consulting has been engaged by Jemena Electricity Networks (JEN) to prepare a forecast of the replacement needs of its network, covering the assets providing standard control services. This forecast *must* use the predictive model the Australian Energy Regulator (AER) has indicated it will use as part of the process it will apply to assess expenditure forecasts. This model is called the AER repex model.

We have developed a forecast within this model using:

- the data JEN recently submitted to the AER in the 2009-2013 category analysis Regulatory Information Notice (RIN), namely:
  - Table 5.2.1 – asset age profiles for 2013
  - Table 2.2.1 – replacement expenditure and replacement volumes (2009 to 2013)
- replacement expenditure and replacement volumes for 2014, provided by JEN in a similar format to Table 2.2.1 of the category analysis RIN.

The repex model forecast has been prepared to represent a "calibration" of the model parameters (i.e. asset lives and unit costs) reflecting JEN's replacement levels over the 5-year period from 2010 to 2014. This "calibration" of the model has used the process the AER has set out in its accompanying handbook to the AER repex model.

This repex model forecast has been compared to JEN's replacement expenditure forecast over the 2016 to 2020 period. The JEN forecast has been adjusted to remove a number of projects and programs that are not considered appropriate to be modelled using the repex model[1].

We have also conducted a brief review of the programs within the remaining JEN forecast to gauge whether there may be limitations in using the repex model forecast, calibrated in this way, to assess JEN's forecast.

It is worth noting that, as part of its draft decisions on the NSW distribution network service providers, the AER has discussed the repex modelling it undertook to inform these decisions. This indicates that it used a number of repex model scenarios to inform its views in addition to the one which we applied and discuss here. The two main additional scenarios covered a calibration of replacement volumes similar to that presented here, but using unit costs that reflect 1) the DNSP's forecast and 2) industry benchmark unit costs.

Information suitable to apply these scenarios was not available at the time we prepared the JEN repex model.

[1] This primarily covers replacements associated with special capital works and recoverable works programs, and IT replacement projects associated with JEN's real-time network management systems. These project represents 18% of JEN's replacement expenditure forecast over the 2016-2020 period.

Limitations with the JEN repex model forecast and the repex model

Our review of the programs within JEN's forecast (excluding the unmodelled component) found that the repex model forecast could lead to inaccurate inferences for just over a quarter of JEN's replacement expenditure over the next period (26% or $46 million). Most notably, with regard to JEN's forecast:

- $33.2 million is age-related, but is limited in how it is being treated within the repex model. This was most significant for:
  - the pole top structures asset group, which includes a program to replace a cohort of pole top structures that have cross arms in poor condition with a certain type of insulator, which together can result in pole top fires in certain circumstances – and hence typically a different life to other pole top structures
  - the poles asset group, which includes a program to replace a cohort of poles in poor condition; this cohort were design appropriately when installed, but to a lower diameter, such that this narrower design girth combined with age-related internal rot results in this cohort having a lower structural standard than JEN's typical poles – and hence typically a shorter life
  - the underground cable asset group, which includes a program to replace asset categories not specifically included in the repex model, namely cast iron trifurcating boxes and cable terminations

  The cohorts and assets associated with these programs are not specifically modelled (i.e. they do not have their own age profiles, lives and unit costs in the model), and so, the forecast of these programs is implicitly inferred from the age relationships of the asset categories that are included in the model.
- $10.2 million is considered only weakly age-related, and therefore, the repex model is likely not applying the most significant driver when predicting replacement needs. This is most notable for JEN's overhead conductors, distribution transformers, and other asset groups, which have a number of programs that appear to be driven by non-compliance and performance issues that have a more limited relationship with the age/condition of the existing assets[2].
- $2.1 million appears to be misallocated in the model. That is, capex in the JEN forecast has been allocated by JEN into a different asset group than it appears to have been allocated when JEN prepared its category analysis RIN. This is most notable in the SCADA and protection asset group, where some asset costs and/or volumes in this group may have been captured in the "other" asset group of the category analysis RIN.

It is important to stress that we cannot say if these issues could result in the model over or under stating the replacement forecast; only that this could result in an inaccuracy when comparing the repex model against this forecast. JEN would need to undertake additional analysis through the

[2] For example, non-compliance programs include the requirement to remove LV mains in hazardous bushfire areas and a program to replace pole-mounted distribution transformers that are below the current minimum height standard. Examples of performance programs include the installation of spreaders on some overhead conductors and animal proofing some substations.

repex model to investigate these matters further. Furthermore, these findings do not, on their own, suggest that the repex model is not fit-for-purpose in a regulatory context. This could only be decided in the broader context that the AER uses the model when it assesses JEN's capital expenditure forecast.

JEN repex model findings

The figure below shows the results of our modelling exercise. This figure shows the forecast produced by the repex model, compared to JEN's own replacement forecast (2015-2020) and the replacement expenditure JEN has incurred over the last 5-year period (2010 to 2014). This chart also shows the component of JEN's forecast and historical expenditure that is unmodelled and the component of JEN's forecast that is subject to the model issues summarised above.

The repex model forecasts that JEN's replacement expenditure will need to rise over the next regulatory period from the average level over the previous 5-year period (2010-2014). This finding supports JEN's view that it is in a rising period of the replacement cycle. The repex model suggests that this rise could last at least over the next three to four regulatory periods, assuming similar circumstances. Interestingly, the model suggests that the average age of asset base within the model will still be increasing over this period[3].

Although the model agrees with JEN that replacement expenditure should rise, the aggregate replacement expenditure over the next regulatory period predicted by the model is 5% ($8 million) less than the modelled component of JEN's own forecast. However, this result is near the top end of the range of expenditure that potentially could have some modelling inaccuracy, with the repex model forecast well above (21% higher) than the component of JEN's forecast without these modelling issues.

As noted above, these findings do not say that JEN's forecast compares favourably against the repex model – addressing these limitations in the model could move its forecast up or down. Nonetheless, this finding does suggest that fairly modest improvements in the accuracy of the model could result in JEN's forecast comparing favourably against the model.

[3] Note, the aging discussed here does not allow for other factors, such as new connections and augmentations, which may reduce the average age of the overall asset base in the future.

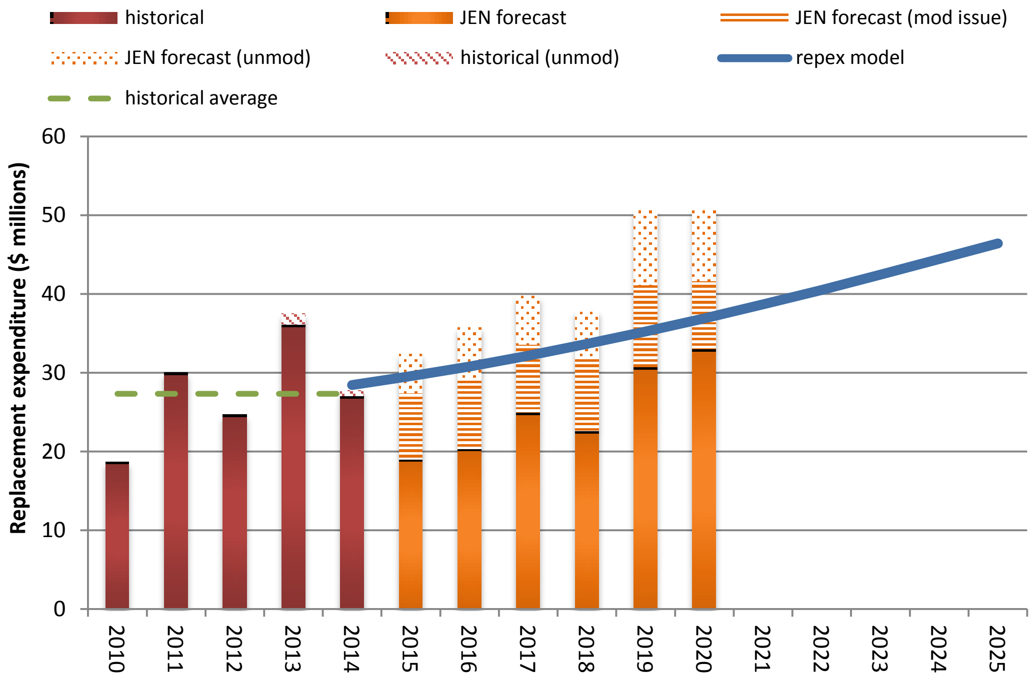

Fig E1 – JEN repex model forecast

We have analysed the asset groups within the model to provide an indication of where the main variances between the forecasts are occurring (see Table E1). This provides an indication of where the AER may target its detailed reviews, provided it uses the repex model for this purpose[4].

These results indicate:

- the model forecasts for poles, pole top structures, services, and zone transformers asset groups are within 10% of JEN's forecast
- underground cables, distribution switchgear, SCADA/protection/control, and "other" asset groups show the greatest underestimate by the repex model compared to JEN's forecast – in aggregate across these four groups, the repex model is 61% below JEN's forecast ($28 million over the next period)
- overhead conductors, distribution transformers, and zone switchgear show the greatest overestimate by the repex model compared to JEN's forecast – in aggregate across these three groups, the repex model is 76% above JEN's forecast ($23 million over the next period).

[4] It is worth noting that the AER is likely to use other methods to target issues for detailed review, which may identify other asset groups.

Table E1 JEN repex model asset group results

Asset Group	2010-14 historical $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions	Repex model volumes
		repex - average per annum 2016-20			
Poles		[c-i-c]		$0.0 ($1.1)	1087 poles
Pole top structures				-$0.5 ($2.5)	1222 cross arms
OH conductors				$3.0 ($4.2)	45990 metres
UG cables				-$0.8 ($0.3)	1391 metres
Services				$0.2 ($0.2)	114519 metres
Transformers				$0.2 ($0.8)	62 transformers
Distribution transformers				*$0.5 ($1.0)*	*61 transformers*
Zone transformers				*-$0.3 (-$0.2)*	*0.7 transformers*
Switchgear				$0.9 ($0.9)	502 switches/fuses
Distribution switchgear				*-$0.2 (-$0.2)*	*489 switches/fuses*
Zone switchgear				*$1.1 ($1.1)*	*13 CBs/switches*
Other				-$1.4 (-$0.2)	18 various assets
SCADA & protection				-$3.1 (-$2.3)	34 relays
Total				**-$1.7 ($7.4)**	

a – the brackets indicate the amount without the modelling issues

Finally, in appreciating the significance of these findings, it is worth noting the following:

- We have not been able to reconcile the volume forecast. The effect of variances in volumes could be different to those presented here.
- In the recent NSW draft decisions, the AER has excluded the “SCADA and protection” and “other” asset groups from its repex modelling exercise. If that was applied here then the aggregate results present above would look far more positive for JEN, with the repex model forecast 10% above the modelled component of JEN’s forecast.

1 Introduction

1.1 Background and scope

Jemena Electricity Networks (JEN) has engaged us, Nuttall Consulting, to assist in its preparations for its next regulatory determination by the Australian Energy Regulator (AER). This determination will cover the period from 2016 to 2020.

As part of this engagement, JEN has requested that we:

- develop a model of JEN's replacement capex (repex) using the AER's repex model
- prepare a forecast using this model using the approach that the AER has described in its documentation on this model
- reconcile the model forecast with JEN's own replacement forecast to identify areas where the two forecasts differ and possible reasons for this difference
- prepare an independent report, which can be used as a supporting document to JEN's building block proposal to the AER, that sets out the forecast and explains how we developed the model and forecast.

This document serves as the report indicated above.

The following definitions are used in this report:

- **Replacement capex** (or **repex**) has the meaning given to it by the AER in its recent advice on how it will conduct expenditure forecast assessments, which broadly covers the non-demand-driven replacement of assets with their modern equivalent asset.
- We use the term **AER repex model** to mean the generic excel workbook that the AER has advised it will use as an assessment technique in its determinations – and the AER calls the repex model.
- We use the term **JEN repex model** to mean the model we have prepared of JEN's network using the AER repex model. The JEN repex model is used here to produce repex forecasts of the JEN network.

In addition, all expenditure and costs shown in this report represent **direct real 2015 dollars, excluding any forecast labour and material price changes**.

1.2 Nuttall Consulting experience in this task

Nuttall Consulting, using Dr Brian Nuttall (the author of this report), developed the excel workbook that serves as the basis of the AER's repex model and advised the AER on its possible roles and application in regulatory determinations.

Moreover, we were engaged by the AER to provide advice that informed the AER's current determinations of the Victorian and Tasmanian Distribution Network Service Providers (DNSPs). As part of these engagements, Dr Nuttall developed repex models and forecasts, using an approach in line with that described in the AER's repex model documentation (and used here).

1.3 Methodology

1.3.1 Data sources

We have used the following information to undertake the scope defined above:

- the AER repex model and AER repex model handbook, published on the AER website
- JEN's Category Analysis Regulatory Information Notice (category analysis RIN), which was submitted to the AER in August 2014
- JEN's asset replacement expenditure and volumes for 2014 in a form consistent with the category analysis RIN[5]
- JEN's replacement capex forecast, covering the period from 2015 to 2020[6]
- various JEN asset management documents that explain the forecast programs and provide their rationale.

We understand that KPMG has audited the data in JEN's category analysis RIN. However, we have not undertaken any formal review or audit of this data, JEN's expenditure forecast or information it has provided to us on its underlying replacement programs. Therefore, this report should not be taken as an assurance of the accuracy or validity this underlying data, including its suitability for this modelling task and the implications on its findings.

1.3.2 Modelling development

We have developed the JEN repex model using JEN's 2013 age profiles, provided in its category analysis RIN.

We have "calibrated" the lives and unit costs used by the JEN repex model to reflect JEN's replacement levels over the 5-year period from 2010 to 2014. This "calibration" of the model has used the process the AER has set out in its accompanying handbook to the AER repex model.

Further details of the JEN repex model development and calibration exercise are provided in Appendix A.

[5] Provided in the email from JEN, 17/3/2015
[6] Provided in the email from JEN, 17/3/2015

Relevance to the NSW draft decisions

It is worth noting that, as part of its draft decisions on the NSW distribution network service providers, the AER has discussed the repex modelling it undertook to inform these decisions. This indicates that it used a number of repex model scenarios to inform its views in addition to the one which we applied and discuss here.

The two main additional scenarios covered a calibration of replacement volumes similar to that presented here, but using unit costs that reflect 1) the DNSP's forecast and 2) industry benchmark unit costs.

Information suitable to apply these scenarios was not available at the time we prepared the JEN repex model and this report[7].

1.3.3 Reconciliation to JEN forecast

We have compared the repex model forecast, over the 2016 to 2020 period, to JEN's repex forecast over this period. This comparison has been made at the aggregate and asset group level.

To inform this reconciliation process, we have conducted a brief review of the programs within JEN's forecast to gauge whether there may be limitations in using the repex model forecast, calibrated in this way, to assess JEN's forecast.

Note on JEN replacement volumes

The JEN forecast data, noted above, did not include volume forecasts[8]. Therefore, we have not been able to reconcile the repex model's volume forecast to JEN's forecast. For the results discussed here, we have focused on comparisons between the expenditure forecast, which are consistent to a greater degree. The volume forecasts produced by the repex model have been provided in some tables, but JEN will need to reconcile these to its own forecasts in order to understand the extent that volume or unit cost differences are driving differences between the repex model and its own forecasts.

1.3.3.1 Comment on unmodelled repex

JEN has identified a number of planned projects and programs within its forecast, which it intends to allocate to the AER's replacement expenditure category but does not consider appropriate to be modelled using the repex model.

JEN has advised that the unmodelled repex component accounts for 18% ($38 million) of its repex over the next period, and covers the following:

- A number of IT replacement projects associated with JEN's real-time network management systems, which are covered by the SCADA and protection asset group. JEN considers that these projects should not be modelled as they have few assets within the population with short lives (relative to most other network assets), and

[7] This would require a completed table 2.2.1 of JEN's Reset RIN and the AER's benchmark unit costs.
[8] A JEN volume forecast was available. However, this was not in the specific format required for this modelling exercise i.e. matching table 2.2.1 of the Reset RIN.

as such, the AER’s repex model is unlikely to be suitable for preparing forecasts via such a calibration process.

- Replacement works within JEN’s special capital works and recoverable works programs. JEN considers that these components of repex should not be modelled because 1) this component of expenditure was not allocated to standard control repex in the category analysis RIN, and so, cannot be allowed for in the calibration process; and 2) third parties tend to be the drivers of replacement activities within these programs and not the age/condition of the existing assets.

Although we have not reviewed these projects or programs in any detail, JEN’s rationale for exclusion appears sound, and therefore, the repex associated with these programs has been excluded from the comparisons discussed here.

1.4 Structure

This report is structured as follows:

- Section 2 discusses the review we have conducted on JEN forecast to determine its suitability for comparisons with the repex model forecast.
- Section 3 summarises the results from this modelling exercise and the reconciliation to JEN’s forecast.
- In appendix A, we provide an overview of the AER repex model, summarising how it develops a forecast, its inputs and outputs, and how the AER may use it to assess a DNSP’s replacement forecasts. We then discuss the methodology we have used to develop the JEN repex model, including the JEN data we have used and the process we applied to generate a forecast.
- Appendix B provides more detailed results for each asset group within the JEN repex model.

2 Review of the JEN forecast

2.1 Introduction

We have conducted a high-level review of the programs that have formed the "modelled" component of JEN's repex forecast. The main aim of this review was to determine how applicable this replacement expenditure (and volumes) is for analysis using the AER repex model, using the structure set up by the AER[9].

Our review has been performed at the asset group level (not asset category level), as follows:

- JEN has provided its repex forecast, categorised into the main programs, indicating how these have been allocated to the various AER asset groups
- we have reviewed (at a high-level) a selection of JEN's management plans, business cases or strategic planning papers to gain a better understanding of the key drivers of these projects and programs
- JEN has provided verbal advice in some circumstances
- based upon this understanding, we have classified the projects or programs into various categories that define potential issues with how we have used the JEN forecast.

These categories are as follows:

- The program is defined as ***weakly age-related*** if the underlying drivers of the need to undertake works within the program are not clearly age-related[10]. For example, if the driver concerns a non-standard design, imposing risks on JEN, of which a decision to replace may be more related to its location than the age or condition of the asset.

  It is important to stress here that provided the program has some history (which is captured in the calibration process), the model will still be producing a forecast for this program. The issue here is that it will be using age relationships to make future predictions which may not be appropriate or accurate because they do not reflect the driver of the program. This issue could under- or over-state the future need.

- The program is defined as ***model-limited*** if the underlying drivers of the need to undertake works within the program are age-related (so the program could be

[9] We have not conducted a similar review of the project/programs that JEN used to prepare its category analysis RIN as appropriate data was not available. This would require the program-level expenditures that were allocated to the various asset categories in Table 2.2.1 of JEN's category analysis RIN and details of these programs.

[10] To avoid confusion, the term age-related here does not mean the decision to replace must be explicitly defined by the age of the asset. Rather the factors that may drive the need to replace an asset should have some correlation to the age of the asset.

assessed through the repex model), but the replaced assets do not have their own asset categories defined within the model.

As above, provided the program has some history (i.e. replacement expenditure and/or volumes that are captured in the calibration process), the model will still be producing a forecast for this program. The issue here is that it will be using an age relationship from an alternative asset category to make future predictions. This could under- or over-state the future need.

- The program is defined as an ***allocation issue*** if the program should be captured appropriately by the repex model (i.e. it is age-related and has an age profile), but the JEN forecast has not been allocated to the same asset group for comparative purposes.

  As above, provided the program has some history (which is captured in the calibration process), the model will still be producing a forecast for this program. However, the model will produce the forecast under an asset group that differs from the group JEN has allocated the program repex to. It worth noting that this suggests a discrepancy in how JEN has allocated repex between the category analysis RIN and the reset RIN.

2.2 Review findings

Table 1 below summarises the findings of this review. These finding indicate that the repex model forecast could lead to inaccurate inferences for just over a quarter of the “modelled” component of JEN’s replacement expenditure over the next period (26% or $46 million). (Noting that the repex model could be over or understating the replacement needs, depending on the circumstances).

Weakly age related

Just below one quarter of this amount ($10.2 million or 6% of JEN’s repex forecast) concerns programs that appear to be only weakly age-related, based upon JEN documentation.

The programs in this category cover:

- overhead conductors (54% of the forecast for this group)
  - commencement of a program to remove LV mains in hazardous bushfire-risk areas ($3.7 million), which is linked to safety obligations associated with the findings of the Victorian Royal Bushfire Commission
  - continuation of a series of programs to replace various connector assets to address issues with some lines that may affect their performance and likelihood of failure ($1.4 million)
  - continuation of a program to replace high risk lines that are not compliant with current vegetation clearance standards ($1.1 million).
- distribution transformers (27% of the forecast for this group)

- continuation of a program to replace pole-mounted distribution transformers that are below the current minimum height standard ($2.5 million)

- "other" assets (19% of the forecast for this group)
    - continuation of various programs to address performance issues with the network driven by to external factors (rather than the age/condition of the asset), covering the installation of line spreaders; "animal proofing" of certain network assets; and the installation of disconnect devices for overhead services ($1.0 million).

It is worth noting that a number of these programs do still relate to assets of a particular age or vintage. However, the JEN documentation suggests the decisions to undertake works in these programs more concerns the location of the assets or their performance (where the performance issues are not related to the age/condition of the asset).

Age-related but model limitation

Although this review has found that 94% of JEN's repex is age-related (and so should be able to be assessed through the AER repex model), 19% ($33.2 million) of the repex forecast produced by the model may have some limitation in how it can be compared to JEN's forecast due to how the asset is being modelled.

This issue primarily concerns programs which may involve assets (or a cohort of assets) that do not have their own age profile within the JEN repex model. As such, the portion of the forecast prepared by the model to cover these programs would implicitly use a relationship developed for assets that are specifically modelled.

The programs in this category cover:

- poles (26% of the forecast for this group)
    - The continuation of a program to replace a cohort of older wooden poles, based on their condition. This cohort of poles were designed appropriately when installed, but with a lower diameter than typical poles. This narrower design girth combined with age-related internal rot results in this cohort having a lower structural standard than JEN's typical poles – and hence typically a shorter life ($5.8 million).

- pole top structures (40% of the forecast for this group)
    - The most significant program within this category is the continuation of the pole-top fire mitigation program ([c-i-c]), which represents 33% of this group's forecast. This program involves the condition-based replacement of a cohort of pole top structures. However, this cohort is defined by those that use certain types of insulator that can be prone to dust build-up (under the right circumstances). This build up can cause arcing in wooden cross-arms that are in poor condition, leading to pole top fires.
    - The continuation of a program to replace pole tops associated with aged insulators and cross arms ($2.6 million).

- underground cables (57% of the forecast for this group)
  - The continuation of two programs for which the assets being replaced are not explicitly represented in the JEN repex model. These programs cover the replacement of trifurcating boxes and cable terminations ($5.7 million).
- zone substation transformers (3% of the forecast for this group)
  - The continuation of programs to replace assets associated with transformers, but not the transformers themselves (e.g. enclosures, bushings, oil regeneration) ($0.7 million).
- SCADA, network control and protection (10% of the forecast for this group)
  - The continuation of programs to replace aged, but unspecified "miscellaneous" secondary plant ($1.9 million).
- Other (53% of the forecast for this group)
  - The continuation of programs to replace various aged zone substation assets, without specific asset categories in the model, covering control buildings and unspecified "miscellaneous" primary plant ($1.9 million).

Age-related but allocation issue

Within JEN's forecast, there is also 1% ($2.1 million) that appears to be allocated in a way that may be inconsistent with the allocation JEN used for the category analysis RIN (used in the JEN repex model).

This issue only appears to concern the SCADA, network control and protection group, accounting for 10% of this groups forecast. This is linked to a number of programs in this category for which the assets being replaced appear to be in the "other" AER asset group, namely:

- zone substation battery banks and chargers
- other secondary equipment, including power quality and Vicpool meters.

Table 1 Asset group reconciliation summary

		2016 to 2020 repex forecast ($ millions)			
Asset group	JEN repex	weakly age-related [a]	age-related [a]	model limitation [b]	allocation issue [b]
Poles	[c-i-c]		[c-i-c]	$5.8 (26%)	
Pole top structures				$14.7 (40%)	
OH conductors		$6.1 (54%)			
UG cables				$5.7 (57%)	
Services					
Distribution transformers		$2.5 (27%)			
Distribution switchgear					
Zone transformers				$0.7 (3%)	
Zone switchgear					
Other		$1.5 (18%)		$4.3 (60%)	
SCADA & protection				$1.9 (10%)	$2.1 (11%)
Total		**$10.2 (6%)**		**$33.2 (20%)**	**$2.1 (1%)**

a – the percentage provided in brackets is the percentage of the JEN capex forecast
b – the percentage provided in brackets is the percentage of the age-related component

3 Overview of repex model results

3.1 Age profile and key planning parameters

Before turning to the replacement forecasts produced by the JEN repex model, it is useful to first provide results that show the network that is contained within the model. This should assist JEN in verifying the model and in appreciating the factors driving the forecasts produced by the model.

