GHD Advisory

# 2021-26 Repex Modelling Review

## CitiPower

18 December 2019

GHD

# Contents

# 1. Executive Summary

GHD Advisory (we, us, our) was engaged by CitiPower to review its approach to populating the Australian Energy Regulator (AER) repex model and also in completing the necessary data analytic to support the modelling activities. This report summarises our review comments provided to CitiPower. This report also summarises the salient features of the AER repex model and the associated data analytics and modelling approach advised to and adopted by CitiPower.

This report describes the step-by-step process that follows the recent AER's modelling approach and its basis for sourcing and preparing the input data for comparative input analysis, scenario modelling, and setting the repex model threshold. We consider that the following six asset groups can be modelled to forecast CitiPower repex and hence be reviewed using the AER repex model:

- Poles,
- Overhead Conductors,
- Underground Cables,
- Service Lines,
- Transformers, and
- Switchgear.

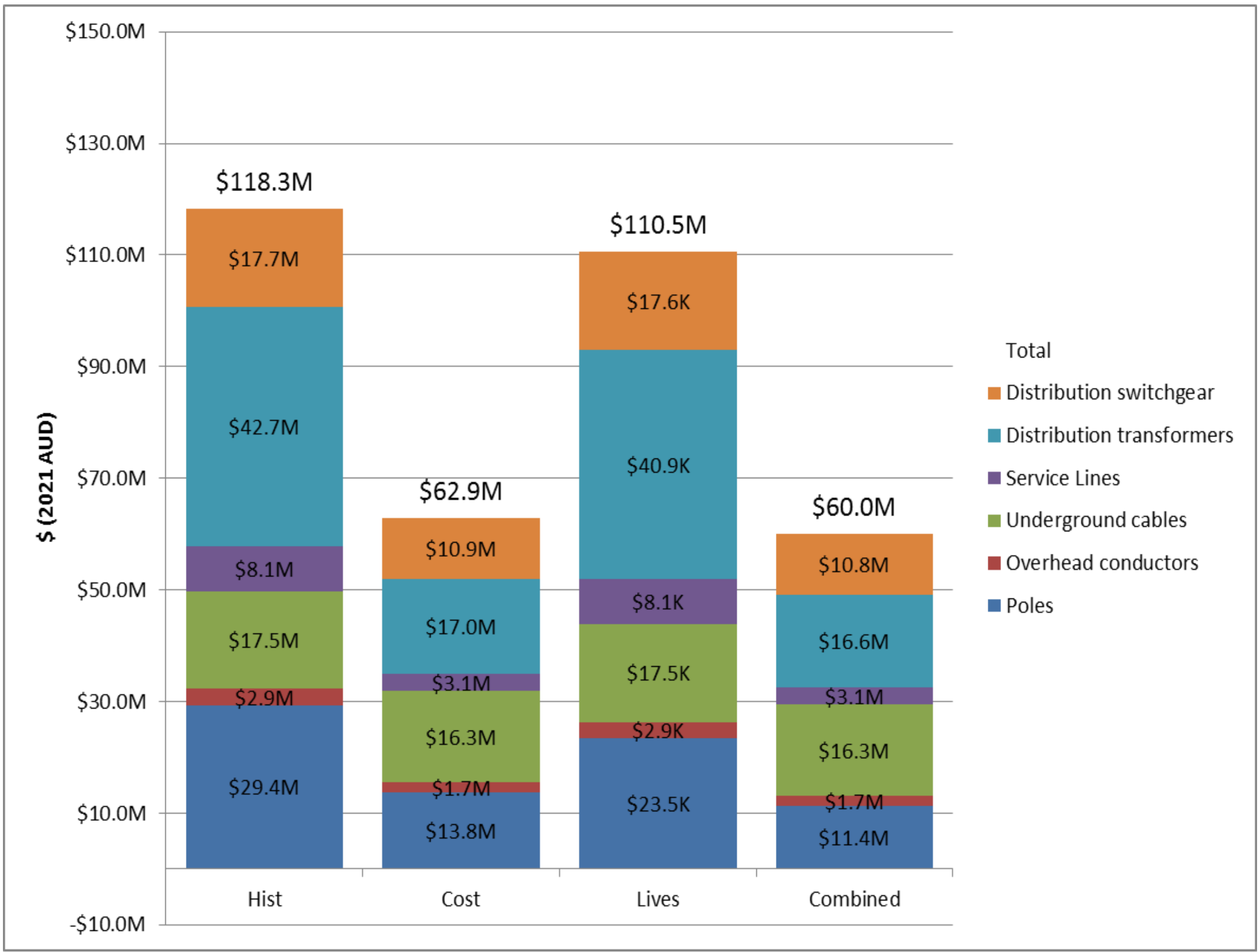
The AER has refined and adopted a consistent and transparent approach of using its repex model. It employed this new approach in its most recent round of determinations of all Distribution Network Service Providers (DNSPs) in 2018 and 2019 (i.e. DNSPs from ACT, NSW, NT, TAS, SA and QLD). This new approach assesses the various input data set (historical, forecast and National Electricity Market or NEM medians) for efficiency prior to inputting them in the repex model. These are then used to forecast the 'historical scenario', 'cost scenario', 'lives scenarios', and 'combined scenario' and then for determining the repex model threshold. This new approach gives consideration to the inherent interrelationship between the unit cost and expected replacement life of network assets. The AER in these determinations has also advised that it does not view the repex model as the final or absolute tool to review and determine the DNSP's required repex level. For example, the AER is now using the repex model as a first-pass review tool to inform itself to focus on priority issues for further detailed assessments.

The AER review process and its determination of likely repex is also influenced by a DNSP's historical expenditure trend and risk and asset management practices (such as risk-deferral analysis, capacity to deliver, performance analysis) as well as industry direction.

Our analysis incorporating the latest available information from CitiPower and following the same modelling approach as adopted by the AER indicates that the likely 'modelled' portion of the repex forecast would be approximately $110M total (direct cost) for the 2021-26 regulatory period.

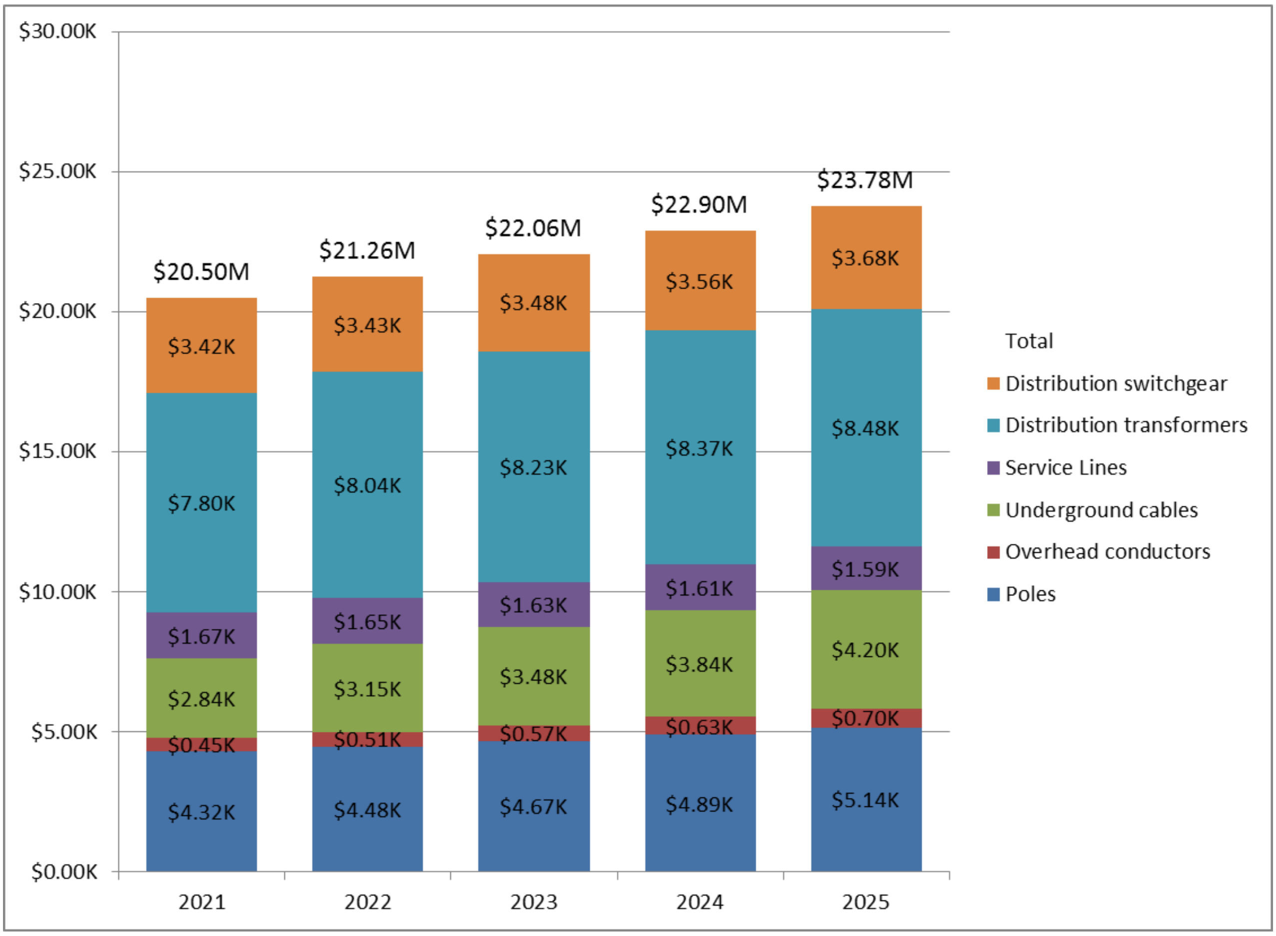
Figure 1 provides a high level summary of this analysis. This total is based on the repex model threshold which is equal to the higher of the 'cost scenario' or the 'lives scenario' modelled outputs and corresponds to 4 years history for average unit cost and calibration period.

