GHD Advisory

Repex benchmark comparison

2023-28 Revenue Proposal

Transgrid

22 November 2022

→ The Power of Commitment

Executive summary

The Australian Energy Regulator (AER) published its Draft Decision Transgrid Transmission Determination 2023 to 2028 (Draft Determination) in September 2022. The Draft Determination documents indicate that the AER have completed a top-down and bottom-up assessment of the replacement expenditure (Repex) program included in the 2023-28 Revenue Proposal. The AER's top-down view indicates that Transgrid's proposed Repex program is "*broadly in line with the long-term trend*[1]*".* Their bottom-up review results in a 20 percent reduction to the Repex program.

Transgrid has engaged GHD to perform a benchmarking assessment of Transgrid's Repex program against comparator Transmission Network Service Providers (TNSPs) incorporating the impact of the AER's feedback.

Transgrid has provided us with its most recent Repex and inflation forecasts. We understand that the revised Repex forecast reflects updated unit rate costs since Transgrid's initial Regulatory Proposal published in January 2022. This is referred to in this report as "Transgrid's revised Repex forecast".

Attachment 5 Capital Expenditure of the Draft Determination documents details the results of the AER's bottom-up review and provides some overarching commentary supporting their decision –

> *"Top-down indicators reveal that Transgrid's network performance is improving over time compared against itself and its peers. We commend Transgrid on achieving this improvement, but this result may also suggest that less capex investment in the forecast period is required for Transgrid to maintain its network. Appendix A.1 provides more detail around how we have examined the metrics. In summary, the results indicate that:*
>
> - *Transgrid's assets are on average the second youngest of the transmission businesses in the National Electricity Market (NEM) after Powerlink Queensland. They are also second youngest in most of the Regulatory Information Notice (RIN) asset categories*
> - *Transgrid's assets have the lowest average outage rate among the transmission businesses over the last 5 years. In relative terms, its transformers performance has been around the average, and performance for all other assets has been better than average*
> - *Transgrid's average outage rate has improved substantially in recent years. This suggests that it has invested enough repex over the last two regulatory control periods to improve, rather than maintain, service levels*[2]*".*

Our analysis indicates that Transgrid's historical Repex analysed by customer numbers, energy delivered, and maximum demand is the lowest of the TNSPs. Transgrid's revised Repex forecast brings it into line with the historic expenditure rates of other TNSPs with regards to these metrics, while the AER's draft decision would reduce Transgrid's ratios further.

Considering network performance, our review of leading and lagging network performance indicators that speak to the potential requirement for additional Repex above the historic levels or reductions if the performance is above minimum standards, suggests a complex picture:

- Lagging indices of annual unserved energy and non-process outages leading to >5 system minimum losses have remained constant or slightly reduced over the period going back to 2003. In the most recent 10-year period from 2011 onwards, these indices have been flat. It is noted that these metrics may be weak indicators of Repex requirements as the response times to outages are heavily influenced by Opex.
- The leading index of outages of transmission lines and cables have remained constant. Given this is the largest contributor to Repex, it is a strong indicator that the historic expenditure levels have been appropriate to maintain performance.
- Other leading indices that consider smaller Repex contributors – transformers and reactive plant – indicate slightly improved outcomes over the period.
- The Market Impact Component (MIC) parameter, detailed in section 5.1, provides additional insights to the above trends. Analysis of this metric for unplanned outages, which are most likely to be influenced by Repex,

[1] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure p. 33
[2] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure p. 20

is that the severity of outages as measured by market affects has been increasing over the period 2011 to 2022.

These observations indicate mixed results rather than a clear indication of improved performance, meaning that less capex is needed in the forecast period for Transgrid to maintain its network, as the AER's Draft Determination suggest. A 20 percent reduction to the Repex program might not immediately impact performance, but over time could contribute to degraded performance.

Our benchmark analysis also considered the age of Transgrid's network assets compared with other TNSPs. Age of existing assets is a significant driver of Repex. As the asset base ages, there is an increasing possibility of asset failures / defects on the network, thereby increasing the risk profile consisting of safety, reliability, environmental, financial, and reputational consequences.

As detailed in section 4.1, our analysis indicates that Transgrid has a relatively old network, with a relatively low estimated residual service life across the various categories of transmission network assets. This contrasts to the finding made by the AER in their Draft Determination.