Figure 1 shows the age profile of the JEN network, broken down into the various AER asset groups. Table 2 shows various measures of the network that define its size and age.

The figure and table indicate:

- there is a sharp rise in the profile from around the early 1950s to the late 1960s
- the average age of the network is 23 years, with average age of asset groups ranging from 15 years for underground cables to 35 years for "other" assets
- the average life of the network (via the calibration process) is 61 years, with the average life ranging from 49 years for distribution transformers to 70 years for underground cables
- given the age profile and the asset life, the network appears to be in the early stages of a replacement cycle, and therefore, it would be expected that replacement needs will be rising in general.

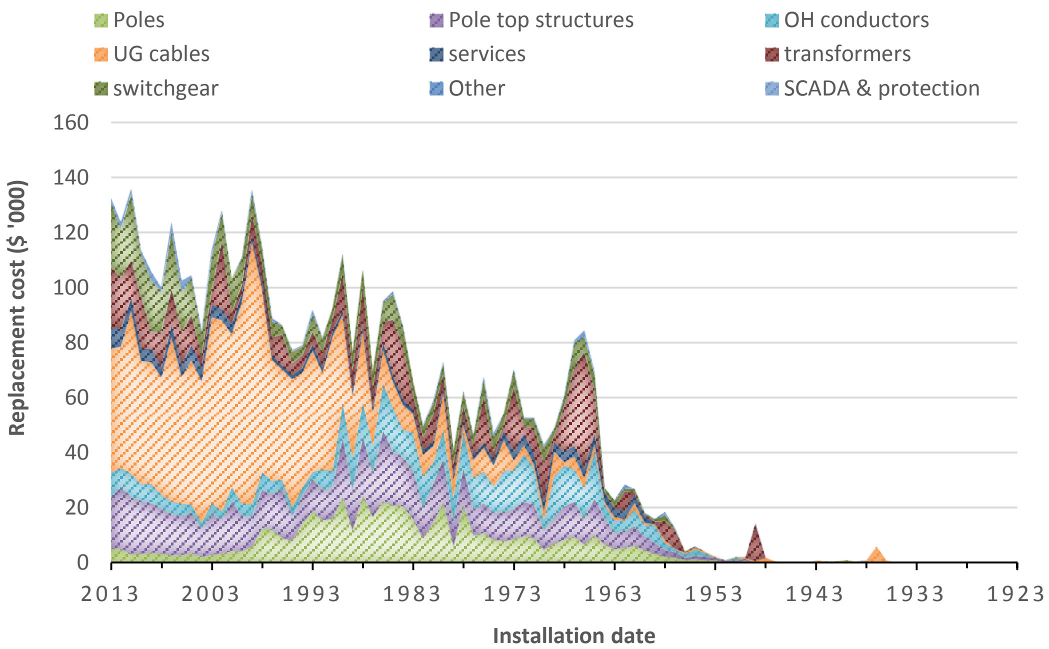

Figure 1 - JEN repex model age profile

Table 2 - Summary of JEN repex model network measures, by asset group

Asset Group	quantity units	replacement cost $millions	age years	life years	unit cost $'000
Poles [a]	78,654	[c-i-c]	30	59	[c-i-c]
Pole top structures [b]	136,991		25	57	
OH conductors [c]	4,453,624		31	61	
UG cables [c]	1,672,498		15	70	
Services [c]	4,660,817		25	50	
Transformers [d]	6,124		28	57	
Distribution transformers	*6,063*		*22*	*49*	
Zone transformers	*61*		*32*	*63*	
Switchgear [e]	62,389		18	54	
Distribution switchgear	*61,448*		*16*	*56*	
Zone switchgear	*941*		*22*	*50*	
Other [f]	549		35	50	
SCADA & protection [g]	187,168		20	49	
Total	**NA**		**23**	**61**	

a- pole units are measured as individual poles, the ages, costs and lives allow for a blending of replacement and staking, where the age and life for a staked pole is measured from the time of pole installation, not staking.

b- pole top structure units are measured as the volume of crossarms

c- conductor, cable and service units are measured in metres

d- transformer units are measured in individual transformers

e- switchgear units are measured as individual switch- and fuse-gear sets i.e. a 3-phase set for a 3-phase system and 1-phase unit for single phase system

f- "Other" units represent the aggregation of a range of assets mapped to this asset group

g- SCADA & protection units represent the aggregation of relays (measured by individual relays) and communication cables (measured in metres); it is worth noting that communication cables represent the predominant volume, but relays represent the predominant cost, and therefore, the unit cost represented in this table will be anomalous.

3.2 Aggregate repex model results

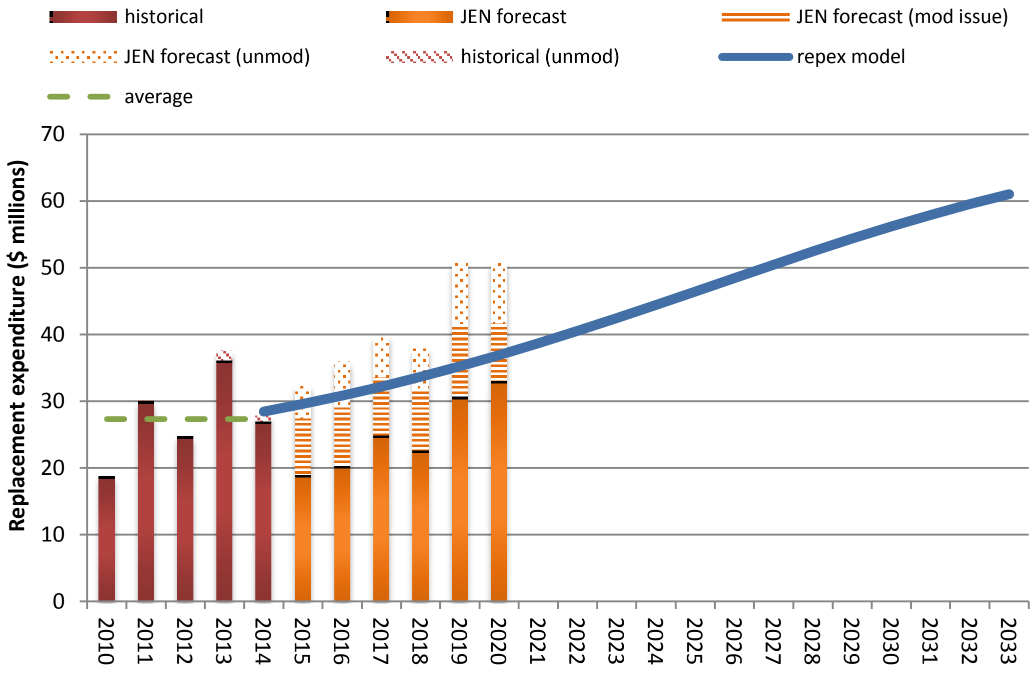

Figure 2 JEN repex model forecast comparison

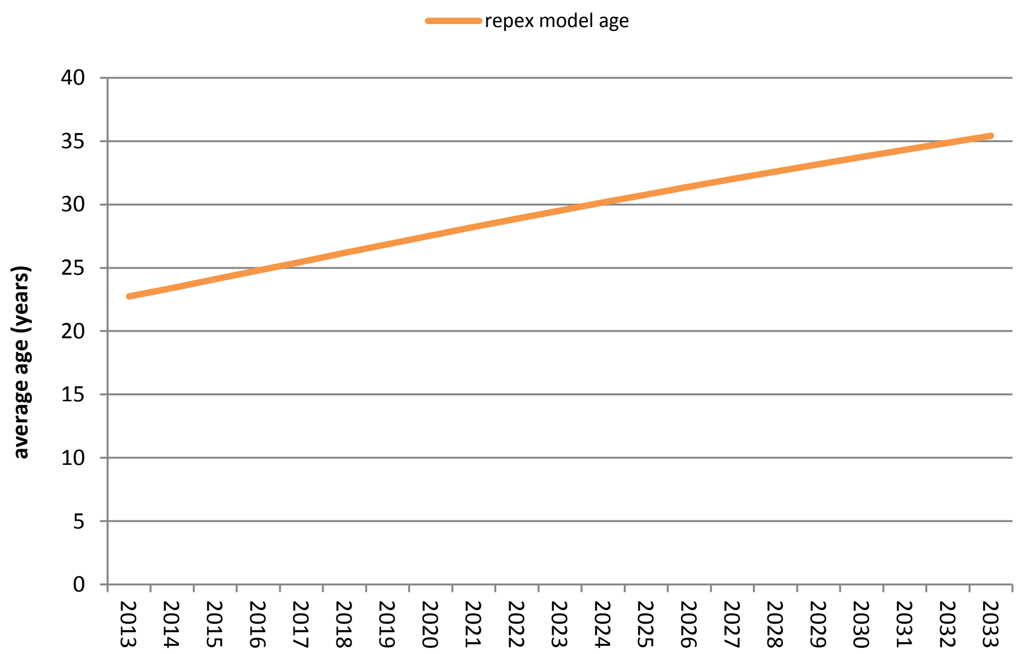

Figure 3 JEN repex model forecast average network age

Figure 2 above shows the aggregate repex forecast produced by the JEN repex model (blue line) compared against JEN's repex forecasts (the orange bars). The chart also shows the historical expenditure taken from the JEN's category analysis RIN (red bars), and the average historical expenditure (green dash)[11]. This chart also shows the component of JEN's forecast and historical expenditure that is unmodelled (see Section 1.3.3.1) and the component of JEN's forecast that is subject to the model issues discussed in Section 2.

The JEN repex model forecasts that JEN's repex will need to rise (assuming the calibration basis is valid), as suggested by the age profile above. The repex model suggests that this rise could last at least over the next three to four regulatory periods, assuming similar circumstances. It is also worth noting, the model forecasts that the (existing) network will still age over this period (see Figure 3), with the average age of the network increasing from around 23 years in 2013 to around 28 in 2020 – a 20% increase[12].

Although the model agrees with JEN's forecast that replacement expenditure should rise, the aggregate replacement expenditure over the next regulatory period predicted by the model is 5% ($8 million) less than the modelled component of JEN's forecast. However, this result is near the top end of the range of expenditure that potentially could have some modelling inaccuracy, with the repex model forecast well above (21% higher) than the component of JEN's forecast without these modelling issues.

As discussed in Section 2, these findings do not necessarily say that JEN's forecast compares favourably against the repex model – addressing these limitations in the model could move its forecast up or down. Nonetheless, this finding does suggest that fairly modest improvements in the accuracy of the model could result in JEN's forecast comparing favourably against the model.

3.3 Asset group repex model results

We have also analysed the asset groups within the model to identify where the main variances between the forecasts are occurring. Table 3 below summarises the findings of this analysis, showing a comparison between JEN's historical repex over 2010-2014, its repex forecast over the next period and the repex model's forecast over this period.

This table indicates the following:

- the model forecast for the poles, pole top structures, services, and zone transformers asset groups are within 10% of JEN's forecast
- underground cables, distribution switchgear, SCADA/protection/control, and "other" asset groups show the greatest underestimate by the repex model compared to JEN's forecast – in aggregate across these four groups, the repex model is 61% below JEN's forecast ($28 million over the next period)
- overhead conductors, distribution transformers, and zone switchgear show the greatest overestimate by the repex model compared to JEN's forecast – in

[11] This chart also shows a small amount of historical expenditure we have been unable to allow for within the model (red hatching). This situation can arise when there is an inconsistency in the expenditure and volume data in RIN 2.2.1 (e.g. expenditure without a volume) or when the mapping between RIN 5.2.1 and 2.2.1 is not possible.

[12] It is important to note however that this only represents the age change of the assets that form the existing network. New assets, associated with augmentation and customer connection, will likely reduce this age across the whole network that will exist in 2020.

aggregate across these three groups, the repex model is 76% above JEN's forecast ($23 million over the next period).

These results indicate that there are range of variances across the asset groups, with the repex model forecast above JEN's forecast for some asset groups and below in others. To a large extent, the repex model's higher forecast for the "overhead conductor" and "zone switchgear" groups balance out much of its lower forecast for the "SCADA, network control and protection" and "other" groups to produce the aggregate variance discussed above.

This table also shows the significance of the model issues discussed in Section 2 on these results (the bracketed values). This shows that a number of the asset groups with significant difference between JEN's repex forecast and the repex model forecast suffer from these limitations.

Most notably, for three of the asset groups, identified above, where the JEN repex model is significantly lower than JEN's forecast:

- the underground cable group has 57% of JEN's forecast in the *model limitation* category
- the SCADA and protection group has 10% of JEN's forecast in the *model limitation* category and 11% of the forecast the *allocation issue* category
- the "other" group has 60% of JEN's forecast in the *model limitation* category.

Further, in the asset group where the JEN repex model is significantly higher than JEN's forecast, the overhead conductor group, JEN's forecast has 54% in the *weakly age-related* category.

With regard to this review, it is important to note that we have identified these issues, but we have not attempted to gauge their effect or correct them. JEN will need to consider the findings presented here and decide the best course of action. Possible solutions would be:

- *weakly-age related*: correcting this issue would need the historical program expenditure and volumes to be removed from the calibration data
- *model-limitation*: if the age profile of the alternative asset was not considered a good proxy for the program in question then additional age profiles would be required to develop the forecast
- *allocation issue*: this will require JEN to either reallocate the category analysis RIN data (and recalibrate the model) or reallocate the forecast data.

Finally, it is also important to note that the comments JEN has provided on the programs underlying its repex forecast (provided in Appendix B), indicate another matter that may have significance in drawing inferences from the JEN repex model, as calibrated here. This calibration process used here produces a benchmark repex forecast, which implicitly assumes that JEN's repex over the calibration period reflected the prudent and efficient actions to maintain the reliability, security and safety of the network, and comply with its obligations (i.e. the NER capital expenditure objectives and criteria).

JEN's comments on the drivers of the services asset group (and possibly the poles and pole top structures asset groups), indicates that there may have been a degradation of performance over the calibration period for these asset groups. For example, JEN's comments on the program to replace non-preferred services suggests the failure rate (and hence, in particular, safety risk) has degraded over the calibration period.

Therefore, the calibration process may be affected by this. If this is the case then the forecast produced by the calibrated model may have a level of further degradation implicitly within it. This would not be in accordance with the NER objectives, and so, the repex model may be understating the repex forecast necessary to maintain reliability, security, and safety.

JEN would need to investigate this matter further to understand whether this is materially affecting the calibration process or not. If considered material, JEN would need to determine what should have been the volume of replacements required over the calibration period to maintain performance, and in turn what effect this volume would have on the calibrated planning parameters (i.e. life) and the forecast repex.

It is important to stress that these findings on the model limitations in JEN forecast do not, on their own, suggest that the repex model is not fit-for-purpose in a regulatory context. This could only be decided in the broader context that the AER uses the model to assess JEN's capital expenditure forecast.

More detailed results for each asset group are provided in the Appendix B of this report.

This appendix also include some comments that JEN has provided on the underlying programs within each asset group, including JEN's view of the drivers of these programs, and how these programs affect the profile of repex (historical and forecast). These comments may be helpful for external readers of this report to appreciate the context of JEN's historical and forecast repex with regard to the results of the repex modelling exercise discussed here.

3.4 Concluding comments

The results presented above show that the aggregate JEN repex model forecast, as applied here, is 5% ($8 million) below the modelled component of JEN's forecast. However, there is 26% of JEN's forecast that may have some limitation in how it can be assessed using the repex model.

In appreciating the significance of these findings, it is worth noting the following:

- Owing to the form of JEN's forecast provided for our analysis, we have not been able to reconcile the volume forecasts. Variances in volumes could be different to the expenditure variances presented here. On this matter, it is worth noting that the scenarios that the AER applied for its NSW draft decision, using JEN's forecast unit costs (discussed in the introduction) would draw out these differences, if they exist.

- In the recent NSW draft decisions, the AER has excluded the "SCADA and protection" and "other" asset groups from its repex modelling exercise. If that was applied here then the aggregate results present above would look far more positive for JEN, with the repex model forecast 10% above the modelled component of JEN's forecast.

Table 3 – JEN repex model forecast – summary results by asset group

	repex - average per annum				
	2010-14	2016-20			
	historical	JEN forecast[a]	Repex model	difference[a]	Repex model
Asset Group	$millions	$millions	$millions	$millions	volumes
Poles		[c-i-c]		$0.0 ($1.1)	1,087 poles
Pole top structures				-$0.5 ($2.5)	1,222 cross arms
OH conductors				$3.0 ($4.2)	45,990 metres
UG cables				-$0.8 ($0.3)	1,391 metres
Services				$0.2 ($0.2)	114,519 metres
Transformers				$0.2 ($0.8)	62 transformers
Distribution transformers				*$0.5 ($1.0)*	*61 transformers*
Zone transformers				*-$0.3 (-$0.2)*	*0.7 transformers*
Switchgear				$0.9 ($0.9)	502 switches/fuses
Distribution switchgear				*-$0.2 (-$0.2)*	*489 switches/fuses*
Zone switchgear				*$1.1 ($1.1)*	*13 CBs/switches*
Other				-$1.4 (-$0.2)	18 various assets
SCADA & protection				-$3.1 (-$2.3)	34 relays
Total				**-$1.7 ($7.4)**	

a – the brackets indicate the amount without the modelling issues

A JEN repex model development

A.1. The AER's repex model

A.1.1. Overview of repex model

The AER repex model is an excel workbook, with a structure, formulas and VBA functions and macros pre-defined in order that it can be used by the AER to develop a network model of a DNSP and use this to prepare repex forecasts. The model is very similar in principle to a model used by the UK energy regulator, Ofgem.

The DNSP's network is constructed within the AER repex model as a series of asset populations. The model uses a probabilistic replacement algorithm to make predictions of replacement needs for this population. The probabilistic replacement algorithm assumes the economic life is normally distributed for any asset population represented within the model. From this, the model predicts future replacement volumes based upon a current age profile for the asset population. This approach is similar to survivor-type models, which are used in various disciplines to model mortality, replacement and reliability.

From an engineering point of view, it is worth noting that although the model relies upon the ages of assets and uses age-based lives, there is no inherent assumption within the model (or its use) that purely age-based replacement strategies are used by the DNSP. The asset life simply reflects the distribution in the life of a population of assets[13] - irrespective of the factors that define the life.

The AER has indicated that it will use this model to make top-down assessments of a DNSP's repex forecast, covering both intra-company and inter-company benchmark forecasts.

Importantly, for the repex modelling discussed here, we have only considered an intra-company benchmark role, where a forecast is prepared that reflects the last 5 years of JEN's historical replacement levels (i.e. reflecting historical asset lives and unit costs).

A.1.2. AER repex model form, inputs and output

Network specification inputs – asset categories, groups and age profiles

As indicated above, a DNSPs network is defined as a series of distinct asset categories within the repex model. To facilitate analysis and reporting, each asset category is assigned to a smaller set of asset groups. In this regard, a model may use 100 asset categories or more, to improve the accuracy of the analysis, but may use 10 asset groups to provide aggregate forecast for reporting (and benchmarking) purposes.

[13] For example, for many assets, the distribution in the life could result from detailed condition and risk analysis to determine the optimal time to proactively replace each asset. For others, it could be simply the age when each asset fails.

An age profile must be provided for each asset category used in the model. This age profile represents a snap shot of the ages of the population of assets in that category for the initial year of the model. That is, the age profile is essentially a vector that holds the volume of assets at one-year increments of age.

The AER has predefined the asset categories and asset groups that the DNSP should use as the basis of their models. This will be discussed further in A.2.1.

Planning parameters inputs

The model uses three planning parameters to define the approach it uses to predict future replacement needs:

- The replacement life, which is represented as a normal probability distribution is defined by two parameters: its mean life and the standard deviation of the life.

  It is worth noting that the replacement life actually represents the life that an asset is replaced or the life when a life extension may be used, if this is a feasible option. These parameters, via the asset age profile, allow the model to predict the future volume of assets that will need to be replaced (or have their life extended).

- The third parameters reflects the average replacement unit cost.

  That is, the volume forecast multiplied by the replacement unit cost produces the expenditure forecast.

  Importantly, depending on the asset, the replacement cost parameter may represent an actual replacement cost, or a life extension cost, or in some cases a blended cost that represents both.

Model outputs

The model produces various outputs. These outputs provide various measures of the input age profiles, such as average age, average life, total quantity, and total replacement cost (i.e. quantity x replacement unit cost).

The model also produces forecasts (by year over a 20-year period), including replacement volumes, replacement expenditure, average age, and average remaining life.

These various outputs are provided at the asset category, asset group and total network level. When averages are calculated at the asset group or network level, the model uses a weighted average using the replacement cost of each asset category as the weighting.

A.1.3. Calibration

The calibration of a DNSP's model is the critical process that is applied to produce the intra-company benchmark model.

The calibration process concerns deriving the set of planning parameters that reflects historical replacement outcomes (volumes and expenditure) over the calibration period (e.g. the last 5 years)[14].

Assuming the actual volumes and expenditure data is available for each asset category in the model (or a reasonable estimate) then the following process can be used (this process should be in line with the explanation provided in the AER repex model handbook).

Replacement unit cost

The replacement unit cost parameters for each asset category is simply the actual expenditure over the calibration period divided by the actual replacement volume over that period.

Life planning parameters

The two life parameters for each asset category need to be set to ensure the model reflects the volume replaced over the calibration period.

However, the calculation of the two life planning parameters is more complicated because:

- we have two parameters to determine and typically only one variable (the total volume replaced)
- the replacement volume calculated by the model is dependent on the probabilistic replacement algorithm, and therefore, we need to perform a simulation through the model
- the available age profile represent the end point of the calibration period – not the start or mid-point.

Therefore, the calibration of the life parameters is slightly more involved and involves the following two assumptions.

- First, in the absence of better information, the need to determine the standard deviation is removed by making it dependent on the mean. The AER has advised that it will assume that the standard deviation is taken to be the square root of the mean. We have used this assumption here.
- Second, the mean life is set to ensure that the first year of the forecast produced by the model equals an *adjusted* average annual replacement volumes during the calibration period. The adjustment is set to reflect the initial growth rate in replacement volumes that is forecast by the model. This adjustment is necessary to approximate the change due to using the end-point age profile, rather than the profile that reflect the mid-point of the calibration period[15].

[14] It worth noting that a similar process could be applied to calibrate the model to other outcomes, for example the forecast replacement volumes and expenditure.

[15] It is worth noting that the actual trend in the historical replacement volumes is typically not used as this may be influenced by incentives associated with the regulatory regime.

Given the above, and allowing for the 5-year calibration period, the *adjusted* average annual replacement volumes is calculated as:

(1 + x%)^3.(total volume replaced of asset replaced over calibration period) / 5

where *x*% is the initial forecast growth rate calculated through the model, and the power of 3 is necessary to advance the growth over 3 years i.e. from the mid-point in the calibration period (2011) to the first year of the forecast (2014).

A.2. JEN repex model

A.2.1. JEN repex model structure set up

Setting up the model structure concerns defining the asset categories and asset groups, and populating the JEN model with the relevant age profiles.

Repex model asset categories and age profiles

The JEN network is constructed within the repex model using the asset classifications and JEN's asset age profiles defined in table 5.2.1 of the category analysis RIN. That is, each asset category in the JEN repex model correspond to a line item in table 5.2.1 (i.e. the individual asset categories defined by the AER.

the pole top structure enhancement to age profiles

We have made one enhancement to the RIN classification to improve the reconciliation of the model forecast to JEN's forecast.

The final version of the category analysis RIN that JEN submitted to the AER had the asset categories for pole top structures removed from table 5.2.1. We understand that this was at the request of the AER, as many other DNSPs cannot provide age profile at this granularity.

However, we understand that JEN has a number of significant replacement programs associated with pole top structures. Therefore, to ensure that these can be assessed on their merits, we have added in pole top structure asset categories, using the age profiles JEN produced for the category analysis RIN it provided to the AER in July 2014.

Repex model asset groups

The asset groups in the model have been defined using the asset groups specified by the AER in table 5.2.1 of the category analysis RIN (with the addition of pole top structures group noted above.

the transformer and switchgear enhancement to asset groups

The AER defines two asset groups to cover all switchgear and all transformers. However, JEN – like many other DNSPs – classifies switchgear and transformers into distribution and zone substations when developing its plans[16].

[16] This more detailed breakdown has also used in the repex modelling that the AER applied in its current determination for the Victorian DNSPs.

Therefore, we have added these additional groups in the model to make the distinction between them more transparent. We have shown both the AER group and the more detailed breakdown into distribution and zone substation for most of the results presented in the main body of this report.

A.2.2. Model calibration set up

The model calibration set up involves developing the historical data necessary to perform the calibration process (discussed in Section A.1.3). This involves calculating for each asset category in the model (i.e. in table 5.2.1), for the calibration period (2010 to 2014):

- historical repex
- historical replacement volumes.