*Figure 1 Total 2021-26 summary of modelled repex forecast scenarios [2021 $ value]*



The following Figure 2 provides the annual breakdown of the lives scenarios modelled output which is the repex model threshold.

***Figure 2 Annual breakdown of the repex model threshold (lives scenario) [2021 $ value]***




The remaining of the total proposed repex forecast cannot be modelled and hence will be reviewed by the AER using other techniques such as business cases, engineering review, trend analysis etc. This remaining 'un-modelled' repex constitute of the following four asset groups:

- Pole Top Structures,
- Public Lighting,
- SCADA, Network Control and Protection Systems, and
- Other.

# 2. Introduction

## 2.1 Background

Replacement expenditure (or repex) is a material component of a mature utility's network investment, and as such, its forecasting, regulatory review and determination is important. Typically, the non-demand driven replacement of an asset with its modern equivalent, where the timing of the need can be directly or implicitly linked to the age of the asset, forms the major portion of the network repex. The timing of the need for asset replacement can be driven by a number of factors such as increasing asset maintenance and operating costs as assets age, decreasing network reliability, increasing failure risk, deteriorating network performance and condition, and asset management issues. These factors often are related to the age of the asset and the management of the asset over its life cycle impacting condition. Therefore the asset age can be used as a proxy for many factors that drive individual asset replacements.

The AER has been using a tool (repex model) to inform its assessment of the repex forecast proposed by the DNSPs in the NEM in its recent determinations to establish the respective maximum allowable revenues.

CitiPower engaged us in 2019 to review its approach to populating the Australian Energy Regulator (AER) repex models, and also in completing the necessary data analytic to support the modelling activities. This work involved reviewing proposed input data, performing supporting data analytics activities, and advising to formulate input data from the available sources within the businesses and from across the National Electricity Market or NEM (i.e. industry benchmark input data) to model various forecast scenarios. Based on this work, we determined the AER's view of the 'modelled' portion of the repex for the respective businesses for the 2021-26 regulatory period.

## 2.2 Purpose and Scope of this Report

This report addresses the work brief included in the original Request for Quotation (RFQ) by CitiPower, Powercor and United Energy dated 6 December 2018, and also reflected in our proposal dated 21 December 2018. This report summarises our review comments provided to CitiPower on the reasonableness of their approach to populating the AER repex model. This report also summarises the salient features of the AER repex model and the associated data analytics and modelling approach advised to and adopted by CitiPower.

Finally this report also provides the modelling outcome for the 'modelled' repex forecast.

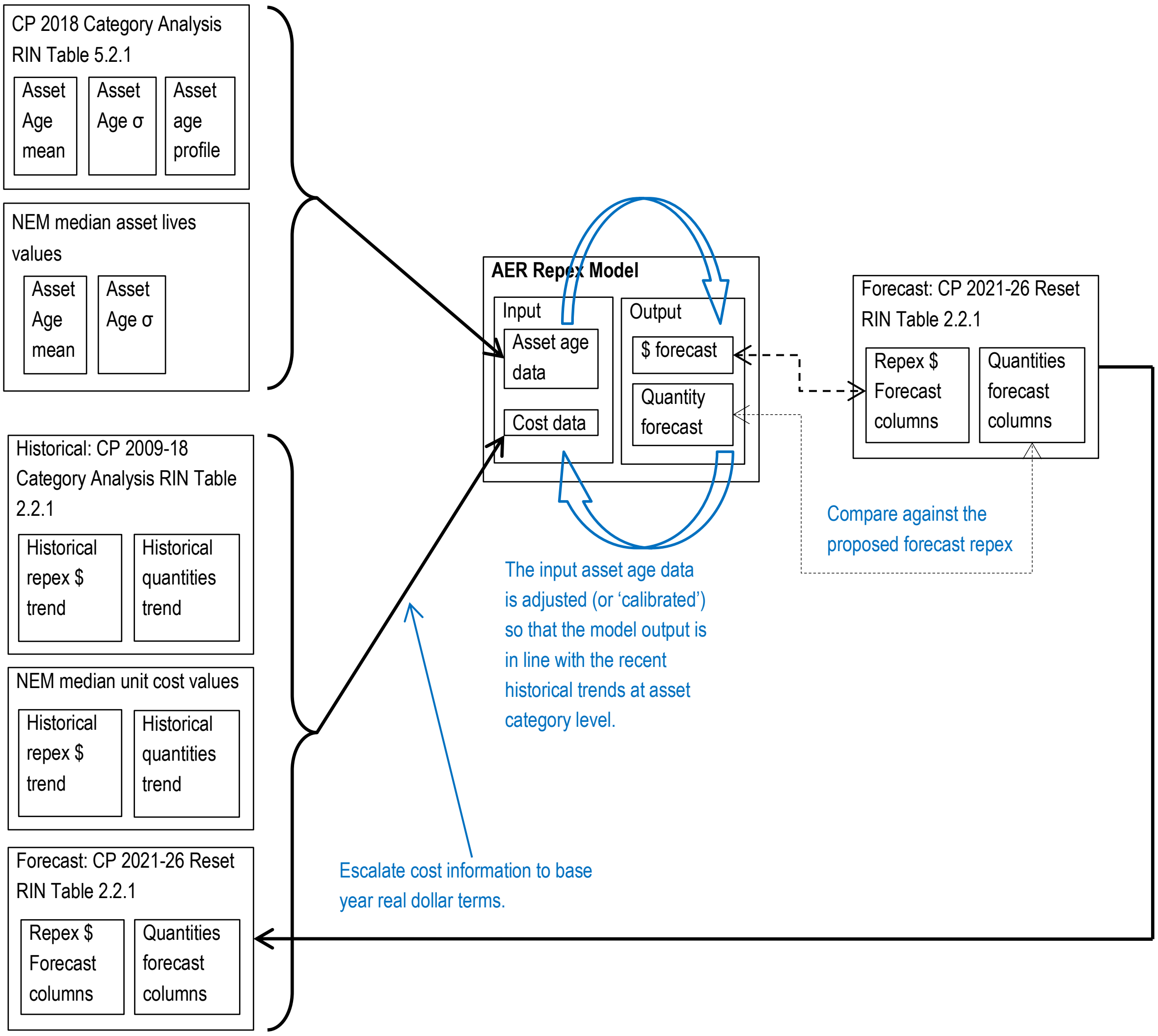
# 3. AER Repex Model

## 3.1 Overview

The AER has published a tool (repex model) to analyse the DNSPs asset replacement forecast profile based on a combination of historical, forecast and industry benchmark information that they have collected and using the asset age data as a proxy to summarise many factors that drive repex. The model uses the historical repex behaviour in the NEM reported in the DNSPs’ Category Analysis Regulatory Information Notice (RIN) and also the repex forecast proposed in the Reset RIN of the DNSP under consideration to review repex estimates and asset quantities forecast for the upcoming regulatory period for that DNSP.

Given the complexity in predicting the need to replace assets and to review such forecast, the aim of the model is to simplify the analysis, while maintaining some accuracy at the aggregate level. To achieve this, assets are considered as populations rather than individual items. The key parameter for predicting asset replacement needs across the population is the asset lives. This life could be the technical or economic life depending on the circumstances of the particular asset population. An overview of this modelling process is illustrated in Figure 3.

*Figure 3 AER repex modelling process overview*




The repex model is designed to predict and benchmark replacement expenditure for DNSPs using a probabilistic replacement model. The probabilistic model predicts future repex as a function of the age of individual network assets, their failure probability distribution characteristics, and replacement cost.