The majority of Transgrid's current transmission network was developed in the 1950s and 1960s. These assets, which typically have a 40-to-60 year economic life, are now nearing retirement. All TNSPs have assets installed across the period of analysis (1949-50 to 2020-21). However, due to the size of Transgrid's network, there are comparatively more assets and therefore more are due for replacement or refurbishment.

Focusing in on the transmission towers in the current asset bases that were constructed between 1950 and 1970, we can see Transgrid has relatively more assets than any other TNSPs with approximately 39 percent of the transmission tower assets constructed during this period in the NEM. Based on this information and all other factors being equal, we would expect Transgrid's Repex to be higher than other TNSPs.

The current regulatory period and the most recent years of data coincide with a rapid increase in distributed and large-scale renewables. It is likely that these factors are making networks more challenging to manage and also energy markets are becoming more sensitive to any network non-performance.

A proportion of Repex is associated with mitigating bushfire, worker and public safety risks. Recent Revenue Proposals for Electranet and Ausnet show a great deal of variation over time. Repex relating to mitigating bushfire, worker and public safety risks may be driven by life cycle risks, events or incidents rather than being driven by asset age as a single factor.

Data provided by Transgrid shows a strong performance in terms of bushfire starts. Given the community tolerance for bushfire starts is very low, we suggest continued expenditure in maintaining this performance is appropriate. Dangerous asset failure data was also considered. Noting there are very few events in any one year (average of 6 per year across the analysis period), this data shows the total number of events has increased in the most recent years.

Acronyms and abbreviations

The following acronyms, terms and abbreviations have been used in this report.

Table 1 Acronyms, terms and abbreviations

Term	Meaning
AER	Australian Energy Regulator
ALARP	As Low As Reasonably Practicable
DI	Dispatch Intervals
DF	Disproportionality Factors
DNSP	Distribution Network Service Provider
GEIP	Good Electricity Industry Practice (as defined in the National Electricity Rules)
OER	Option Evaluation Report
Opex	Operational Expenditure
MIC	Market Impact Component
NER	National Energy Rules
NPV	Net Present Value
Repex	Replacement Expenditure
RIN	Regulatory Information Notice
SFAIRP	So Far As Is Reasonably Practicable
STPIS	Service Target Performance Incentive Scheme
TNSP	Transmission Network Service Provider

Project name		Transgrid 2023-28 Revised Revenue Proposal - Repex Support					
Project number		12591700					
Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
Final	0	Lizzie O'Brien	Anuraag Malla	[i-Connect]	Bruce Clarke	[redacted]	22/11/22

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1. Introduction and background

Transgrid submitted its 2023-28 Revenue Proposal in January 2022 which included a Repex forecast of $798M (Real 2022-23) across the regulatory period.

The AER have completed their review of the 2023-28 Revenue Proposal and noted within their Draft Determination that -

> *"Transgrid's forecast of $797.6 million is $30.1 million or 4% higher than current period repex and broadly in line with the long-term trend[3]".*

Having noted this top-down perspective a bottom-up review of the Repex forecast performed by the AER reduced the program to $635M (Real 2022-23) representing a 20 percent reduction.

Concerned with the potential impact of a 20 percent reduction Transgrid engaged GHD to perform a benchmarking assessment against comparator TNSPs incorporating the impact of the AER's feedback.

1.1 Purpose of this report

This report outlines an independent assessment of Transgrid's Repex based on a benchmark assessment of proposed expenditure against historical expenditure and approved expenditure for comparator TNSPs.

This report supports Transgrid's 2023-28 Revised Revenue Proposal to be submitted at the AER.

1.2 Regulatory requirements

The National Energy Rules[4] (NER) require the AER to prepare and publish an annual benchmarking report that describes the relative efficiency of each TNSP. The AER collects two sets of data from TNSPs via Regulatory Information Notices (RIN) that inform its preparation of the annual benchmarking reports:

– Economic Benchmarking – RIN response
– Category Analysis – RIN Reponses

The AER must have regard to the most recent annual benchmarking report when assessing whether operating and capital expenditure forecasts provided by a TNSP within its Revenue Proposal represent efficient expenditure[5].

1.3 Our approach

For this analysis, we compared Transgrid's overall proposed Repex to that of other TNSPs. Our analysis is based on Transgrid's revised Repex forecast and the AER's Draft Determination.