The basis of this data, is the historical replacement volumes and expenditure that JEN has reported in table 2.2.1 of the category analysis RIN. This data covers the period from 2010 to 2013 and across categories that are largely equivalent to table 5.2.1. This data has been enhanced by adding the equivalent 2014 data as provided by JEN to form the equivalent table 2.2.1 data set spanning the 2010 to 2014 period.

The key steps in preparing the table 2.2.1 data set for the calibration process are as follows:

1. **Escalation** - the table 2.2.1 expenditure has been escalated using CPI data (provided by JEN) to place all expenditure on a real 2015 basis.
2. **2.2.1 to 5.2.1 mapping** - rules have been developed that map the 2.2.1 asset categories (i.e. the asset that was installed) to the 5.2.1 asset categories (i.e. the asset that was retired). In most cases this was considered to be a direct one-to-one mapping using the equivalent asset categories in 2.2.1 and 5.2.1. However, in some circumstances, categories do not map directly or map to multiple categories. In these case, JEN advised the mapping rules.

A.2.3. Model calibration process

For each asset category in the JEN model, the calibration process has involved the following steps:

1. Calculate the replacement unit cost as the total historical escalated repex divided by the total historical replacement volumes (using the mapping described above)[17].
2. Determine the mean life that sets the 1st year of the forecast equal to the (unadjusted) average annual historical volume. Excel's goal seek function is used for this purpose.
3. Determine the initial growth rate in the volumes predicted by model i.e. the growth from the first to the second year of the forecast.

[17] If mapping data results in no historical replacement volumes, for an asset with an age profile, we have applied a "dummy" unit cost of 0.001. This "dummy" unit costs is necessary to stop the model producing errors, but should not have a material effect on the forecast.

4 Calculate the adjusted average annual historical volume using this growth rate and the formula above.

5 Determine the mean life parameter that sets the 1st year of the forecast equal to the adjusted average annual historical volume. Excel's goal seek function is used for this purpose.

A.2.4. Alterations to the published AER model

We have not changed the underlying structure, format, and predictive algorithms of the AER repex model. However, we have added a number of sheets to aid in the modelling and reporting exercise.

These additions are:

- Three sheets have been added to contain the JEN input data, covering:
  - RIN table 2.2.1
  - RIN table 5.2.1
  - JEN forecast.
- Three sheets have been added to facilitate the mapping between tables 5.2.1 and 2.2.1, and the calibration process. These sheets are:
  - Asset map
  - Volume map[18]
  - Other data.
- A sheet has been added to aid in the reporting of results and to produce comparisons with the JEN forecast:
  - Comparison Ch.

[18] The assumptions that map table 5.2.1 to table 2.2.1 are provided on the Volume map sheet.

B Asset group results

This appendix provides a more detailed summary of the outputs from the JEN repex model. This appendix is structured in terms of the asset groups in the JEN repex model, but also provides results at the AER asset category level (for those categories that JEN prepared an age profile in the category analysis RIN).

This section also provides summary comments, JEN provided during the course of this modelling exercise, that explain some of the underlying programs within each asset group, including JEN's view of the drivers of these programs, and how these programs affect the profile of repex (historical and forecast).

The results in this section should be viewed with reference to the JEN repex model and JEN's category analysis RIN for further context.

B.1. Poles

B.1.1. Overview of key results

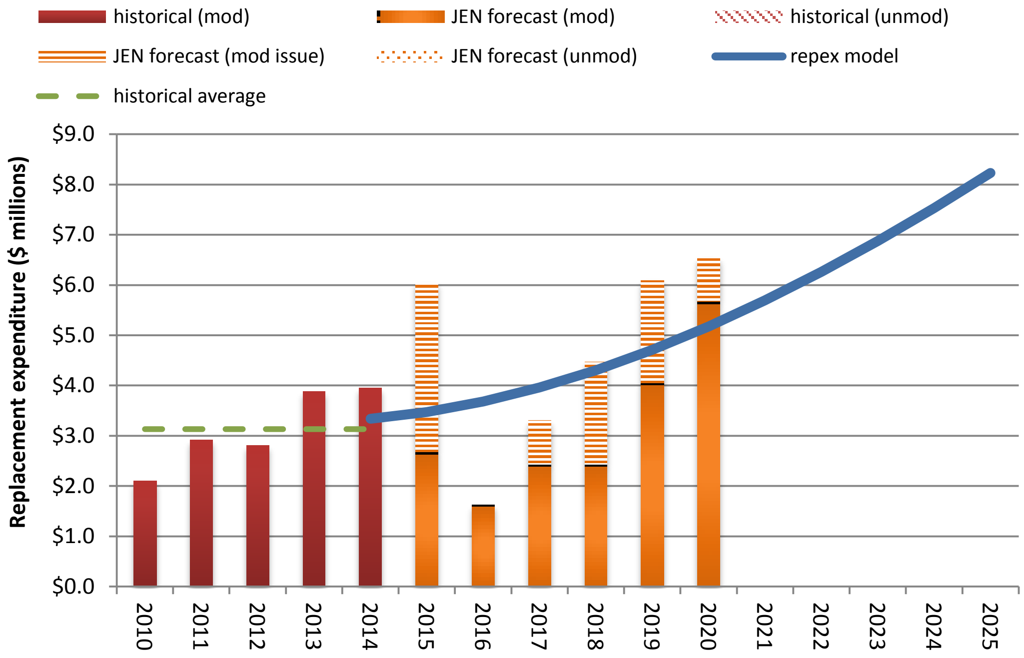

Figure 4 JEN repex model – poles repex forecast

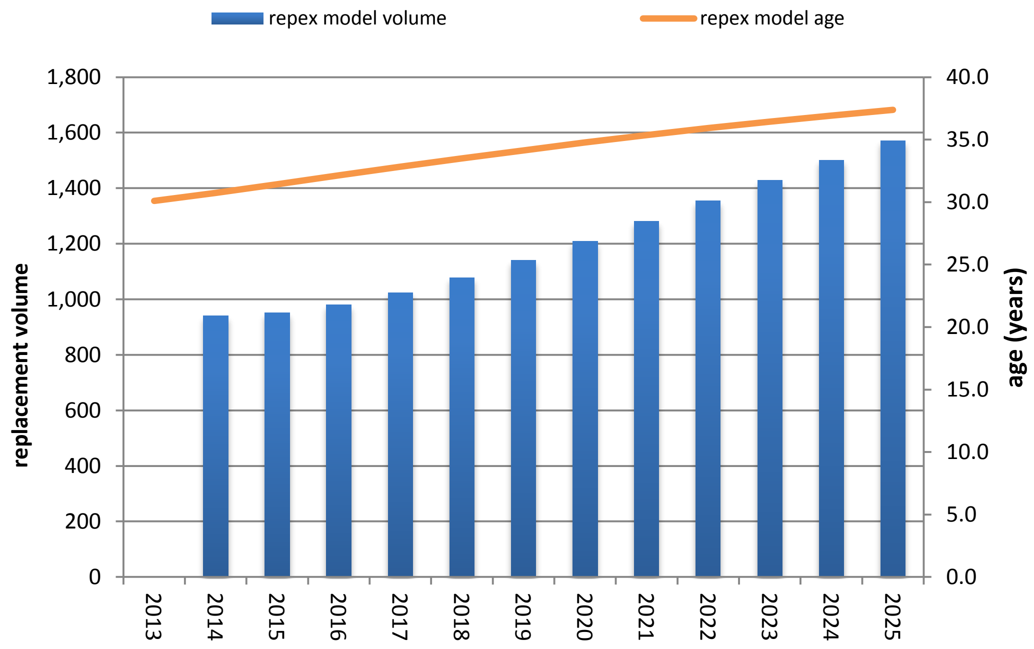

Figure 5 JEN repex model forecast – replacement volumes and age - poles

Table 4 JEN repex model forecast – summary - poles

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
Poles	[c-i-c]	[c-i-c]	[c-i-c]	**$0.0 ($1.1)**

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the poles asset group, JEN has advised:

"There are groups of our wood pole population that were not constructed to current design standards:

- *The first concerns a group of our wood poles that are undersized; that is, their original design diameter is less than that required to meet our minimum mechanical loading standards.*
- *The second concerns a group of our LV wood poles that had HV raisers added (later in their life) to allow them to carry HV circuits above the LV circuits. These steel raisers are no longer considered acceptable in Victoria under current health and safety standards.*

2015 saw a greater volume of undersize poles being replaced or reinforced. These activities start to ramp up again in 2017.

From 2017 the LV pole replacement program is stepping up. The key drivers underlying the LV pole replacement is the ongoing aging of our pole population, which is causing greater volumes of poles to be found to be below the minimum standards."

B.1.2. Set up and calibration parameters

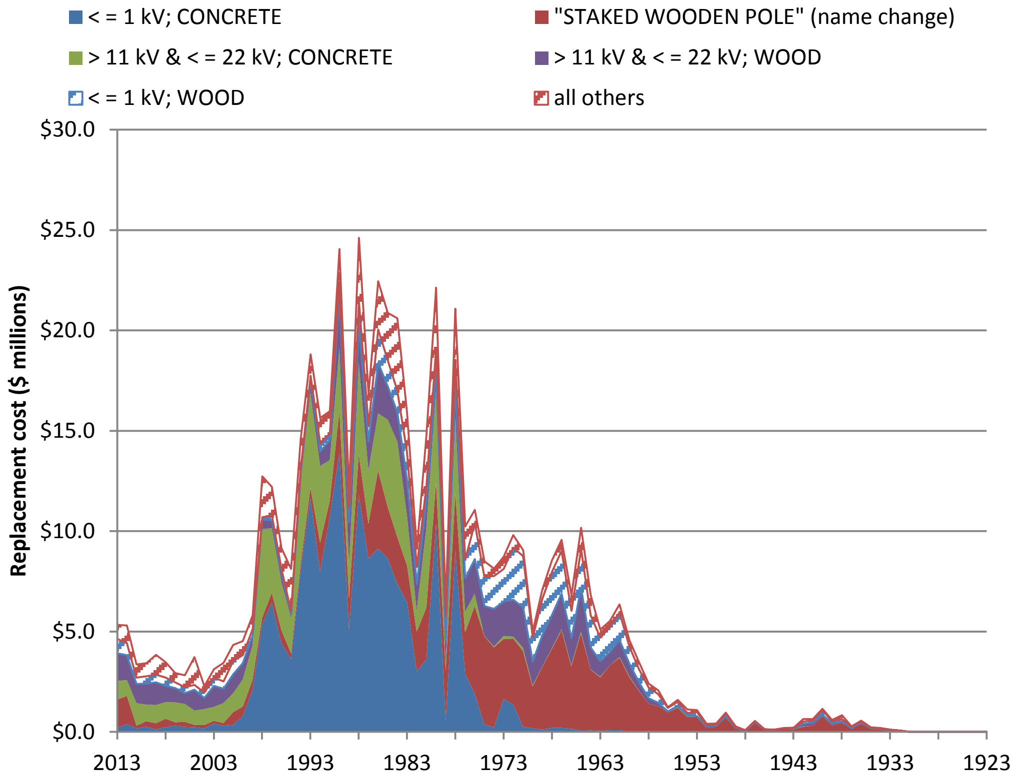

Figure 6 pole age profile

Table 5 RIN 2.2.1 data required for calibration - poles

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
"STAKED WOODEN POLE" (name change)	84.4		[c-i-c]	not one-to-one mapping
< = 1 kV; WOOD	2,285.9			not one-to-one mapping
> 1 kV & < = 11 kV; WOOD	427.9			not one-to-one mapping
> 11 kV & < = 22 kV; WOOD	1,479.0			not one-to-one mapping
> 22 kV & < = 66 kV; WOOD	182.6			not one-to-one mapping
< = 1 kV; CONCRETE	91.5			not one-to-one mapping
> 1 kV & < = 11 kV; CONCRETE	7.5			not one-to-one mapping
> 11 kV & < = 22 kV; CONCRETE	36.9			not one-to-one mapping
> 22 kV & < = 66 kV; CONCRETE	2.0			
< = 1 kV; STEEL	0.0			RIN data zero - caution with calibration
> 1 kV & < = 11 kV; STEEL	0.0			RIN data zero - caution with calibration

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
> 11 kV & < = 22 kV; STEEL	0.0		[c-i-c]	RIN data zero - caution with calibration
> 22 kV & < = 66 kV; STEEL	0.0			RIN data zero - caution with calibration
Total	**4,597.7**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Note: one-to-one mapping between the asset categories in table 2.2.1 and table 5.2.1 are not possible with poles, because:

- Pole staking volumes in table 2.2.1 map to the wooden poles categories (i.e. a wooden pole is staked when it reaches the end of its life)
- A portion of the wooden poles categories in table 2.2.1 map to the staked poles category in 5.2.1 (i.e. staked wooden poles must be replaced with a new pole when they reach then end of their life)
- A portion of the concrete poles category in table 2.2.1 map to wooden poles in table 5.2.1 (i.e. some wooden poles are replaced with concrete poles).

JEN provided the mapping rules for these allocations (see associated repex model files).

Table 6 calibrated planning parameters - poles

Asset category	life	unit cost ($'000)	S1 life[a]	volume growth rate
"STAKED WOODEN POLE" (name change)	77.5	[c-i-c]	78.6	7.3%
< = 1 kV; WOOD	58.8		58.9	1.0%
> 1 kV & < = 11 kV; WOOD	61.8		61.2	-3.2%
> 11 kV & < = 22 kV; WOOD	55.3		55.4	0.9%
> 22 kV & < = 66 kV; WOOD	63.4		63.3	-0.5%
< = 1 kV; CONCRETE	51.7		53.1	15.4%
> 1 kV & < = 11 kV; CONCRETE	51.9		54.0	29.2%
> 11 kV & < = 22 kV; CONCRETE	50.5		52.0	16.1%
> 22 kV & < = 66 kV; CONCRETE	61.3		60.1	-6.4%
< = 1 kV; STEEL	107.7		105.4	30.3%
> 1 kV & < = 11 kV; STEEL	47.5		48.0	53.1%
> 11 kV & < = 22 kV; STEEL	83.8		82.7	39.2%
> 22 kV & < = 66 kV; STEEL	72.0		71.4	44.5%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes

B.1.3. JEN repex model forecasts

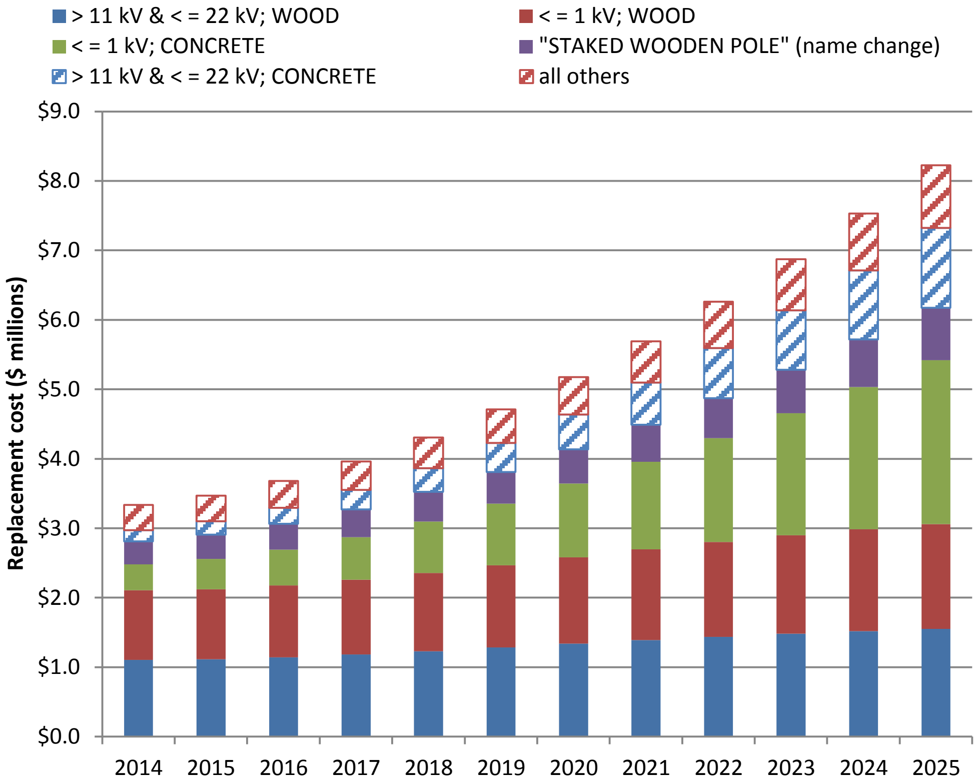

Figure 7 JEN repex model – asset category repex forecast - poles

Table 7 JEN repex model – asset category summary - poles

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
"STAKED WOODEN POLE" (name change)	[c-i-c]	126.7	39.8	42.2	45.3
< = 1 kV; WOOD		2,642.8	37.0	37.1	37.5
> 1 kV & < = 11 kV; WOOD		394.7	35.8	36.0	37.0
> 11 kV & < = 22 kV; WOOD		1,681.7	30.7	31.3	32.3
> 22 kV & < = 66 kV; WOOD		194.5	31.5	32.9	34.9
< = 1 kV; CONCRETE		248.3	25.6	28.3	31.6
> 1 kV & < = 11 kV; CONCRETE		34.7	24.6	27.3	30.6
> 11 kV & < = 22 kV; CONCRETE		107.2	22.7	25.4	28.8
> 22 kV & < = 66 kV; CONCRETE		1.9	20.5	23.3	27.2
< = 1 kV; STEEL		0.0	23.8	26.8	30.8
> 1 kV & < = 11 kV; STEEL		0.0	9.8	12.8	16.6
> 11 kV & < = 22 kV; STEEL		0.0	24.6	27.6	31.6
> 22 kV & < = 66 kV; STEEL		0.0	26.2	29.2	33.2
Total		**5,432.5**			

B.2. Pole top structures

B.2.1. Overview of key results

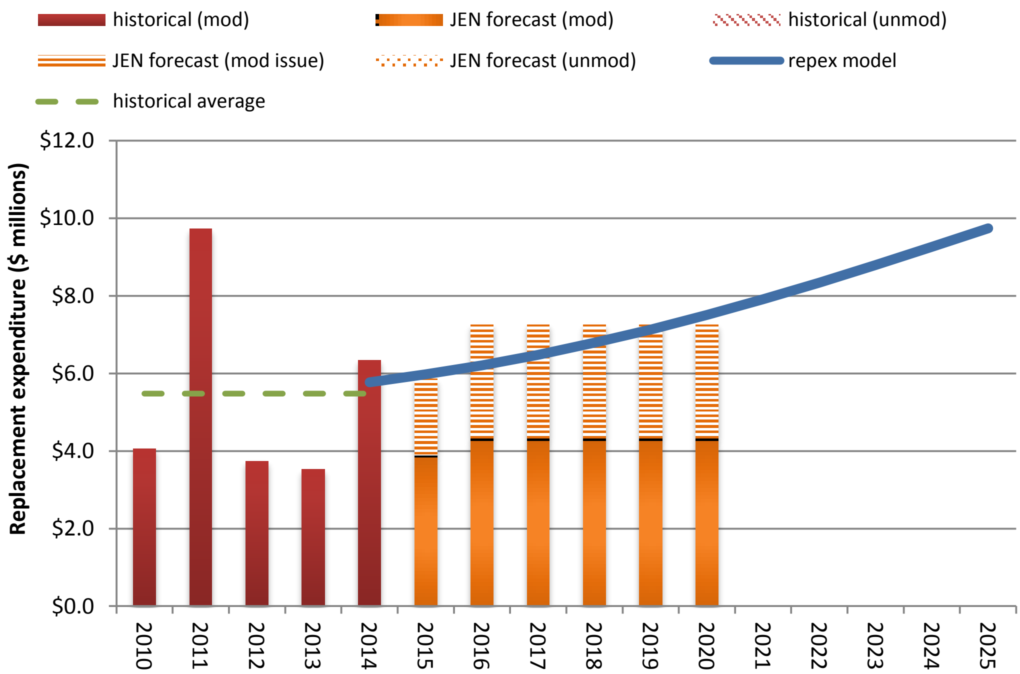

Figure 8 JEN repex model – pole top structures repex forecast

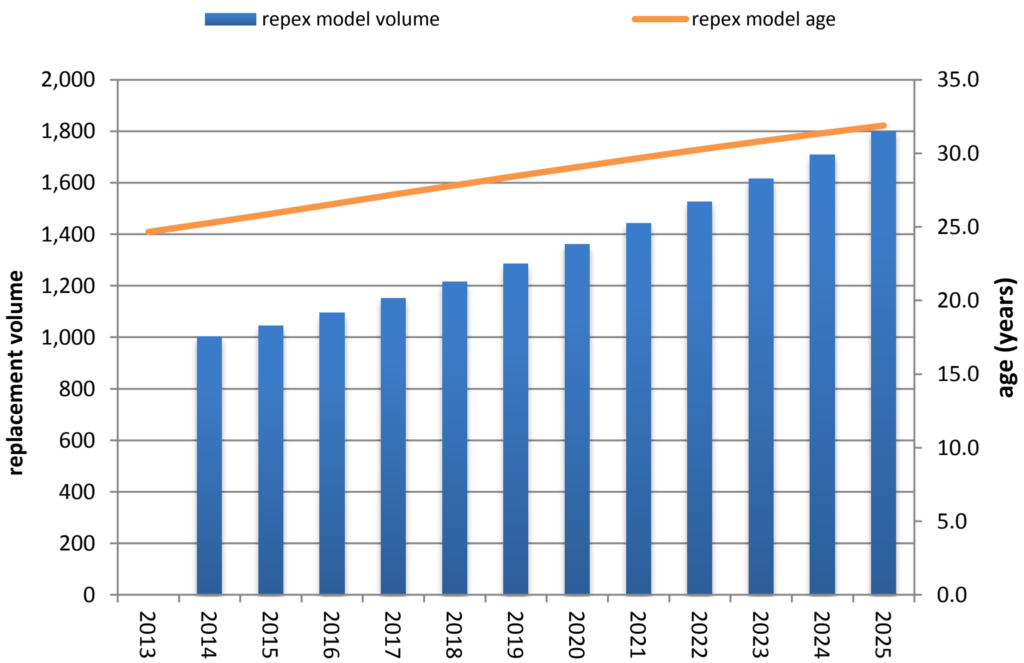

Figure 9 JEN repex model forecast – replacement volumes and age - pole top structures

Table 8 JEN repex model forecast – summary - pole top structures

Asset Group	repex - average per annum 2010-14 (RIN) $millions	2016-20 JEN forecast[a] $millions	 Repex model $millions	 difference[a] $millions
Pole top structures	[c-i-c]		$6.8	-$0.5 ($2.5)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the pole top structures asset group, JEN has advised:

"In addition to the routine crossarm replacements, 2011 saw a higher volume of crossarms being replaced. This included replacement of significantly deteriorated crossarms on the critical feeders supplying Heidelberg and Fairfield areas.

The step up from 2014 relates to higher volumes of HV crossarm and LV crossarm replacements as well as increases in pole top fire mitigation programs.