A key part of the model's functionality is the 'calibration' stage, during which the model outputs are 'forced' to aligned to recent past replacement volumes by adjusting input parameters. The calibration process involves manipulating (or goal-seeking) asset lives input data in the model so that future asset quantity replacement trends form a continuous pattern with recent replacement quantities. The logic behind this step is to mathematically reflect the organisations asset replacement practices, in contrast to the replacement life being reported in the Category Analysis RIN, in the model.

## 3.2 Application

This AER tool is meant to model the non-demand driven network capital expenditure that involves replacing existing assets with modern equivalent assets of similar service levels, where the timing of the need can be directly or implicitly linked to the age of the existing asset. This is illustrated in Table 1.

*Table 1 Network capex categories*

| Capex driver | Activity | |
|---|---|---|
| | Replace | Addition |
| Demand driven: Customer connection | Replacement of assets to facilitate the connection | Development of new network assets to facilitate the connection |
| Demand driven | Replacement of existing assets with increased capacity (higher service level) | Development of new network assets to increase the capacity |
| Non-demand driven | *Replacement of existing assets with modern equivalent (similar service level)* | Installation of new assets |

Note the distinction with replacement activity driven by demand. Demand driven replacement, by its nature, will require assets of a higher capacity. Non-demand driven replacement should not necessarily require additional capacity, although, additional capacity may result due to replacement with modern equivalent assets and/or asset specification (capacity) standardisation practice.

This is a high level model and it is not meant to be treated as a planning tool, rather as part of the suite of tools used in the forecast review process. The regulatory review process using this tool is intended to account for major drivers of replacement expenditure at an aggregate level and is not designed to process disaggregate level of detail. This tool however can be used to target replacement expenditure areas for further detailed assessment and planning review.

## 3.3 AER Repex Modelling Approach

The AER in its recent revenue determinations has refined and adopted a consistent and transparent approach of using its repex model that, in brief, involves the following steps:

- Reviewing the asset age profile (reported in the latest CA RIN) and selecting asset categories with a moderate to large population of relatively homogenous assets. This usually results in selection of the six asset groups identified in the Executive Summary.
- Comparing two of the input data sets to known industry information for efficiency and identifying **comparative unit costs** and **comparative asset lives**. Along with the DNSP’s reported data sets, using the combination of the two comparative input data in the repex model to forecast ‘historical scenario’, ‘cost scenario’, ‘lives scenario’ and ‘combined scenario’ outputs as shown in the following table.

*Table 2 Combination of input data to populate repex model*

| Output scenarios | Input Data | | |
|---|---|---|---|
| | Age Profile | Unit cost | Asset lives |
| Historical | Reported DNSP specific information in the latest CA RIN | DNSP average historical unit cost reported in past CA RINs | DNSP asset lives reported in the latest CA RIN and calibrated |
| Cost | | **Comparative unit cost =** Minimum of either historical average or NEM median or forecast average unit cost | DNSP asset lives reported in the latest CA RIN and calibrated |
| Lives | | DNSP average historical unit cost reported in past CA RINs | **Comparative asset lives =** Maximum of either DNSP calibrated asset lives or NEM median calibrated lives |
| Combined | | **Comparative unit cost =** Minimum of either historical average or NEM median or forecast average unit cost | **Comparative asset lives =** Maximum of either DNSP calibrated asset lives or NEM median calibrated lives |

- Performing the calibration step by changing or forcing the reported asset replacement lives in the repex model in order to produce the first year asset quantities forecast to be similar or aligned with the recent historical trend. Depending on a few factors, the AER determines the length of the historical period analysed in this step which is referred as the 'calibration period'. For e.g., in the cases of the most recent determinations for NSW DNSPs, the AER decided on a 3 years calibration period in its repex modelling. Where a calibrated replacement life cannot be determined (due to absence of historical trend), the AER substitutes the value of a similar asset category.
- The NEM median unit costs are based on each DNSP's historical unit cost for each asset category. The NEM median replacement lives are based on each DNSP's calibrated historical replacement practices for each asset category. Use of the NEM median (instead of NEM mean, NEM least cost, NEM longest lives) effectively accounts for any outliers in the industry data set.
- Based on the outcomes of the four modelled scenarios, the AER determines the **repex model threshold** which is the highest repex forecast out of the cost scenario or the lives scenario. This approach gives consideration to the inherent interrelationship between the unit cost and expected replacement lives, i.e. if an equipment/project cost more it is expected to outlast its cheaper version. The historical scenario is solely based on the DNSP's historical practices and does not incorporate any comparative efficiency and results in the highest repex forecast scenario. Conversely, the combined scenario, which is solely based on the comparative efficient input data, results in the lowest repex forecast scenario.

This refined comparative analysis repex modelling approach adopted by the AER is now more transparent and reproducible than previous determinations. The repex models used in recent determinations use consistent set of benchmark or NEM median input data. We have followed this same approach as outlined above in our review and advise in assisting CitiPower to model its repex forecast.

The repex review process using the repex model has also been better described in the AER recent determinations. The AER has gone to some length in explaining that it is using the repex model as a first-pass review tool to inform areas of expenditure for which to target and priority issues on which to focus for further top-down assessments and bottom-up reviews. This modelling enables the AER to form an initial view on repex forecast volume that it may consider reasonable and prudent to meet the National Electricity Rules (NER) capex criteria prior to undertaking a more detailed assessment to account for any other factors.

## 3.4 Exclusions

The AER in its recent determinations has reviewed the proposed forecast repex of the following asset groups outside the repex model using other assessment approaches (trend analysis, bottom-up estimate, business case etc.).

- Pole top structures
- Public Lighting
- SCADA, Network Control and Protection Systems
- Other

These asset groups are deemed not suitable for forecasting repex because of the nature of these assets, their drivers, and the difficulty in establishing an asset boundary in project work. In many cases the replacement timing of assets in these groups may not be a function of their age (e.g. technological obsolescence and lack of market support for after sale services is the case for most secondary system assets). The replacement timing for these assets is therefore driven by various factors other than age related condition, deterioration, operational or maintenance issue, and failure.

In the case of pole top structure asset group, the AER has not collected the asset age profile data in Category Analysis RIN Table 5.2.1.

In other cases, asset items or types may be difficult to group into a particular category, or/and has small population, or/and sparsely distributed age profiles, or/and were relatively new, thereby not incurring replacement in the recent past.

We have excluded these asset groups in this engagement also, for similar reasons. It is expected that the proposed forecast repex for these excluded asset groups will likely be reviewed through engineering assessments commissioned by the AER, as this has been the case for other DNSPs in their latest determinations.

## 3.5 Limitation of the Repex Model

The use of the AER repex model is suited to mature DNSP with large asset portfolio and continuous volume of replacement works in each portfolio. Such network businesses tend to have a relatively more consistent asset replacement profile over time. This more frequent and steady replacement means that even short historical timeframe can be used as an indicative or reasonable estimation of such network businesses' replacement needs in the next regulatory control period.

The replacement profile of the network businesses with smaller volume of asset portfolio (for e.g. TNSPs or smaller DNSPs) are usually lumpy over time. The infrequency of replacement and fewer assets means that it is more difficult to use the AER repex mode to review such repex profile.

The AER repex model assumes the key factor that predicts replacement is the asset age and thus this model is only suitable to model asset classes where age is a good predictor of the need to replace and timing. Since not all asset groups necessarily fit this pattern (as explained in the previous Section), the AER has split repex assessment into two portions – 'modelled' repex and 'un-modelled' repex. Assets where age is considered a good predictor are classed as 'modelled' repex, whereas those for which it is not, are considered 'un-modelled' repex. Some limitation of the repex model are summarised below.

Limitation regarding the model itself includes the following:

- Age alone is not a sufficient and accurate predictor of replacement.

  While age certainly has predictive value for forecasting asset replacement, replacement also depends on other factors, such as reliability, obsolescence, and condition of assets, which may not correlate exactly with age. The repex model fails to make any allowance for covariates such as these, which must be accounted or corrected for in any accurate assessment. While the repex model is more suitable for forecasting repex for high volume–low value asset categories such as poles, it is not suitable for forecasting low volume–high value asset categories such as large power transformers. The replacements of such assets are dependent on item specific considerations such as condition based risk management which may not correlate directly to asset age. The case for replacing such assets and its expenditure are specific to each project.

- Use of a 'normal' (or standard bell curve) probability distribution of mean asset replacement age.

  The probability distribution of mean ages at which assets require replacement is not necessarily normally distributed. In prevalent asset management or asset lives study a Weibull or exponential function often provides a more accurate fit. While a normal distribution function relies on parameters more commonly produced and understood by businesses, and provides forecasts with predictive value, this approach can introduce inaccuracy in forecast estimates, especially for low volume asset portfolio.

Limitation regarding the calibration process includes the following:

- Assumption that the future requirement for long term replacement expenditure can be predicted by looking at recent past expenditure.