The comparison to other TNSPs is based on data collected and published by the AER in Economic Benchmarking – RIN response and Category Analysis – RIN responses. We consider the overall age of TNSP assets as well as the historic Repex levels as a ratio of various network characteristics including based on:

– Customer numbers (supplied by the connected DNSPs)
– Circuit length
– Energy consumption

We also consider the implications of Repex on network performance as considered through a range of leading and lagging network performance indicators.

[3] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure P33
[4] National Electricity Rules, clause 6A.31.
[5] National Electricity Rules, clauses 6A.6.6(e)(4) and 6A.6.7(e)(4).

Limitations in the analysis are outlined in the report where appropriate. We note economic benchmarking is impacted by the small number of TNSPs in Australia. Further, there are a wide range of operating environment factors that may be specific to one or a subset of TNSPs, which can influence outcomes. For example:

– Application of different capitalisation policies i.e. instances where a TNSP incorporates expenditure into opex where another would capitalise it
– Differences in network terrain, that may influence expenditure necessary to maintain the network
– Differences in the geographic nature of networks, which may mean some TNSPs need to invest in particular infrastructure that another TNSP would not.

As appropriate, Transgrid has prepared the business cases for Repex project with consideration to the individual asset conditions and risks of asset failure. However, to the extent that an overall approach to reducing or otherwise modifying Repex is adopted, the findings of this report are relevant.

1.4 Limitations

This report has been prepared by GHD for *Transgrid* and may only be used and relied on by *Transgrid* for the purpose agreed between GHD and *Transgrid* as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person or organisation other than *Transgrid* arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

2. AER Draft Determination

The Draft Determination indicates that the AER undertook a top-down and a bottom-up review of Transgrid's Capex proposal. Based on the top-down assessment, the AER noted the following –

> *"Transgrid's forecast of $797.6 million is $30.1 million or 4% higher than current period repex and broadly in line with the long-term trend[6]".*
>
> *"Top-down testing of Transgrid's network performance revealed that its network performance is improving, suggesting forecast capex lower than actual/estimated capex in the current period may be sufficient for Transgrid to maintain its network[7]"*

Having noted this top-down perspective a bottom-up review of the Repex forecast performed by the AER reduced the program to $635M (Real 2022-23) representing a 20 percent reduction.

In our view, there is a misalignment between the conclusions reached in the AER's top-down review and the outcome of their bottom-up review. Their top-down view reflects that the forecast is broadly in line with the long-term trend, whilst their bottom-up review results in a 20 percent reduction to the program.

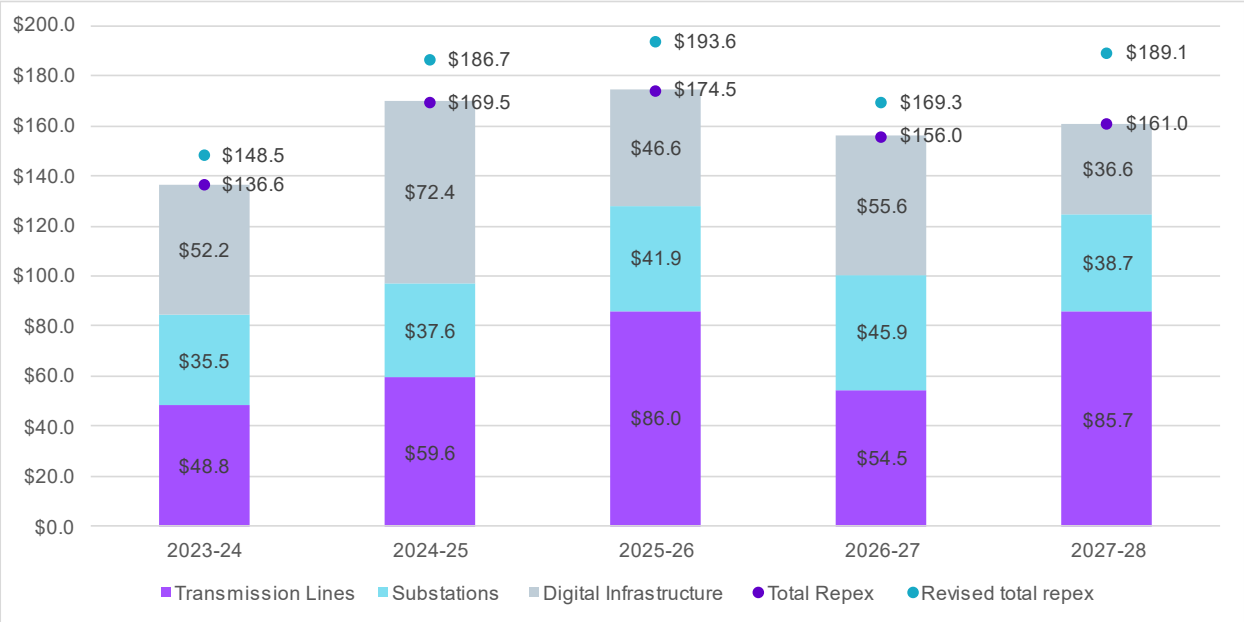
GHD has reviewed Transgrid's approach for several of the detailed Repex programs and reported on these separately. In this report, we consider the overall level of expenditure and the network performance indicators that speak to consequences of an overall 20 percent reduction in the program.