The key drivers underlying the need for increases in these programs over the next period are:

- *the ongoing aging of our pole population, which is causing greater volumes of poles to be found to be below the minimum standards*
- *the need to reduce the backlog of crossarm replacement that has been growing over the current period.*
- *replacing our highest risk HV and sub-transmission cross arms that are still of a wooden construction. This replacement program, together with an enhanced inspection program, represents our pole top fire mitigation program, which has been verbally endorsed by ESV."*

B.2.2. Set up and calibration parameters

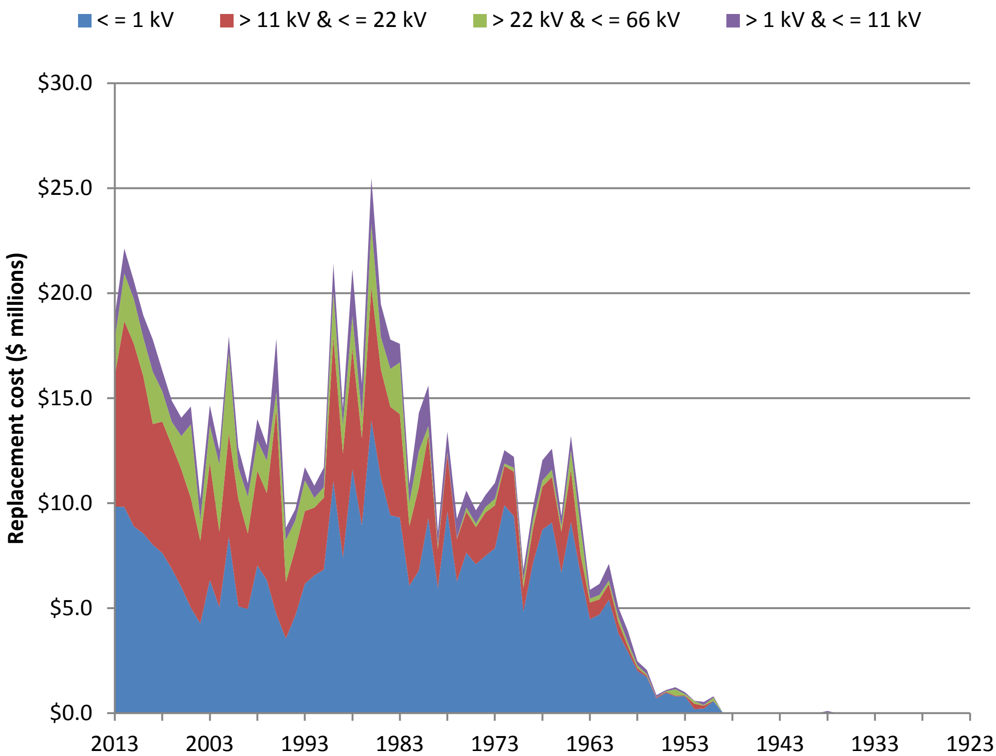

Figure 10 pole top structures age profile

Table 9 RIN 2.2.1 data required for calibration - pole top structures

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
< = 1 kV	1,170.0		[c-i-c]	
> 1 kV & < = 11 kV	203.0			
> 11 kV & < = 22 kV	3,089.0			
> 22 kV & < = 66 kV	221.0			
Total	**4,683.0**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Table 10 calibrated planning parameters - pole top structures

Asset category	life	unit cost ($'000)	S1 life[a]	volume growth rate
< = 1 kV	62.6	[c-i-c]	64.4	17.5%
> 1 kV & < = 11 kV	60.8		62.0	9.1%
> 11 kV & < = 22 kV	45.5		45.1	-2.9%
> 22 kV & < = 66 kV	56.7		57.4	4.6%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes

B.2.3. JEN repex model forecasts

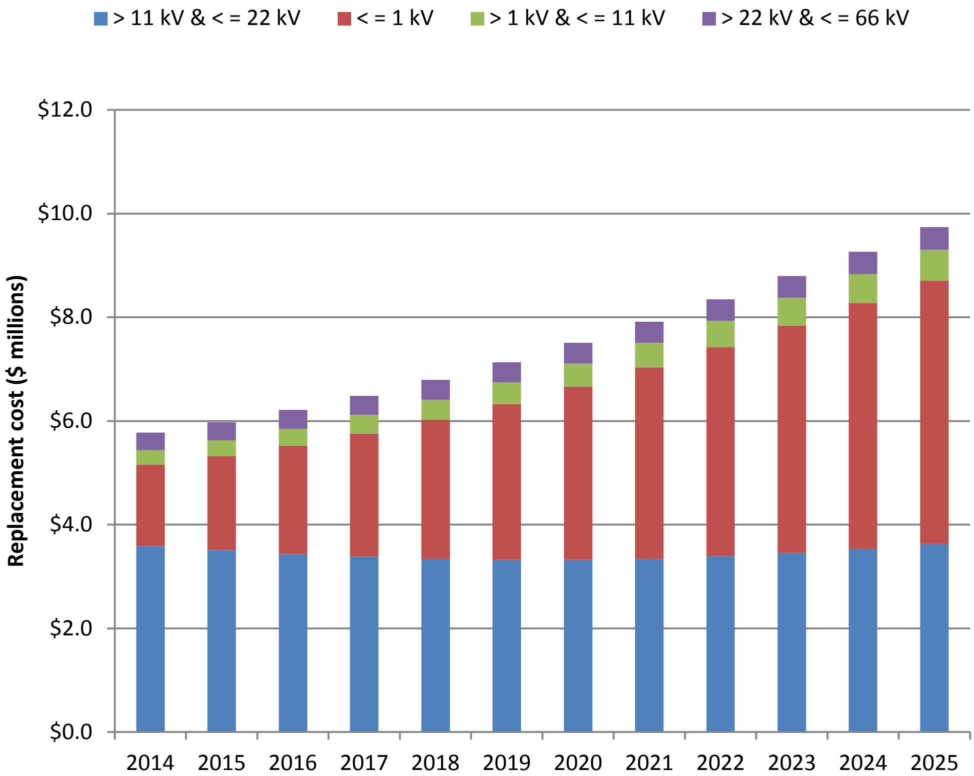

Figure 11 JEN repex model – asset category repex forecast - pole top structures

Table 11 JEN repex model – asset category summary - pole top structures

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
< = 1 kV	[c-i-c]	2,774.3	27.7	30.0	32.7
> 1 kV & < = 11 kV		333.4	26.0	28.1	30.8
> 11 kV & < = 22 kV		2,729.7	20.1	21.0	23.1
> 22 kV & < = 66 kV		274.3	19.4	21.6	24.6
Total		**6,111.8**			

B.3. Overhead conductors

B.3.1. Overview of key results

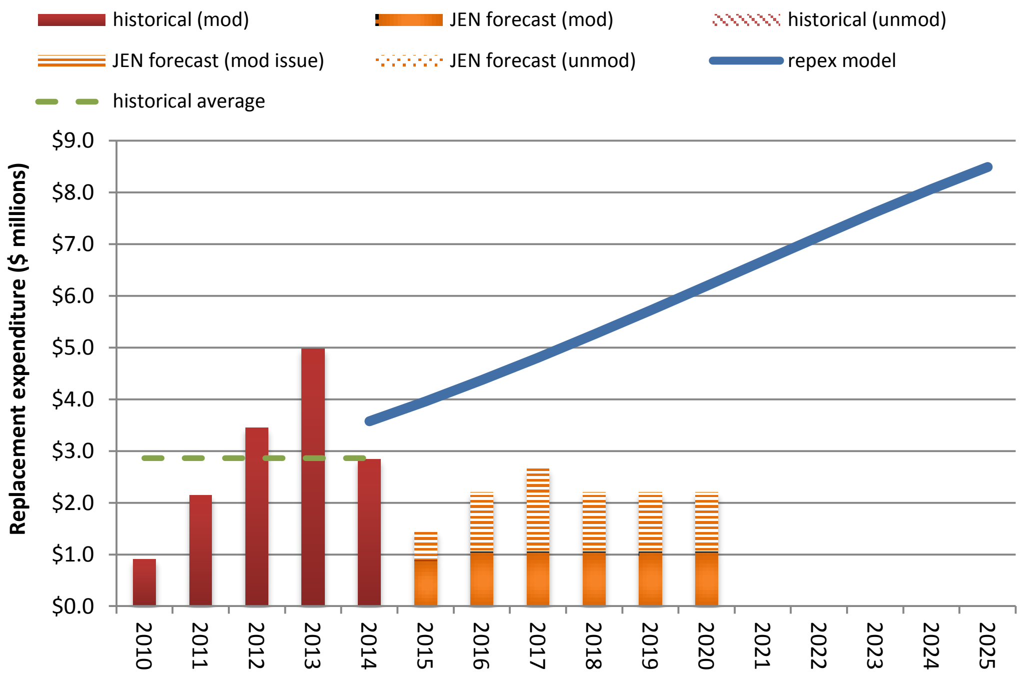

Figure 12 JEN repex model – overhead conductors repex forecast

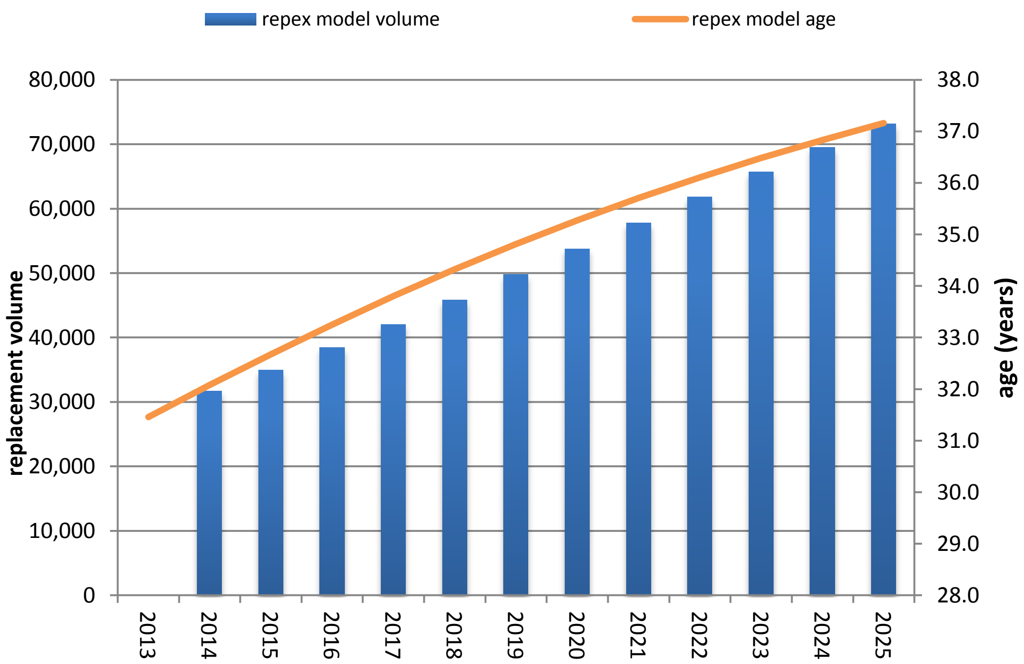

Figure 13 JEN repex model forecast – replacement volumes and age - overhead conductors

Table 12 JEN repex model forecast – summary - overhead conductors

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
OH conductors		[c-i-c]		$3.0 ($4.2)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the overhead conductor asset group, JEN has advised:

"In 2011 and 2012, 100km of steel overhead conductor in the Hazardous Bushfire Risk Area (HBRA) was replaced. The condition based replacement was initiated as a result of the introduction of an enhanced inspection program for overhead conductor.

In 2013, JEN removed 13km of SWER (Single Wire Earth Return) from the network. The removal of SWER was recommended by the Victorian Bushfire Royal Commission (VBRC)"

B.3.2. Set up and calibration parameters

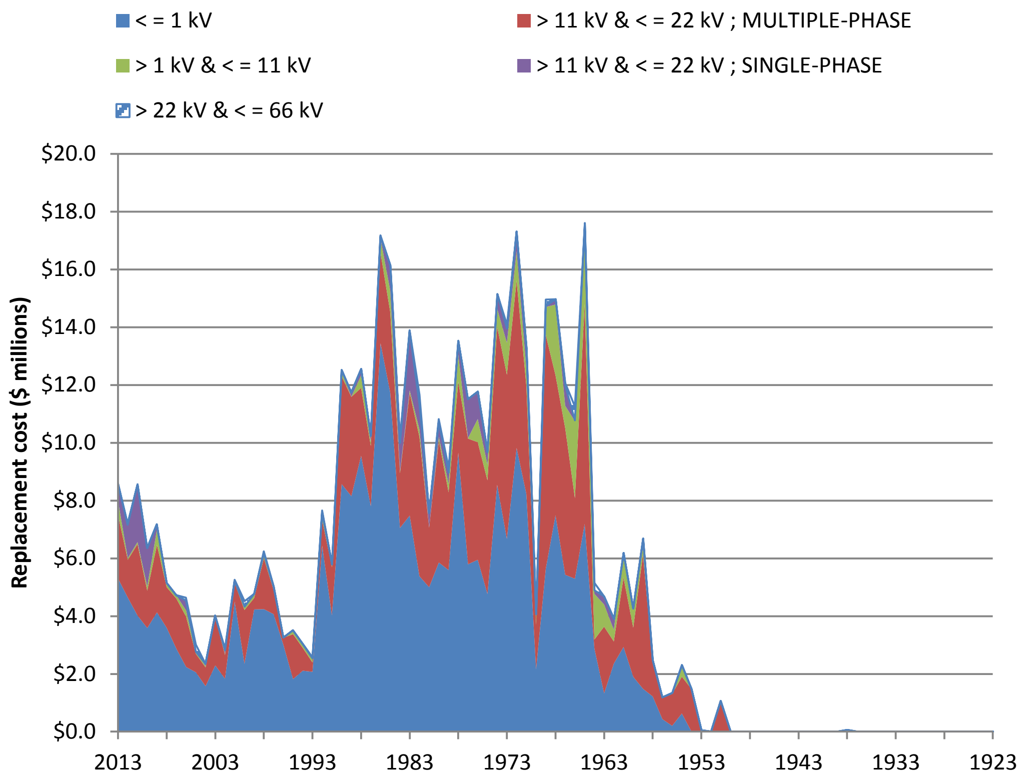

Figure 14 overhead conductors age profile

Table 13 RIN 2.2.1 data required for calibration - overhead conductors

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
< = 1 kV	38.7	1,000.0	[c-i-c]	
> 1 kV & < = 11 kV	0.0	1,000.0		
> 11 kV & < = 22 kV ; SINGLE-PHASE	37.8	1,000.0		
> 11 kV & < = 22 kV ; MULTIPLE-PHASE	52.5	1,000.0		
> 22 kV & < = 66 kV	0.0	1,000.0		RIN data zero - caution with calibration
Total	**129.0**			

a – 2010 to 2014 volume calculated from table 2.2.1 (km)
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Note: The conductor volumes are provided in kilometres in table 2.2.1 and metres in table 5.2.1; hence the unit scale.

Table 14 calibrated planning parameters - overhead conductors

Asset category	life	unit cost ($'000)[c]	S1 life[a]	volume growth rate
< = 1 kV	59.9	[c-i-c]	61.8	19.0%
> 1 kV & < = 11 kV	88.1		90.4	34.1%
> 11 kV & < = 22 kV ; SINGLE-PHASE	46.1		46.2	1.1%
> 11 kV & < = 22 kV ; MULTIPLE-PHASE	59.9		61.3	11.5%
> 22 kV & < = 66 kV	105.1		105.0	69.6%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes
c – unit cost is $'000 per metre for cables

B.3.3. JEN repex model forecasts

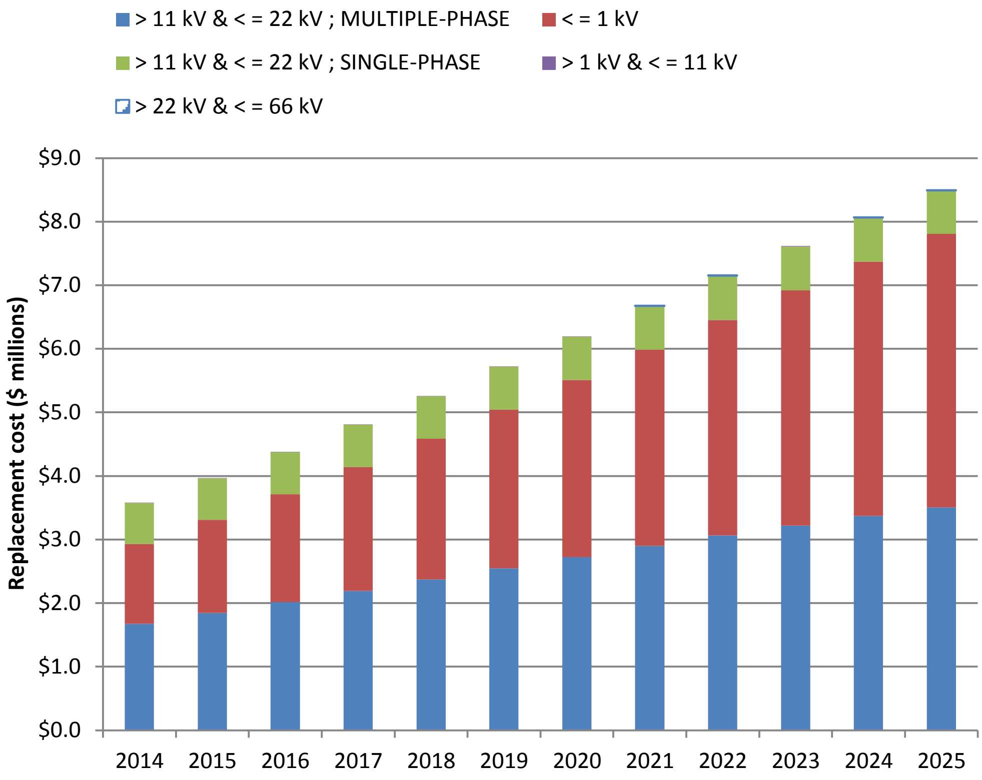

Figure 15 JEN repex model – asset category repex forecast - overhead conductors

Table 15 JEN repex model – asset category summary - overhead conductors

Asset category	2016-2020 repex ($million)	Volumes [a]	2013 age	2016 age	2020 age
< = 1 kV	[c-i-c]	97,433.6	29.4	31.6	34.1
> 1 kV & < = 11 kV		104.9	39.8	42.8	46.7
> 11 kV & < = 22 kV ; SINGLE-PHASE		39,977.1	26.9	26.0	25.8
> 11 kV & < = 22 kV ; MULTIPLE-PHASE		92,434.8	34.5	35.6	36.7
> 22 kV & < = 66 kV		0.0	31.1	34.1	38.1
Total		**229,950.5**			

a – volumes in table 5.2.1 units (metres)

B.4. Underground cables

B.4.1. Overview of key results

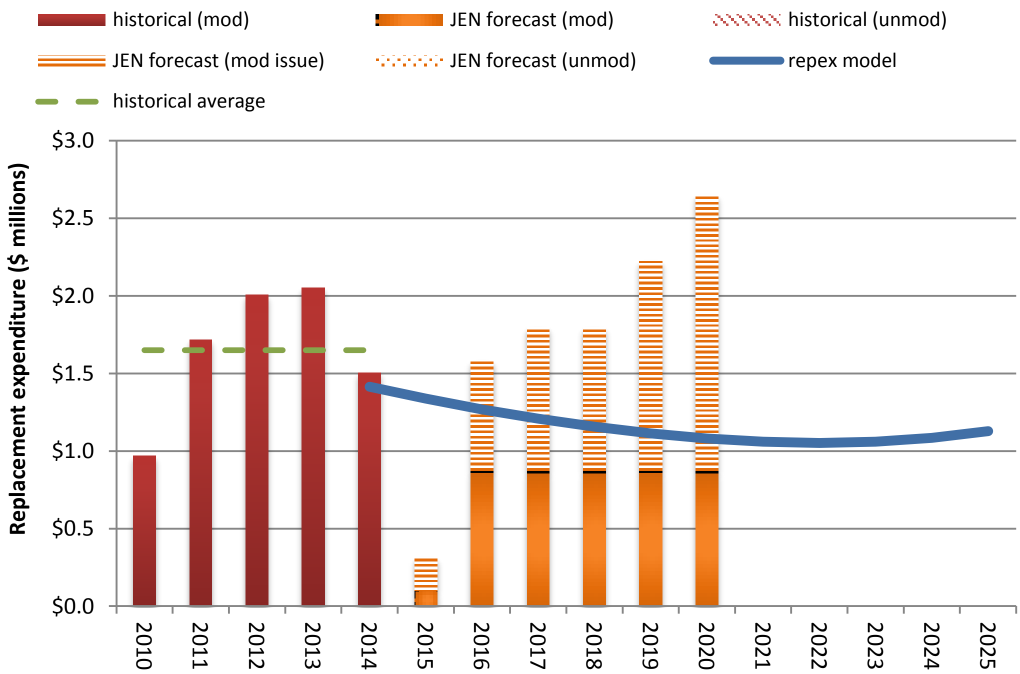

Figure 16 JEN repex model – underground cables repex forecast

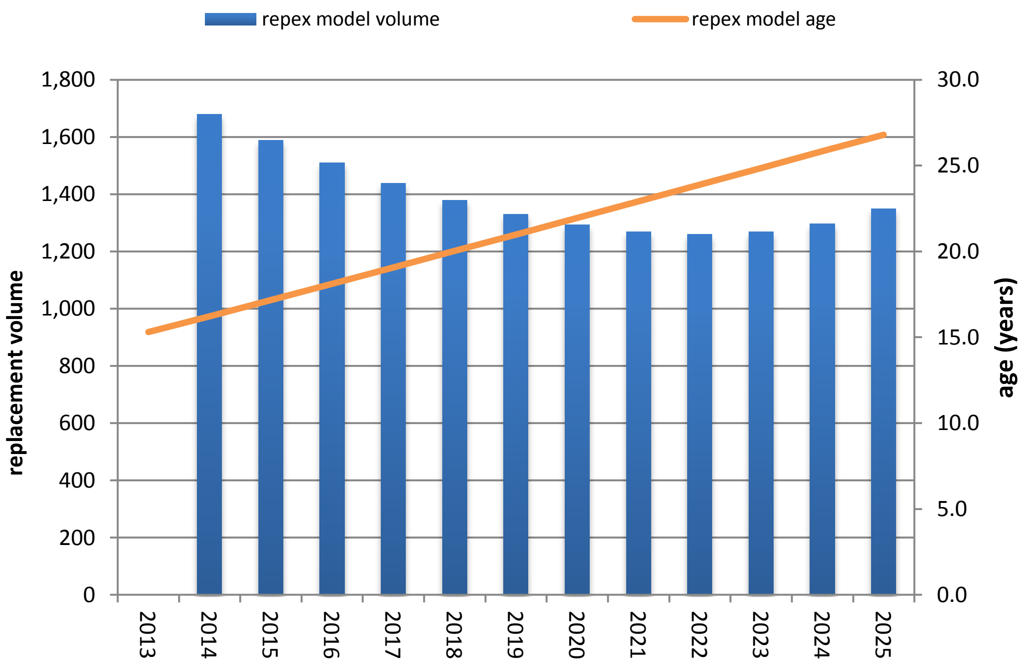

Figure 17 JEN repex model forecast – replacement volumes and age - underground cables

Table 16 JEN repex model forecast – summary - underground cables

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
UG cables		[c-i-c]		-$0.8 ($0.3)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the underground cable asset group, JEN has advised:

"*Between 2011 and 2013 JEN was required to replace HV underground cables and cable joints in Coolaroo, Flemington and Sunbury. The driver for the replacement was the high frequency of cable and joint failures.*

The main program contributing to the increase in the underground cable asset class relates to the replacement of our older trifurcating boxes with modern cable terminations. These boxes are located on our poles and connect our underground cables to our overhead network. The boxes have a history of catastrophic failure as a result of partial discharge and internal flashover.

This program commenced in 2013 and will be further implemented between 2016 and 2020."

B.4.2. Set up and calibration parameters

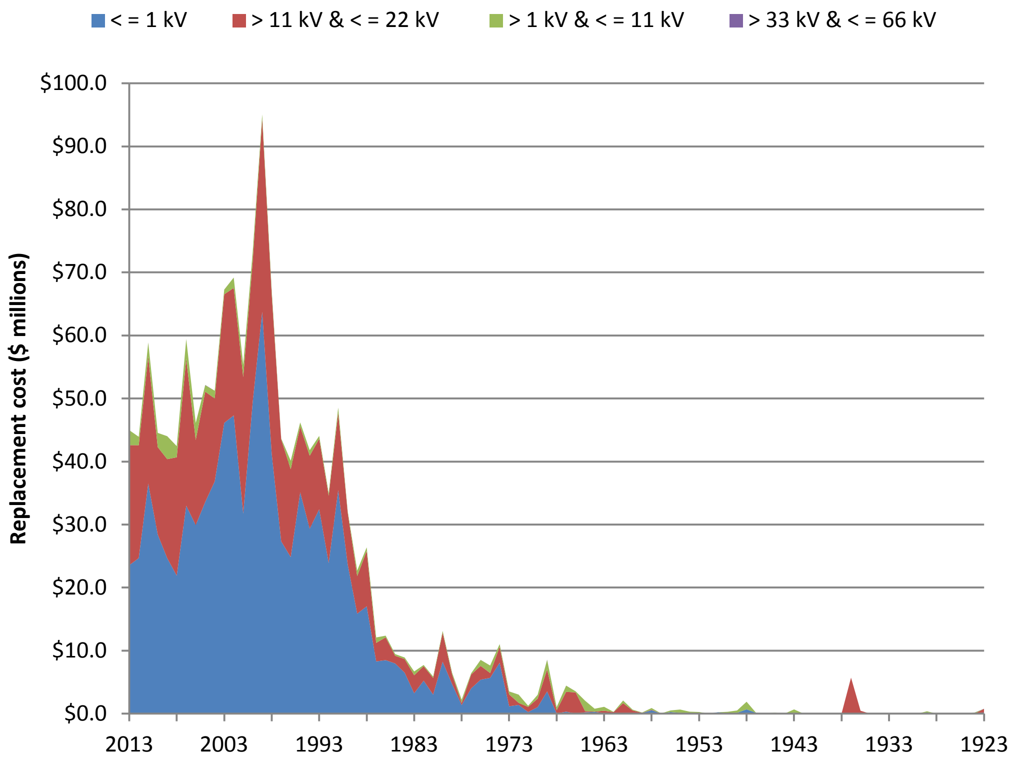

Figure 18 underground cables age profile

Table 17 RIN 2.2.1 data required for calibration - underground cables

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
< = 1 kV	1.9	1,000.0	[c-i-c]	
> 1 kV & < = 11 kV	2.3	1,000.0		
> 11 kV & < = 22 kV	5.6	1,000.0		
> 33 kV & < = 66 kV	0.0	1,000.0		RIN data zero - caution with calibration
Total	**9.8**			

a – 2010 to 2014 volume calculated from table 2.2.1 (km for cable lengths)
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Note: The conductor volumes are provided in kilometres in table 2.2.1 and metres in table 5.2.1; hence the unit scale.