  The calibration process involves manipulating model input data so that future replacement quantity trends form a continuous pattern with recently replaced quantities. This approach fails to recognise where in the investment cycles each asset class sits relative to the expected life of the asset, as well as allowing no provision for one-off major projects requiring replacement of assets.

Limitation regarding the parameters predicted by modelling includes the following:

- The calibration process used by the AER produces economic life mean input data for some asset categories far beyond any technical or feasible range for this parameter. This step is performed to replicate organisational recent asset replacement practices in the model (instead of purely relying on economic life mean data being reported by the DNSP themselves). The 'calibrated' or goal-sought parameter produced by this process is purely an artefact of the model's calibration, and is not related to any real replacement data or technical assessment.

Like most models, this repex model also has some limitations, therefore it is important to consider the results within the context of wider assessment tools. Recognising these limitations is helpful in understanding the nature of the forecast provided by the model and how it compares with the proposed program of works. The AER has stated "*We further note, as foreshadowed in the Explanatory Statement to our Guideline that we will use the REPEX model as a first pass model, in combination with other techniques. It is not used in* *isolation, but one of a number of analytical tools*"[1]. This statement suggests that the repex model is designed as a tool to inform decisions on proposed repex and is not suitable to base a regulatory determination on its own.

## 3.6 AER recent determinations

The AER has reviewed the proposed repex of most of the NEM DNSPs using the above described approach during their respective revenue determinations in 2018 and 2019.

The repex model threshold (as described in Section 3.3) provides the AER with a first-pass view of what an efficient repex level should be for the proposed period and for a given DNSP. The AER compared the repex model threshold against the DNSP's proposed repex at each asset group level to understand the factors driving the differences. The AER then targeted its assessments and focused on those asset groups where material differences were noted.

The AER determination may or may not be equal to the repex model threshold. In instances where the AER can satisfy itself through assessment of a DNSP's compelling business cases for the noted difference (i.e. cost-benefit analysis, risk quantification, top down assessment, capital program optimisation etc.), it is likely that the AER determination would be greater than the repex model threshold. In instances where it cannot satisfy itself, its determined efficient expenditure is equal to the repex model threshold.

## 3.7 Review basis

The discussion documented in this section of the report provided us the basis for reviewing CitiPower's approach in populating their repex model and also assisting them with the associated data analytics to support a consistent repex proposal to be presented to the AER. This includes assisting CitiPower to report coherent set of forecast information in the Reset RIN when compared to their historical repex behaviour and the NEM median performance.

[1] Page 6-93, Attachment 6: Capital Expenditure | Essential Energy draft decision, AER Nov 2014.

# 4. Input Data Review & Advice

## 4.1 Unit Cost

### 4.1.1 Historical – Based on Category Analysis RINs

#### 4.1.1.1 Consideration of historical duration

We referred to the historic annual repex and replacement quantities[2] to review the unit cost calculation for each asset category which is used to predict the cost of future replacements in this scenario. After consultation with CitiPower we used a 4 year duration over the historical period for our modelling to attempt to best reflect the CitiPower asset replacement behaviour going forward. This duration also provides a good balance between including many asset categories and also representing recent project delivery cost experience in competitive market environment.

The historical annual repex information is reported in CA RIN in nominal dollars of each respective year. We reviewed the escalation of this historic information to a real dollar base of 2021 using the Australian Bureau of Statistics (ABS) published historic data of Consumer Price Index (CPI) specific to Melbourne and the Reserve Bank of Australia (RBA) national inflation outlook. The escalation indices used for this conversion is shown in Table 3.

***Table 3 Escalation indices***

| Time period (from, to) | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|
| | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| Cumulative CPI | 1.144 | 1.131 | 1.115 | 1.091 | 1.064 | 1.051 | 1.025 |

#### 4.1.1.2 Averaging calculation

The average unit cost can be calculated for individual asset categories in two ways, namely a weighted or an unweighted average unit cost as shown below.

$$Weighted\ average = \frac{Expenditure1 + Expenditure2\ ... + ExpenditureN}{Volume1 + Volume2\ ... + VolumeN}$$

$$Unweighted\ average = \frac{\left(\frac{Expenditure1}{Volume1} + \frac{Expenditure2}{Volume2}\ ... + \frac{ExpenditureN}{VolumeN}\right)}{N}$$

[2] We only considered asset replacement quantities in this calculation. We understand that the asset failure quantities reported in Category Analysis RIN Table 2.2.1 is the count of failure occurrence/event and not the count of failed asset quantities. Therefore, we excluded asset failure quantities from calculating the unit cost.

We consider that the weighted average method is more appropriate than the 'average of the average'. The weighted average is the total cost (in real 2021 dollar terms) of replacement over the past 4 year period (i.e. 2015-19) divided by the total volume of replacements over the same period. This contrasts with the unweighted method, which calculates a unit cost for each year, and then averages these results.

The advantage of the weighted averaging method is that it better accounts for variable levels of replacement in different years, and better accommodates outliers. For example, if only a minimal number of assets were replaced in one year, at a relatively high price, we would not want to consider that unit price to be of equal weight to one derived from a year with a lot of replacements. The average price of an asset should be closer to the replacement cost for the majority of the replaced assets. If only a few assets in a particular category are replaced in one year, economies of scale will not be appropriately represented.

We advised this methodology and was adopted by CitiPower.

#### 4.1.1.3 Missing unit costs data

There are few asset categories whose unit cost data could not be determined because CitiPower has not replaced such assets and thus have not incurred repex for these asset categories in the last 4 years period. However, these assets exist in CitiPower's asset portfolio and have been 'identified' for replacement in the repex model in the near future. In such situations, the unit cost of a similar asset is assumed to be the same/similar assigned to the asset in question (i.e. substitution), or estimated based on CitiPower project manager's experience (i.e. estimation). This is the same as the approach adopted by the AER. We reviewed the substitution and estimation of these asset categories with missing unit cost which resulted in CitiPower revising this data. The following tables list the asset categories with such missing historical unit cost data and the revised substitutes/estimates.

***Table 4 Assumption for missing historical unit cost data (Real 2021 $)***

| Asset Groups | Asset Categories | Unit Cost Substitution/Estimation and Basis of Assumptions |
|---|---|---|
| Poles | > 11 kV & < = 22 kV; CONCRETE | $37.8k/Unit, referred from > 1 kV & < = 11 kV; CONCRETE Pole historically reported repex data, escalated by 10% |
| | > 22 kV & < = 66 kV; CONCRETE | $41.28k/Unit, referred from > 1 kV & < = 11 kV; CONCRETE Pole historically reported repex data, escalated by 20% |
| | > 11 kV & < = 22 kV; STEEL | $29.67k/Unit, referred from > 1 kV & < = 11 kV; STEEL Pole historically reported repex data, escalated by 10% |
| | > 22 kV & < = 66 kV; STEEL | $32.37k/Unit, referred from > 1 kV & < = 11 kV; STEEL Pole historically reported repex data, escalated by 20% |
| Overhead Conductors | > 11 kV & < = 22 kV ; MULTIPLE-PHASE | $88.85k/km, referred from > 1 kV & < = 11 kV Overhead Conductor historically reported repex data |
| | > 22 kV & < = 66 kV | $88.85k/km, referred from > 1 kV & < = 11 kV Overhead Conductor historically reported repex data |

| Asset Groups | Asset Categories | Unit Cost Substitution/Estimation and Basis of Assumptions |
|---|---|---|
| | SUB TRANSMISSION 22kV CONDUCTOR - 2017 RIN does not differentiate | $88.85k/km, referred from > 1 kV & < = 11 kV Overhead Conductor historically reported repex data |
| | PUBLIC LIGHTING CONDUCTOR | $127.93k/km, referred from < 1 kV Overhead Conductor historically reported repex data |
| Service Lines | LV UNDERGROUND SERVICE CABLE | $1.98k/Customer, referred from LV Overhead Service Cable historically reported repex data |
| Transformers | POLE MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE | $80.31k/Unit, referred From POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | KIOSK MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE | $173.98k/Unit, referred From KIOSK MOUNTED ; > 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; < = 60 kVA ; MULTIPLE PHASE | $80.72k/Unit, referred From GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE | $80.72k/Unit, referred From GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; < = 15 MVA | $1,554.33k/Unit, referred from 2011/2012 replacement data for this Asset Category |
| | GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; > 40 MVA | $1,554.33k/Unit, referred From GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; < = 15 MVA Transformer historically reported repex data |
| | AUTO TRANSFORMERS | $80.72k/Unit, referred From POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| Switchgear | > 11 kV & < = 22 kV ; Circuit Breaker | $75k/Unit; GHD Estimate |
| | > 33 kV & < = 66 kV ; Switch | $133.45k/Unit, referred from > 33 kV & < = 66 kV ; Circuit Breaker |

| Asset Groups | Asset Categories | Unit Cost Substitution/Estimation and Basis of Assumptions |
|---|---|---|
| | | historically reported repex data |