3. Revised replacement expenditure forecast

As detailed above, Transgrid submitted its 2023-28 Revenue Proposal in January 2022 which included a Repex forecast of $798M (Real 2022-23) across the regulatory period. The revised Repex forecast for the 2023-28 regulatory period is $887M.

Figure 1 shows the initial and revised Repex forecast for the period, including the breakdown of expenditure between the three categories of assets (transmission lines, substations and digital infrastructure).

Figure 1 Proposed and revised replacement expenditure 2023-28 ($ million) (Real 2022-23)



Source: Transgrid, Repex Overview Paper, 31 Jan 2022 and advice from Transgrid on their intended revised Repex.

[6] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure, p. 33
[7] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure, p. 8

4. Benchmark comparisons

Repex is primarily concerned with replacement and refurbishment of assets that might fail and cause risks to power system security, customer reliability or network safety. The quantum of Repex is, to various extents, correlated to the:

– Age profile of assets
– Length of the network
– Number of connections
– Maximum demand catered for on the network
– Planning standards applicable at capital investment times.

Where digital infrastructure is concerned, replacement requirements are predominantly driven by lack of contemporary functionality, accuracy and technology obsolescence of existing asset portfolio.

Transgrid's network services the highest number of customers based on the number of distribution customers with a significantly higher maximum demand and energy delivered compared with Powerlink and other TNSPs (Table 2)

Transgrid has the second longest network after Powerlink (Table 2) and has more transmission infrastructure at higher voltage levels (≥330 kV) compared with all Australian TNSPs (Table 3), which is more expensive to replace and refurbish.

The following benchmark analysis considers the various drivers of replacement expenditure in turn and presents a comparison of Transgrid's revised proposed Repex compared with historical levels of expenditure by Transgrid and comparator TNSPs.

For each of the comparisons, the AER's suggested reduction in Repex is shown as an average across the period. As discussed, in most cases, the effect of the AER's suggested reduction brings Transgrid's performance metric to the bottom of the range of possible outcomes.

Table 2 Comparison statistics 2021

TNSPs	End-customers ('000's)^	Maximum demand (MW)	Energy delivered (GWh)	Circuit length (km)
Powerlink	2,303	8,479	51,783	14,534
Transgrid	**3,989**	**11,700**	**71,300**	**13,038**
AusNet (T)	3,084	7,786	42,259	6,734
ElectraNet	921	2,744	13,622	5,515
TasNetworks (T)	298	2,041	12,909	3,350

^Based on distribution connected customers for the jurisdiction. Transgrid numbers include customers from the ACT.

Table 3 Transmission towers assets by voltage (2020-21)

Count of assets	Powerlink	Transgrid	AusNet (T)	ElectraNet	TasNetwork (T)
Single Circuit					
> 33 kV & < = 66 kV	16	**5**	93	28	0
> 66 kV & < = 132 kV	3162	**21045**	2	8738	2534
> 132 kV & < = 275 kV	8310	**1710**	4663	2087	982
> 275 kV & < = 330 kV	14	**9445**	1778	0	0
> 330 kV & < = 500 kV	0	**1**	2489	0	0
Multiple Circuit					
> 33 kV & < = 66 kV	3	**0**	310	63	0

Count of assets	Powerlink	Transgrid	AusNet (T)	ElectraNet	TasNetwork (T)
> 66 kV & < = 132 kV	4619	**1503**	0	123	1898
> 132 kV & < = 275 kV	6087	**0**	3212	2154	1726
> 275 kV & < = 330 kV	888	**2419**	0	0	0
> 330 kV & < = 500 kV	1	**1177**	643	0	0
Other	433	**0**	0	0	0