Table 18 calibrated planning parameters - underground cables

Asset category	life	unit cost ($'000) [c]	S1 life[a]	volume growth rate
< = 1 kV	68.0	[c-i-c]	66.0	-8.7%
> 1 kV & < = 11 kV	69.2		68.8	-2.3%
> 11 kV & < = 22 kV	74.6		72.3	-8.8%
> 33 kV & < = 66 kV	93.4		93.0	65.7%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes
c – unit cost is $'000 per metre for cables

B.4.3. JEN repex model forecasts

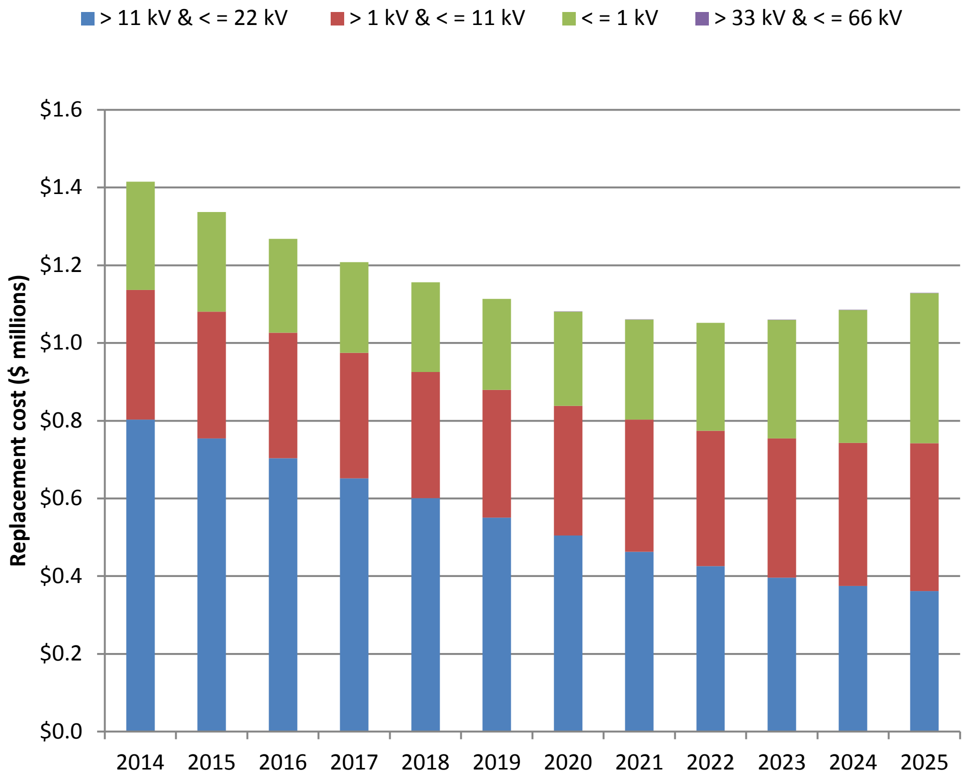

Figure 19 JEN repex model – asset category repex forecast - underground cables

Table 19 JEN repex model – asset category summary - underground cables

Asset category	2016-2020 repex ($million)	Volumes [a]	2013 age	2016 age	2020 age
< = 1 kV	[c-i-c]	1,310.9	14.9	17.8	21.8
> 1 kV & < = 11 kV		2,144.0	22.7	24.6	27.4
> 11 kV & < = 22 kV		3,497.5	15.2	17.9	21.6
> 33 kV & < = 66 kV		0.0	26.6	29.6	33.6
Total		**6,952.5**			

a – volumes in table 5.2.1 units (metres for cable)

B.5. Services

B.5.1. Overview of key results

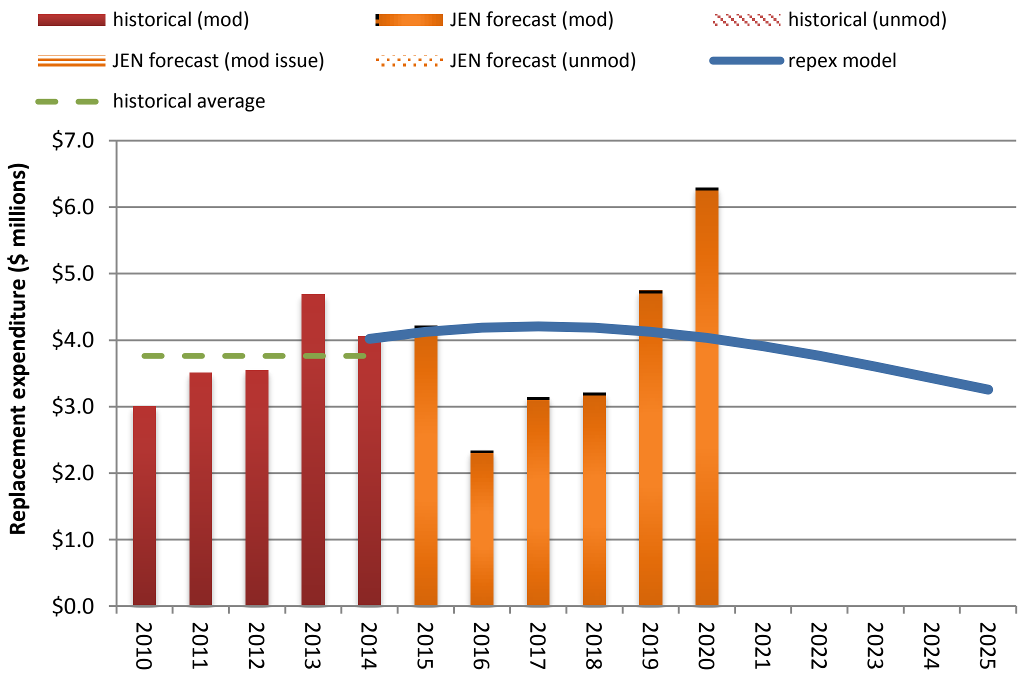

Figure 20 JEN repex model – services repex forecast

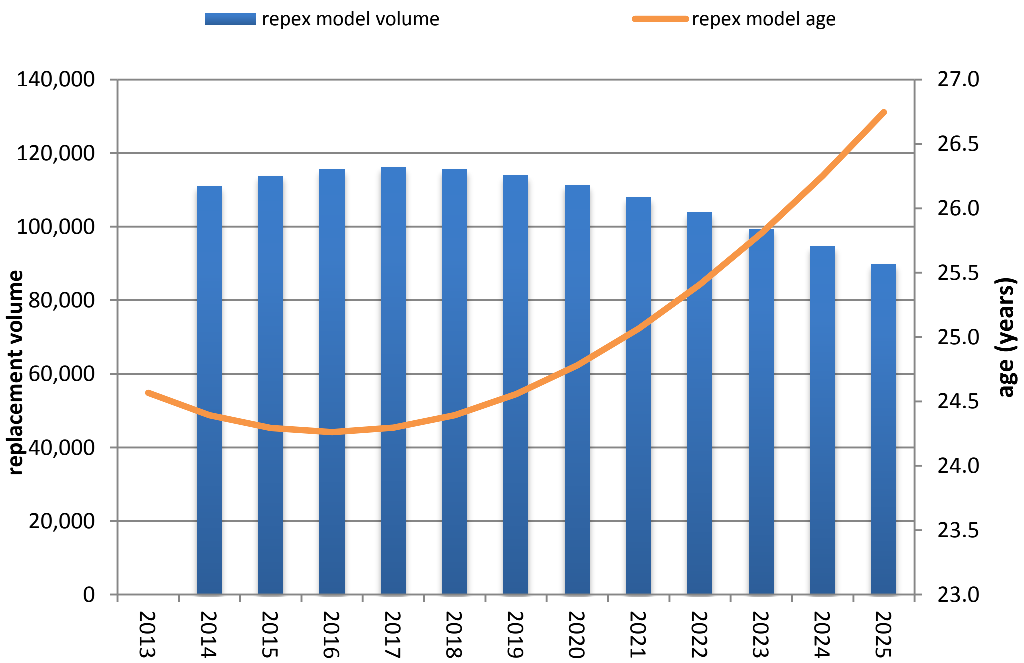

Figure 21 JEN repex model forecast – replacement volumes and age - services

Table 20 JEN repex model forecast – summary - services

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
services		[c-i-c]		$0.2 ($0.2)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the services asset group, JEN has advised:

"In 2011, we commenced a program to replace all our non-preferred services. The initial phase of the program, covering the current period, was endorsed by ESV and we have followed this program.

From 2016 we will be ramping up our non-preferred service rectification program. The key drivers of the need for this increase are:

- *increased volume of service failures that have occurred over the current period*
- *the ongoing aging of the non-preferred service population."*

B.5.2. Set up and calibration parameters

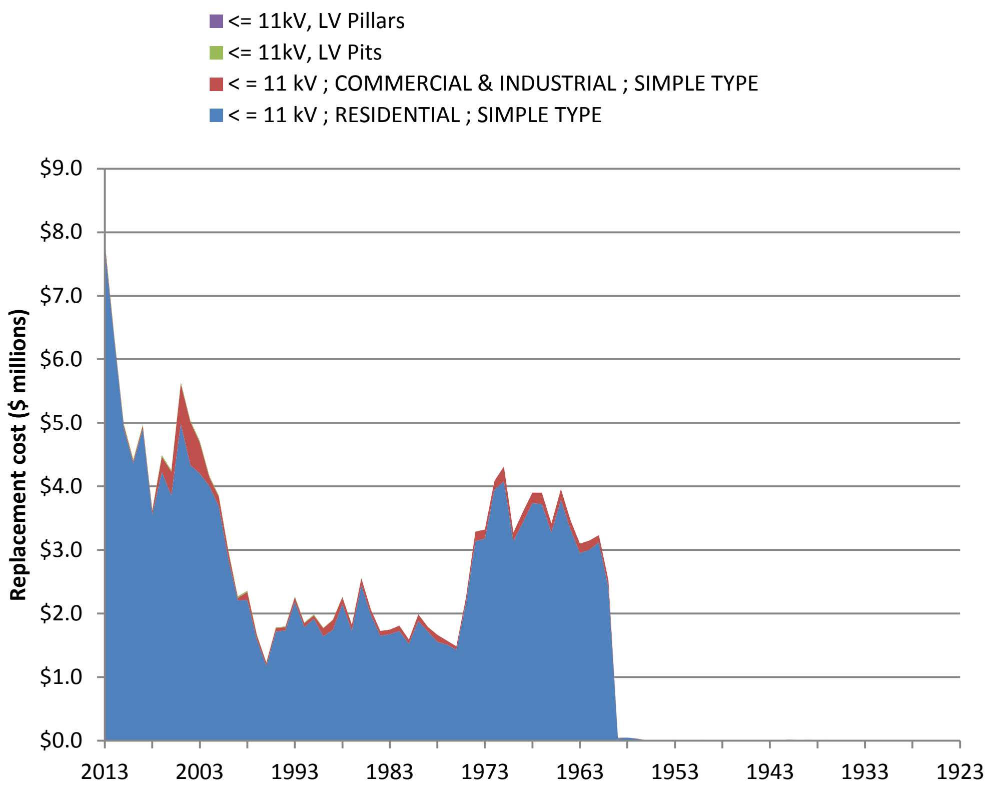

Figure 22 services age profile

Table 21 RIN 2.2.1 data required for calibration - services

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
< = 11 kV ; RESIDENTIAL ; SIMPLE TYPE	25,011.0	20.0	[c-i-c]	
< = 11 kV ; COMMERCIAL & INDUSTRIAL ; SIMPLE TYPE	962.0	20.0		
<= 11kV, LV Pillars	18.0			No expenditure data
<= 11kV, LV Pits	35.0			No expenditure data
Total	**26,026.0**			

a – 2010 to 2014 volume calculated from table 2.2.1 (per service)
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Note: The services volumes are provided per service in table 2.2.1 and metres in table 5.2.1; hence the unit scale.

Table 22 calibrated planning parameters - services

Asset category	life	unit cost ($'000) [c]	S1 life[a]	volume growth rate
< = 11 kV ; RESIDENTIAL ; SIMPLE TYPE	50.4	[c-i-c]	50.9	3.4%
< = 11 kV ; COMMERCIAL & INDUSTRIAL ; SIMPLE TYPE	51.3		51.8	3.1%
<= 11kV, LV Pillars	52.9		55.0	27.8%
<= 11kV, LV Pits	50.6		51.9	12.2%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes
c – unit cost for services ($'000 per metre of service)

B.5.3. JEN repex model forecasts

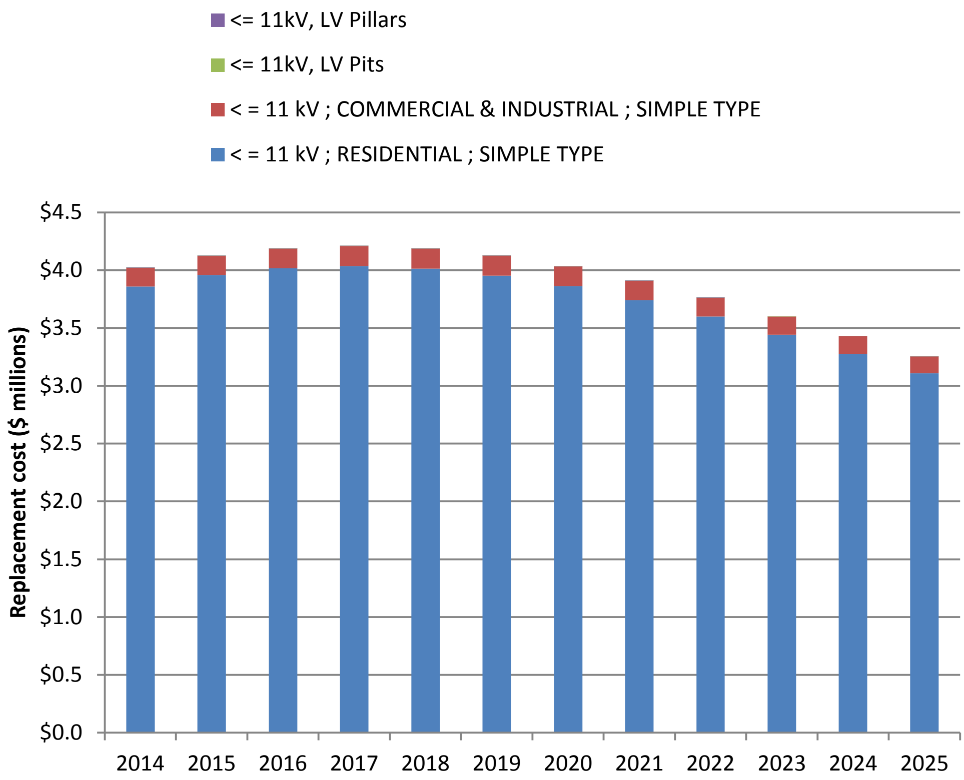

Figure 23 JEN repex model – asset category repex forecast - services

Table 23 JEN repex model – asset category summary - services

Asset category	2016-2020 repex ($million)	Volumes [a]	2013 age	2016 age	2020 age
< = 11 kV ; RESIDENTIAL ; SIMPLE TYPE	[c-i-c]	550,896.6	24.6	24.2	24.7
< = 11 kV ; COMMERCIAL & INDUSTRIAL ; SIMPLE TYPE		21,540.1	25.4	25.4	26.0
<= 11kV, LV Pillars		65.3	23.2	25.8	28.6
<= 11kV, LV Pits		93.8	11.3	14.3	18.2
Total		**572,595.8**			

a – volumes in table 5.2.1 units (metres for services)

B.6. Distribution transformers

B.6.1. Overview of key results

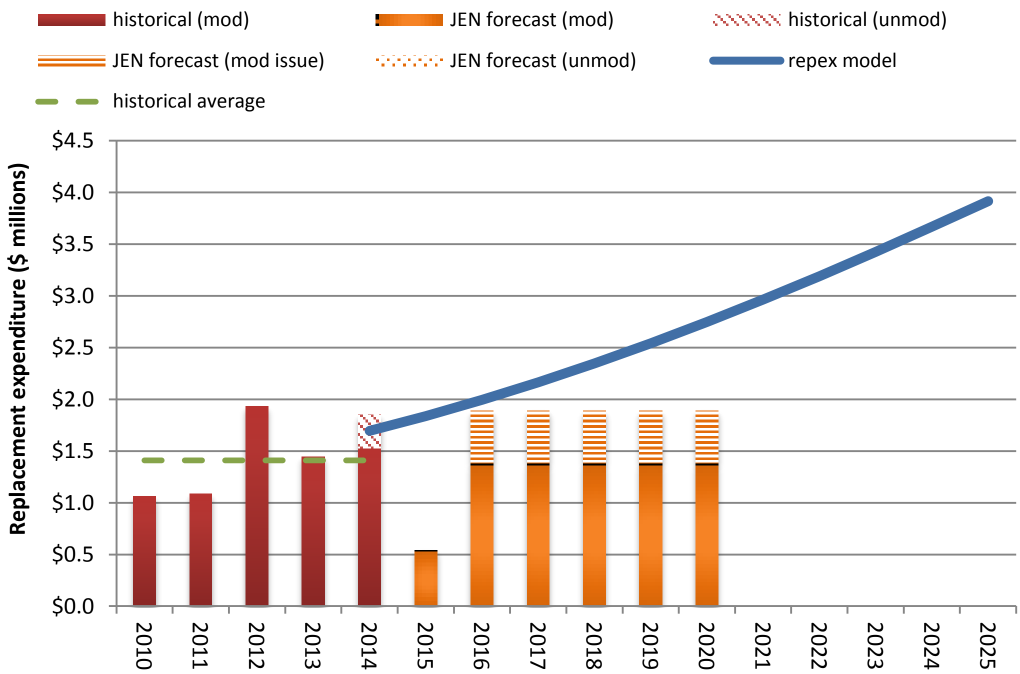

Figure 24 JEN repex model – distribution transformers repex forecast

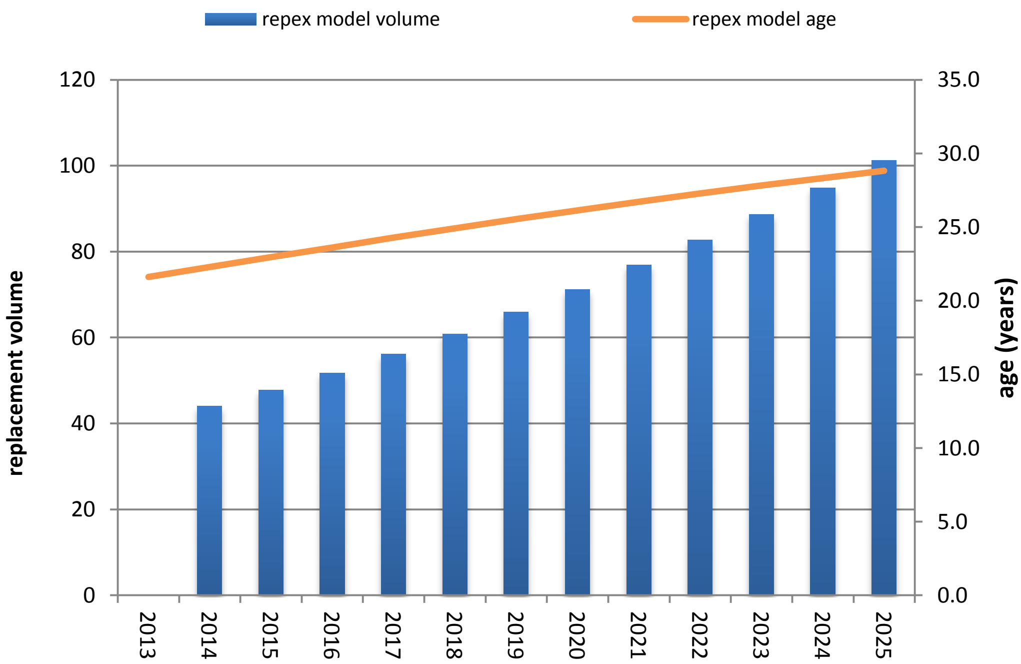

Figure 25 JEN repex model forecast – replacement volumes and age - distribution transformers

Table 24 JEN repex model forecast – summary - distribution transformers

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
Distribution transformers		[c-i-c]		$0.5 ($1.0)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the distribution transformer asset group, JEN has advised:

"In 2015 there are no ground/indoor transformer replacements and there are no transformer platform rectification projects proposed.

From 2016 the replacement expenditure will remain relatively flat and is required to replace pole mounted and ground/indoor distribution transformers that are in poor condition."

Furthermore, with regard to the higher forecast by the model, JEN has advised that it has an augmentation program that replaces overloaded substations, which are typically the older pole mounted substations. Therefore, this program could have the effect of reducing a portion of the transformers replacements forecast by the repex model, depending on how this program affected volumes in the calibration period compared to the forecast period.