#### 4.1.1.4 Data discrepancies

During our review of CitiPower historical unit cost input data to the repex modelling, we noted the following issues:

- In 2018 the calculated unit cost of two Ground Outdoor/Indoor Chamber Mounted Transformers asset categories are negative. We believe this to be an artefact of historical cost allocation between multiple asset categories and/or allocation between multiple historical years to balance the accounting book. This usually leads to inconsistent reporting of the expenditure against the corresponding asset quantities in the past CA RIN Table 2.2.1, i.e. there are delay or disjointed dollar-quantities reporting. We believe that adopting the weighted unit cost calculation method (as explained in Section 4.1.1.2) addresses such situation if such data discrepancy occurred during the considered historical period. Further, we analysed the impact due to this data discrepancy in the repex modelling outcome and concluded that it only effects the 'historical scenario' which does not get to determine the repex model threshold during the AER review. As such this data discrepancy is only noted and not addressed.
- For the Public Lighting asset group reporting, the Brackets asset category has expenditure, but no asset replaced quantities and the Lamps asset category has no expenditure, but asset replaced quantities. However, given the Public Lighting asset group is excluded from the AER repex modelling review, this data discrepancy is only noted and not addressed.
- CitiPower started to inconsistently report its quantities of Service Lines asset group in historical CA RINs from 2015 onwards. Since 2015, the asset age profile in Table 5.2.1 correctly reports the quantities of customers, however the repex quantity information in Table 2.2.1 incorrectly reports the km length. As such the calculated historical unit cost for this asset group is per km cost which is magnitude time expensive than the NEM median. When the repex model process these information (unit cost in per km basis and the asset age profile in quantities of customers), the resulting repex forecast output is very large and incorrect. This impacts the 'historical scenario' and 'lives scenario' resulting in the repex model threshold to be equal to the 'cost scenario'. We addressed this issue by converting the incorrectly reported km length data in the re-casted historical CA RINs Table 2.2.1 into quantities of customers by referring to the average service line length per customer based on CitiPower asset register and GIS data. This revision of this asset group historical data now produces all scenarios of repex modelling forecast correctly.

### 4.1.2 NEM Median Unit Costs

We referred to the most recent set of NEM median unit cost data published and used by the AER for the draft determinations of SAPN, Energex and Ergon in October 2019, and advised CitiPower to use them to determine the comparative unit cost for modelling the 'cost scenario' and 'combined scenario' forecast outputs.

### 4.1.3 Forecast – Based on 2021-26 Reset RIN

CitiPower advised us that it plans to propose the forecast repex and asset quantities in the 2021-26 Reset RIN Table 2.2.1 in a manner where the calculated forecast unit cost for all asset categories will be consistent with the historical unit cost. As such we only reviewed and considered the historical unit cost (as described in Section 4.1.1) and NEM median unit cost (as described in Section 4.1.2) input data sets. In other words, we did not consider the third unit cost data set (i.e. forecast unit cost) to determine the comparative unit cost applicable to run the cost scenario and combined scenario modelling forecast.

## 4.2 Blended Unit Cost

Staking of a wood pole is an ‘activity’ to reinforce and prolong the life of an existing wood pole. A ‘staked’ wood pole is replaced with a new wood pole, and an existing wood pole may be either replaced with a new wood pole or reinforced with stake to prolong its life. In other words, the asset age profile of the staked wood poles does not determine the expenditure for the staking of wood poles. The asset age profile of a proportion of the existing wood pole determines the staking activity. The main driver for this expenditure or activity is the asset management practice for existing wood poles (and not staked wood poles).

This particular asset category denotes those wood poles that are staked and therefore have longer asset lives than wood poles. The proposed replacement economic life for a staked wood pole is the additional years of life extension of a wood pole arising from of staking that wood pole. Staked poles are replaced with non-like-for-like assets (i.e. with a brand new wood pole) so the unit cost input data for this asset category will be same as the unit cost of wood pole asset categories.

Consequently, some proportion of wood pole asset categories will be staked instead of being immediately replaced and therefore such replacement unit cost input data will be different for a wood pole that is staked (captured as replacement in the RIN) to wood pole replacement. The unit cost of wood poles used for repex modelling must therefore account for this non-like-for-like replacement (i.e. staking as opposed to wood pole replacement), and a ‘blended’ unit cost calculated based on the proportion of wood poles that get staked versus the total of wood poles replaced. Based on the AER Repex Model Handbook guideline and recent determinations for NEM DNSPs, the AER will request information from CitiPower on the proportion of wood poles staked, in order to arrive at this blended unit cost.

We reviewed recent years of asset replacement data (as reported in CA RIN Tables 2.2.1 and 5.2.1) to note than on average 70% of the existing wood poles are staked each year (non-like-for-like replacement) instead of like-for-like replacement by CitiPower. This proportion has been used by CitiPower to calculate the blended unit cost for the wood pole asset categories as shown in Table 5 to apply in the repex modelling. The following table illustrates this calculation for deriving the historical unit cost based on internal records, as an example.

***Table 5 Blended Unit Cost (Real 2021 $) – Based on Historical Records (an example)***

| Asset Group | Asset Categories | Pre-adjustment | | Blended Cost | |
|---|---|---|---|---|---|
| | | Unit Cost | Comments | Unit Cost | Comments |
| Poles | Staking of wood pole | $1.15k | Per unit cost of staking (nailing or reinforcing) | $22.47k | All non-like-for-like replacement, thus weighted average of all wood poles. |
| | < = 1 kV; Wood | $22.12k | Per unit cost of a wood pole | $7.55k | Some like-for-like replacement with unit cost of $22.12k and remaining non-like-for-like replacement with unit cost of $1.15k |

| Asset | Asset Categories | Pre-adjustment | | Blended Cost | |
|---|---|---|---|---|---|
| | > 1 kV & < = 11 kV; Wood | $22.24k | Per unit cost of a wood pole | $7.59k | Some like-for-like replacement with unit cost of $23.24k and remaining non-like-for-like replacement with unit cost of $1.15k |
| | > 11 kV & < = 22 kV; Wood | $32.41k | Per unit cost of a wood pole | $10.69k | Some like-for-like replacement with unit cost of $32.41k and remaining non-like-for-like replacement with unit cost of $1.15k |
| | > 22 kV & < = 66 kV; Wood | $27.84k | Per unit cost of a wood pole | $9.29k | Some like-for-like replacement with unit cost of $27.84k and remaining non-like-for-like replacement with unit cost of $1.15k |

## 4.3 Expected Replacement Life

The un-calibrated or base model uses the mean age (i.e. expected replacement life) of each asset category as the mean replacement age for all individual assets in that category. The replacement age may refer to either the economic or technical life of the asset, and represents the mean age at which assets in a category are replaced in practice, due to condition or other DNSP asset management practices.

### 4.3.1 CitiPower reported data

CitiPower used the economic life mean data (reported in years) from their latest reporting in the CA RIN Table 5.2.1 and used them to set-up or populate the un-calibrated models in all scenarios.

### 4.3.2 Missing mean asset lives data

There are few asset categories whose mean asset lives or expected replacement lives input data were not reported because CitiPower has not replaced such assets and thus have not incurred repex for these asset categories in the last 4 years period. However, these assets exist in CitiPower's asset portfolio and have been 'identified' for replacement in the repex model in the near future. In such situations, the mean asset lives of a similar asset is assumed to be the same assigned to the asset in question (i.e. substitution), or estimated based on CitiPower project manager's experience (i.e. estimation). This is the same as the approach adopted by the AER. We reviewed the substitution and estimation of these asset categories with missing mean asset lives which resulted in CitiPower revising this data. The following tables list the asset categories with such missing mean asset life data and the revised substitutes/estimates.