Source: GHD analysis of "Category Analysis 2020-21 – RIN Response" files published by the AER

4.1 Comparative age of network

Age of existing assets is the most significant driver of Repex. As the asset base ages, there is an increasing possibility of asset failures / defects on the network, thereby increasing the risk profile consisting of safety, reliability, environmental, financial, and reputational consequences. Importantly, Transgrid is legislatively required to mitigate this increasing risk profile to comply with its safety (WHS[8] and ENSMS[9]), reliability (licence conditions[10]), and environmental (EPA[11] and POEO[12]) obligations.

4.1.1 Residual service life of assets

Compared with other TNSPs, Transgrid has a relatively old network, with a relatively low estimated residual service life across the various categories of transmission network assets (Figure 2). These observations contrast with the comments made by the AER in their Draft Determination –

> *"Transgrid's assets are on average the second youngest of the transmission businesses in the National Electricity Market (NEM) after Powerlink Queensland. They are also second youngest in most of the Regulatory Information Notice (RIN) asset categories[13]"*

Our analysis relies on the same underlying data used by the AER – the Economic Benchmarking RIN Responses from TNSPs for 2020-21. Our finding that Transgrid's assets are on average older than other network's assets is also supported in RIN response data for Category Analysis (data from 2020-21 is presented in the subsections that follow) that provides the number of assets commissioned each year going back to 1912-13 (data going back to 1949-50 is shown in this report). We note that the AER may have weighted the data when calculating its average ages in its Draft Determination, in which case this the results may differ. However, it is not clear what weighting basis may have been used by the AER. The data in Figure 2 is unchanged from that reported in the TNSPs RIN response files.

It is noted that TNSPs have calculated the estimated residual service life as follows:

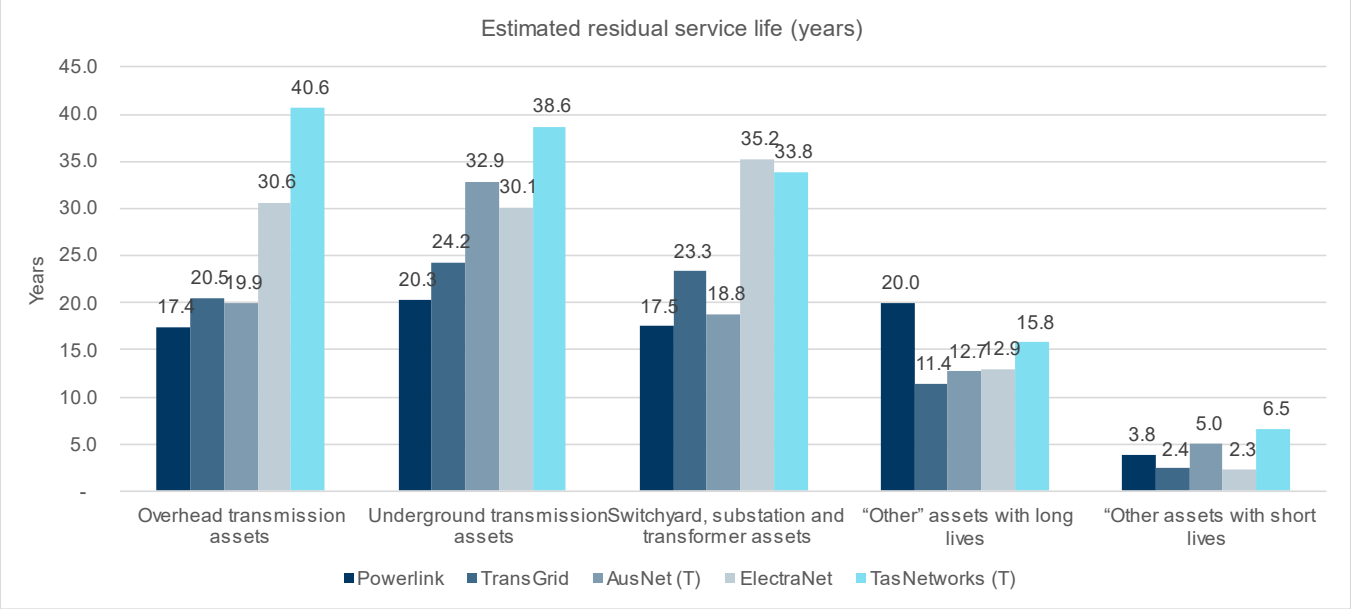
– Transgrid – Calculated as a straight-line depreciation for each year for the relevant categories.[14]
– AusNet - The difference between the 'Estimated Service Life of New Assets' and the Average Asset Lives.[15]
– Powerlink - Estimated residual service life is based on an estimate of the average expended life of each type of asset. This is then subtracted from the corresponding estimated service life of new assets to derive the estimated residual service life.[16]
– ElectraNet - Remaining regulated life of each individual asset is calculated with reference to the asset register acquisition date and the RFM asset class service life.[17]