B.6.2. Set up and calibration parameters

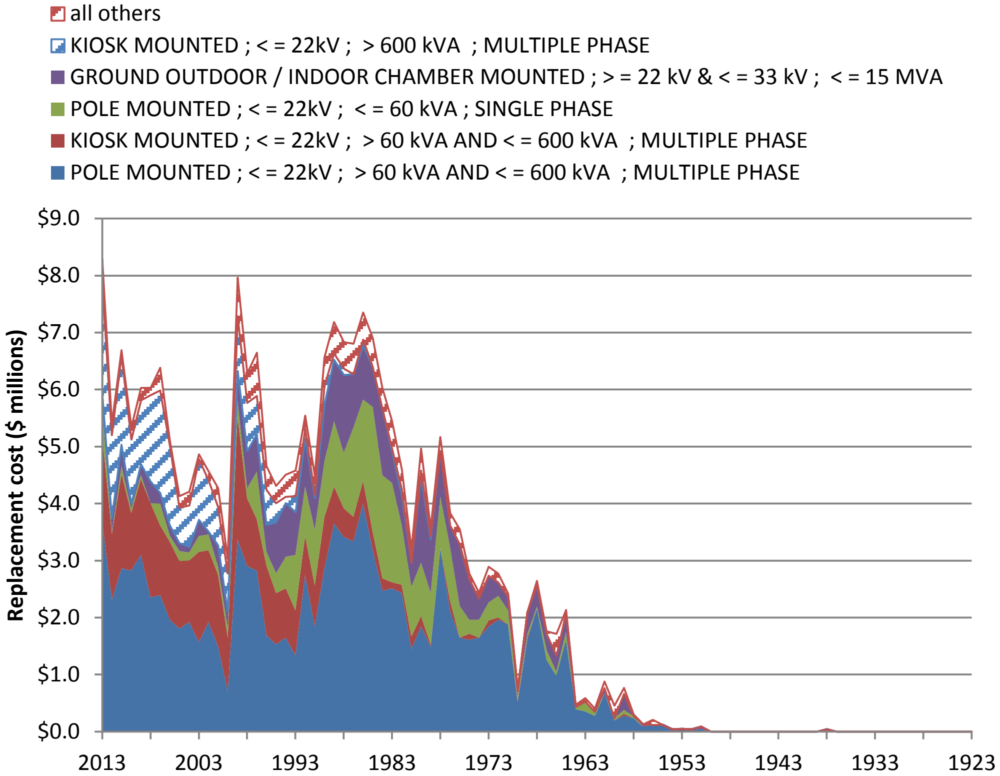

Figure 26 distribution transformers age profile

Table 25 RIN 2.2.1 data required for calibration - distribution transformers

Model asset category	2010-2014 replaced volume[a]	unit scale	Repex ($'000)	comment
POLE MOUNTED ; < = 22kV ; < = 60 kVA ; SINGLE PHASE	45.0		[c-i-c]	
POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; SINGLE PHASE	0.0			RIN data zero - caution with calibration
POLE MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE	3.0			
POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE	98.0			
POLE MOUNTED ; < = 22kV ; > 600 kVA ; MULTIPLE PHASE	0.0			RIN data zero - caution with calibration
KIOSK MOUNTED ; < = 22kV ; < = 60 kVA ; SINGLE PHASE	0.0			RIN data zero - caution with calibration
KIOSK MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE	0.0			RIN data zero - caution with calibration
KIOSK MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ;	23.0			

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
MULTIPLE PHASE			[c-i-c]	
KIOSK MOUNTED ; < = 22kV ; > 600 kVA ; MULTIPLE PHASE	4.0			
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE	0.0			RIN data zero - caution with calibration
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE	4.0			
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > = 22 kV & < = 33 kV ; < = 15 MVA	7.0			
Total	**184.0**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Table 26 calibrated planning parameters - distribution transformers

Asset category	life	unit cost ($'000)	S1 life[a]	volume growth rate
POLE MOUNTED ; < = 22kV ; < = 60 kVA ; SINGLE PHASE	45.9	[c-i-c]	47.0	9.2%
POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; SINGLE PHASE	53.1		53.1	52.0%
POLE MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE	57.0		58.5	13.6%
POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE	52.8		54.0	9.4%
POLE MOUNTED ; < = 22kV ; > 600 kVA ; MULTIPLE PHASE	58.1		58.1	45.3%
KIOSK MOUNTED ; < = 22kV ; < = 60 kVA ; SINGLE PHASE	39.4		39.4	70.3%
KIOSK MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE	39.5		39.5	71.2%
KIOSK MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE	37.6		38.4	6.5%
KIOSK MOUNTED ; < = 22kV ; > 600 kVA ; MULTIPLE PHASE	34.1		35.6	16.0%
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE	96.4		96.4	36.3%
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE	58.1		59.5	10.9%
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > = 22 kV & < = 33 kV ; < = 15 MVA	58.2		59.8	14.4%

a – life derived using the unadjusted average annual volumes

b - growth used to determine adjusted average annual volumes

B.6.3. JEN repex model forecasts

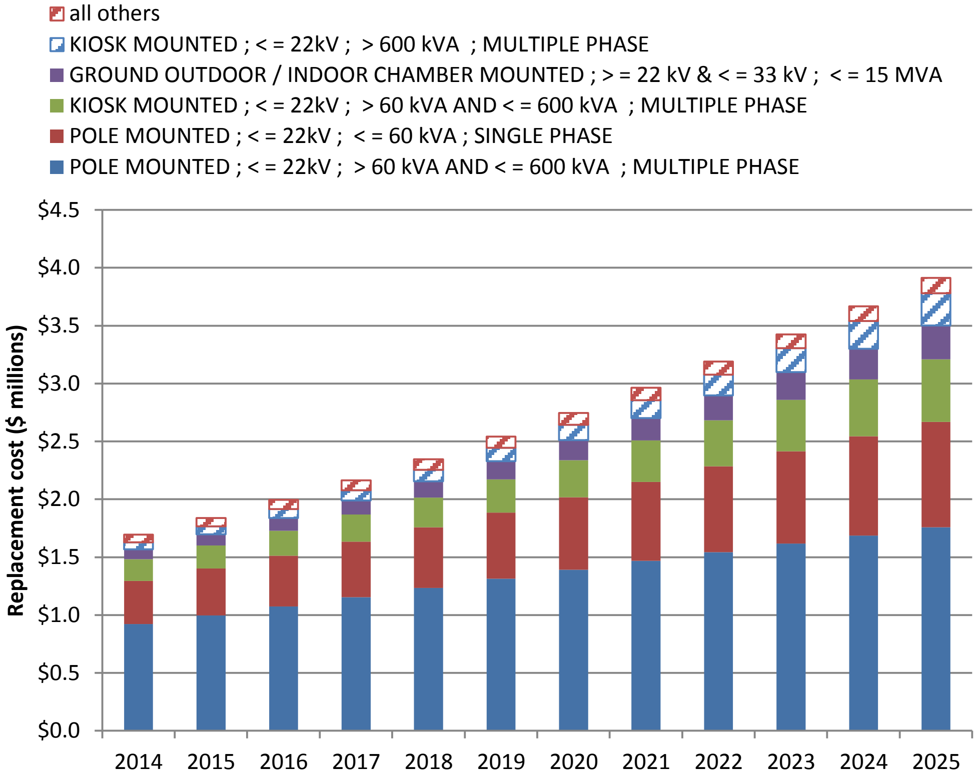

Figure 27 JEN repex model – asset category repex forecast - distribution transformers

Table 27 JEN repex model – asset category summary - distribution transformers

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
POLE MOUNTED ; < = 22kV ; < = 60 kVA ; SINGLE PHASE	[c-i-c]	75.9	27.2	28.5	29.9
POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; SINGLE PHASE		0.0	16.1	19.1	23.0
POLE MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE		5.9	22.5	25.1	28.5
POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE		157.0	23.6	25.3	27.6
POLE MOUNTED ; < = 22kV ; > 600 kVA ; MULTIPLE PHASE		0.0	25.8	28.8	32.6
KIOSK MOUNTED ; < = 22kV ; < = 60 kVA ; SINGLE PHASE		0.0	17.3	20.3	24.1
KIOSK MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE		0.0	12.3	15.2	19.2
KIOSK MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE		36.5	13.1	15.5	18.6
KIOSK MOUNTED ; < = 22kV ; > 600		9.2	8.9	11.7	15.2

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
kVA ; MULTIPLE PHASE	[c-i-c]				
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE		0.0	33.1	36.1	40.1
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE		6.5	26.5	28.1	30.0
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > = 22 kV & < = 33 kV ; < = 15 MVA		14.9	27.0	29.5	32.5
Total		**306.1**			

B.7. Distribution switchgear

B.7.1. Overview of key results

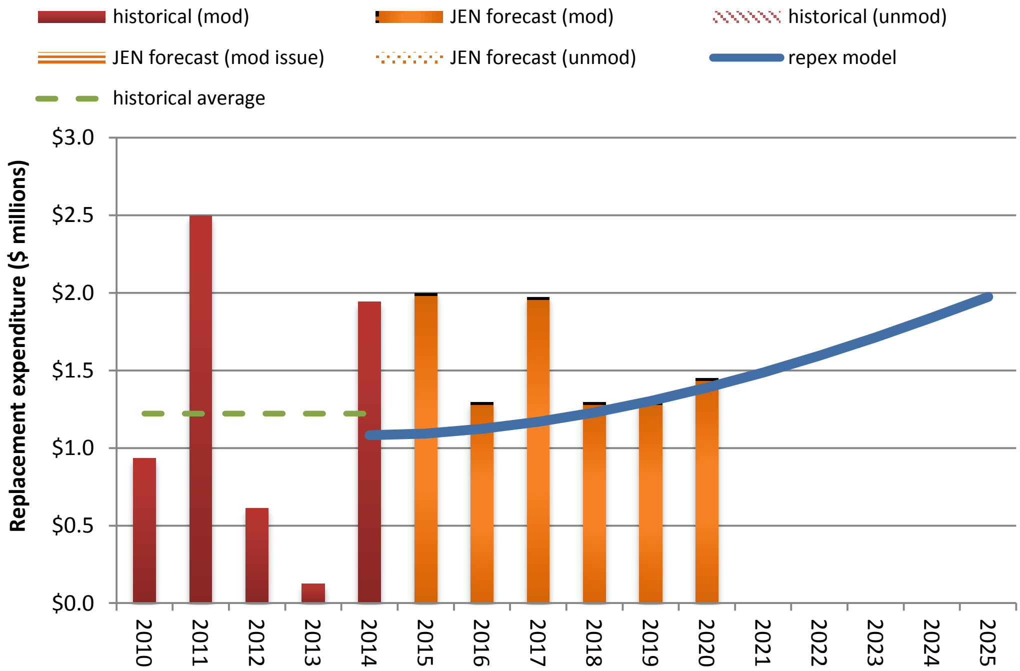

Figure 28 JEN repex model – distribution switchgear repex forecast

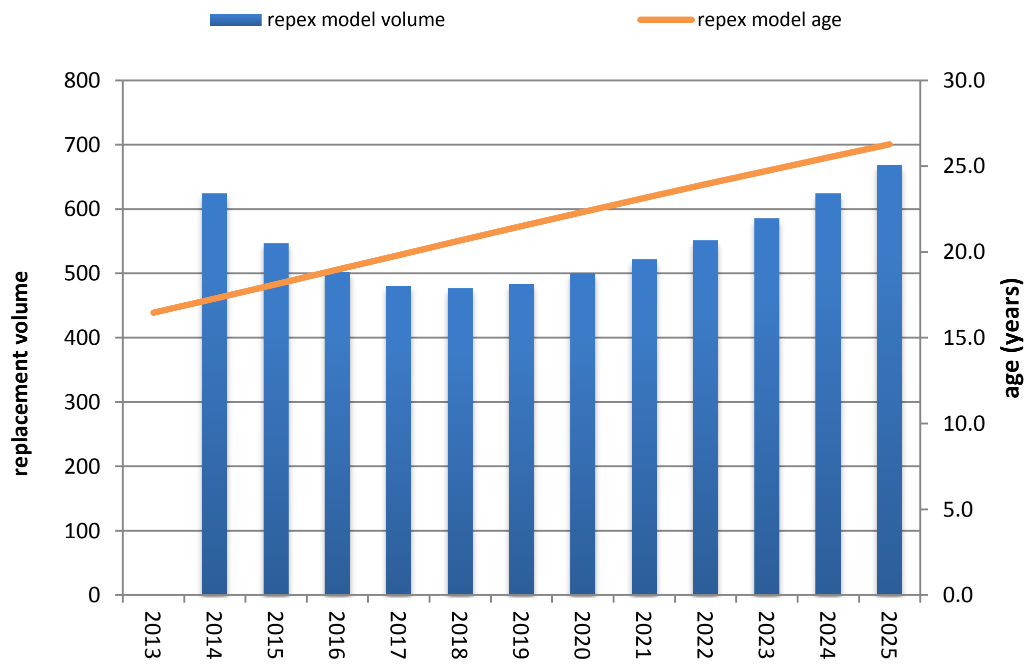

Figure 29 JEN repex model forecast – replacement volumes and age - distribution switchgear

Table 28 JEN repex model forecast – summary - distribution switchgear

Asset Group	repex - average per annum 2010-14 (RIN) $millions	2016-20 JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
Distribution switchgear		[c-i-c]		-$0.2 (-$0.2)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the distribution switchgear asset group, JEN has advised:

"We manage our HV switches that have a high risk of failure by placing operational restrictions on their use. We label these switches as CRO'd switches – Caution Re Operation.

In 2011 a backlog of CRO'd (Caution Re Operation) HV switches were replaced

Reduction in 2015 is due to CRO'd switch replacement expenditure ramping down and remaining flat at around $0.5M up until 2020.

The work that is finishing up in 2015 and causing reduction in future years is:

- *ABB isolator replacement*
- *Gellibrand switchyard replacement*
- *Surge diverter replacement at ST/COO*

On average distribution switchgear replacement is around $1.7M from 2016.”

B.7.2. Set up and calibration parameters

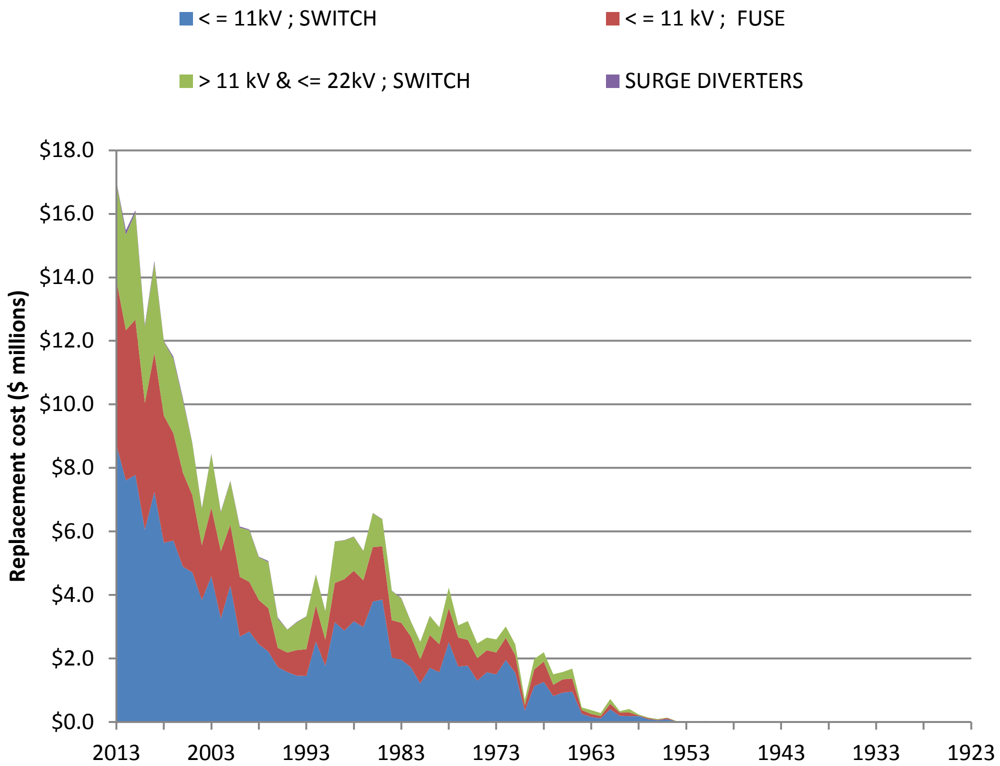

Figure 30 distribution switchgear age profile

Table 29 RIN 2.2.1 data required for calibration - distribution switchgear

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($’000)	comment
< = 11 kV ; FUSE	52.0		[c-i-c]	
< = 11kV ; SWITCH	139.0			
> 11 kV & <= 22kV ; SWITCH	907.0			
SURGE DIVERTERS	7,469.0			
Total	**8,567.0**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Table 30 calibrated planning parameters - distribution switchgear

Asset category	life	unit cost ($’000)	S1 life[a]	volume growth rate
< = 11 kV ; FUSE	59.1	[c-i-c]	61.0	19.5%
< = 11kV ; SWITCH	59.8		61.6	19.1%
> 11 kV & <= 22kV ; SWITCH	44.0		43.2	-5.0%
SURGE DIVERTERS	20.9		11.4	-47.9%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes

B.7.3. JEN repex model forecasts

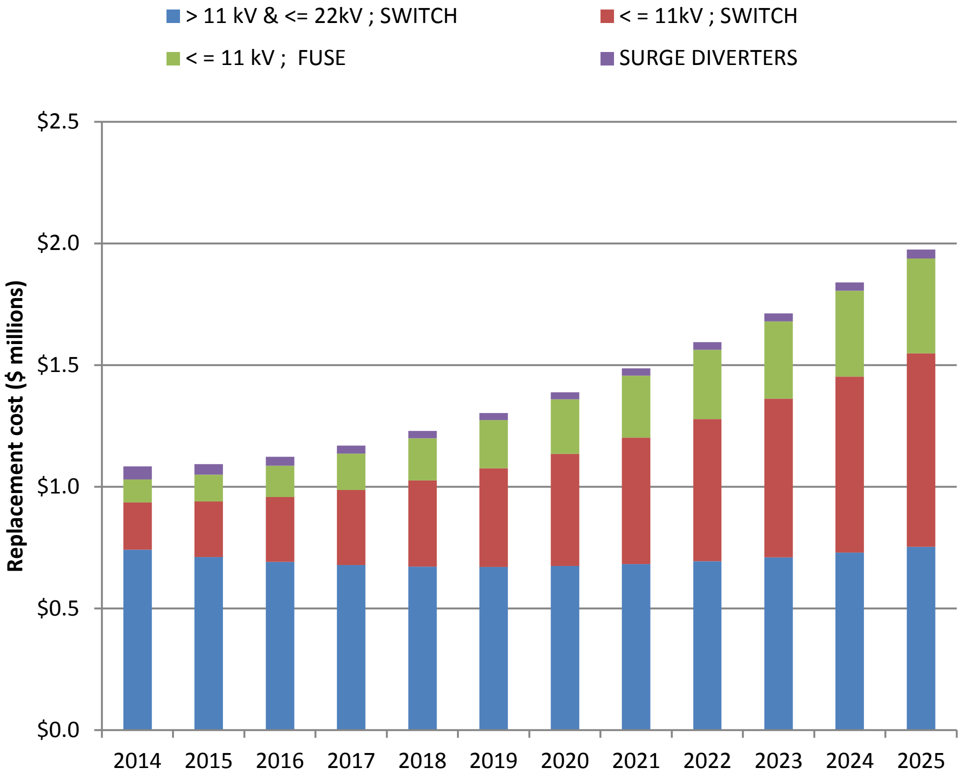

Figure 31 JEN repex model – asset category repex forecast - distribution switchgear

Table 31 JEN repex model – asset category summary - distribution switchgear

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
< = 11 kV ; FUSE	[c-i-c]	137.9	15.7	18.5	22.1
< = 11kV ; SWITCH		363.8	17.1	19.9	23.4
> 11 kV & <= 22kV ; SWITCH		748.4	15.9	17.4	20.0
SURGE DIVERTERS		1,192.8	9.9	9.9	12.3
Total		**2,442.9**			

B.8. Zone substation transformers

B.8.1. Overview of key results

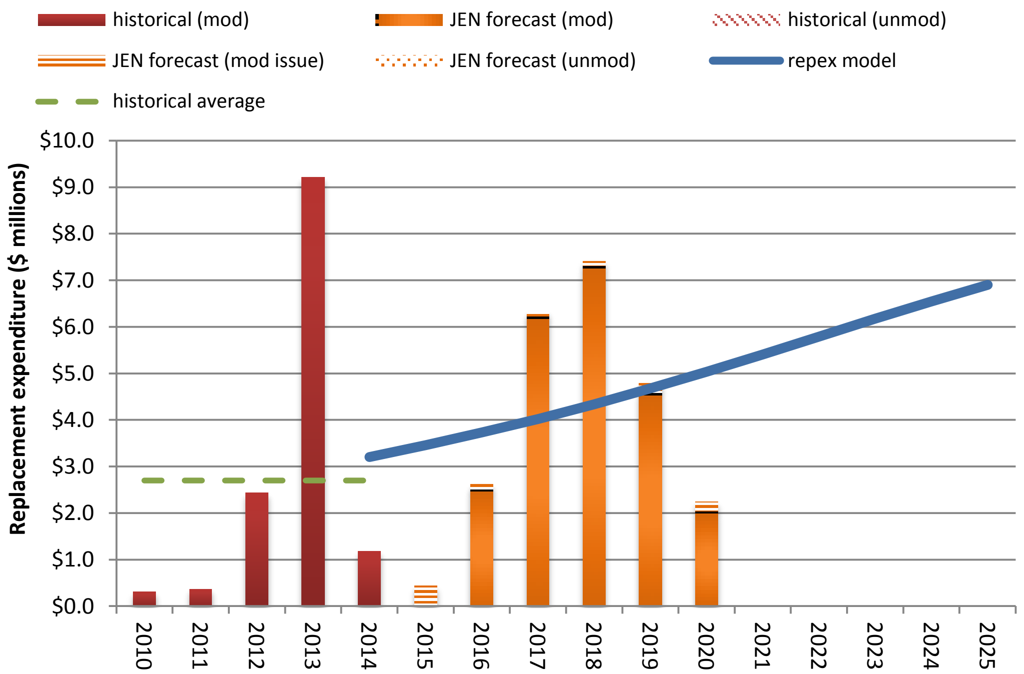

Figure 32 JEN repex model – zone substation transformers repex forecast

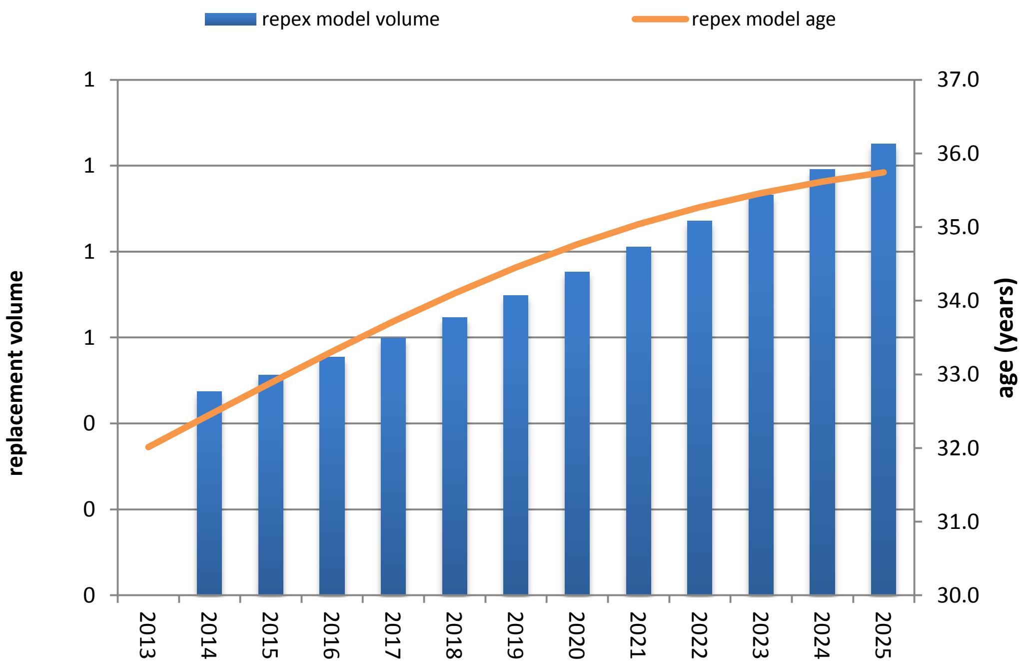

Figure 33 JEN repex model forecast – replacement volumes and age - zone substation transformers

Table 32 JEN repex model forecast – summary - zone substation transformers

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
Zone transformers		[c-i-c]		-$0.3 (-$0.2)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the zone substation transformers asset group, JEN has advised:

"The expenditure in 2013 is in relation to the replacement of transformers at Yarraville Terminal Station.

From 2016 10 zone substation transformers are being replaced with the majority of work occurring during 2017 and 2018.

The main driver of this increased volume of replacements is the emerging poor condition of these transformers, which indicates that their winding insulations will all reach their end-of-life phase during the next period. In addition, there are other issues with some of these transformers that can be opportunistically addressed through their replacement."