***Table 6 Assumption for missing mean asset lives data***

| Asset Groups | Asset Categories | Asset Lives Substitution/Estimation and Basis of Assumptions |
|---|---|---|
| Poles | > 11 kV & < = 22 kV; CONCRETE | 56.8 years, referred from > 1 kV & < = 11 kV; CONCRETE Pole historically reported repex data |
| | > 22 kV & < = 66 kV; CONCRETE | 56.8 years, referred from > 1 kV & < = 11 kV; CONCRETE Pole historically reported repex data |

| Asset Groups | Asset Categories | Asset Lives Substitution/Estimation and Basis of Assumptions |
|---|---|---|
| | > 11 kV & < = 22 kV; STEEL | 56.09 years, referred from > 1 kV & < = 11 kV; STEEL Pole historically reported repex data |
| | > 22 kV & < = 66 kV; STEEL | 56.09 years, referred from > 1 kV & < = 11 kV; STEEL Pole historically reported repex data |
| Overhead Conductors | > 11 kV & < = 22 kV ; MULTIPLE-PHASE | 94.01 years, referred from > 1 kV & < = 11 kV Overhead Conductor historically reported repex data |
| | > 22 kV & < = 66 kV | 94.01 years, referred from > 1 kV & < = 11 kV Overhead Conductor historically reported repex data |
| | SUB TRANSMISSION 22kV CONDUCTOR - 2017 RIN does not differentiate | 94.01 years, referred from > 1 kV & < = 11 kV Overhead Conductor historically reported repex data |
| | PUBLIC LIGHTING CONDUCTOR | 94.01 years, referred from > 1 kV & < = 11 kV Overhead Conductor historically reported repex data |
| Service Lines | LV UNDERGROUND SERVICE CABLE | 82.26 years, referred from LV Overhead Service Cable historically reported repex data |
| Transformers | POLE MOUNTED ; < = 22kV ; < = 60 kVA ; MULTIPLE PHASE | 63.31 years, referred From POLE MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | KIOSK MOUNTED ; < = 22kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE | 62.69 years, referred From KIOSK MOUNTED ; > 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; < = 60 kVA ; MULTIPLE PHASE | 69.47 years, referred From GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE | 69.47 years, referred From GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE Transformer historically reported repex data |
| | GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; > 33 kV & < = 66 kV ; < = 15 MVA | 55 years, CitiPower estimate |
| | GROUND OUTDOOR / INDOOR CHAMBER | 55 years, CitiPower estimate |

| Asset Groups | Asset Categories | Asset Lives Substitution/Estimation and Basis of Assumptions |
|---|---|---|
| | MOUNTED ; > 33 kV & < = 66 kV ; > 40 MVA | |
| | AUTO TRANSFORMERS | 55 years, CitiPower estimate |
| Switchgear | > 11 kV & < = 22 kV ; Circuit Breaker | 50 years, GHD estimate |
| | > 33 kV & < = 66 kV ; Switch | 50.82 years, referred from > 33 kV & < = 66 kV ; Circuit Breaker historically reported repex data |

### 4.3.3 Data discrepancies

During our review of CitiPower expected replacement lives input data to the repex modelling, we noted the following issues:

- Some of the asset categories (for e.g. >1 kV & <=11kV overhead conductor) should be excluded from the calibration process because they have not had any recent historical repex but has been 'identified' for asset replacement due to the nature of its age profile. Originally, CitiPower did not consider this and performed the goal-seeking calculation on the inputted replacement live data resulting in misleading calibrated replacement live values (for e.g. >1 kV & <=11kV overhead conductor had a calibrated replacement life of 127 years). Our review resulted in carefully selecting the asset categories for calibration process depending on their historical and forecast repex trend.
- Conversely some asset categories (for e.g. >33 kV & <=66kV underground cable) were excluded from the calibration step despite the goal seeking function being able to determine a credible solution. These asset categories have now been included in the calibration step.

### 4.3.4 NEM Median Lives

We referred to the most recent set of NEM median calibrated lives data published and used by the AER for the draft determinations of SAPN, Energex and Ergon in October 2019, and advised CitiPower to use them to determine the comparative asset lives for modelling the 'lives scenario' and 'combined scenario' forecast outputs. This is a calibrated asset lives and therefore they are not adjusted or further calibrated in the modelling.

## 4.4 Replacement Life Standard Deviation

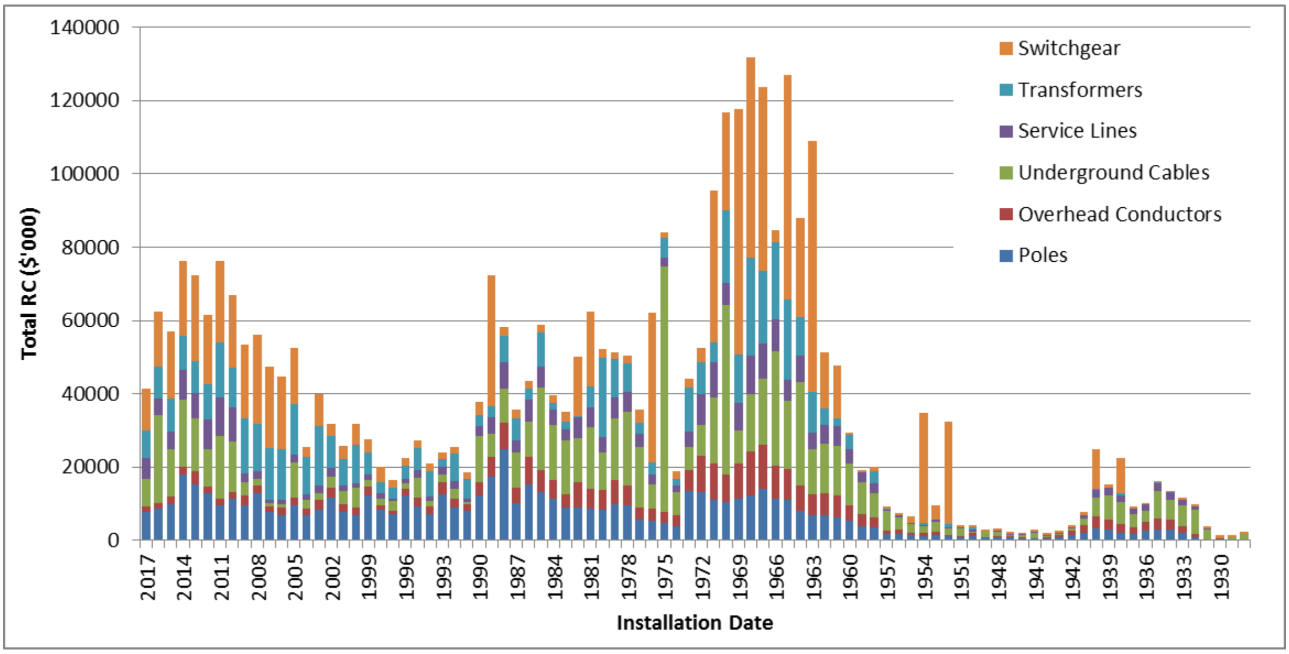
The un-calibrated or base model, along with the expected replacement life data, uses the standard deviation of age distribution (i.e. replacement life standard deviation) of each asset category as the probability function of asset failure in a normally distributed population for all individual assets in that category.

Based on the AER Repex Model Handbook guideline, we reviewed CitiPower base model population of replacement life standard deviation to be the function (square root) of the expected replacement life (in years) for each asset category. This assumption reduces the input variables in repex modelling, and is especially useful for the calibration step where the goal seek calculation reduces to one variable constrain equation.

## 4.5 Asset Age Profile

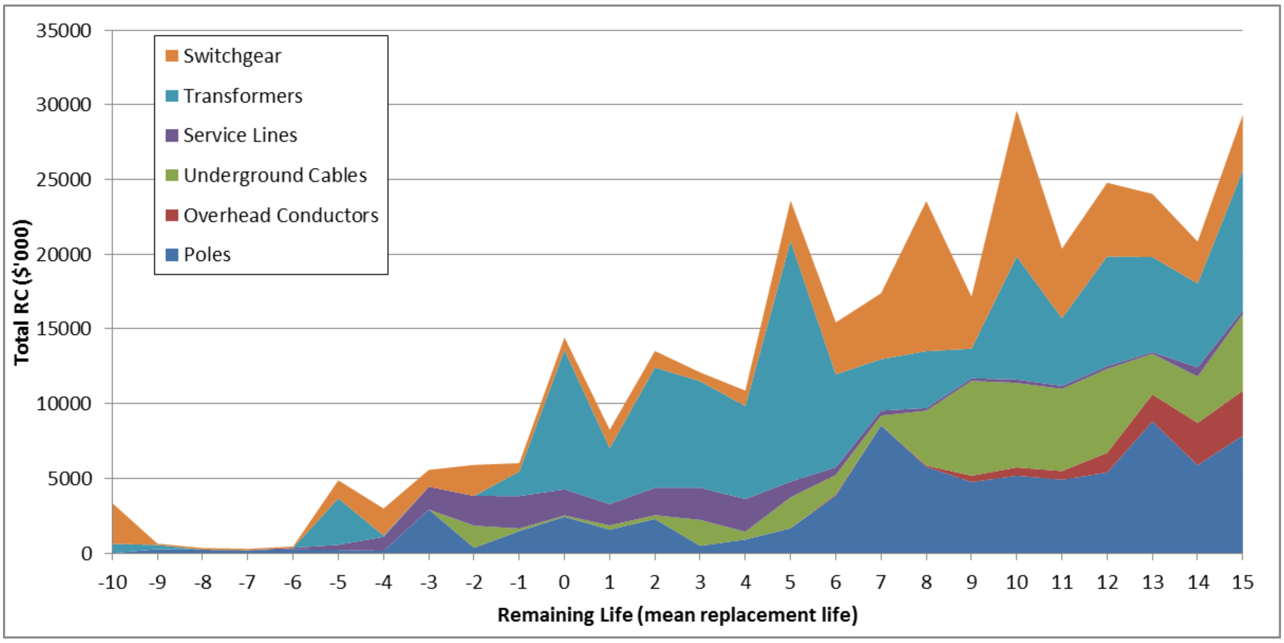
The age profile reflects the age by quantity of all currently installed individual assets. The age profile is populated in the un-calibrated or base model in matrix format with installed quantities against each asset categories and the year of installation. This information for CitiPower's asset portfolio is reported in the latest CA RIN Table 5.2.1 and CitiPower has copied this age profile to populate the model for all scenarios. This is the only set of input data that remains constant across all the scenario modelling as it reflects the state of CitiPower's existing asset portfolio. The following figures graph this information pertaining to the live scenario model, as an example.