B.8.2. Set up and calibration parameters

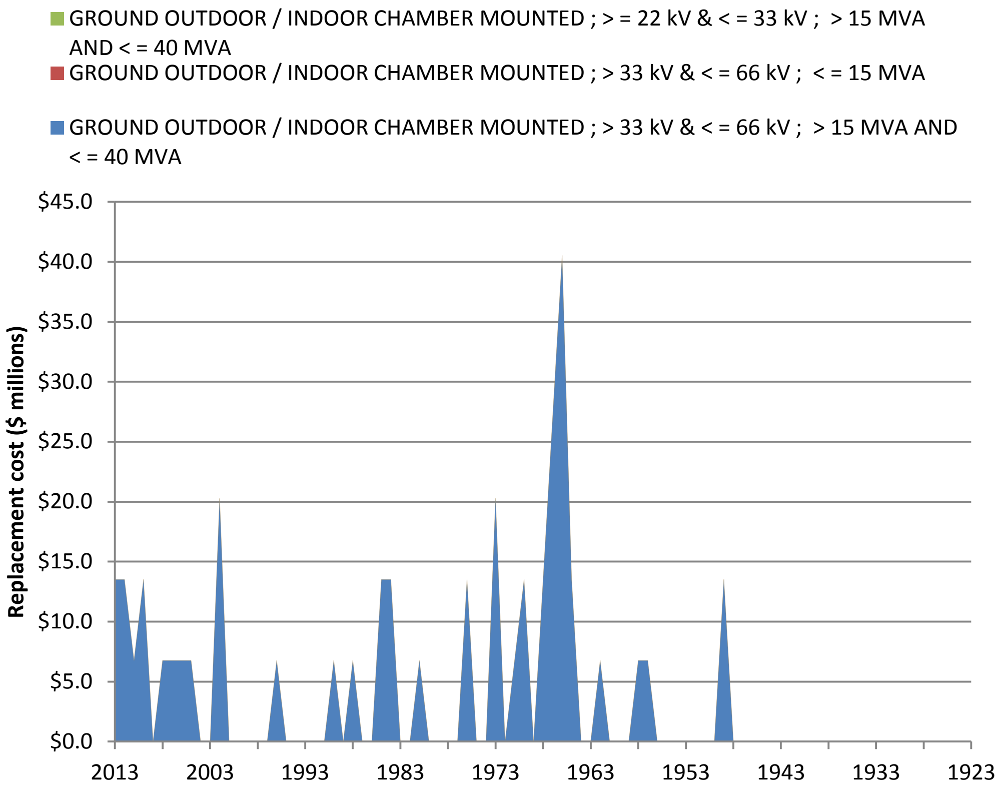

Figure 34 zone substation transformers age profile

Table 33 RIN 2.2.1 data required for calibration - zone substation transformers

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > = 22 kV & < = 33 kV ; > 15 MVA AND < = 40 MVA	0.0		[c-i-c]	RIN data zero - caution with calibration
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; < = 15 MVA	0.0			RIN data zero - caution with calibration
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; > 15 MVA AND < = 40 MVA	2.0			
Total	**2.0**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Table 34 calibrated planning parameters - zone substation transformers

Asset category	life	unit cost ($'000)	S1 life[a]	volume growth rate
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > = 22 kV & < = 33 kV ; > 15 MVA AND < = 40 MVA	91.7	[c-i-c]	91.7	42.0%
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; < = 15 MVA	84.9		84.9	41.0%
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; > 15 MVA AND < = 40 MVA	62.8		64.0	8.9%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes

B.8.3. JEN repex model forecasts

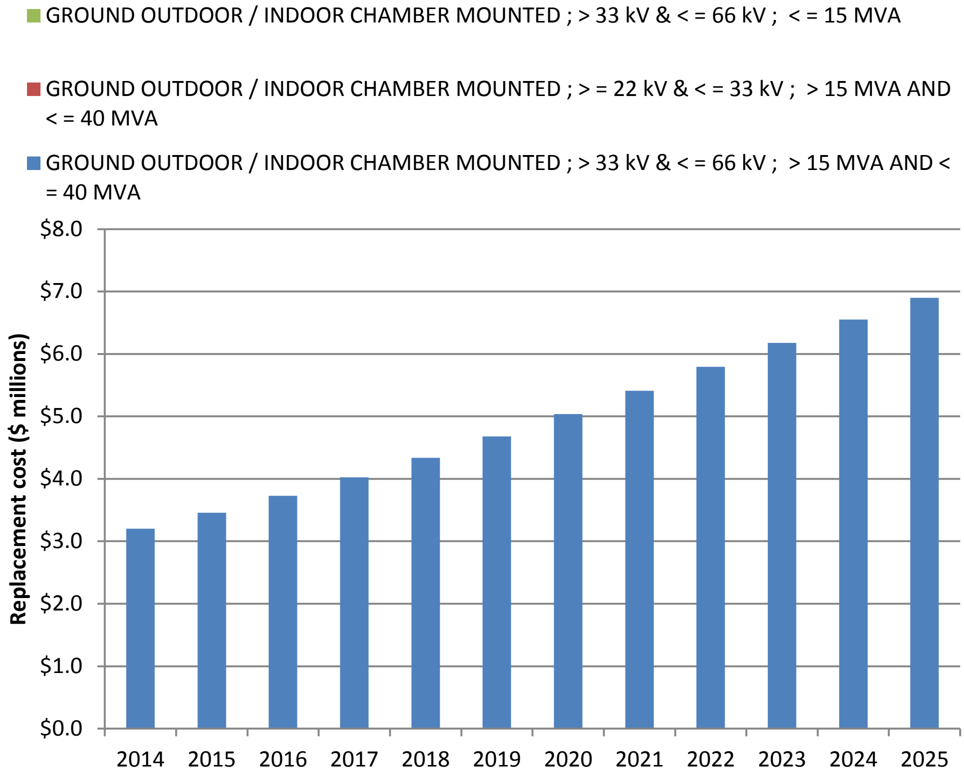

Figure 35 JEN repex model – asset category repex forecast - zone substation transformers

Table 35 JEN repex model – asset category summary - zone substation transformers

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > = 22 kV & < = 33 kV ; > 15 MVA AND < = 40 MVA	[c-i-c]	0.0	58.5	61.5	65.3
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; < = 15 MVA		0.0	33.5	36.5	40.4
GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; > 15 MVA AND < = 40 MVA		3.2	32.0	33.3	34.8
Total		**3.3**			

B.9. Zone substation switchgear

B.9.1. Overview of key results

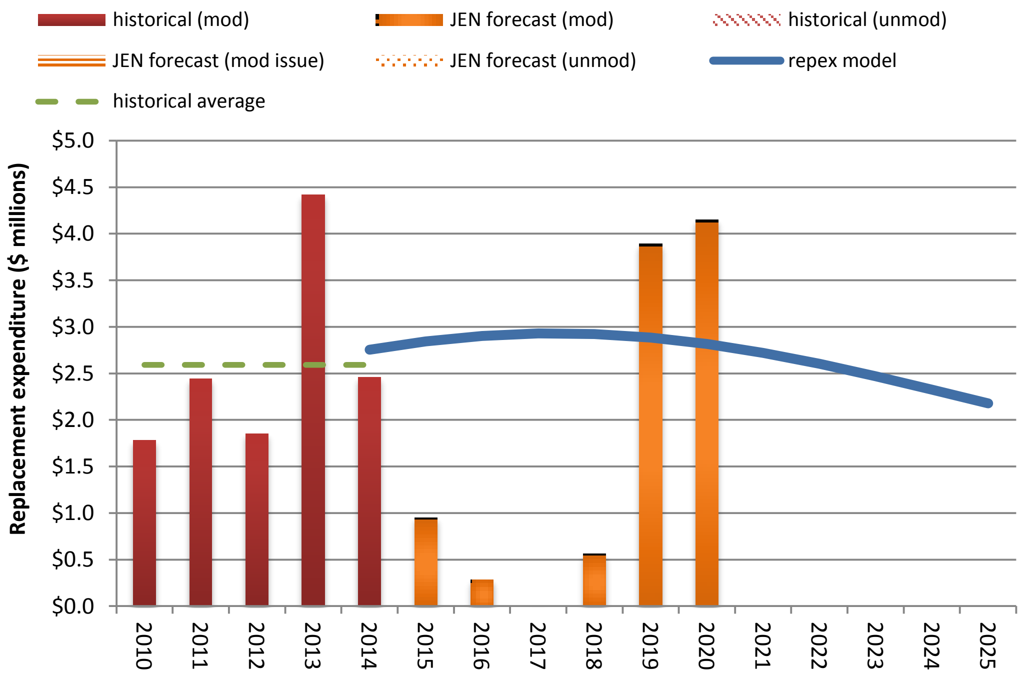

Figure 36 JEN repex model – zone substation switchgear repex forecast

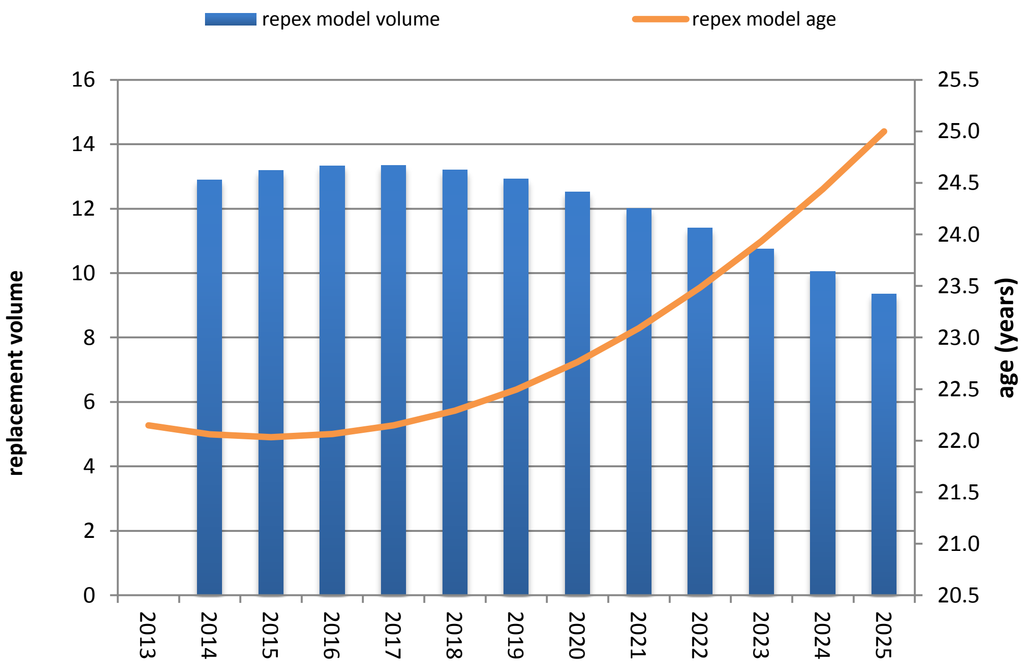

Figure 37 JEN repex model forecast – replacement volumes and age - zone substation switchgear

Table 36 JEN repex model forecast – summary - zone substation switchgear

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
Zone switchgear		[c-i-c]		$1.1 ($1.1)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the zone substation switchgear asset group, JEN has advised:

"The increase in zone substation switchgear replacement in 2013 was required to replace 11 kV switchgear at Essendon zone substation

The majority of the replacement capex in the next period is associated with two significant projects, replacing the switchboards at two zone substations that contain these aged breaker types. These projects are:

- *2019 - Footscray East, where we will replace 20 breakers (18 off MV SB 14 22 kV breakers and 2 off GEC LG4C 66 kV breakers)*
- *2020 - Footscray West, where we will replace 14 breakers (13 off MV SB 14 22 kV breakers and 1 off GEC LG4C 66 kV breakers)*".

B.9.2. Set up and calibration parameters

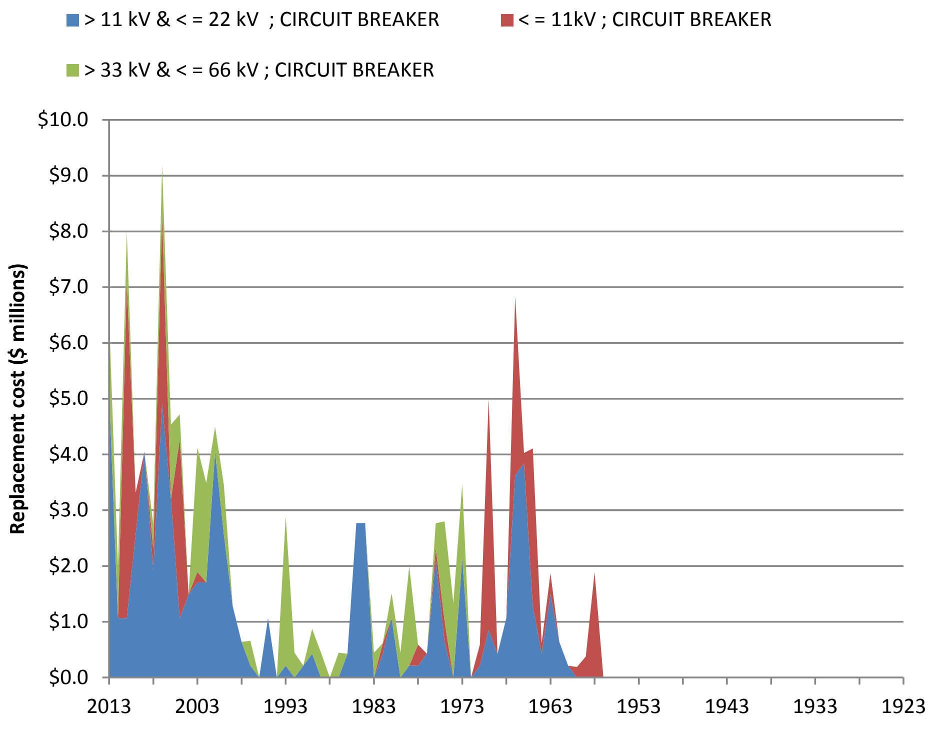

Figure 38 zone substation switchgear age profile

Table 37 RIN 2.2.1 data required for calibration - zone substation switchgear

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
< = 11kV ; CIRCUIT BREAKER	39.0		[c-i-c]	
> 11 kV & < = 22 kV ; CIRCUIT BREAKER	20.0			
> 33 kV & < = 66 kV ; SWITCH	0.0			RIN data zero - caution with calibration
> 33 kV & < = 66 kV ; CIRCUIT BREAKER	3.0			
Total	**62.0**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Table 38 calibrated planning parameters - zone substation switchgear

Asset category	life	unit cost ($'000)	S1 life[a]	volume growth rate
< = 11kV ; CIRCUIT BREAKER	49.1	[c-i-c]	48.6	-3.0%
> 11 kV & < = 22 kV ; CIRCUIT BREAKER	51.8		53.0	9.2%
> 33 kV & < = 66 kV ; SWITCH	90.7		90.7	49.4%
> 33 kV & < = 66 kV ; CIRCUIT BREAKER	44.4		46.0	15.4%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes

B.9.3. JEN repex model forecasts

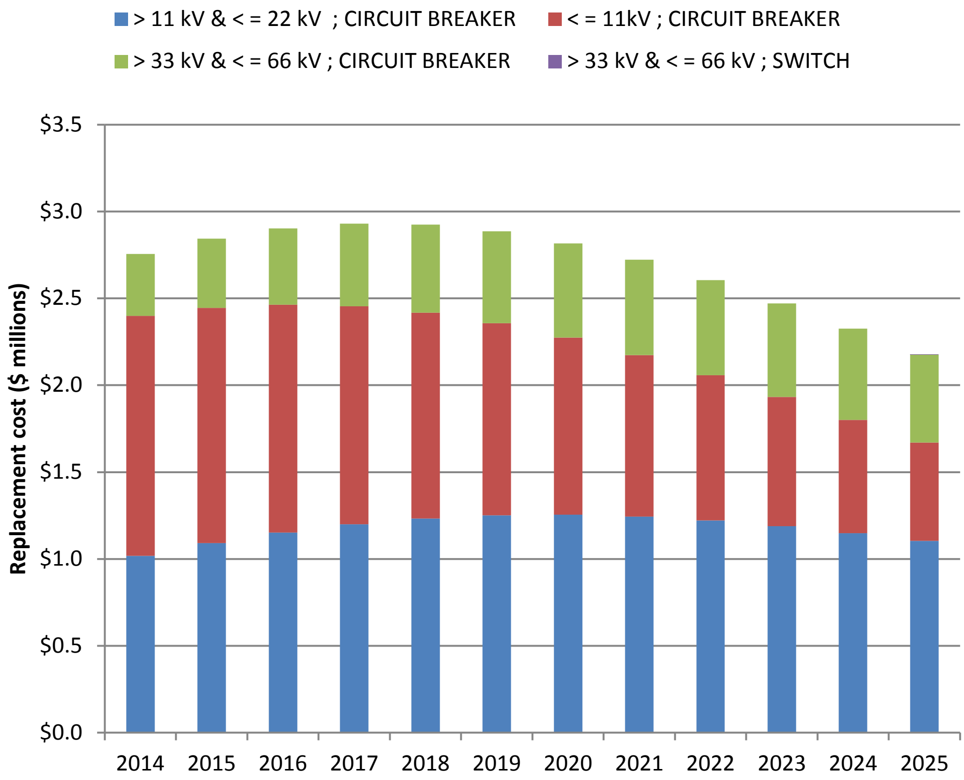

Figure 39 JEN repex model – asset category repex forecast - zone substation switchgear

Table 39 JEN repex model – asset category summary - zone substation switchgear

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
< = 11kV ; CIRCUIT BREAKER	[c-i-c]	31.1	26.6	23.3	22.1
> 11 kV & < = 22 kV ; CIRCUIT BREAKER		28.6	21.0	21.9	23.2
> 33 kV & < = 66 kV ; SWITCH		0.0	27.0	30.0	34.0
> 33 kV & < = 66 kV ; CIRCUIT BREAKER		5.6	20.0	21.1	22.5
Total		**65.3**			

B.10. Other assets

B.10.1. Overview of key results

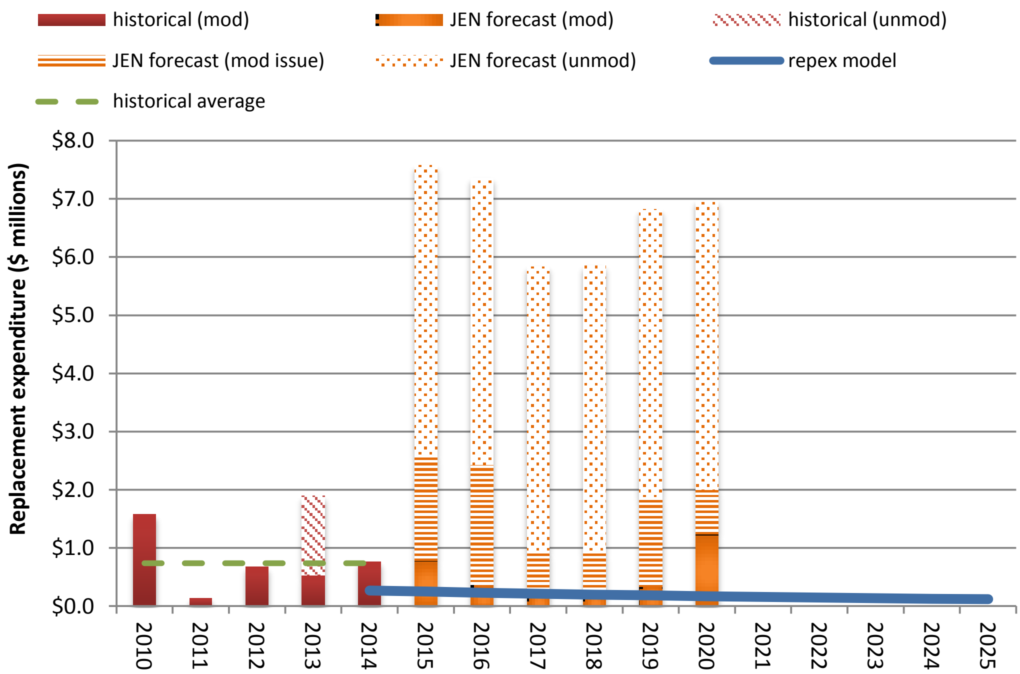

Figure 40 JEN repex model – other assets repex forecast

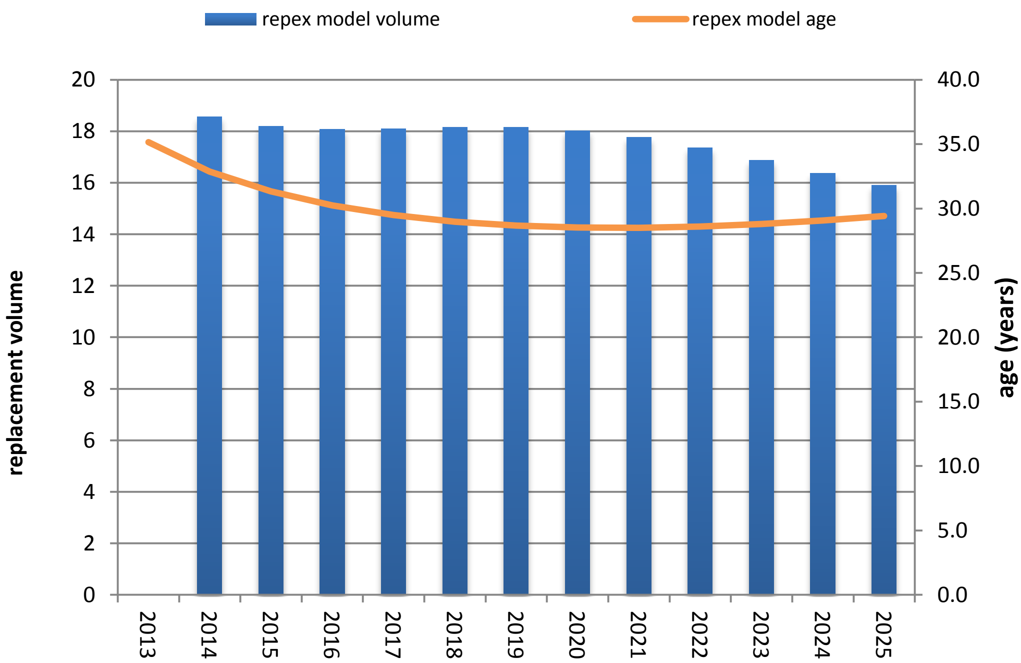

Figure 41 JEN repex model forecast – replacement volumes and age - other assets

Table 40 JEN repex model forecast – summary - other assets

Asset Group	repex - average per annum 2010-14 (RIN) $millions	2016-20 JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
Other		[c-i-c]		-$1.4 (-$0.2)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the "other" asset group, JEN has advised:

"In 2015 the control building at Airport West zone substation is being replaced. This relates to Airport West relay replacement program discussed in SCADA/PROTECTION replacement category.

In 2016 the control building at Broadmeadows is being replaced. This relates to Broadmeadows relay replacement program discussed in SCADA/PROTECTION replacement category.

In 2019 the control building at Coburg North is being extended. This relates to Coburg North relay replacement program discussed in SCADA/PROTECTION replacement category."

B.10.2. Set up and calibration parameters

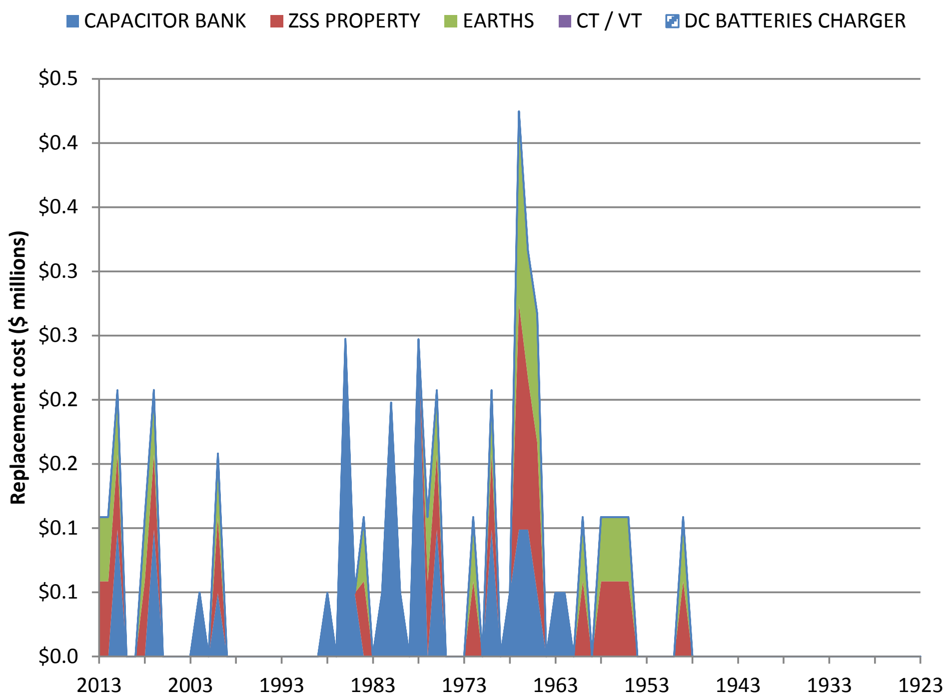

Figure 42 other assets age profile

Table 41 RIN 2.2.1 data required for calibration - other assets

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
CAPACITOR BANK	4.0		[c-i-c]	
EARTHS	16.0			
ZSS PROPERTY	46.0			
CT / VT	60.0			No expenditure
NER	4.0			No expenditure
DC BATTERIES	9.0			No expenditure
DC BATTERIES CHARGER	17.0			No expenditure
PQ METERS	1.0			No expenditure
Total	**157.0**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Table 42 calibrated planning parameters - other assets

Asset category	life	unit cost ($'000)	S1 life[a]	volume growth rate
CAPACITOR BANK	50.0	[c-i-c]	50.9	6.8%
EARTHS	49.0		44.5	-18.2%
ZSS PROPERTY	49.6		28.6	-53.2%
CT / VT	40.7		33.7	-27.3%
NER	15.0		15.8	12.1%
DC BATTERIES	14.9		16.9	39.0%
DC BATTERIES CHARGER	32.1		28.7	-18.6%
PQ METERS	23.4		25.6	43.2%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes

B.10.3. JEN repex model forecasts

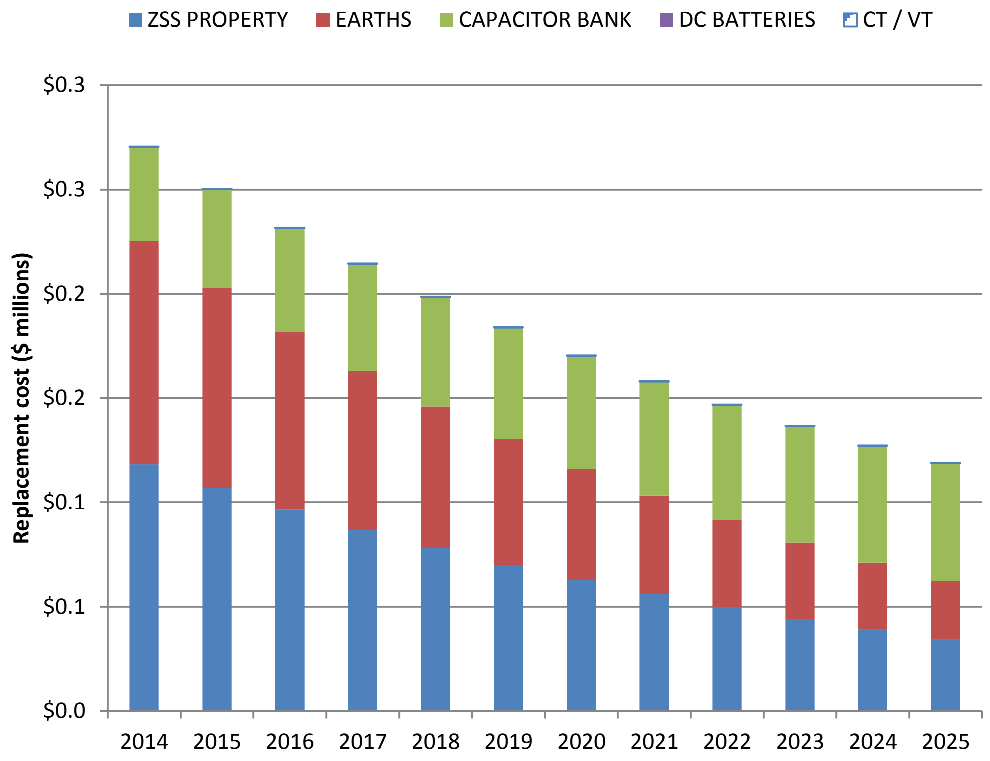

Figure 43 JEN repex model – asset category repex forecast - other assets

Table 43 JEN repex model – asset category summary - other assets

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
CAPACITOR BANK	[c-i-c]	5.3	32.0	31.5	31.4
EARTHS		6.9	37.3	29.1	26.4
ZSS PROPERTY		6.7	37.3	29.6	26.8
CT / VT		17.9	17.7	17.9	20.5
NER		6.5	7.3	8.4	10.2
DC BATTERIES		33.4	8.2	9.5	10.3
DC BATTERIES CHARGER		7.8	14.0	14.8	17.2
PQ METERS		6.1	9.6	12.0	14.3
Total		**90.5**			

B.11. SCADA/protection other

B.11.1. Overview of key results

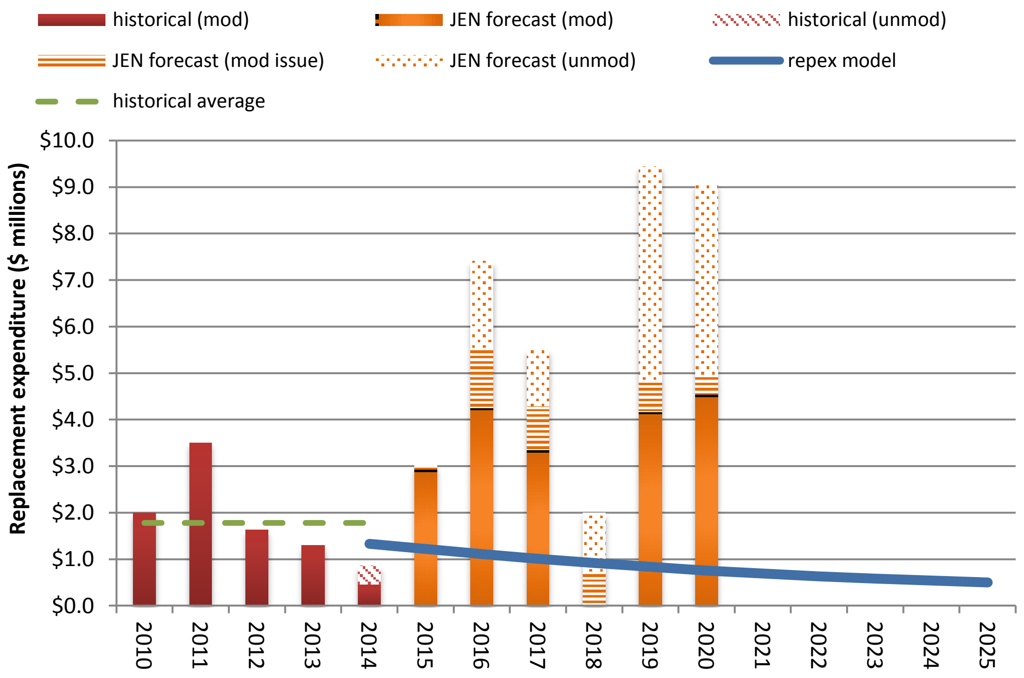

Figure 44 JEN repex model – SCADA/protection repex forecast

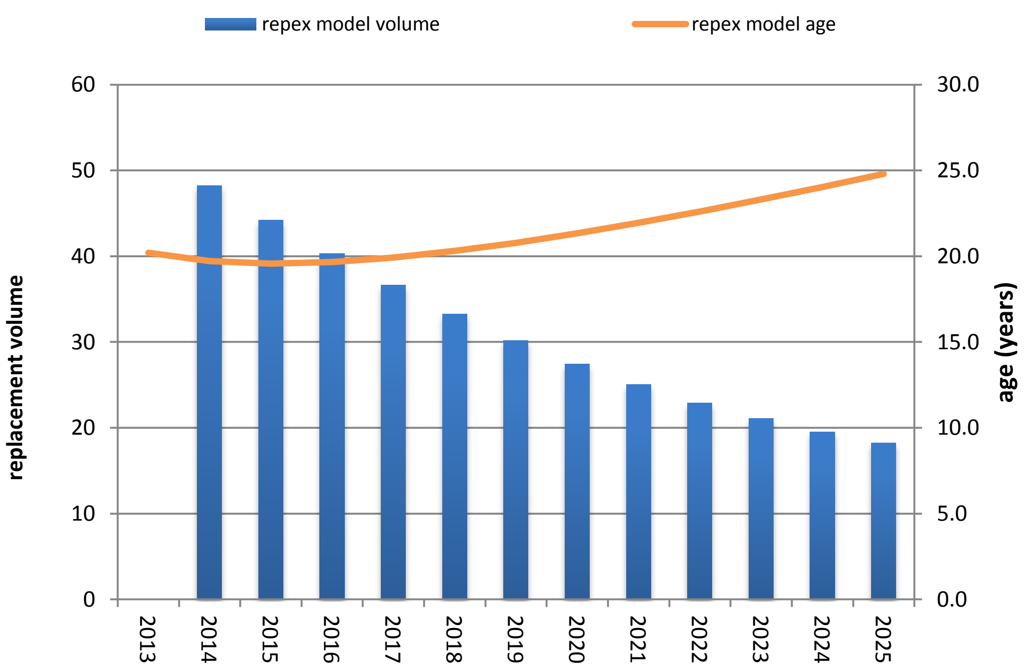

Figure 45 JEN repex model forecast – replacement volumes and age - SCADA/protection

Table 44 JEN repex model forecast – summary - SCADA/protection

	repex - average per annum			
	2010-14	2016-20		
Asset Group	(RIN) $millions	JEN forecast[a] $millions	Repex model $millions	difference[a] $millions
SCADA & protection		[c-i-c]		-$3.1 (-$2.3)

a – the brackets indicate the amount without the modelling issues

With regard to the profile of JEN's repex (historical and forecast) in the SCADA/protection asset group, JEN has advised:

"In 2016 and 2017 expenditure is driven by the relay replacement programs at Airport West and Broadmeadows.

In 2019 and 2020 relay replacement programs will commence at Coburg North and Footscray West.

The main driver of this increased volume of replacements is the emerging poor performance of a number of types of relays. In addition, there are other limitations with some of these protection systems.

A mal-operation of a substation protection scheme due to its unexpected failure can reduce the reliability and security of supply of the customers down-stream of the zone substation and cause significant safety hazards to JEN staff and the public. If these protection projects are not undertaken, the reliability, security and safety of the network would deteriorate significantly over the next period."

B.11.2. Set up and calibration parameters

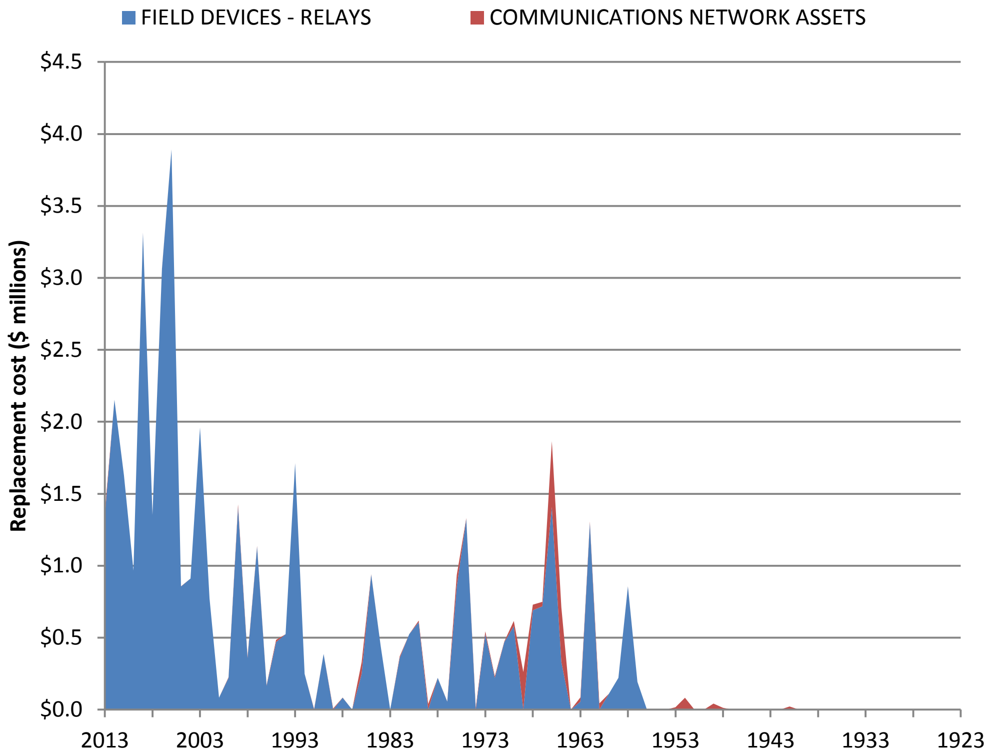

Figure 46 SCADA/protection age profile

Table 45 RIN 2.2.1 data required for calibration - SCADA/protection

Model asset category	volume[a]	unit scale	2010-2014 replaced Repex ($'000)	comment
FIELD DEVICES - RELAYS	322.0		[c-i-c]	
COMMUNICATIONS NETWORK ASSETS	0.0			RIN data zero - caution with calibration
Total	**322.0**			

a – 2010 to 2014 volume calculated from table 2.2.1
b – unit scale to map from units in 2.2.1 to units in 5.2.1 – only shown when units are different

Table 46 calibrated planning parameters - SCADA/protection

Asset category	life	unit cost ($'000)	S1 life[a]	volume growth rate
FIELD DEVICES - RELAYS	45.3	[c-i-c]	42.5	-13.4%
COMMUNICATIONS NETWORK ASSETS	128.3		128.3	54.2%

a – life derived using the unadjusted average annual volumes
b - growth used to determine adjusted average annual volumes

B.11.3. JEN repex model forecasts

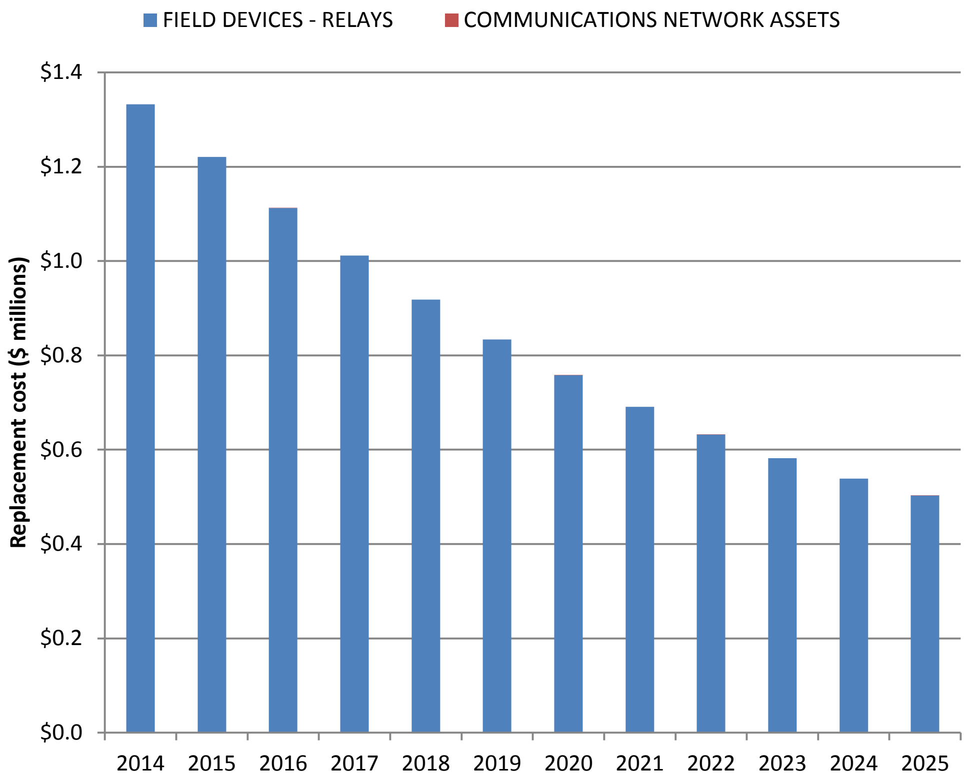

Figure 47 JEN repex model – asset category repex forecast - SCADA/protection

Table 47 JEN repex model – asset category summary - SCADA/protection

Asset category	2016-2020 repex ($million)	volumes	2013 age	2016 age	2020 age
FIELD DEVICES - RELAYS	[c-i-c]	167.9	19.1	18.4	20.0
COMMUNICATIONS NETWORK ASSETS		0.0	44.8	47.8	51.8
Total		**167.9**			

1 Addendum – AER reasonable range studies – 27 April 2015

This section serves as an addendum to the Nuttall Consulting report to JEN, "AER repex modelling: Category Analysis RIN calibration", dated 7 April 2015.

1.1 Introduction

For the NSW/ACT draft determination, the AER calculated a *reasonable range* for each of the NSW/ACT DNSP's replacement expenditure forecast using the repex model. JEN has requested that we apply the equivalent modelling approach to JEN's replacement forecast.

JEN has also requested that we undertake this analysis using its 2014 age profile – noting that the analysis in our report used its 2013 age profile.

It is important to note that the analysis and conclusions presented here are based upon our understanding of the approach the AER applied, which we have determined from explanations provided in the AER draft determinations. We have not confirmed with the AER that this understanding is strictly correct.

Furthermore, our conclusions on the *reasonable range* assume that the AER would follow the same approach and rely solely upon the results of the model; the AER draft determinations are unclear on the circumstances that the AER may depart from this approach when defining the *reasonable range*.

1.2 The AER's reasonable range

1.2.1 Defining the reasonable range

The AER uses its *reasonable range* to test the component of the DNSP's repex forecast that the AER considers is covered by the repex model. This component of the DNSP's repex was accepted if it fell below the AER's reasonable range.

Importantly, the range represented the **aggregate** repex over the regulatory period being assessed i.e. it was not a year-by-year figure or a figure developed for each asset group or category. This range was determined from a set of model scenarios. Each scenario reflected a forecast prepared by the model using a different set of the model's planning parameters (i.e. asset lives and unit costs).

The AER studied a large number of scenarios for each DNSP – over 30. However, it evaluated each scenario (for each DNSP) in order to accept or reject it as an appropriate basis for defining the reasonable range. In this way, only one or two of these scenarios define the reasonable range for each DNSP, and the scenarios that defined the range were common across the DNSPs.

For most scenarios, the AER's reasoning for rejecting the scenario would be relevant to any DNSP. Therefore, for assessing JEN, we have focused on only the three scenarios that could be used to define the reasonable range (assuming the AER applied exactly the same rationale to JEN).

All three of these scenarios use JEN's historical asset lives, which are calibrated to reflect the last five years of JEN's replacement volumes (as reported in its RIN) – 2010 to 2014. Therefore, the scenarios are uniquely defined by three variations in the unit cost parameter set used, as follows:

- **Scenario 1**[19] - historical unit costs - unit costs that are calibrated to reflect the last five years of JEN's replacement expenditure and replacement volumes as reported in its RIN (2010 to 2014)
- **Scenario 2** - forecast unit costs - unit costs that are calibrated to reflect the JEN's replacement expenditure and replacement volume forecasts over the next regulatory period, as reported in its RIN (2016 to 2020)
- **Scenario 3** - AER's benchmark unit cost – unit costs that the AER has calculated as the average historical unit costs (as calculated above) across all the NEM DNSPs[20].

1.2.2 Coverage of the reasonable range

As noted above, the AER only determined a *reasonable range* in this way for the component of the DNSP's forecast that it considers could be assessed through the repex model. Consequently, it excluded the following from its modelling:

- the SCADA, protection and control asset group and the "other" asset group
- other programs within the DNSP's forecast that were defined by the DNSP as not suitable for repex modelling
- the pole top structure group was also excluded – although, presumably, this is because it could not be modelled due to the absence of data, rather than the AER not considering it worthy of assessment through the repex model
- the public lighting group was also excluded – although, presumably, this was because it is treated as an alternative control service.

For the analysis present here, we have ran two sets of scenarios:

- AER exclusions – the first is based upon a model with all the equivalent exclusions that the AER has applied. This model allows all three scenarios to be assessed.

  This model covers **$107 million** (48%) of JEN's repex forecast over the next regulatory period.

[19] This scenario represents the model study that has been discussed in our original report.
[20] See the AER's draft determinations on its website for more information on the methodology the AER applied to derived these benchmarks.

- Expanded model – the second incorporates the forecast for the pole top structure asset group into the measure. However, this only allows scenarios 1 and 2 to be performed, as the AER has not provided benchmark unit costs for the pole top structure asset categories.

  This model covers **$142 million** (64%) of JEN's repex forecast over the next regulatory period.

We have not included the SCADA, protection and control asset group and the "other" asset group into our analysis, as we believe it is less likely the AER will incorporate these into its assessment of the reasonable range. In keeping with our report, we have also excluded the public lighting group as we understand that this will be treated as an alternative control service.

1.3 Reasonable range results

Table 48 below summarises the results of this analysis, indicating that for all scenarios we have studied, covering both model forms, the repex model forecast is above JEN's forecast.

Table 48 JEN reasonable range scenario results

	Repex forecast (2016 - 2020)		Percentage of JEN forecast	
	AER exclusions $ millions	expanded model $ millions	AER exclusions %	expanded model %
Scenario 1	$126	$160	118%	113%
Scenario 2	$117	$149	110%	105%
Scenario 3	$109	n/a	102%	n/a
JEN forecast covered	**$107**	**$142**		

These results indicate that if the AER bounded its *reasonable range* by the lowest scenario (i.e. scenario 3, which uses the AER's benchmark unit costs) then the *reasonable range* would be set to $109 million. This *reasonable range* is 2% above the component of JEN's forecast covered by this model, suggesting that the AER would accept this component (if it applied the same modelling approach).

The results using the expanded model are also favourable, indicating that JEN's forecast is below the scenarios using the JEN's historical and forecast unit costs. As benchmark unit costs for JEN's pole top structure are not available, it is not possible to know whether JEN would also have a favourable result for scenario 3.

The make-up of these three scenarios can also be seen in the two charts below. Figure 48 shows the model forecasts for the three scenarios, indicating the portion of JEN's historical and forecast repex covered by the model that strictly applies the AER's exclusions. Figure 49 shows the equivalent chart for the expanded model and the two scenarios covered by this model.

These charts also show that JEN's forecast compares favourably to the scenario forecasts, with regard to the profile of the forecast. Most notably, JEN's forecast is much lower than the model scenario forecast in the first half of the next regulatory period, and only rises above it in the second half. This means, in a present value sense, JEN's forecast is even lower than the scenario forecasts than is indicated by the percentages in the table above.

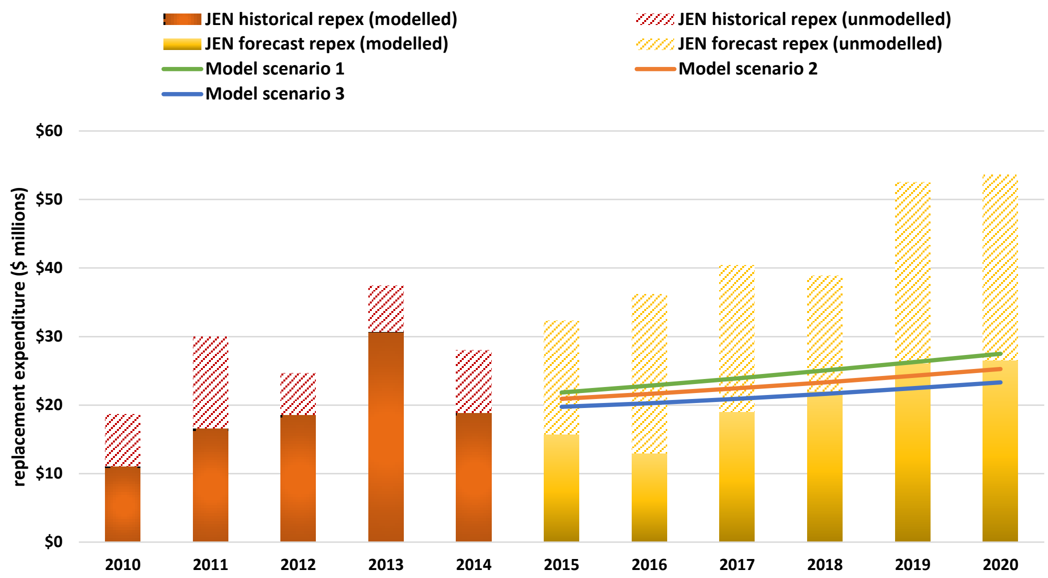

Figure 48 reasonable range results – using AER exclusions

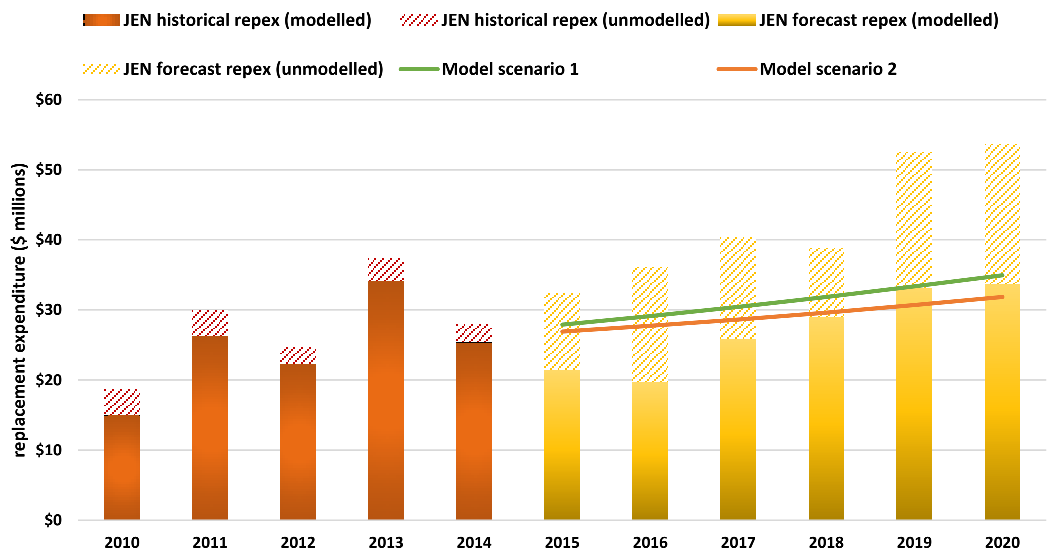

Figure 49 reasonable range results – using expanded model

A.1. Addendum appendix - AER unit costs benchmarks

JEN has provided us with a file containing the AER's unit cost benchmarks. These benchmarks are relatively sparse in places, and therefore, do not cover all of the asset categories defined by the AER and used by JEN. Consequently, to ensure we have a sufficient set of unit costs for the asset groups covered by the model, we have made a number of assumptions, as follows:

- blended wood pole staking/replacement unit costs – we have assumed a 50:50 split for staking or replacing LV and HV wood poles, based upon the similar assumption we understand the AER applied in its analysis. For 66 kV wood poles we have assume a 5 (staking):95 (replacing) split; however, this assumption is relatively immaterial on the results.
- 22 kV and 66 kV wood pole replacement costs – the unit costs benchmarks are not provided for these categories; therefore, we have used relative scaling by voltage level for concrete poles, to scale up the AER unit cost benchmark for 11 kV wood poles
- replacement of staked wood poles - we have used JEN's proportion of replacements in each voltage level to calculate a weighted average replacement cost for the staked poles category (noting the voltage is not specified for this category)
- transformer unit costs – the benchmark unit costs for the transformers asset categories is very sparse in the file provided by the AER. However, the AER appears to have developed benchmarks that it has used in the relevant NSW/ACT DNSP repex model files, which are published on the AER's website. Therefore, where a unit cost was missing in the AER file, we have used the benchmark unit cost that the AER has defined in the NSW/ACT repex model file.

In additional, all unit costs were escalated to convert from real 2014 to 2015 costs.

A.2. Addendum appendix – correction to final report

Correction to Fig 1 – JEN repex model age profile, page 18.

The title of the y-axis should read "replacement costs ($ millions)". This correction does not affect any results, discussions or conclusions provided in the report.