***Figure 4 Age profile of CitiPower's asset portfolio (asset quantum pertains to lives scenario model, for example)***




The Y axis in this figure shows the quantum of asset volume represented by their values (in real 2021 $ replacement costs) and the X axis shows the timeline of their installations or existence.

***Figure 5 Age profile of CitiPower asset portfolio (asset quantum pertains to lives scenario model, for example)***




The Y axis in this figure shows the quantum of asset volume represented by their values (in real 2021 $ replacement costs) and the X axis shows the remaining life (i.e. calibrated replacement life – asset age) of asset groups. The quantum of this ageing asset volume (represented by their replacement costs) will be different for other scenarios arising from the different set of unit costs data used in the model.

# 5. Base Models Setup

The un-calibrated or base model requires inputs for each asset categories assessed for forecast repex by the AER. These input data are sourced from various sources of information. The calculation or derivation of each input variables are as explained in Section 4 of this report. Four versions or scenarios of the base model are created corresponding to various combinations of input data, eventually resulting in the Historical Scenario, Cost Scenario, Lives Scenario and Combined Scenario outputs as discussed earlier in Section 3.3). A summary of this population or setup of base models is shown in Table 7.

***Table 7 Combination of input data for each scenario in the base models***

| Input variables | | Asset unit costs input data | |
|---|---|---|---|
| | | **Historical unit costs** | **Comparative unit costs** |
| **Asset replacement lives input data** | **DNSP *reported* asset lives** | Historical Scenario | Cost Scenario |
| | **Comparative *reported* asset lives** | Lives Scenario | Combined Scenario |

Where:

- The historical unit costs are derived from the historically reported repex information in the previous year's CA RIN Table 2.2.1
- The comparative unit cost for each asset category is the minimum of:
  - The historical unit cost for the asset category as above; or
  - The forecast unit cost, derived from the proposed forecast repex information in the Reset RIN Table 2.2.1; or
  - The NEM median unit cost, the median unit cost for the asset category across the NEM, taken from the most recent draft determination repex models.
- The DNSP reported asset lives are copied from the most recently reported CA RIN Table 5.2.1
- The comparative reported asset lives for each asset category is the maximum of:
  - The DNSP reported asset lives for each asset category as above; or
  - The NEM median expected asset lives are the median expected asset lives for each asset category across the NEM reported by each DNSP, and taken from the most recent draft determination repex models.

In all scenarios the asset life standard deviation is taken as the square root of the expected asset life as described in Section 4.4 and the asset age profile is taken from the CitiPower's latest CA RIN Table 5.2.1 as described in Section 4.5.

# 6. Model Calibrations

The un-calibrated repex model produces extremely high forecast quantities when populated with expected replacement life input data directly from the CA RIN Table 5.2.1. This is the case for CitiPower (and also for other NEM DNSPs). The AER has developed a ‘calibration’ process whereby the model inputs are adjusted until the forecast replacement quantities match recent historical quantities trend.

## 6.1 1st Step Calibration

This adjustment is achieved by varying the expected replacement life in the repex model until replacement quantities in the first year of the forecast period match the average replacement quantities in the past regulatory period for each asset category. As explained earlier, the replacement life standard deviation input data of all asset categories is set to the square root of their expected replacement life input data. This reduces the calibration of the repex model to a single variable problem, which can be solved with an iterative algorithm. The process works as follows, for each individual asset category:

- The unit cost and age profile input data remains unchanged during the calibration process.
- The average replacement quantities over the previous 4 year period (reported in previous years CA RIN Table 2.2.1) are averaged (mean), and this averaged quantity is set as the target of an optimisation function.
- The expected replacement life input data is adjusted or varied, using an optimisation function (such as Microsoft Excel’s Goal Seek) until the repex model produces the average historical replacement quantity in the first year of its forecast.

We reviewed all the asset categories which did not incur any repex in the past regulatory period as these require special treatment.

When an asset category has no recent repex, the goal seeking function will attempt to adjust the replacement mean life input data until zero assets are replaced in the first year of the forecast. Because the repex model predicts replacement quantities on a probabilistic basis, and will therefore predict fractional replacement with an extremely high expected replacement life value, the goal seek algorithm in most cases will not be able to find a solution to this problem, or only a solution with an unrealistically high expected replacement life value (e.g. for >100 years in some cases). In such instances, we advised CitiPower not to perform the calibration step for asset categories with no recent historic repex, and left the ‘calibrated’ repex model populated with expected replacement life data based on the reported value in the latest CA RIN Table 5.2.1 for those asset categories.

## 6.2 2nd step Calibration

Once the 1st step calibration is complete, the repex model will produce forecasts based on individual asset age profiles and historic replacement quantities. However, since the first year of the forecast period is matched to quantities from previous years, the forecast needs to be adjusted to reflect any ongoing trends in replacement quantities. This is based on the assumption that, since the model has been calibrated in the first forecast year based on past replacement quantities, it does not account for any trends in replacement requirements.

The forecast replacement quantities output by the repex model from the 1st step calibration are recorded for each asset category and used to determine an annual percentage increase or decrease (i.e. whether the model predicts increasing or decreasing replacement year to year when looking at the future quantities forecast). The annual changes in replacement quantities forecast are then averaged, and the annual trend added to or subtracted from the replacement target of the 1st step calibration. This produces a new target, so that the model predicts 'next' year's replacement rather than the average 'this' year quantity. This adjustment is generally a minor one. The model is then recalibrated to match the new target, using the same goal seeking algorithm as during the 1st step calibration.

The annual trend can be derived by averaging the changes in forecast quantities over all the years of the forecast, by considering just the first two forecast years, or considering any number of years in between. The AER Repex Model Handbook document and the recent revenue determination of NEM DNSPs does not explain clearly how this function is calculated, only its purpose i.e. to 'offset' the forecasts by one year.

## 6.3 'Calibrated' Models

Following the calibration process, multiple versions or scenarios of 'calibrated' models are created corresponding to the respective un-calibrated or base models. All input data, except for the expected replacement life (and its function, replacement life standard deviation), remains the same for each scenario. The various combination of input data in the multiple scenarios of calibrated model are shown in Table 8.

***Table 8 Combination of input data for each scenario in the 'calibrated' models***

<table>
<tr><th colspan="2" rowspan="2">Input variables</th><th colspan="2">Asset unit costs input data</th></tr>
<tr><th>Historical unit costs</th><th>Comparative unit costs</th></tr>
<tr><td rowspan="2">Asset replacement lives input data</td><td>DNSP calibrated asset lives</td><td>Historical Scenario</td><td>Cost Scenario</td></tr>
<tr><td>Comparative calibrated asset lives</td><td>Lives Scenario</td><td>Combined Scenario</td></tr>
</table>

Where:

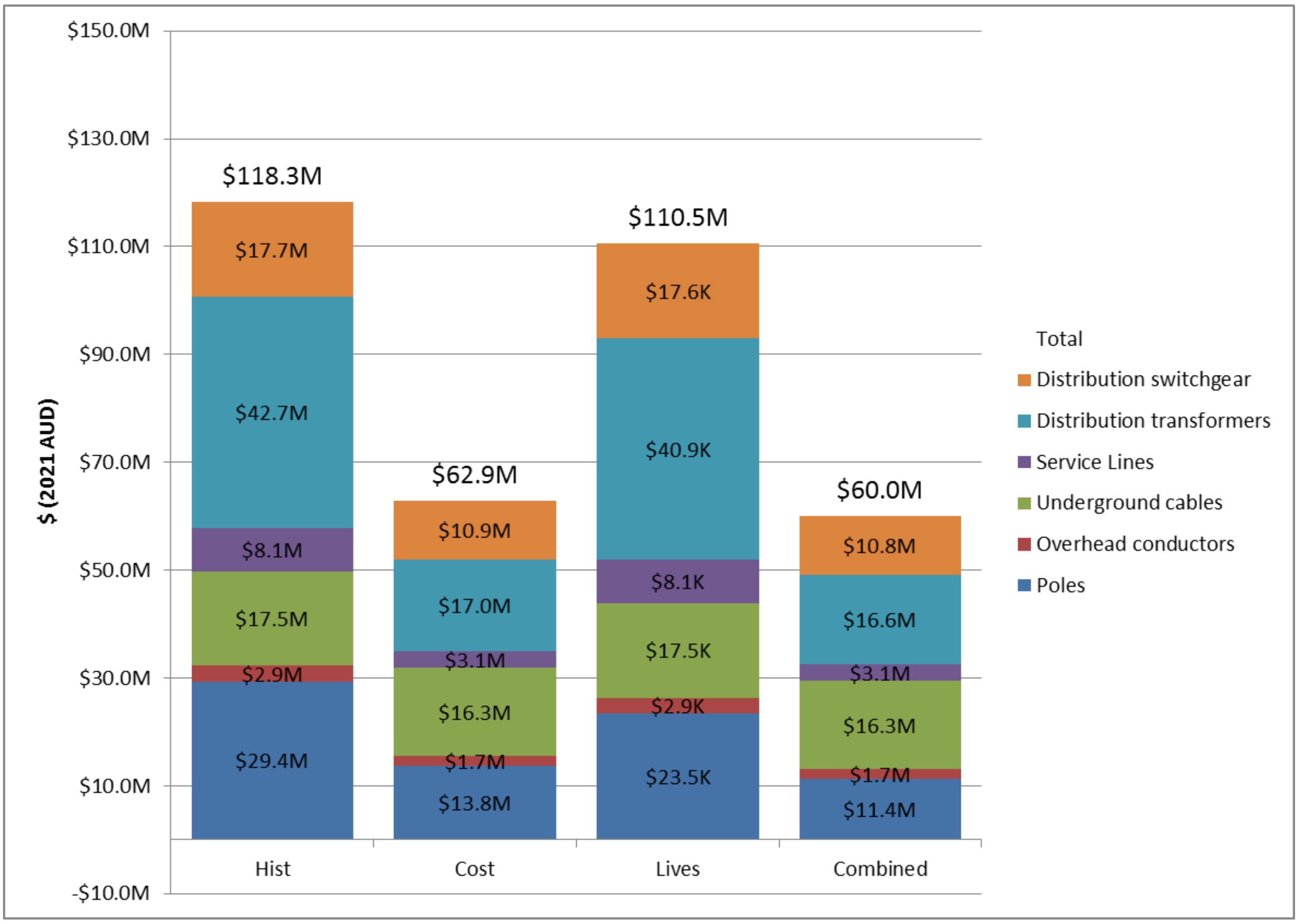
- The DNSP calibrated asset lives are the adjusted values obtained after the 2-steps calibration process for each asset category
- The comparative calibrated asset lives for each asset category is the maximum of:
  - The DNSP calibrated asset lives for each asset category as above; or
  - The NEM median calibrated asset lives are the median calibrated asset lives for each asset category across the NEM and are copied from recent AER draft determination repex models.

In all scenarios the asset life standard deviation is taken as the square root of the calibrated asset life and the age profile is taken from the CitiPower's latest CA RIN Table 5.2.1.

# 7. Modelling Outputs

In similar fashion to the AER review, we ran and reviewed a number of scenarios using the repex model to generate alternate or a range of modelled repex forecast outputs. The modelled repex forecast summary results from this modelling are presented in Figure 6. This modelled repex forecast includes the six asset groups as stated earlier in this report.

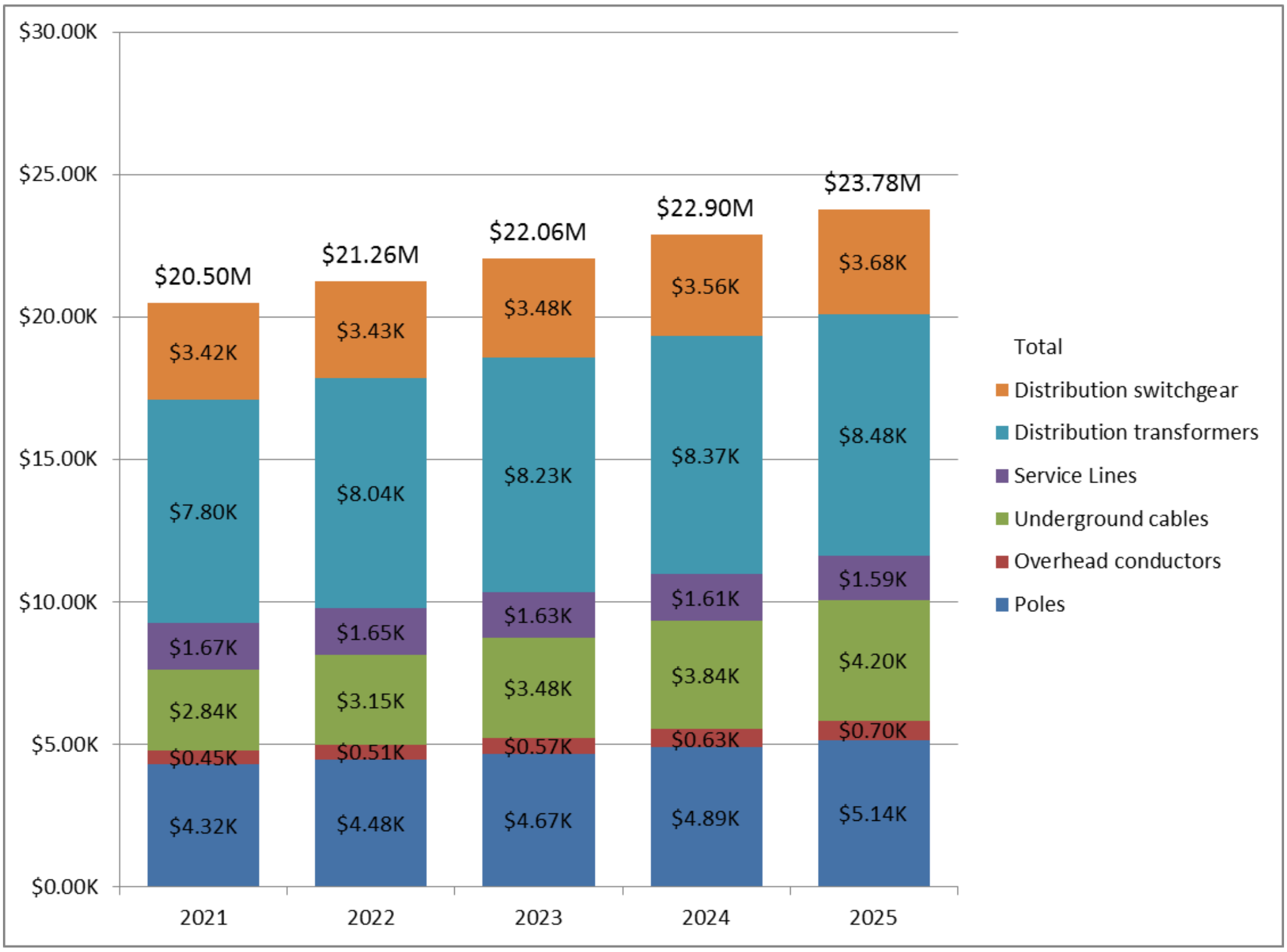
***Figure 6 Total 2021-26 summary of modelled repex forecast scenarios (Real 2021 $)***




Our analysis indicates that the likely ‘modelled’ portion of the repex forecast would be approximately $110m total (direct cost) for the 2021-26 regulatory period. This total is based on the repex model threshold which is equal to the higher of the ‘cost scenario’ or the ‘lives scenario’ modelled outputs.

The following Figure 7 provides the annual breakdown of the lives scenarios modelled output which is the repex model threshold.

***Figure 7 Annual breakdown of the repex model threshold (lives scenario) [2021 $ value]***



# 8. Conclusions

The AER has relied on its repex model to produce various alternative scenarios of the repex forecast (similar to what CitiPower has attempted to model as documented in this report) enabling it to target a few focus areas for more detailed assessment and to establish a likely modelled repex level for CitiPower 2021-26 determination.

We have reviewed the input data formulated and used by CitiPower to populate the repex model and to generate a number of scenarios. Where applicable, we have corrected and advised CitiPower on their formulation of the input data and their use of the AER repex model.

Due to the way the scenarios are calculated (i.e. by taking the minimum of a number of unit costs or maximum of a number of expected lives for each asset category), they cannot return a higher value than the historical scenario based solely on CitiPower data.

This is not the entire repex volume and only corresponds to the six asset groups that have been modelled. There are four asset groups that remains ‘un-modelled.’

Beyond the repex modelling, we understand, from the AER documentation, that the AER will also undertake top-down assessment and detailed reviews of CitiPower’s asset management planning and practices involving cost-benefit analysis, risk quantification, capital program optimisation etc. to assess the prudency and reasonableness of the proposed repex, which we consider is the correct approach than relying on the repex model outcomes alone.

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