[8] Work Health and Safety Act 2011, Work Health and Safety Regulation 2017 and supporting industry (ENA) codes, guidelines and rules.
[9] NSW Electricity Supply (Safety and Network Management) Regulation 2014,
[10] NSW Electricity Transmission Reliability and Performance Standard 2017 under Electricity Supply Act 1997.
[11] Environmental Planning and Assessment Act 1979.
[12] Protection of the Environment Operations (POEO) Act 1997.
[13] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure, p. 20
[14] Transgrid, Economic Benchmarking RIN Response – Basis of preparation 2020-21, p. 33.
[15] AusNet (T), Economic Benchmarking RIN Response – Basis of preparation 2020-21, p. 14.
[16] Powerlink, Economic Benchmarking RIN Response – Basis of preparation 2020-21, p. 17.
[17] ElectraNet, Economic Benchmarking RIN Response – Basis of preparation 2020-21, p. 21.

– TasNetworks (T) – Useful lives presented are calculated as a weighted average of the entire asset calculated in accordance with the instructions in the RIN. Assets are allocated a useful life at acquisition based on the useful lives historically prescribed to relevant assets per the applicable revenue determinations.[18]

In the absence of more detailed asset condition data, age is a good proxy for asset conditions. Therefore, based on the age of Transgrid's assets, we would expect replacement of the transmission line and switchyard assets to be driving replacement and refurbishment expenditure. However, we note that assets covered in "other" typically have shorter economic lives (Table 4), and therefore there is some overlap in the replacement cycles and hence the overall replacement expenditure.

Figure 2 ***Estimated residual service life (years)***



Source: "Economic Benchmarking 2020-21 – RIN Response" files published by the AER (refer to data in rows 85 to 90 in tabs named '3.3 Assets (RAB)' of the relevant Excel workbooks)

Table 4 ***Economic life and Transgrid remaining life for asset categories***

	Economic life	Transgrid remaining life
Transmission lines	15-94 years (average 63 years)	20.5 years (overhead) 24.2 years (underground)
Substations	20-50 years (average 41 years)	23.3 years (switchyard, substation and transformer assets)
Digital Infrastructure	15-60[19] years (most assets are 15 or 20 years)	11.4 years ("Other" assets with long lives) 2.4 years ("Other" assets with short lives)

Source: GHD analysis of "Category Analysis 2020-21 – RIN Response" files and "Economic Benchmarking 2020-21 – RIN Response" files for TNSPs published by the AER.

4.1.2 Transmission towers

The majority of Transgrid's current transmission network was developed in the 1950s and 1960s. These assets, which typically have a 40-to-60 year economic life, are now nearing retirement. Figure 3 shows the number of transmission towers by year and is based on data collected by the AER in annual RIN responses. Transmission towers are a proxy for when the transmission network was developed and therefore the age of the assets, as shown in the figure, is likely to be representative of the entire transmission line assets more generally.

[18] TasNetworks (T), Economic Benchmarking RIN Response – Basis of preparation 2020-21, p. 8
[19] The 60 years life is for old electro-mechanical devices that has not failed yet, but have very limited functionality, accuracy, spare part and supplier or technology support.

All TNSPs have assets installed across the period of analysis (1949-50 to 2020-21). However, due to the size of Transgrid's network, there are comparative more assets and therefore more are due for replacement or refurbishment. Focusing in on the towers in the current asset bases that were constructed between 1950 and 1970, we can see Transgrid has relatively more assets than any other TNSPs (Figure 4). Data collated by the AER indicates Transgrid is responsible for approximately 39 percent of the transmission tower assets constructed during this period in the NEM.

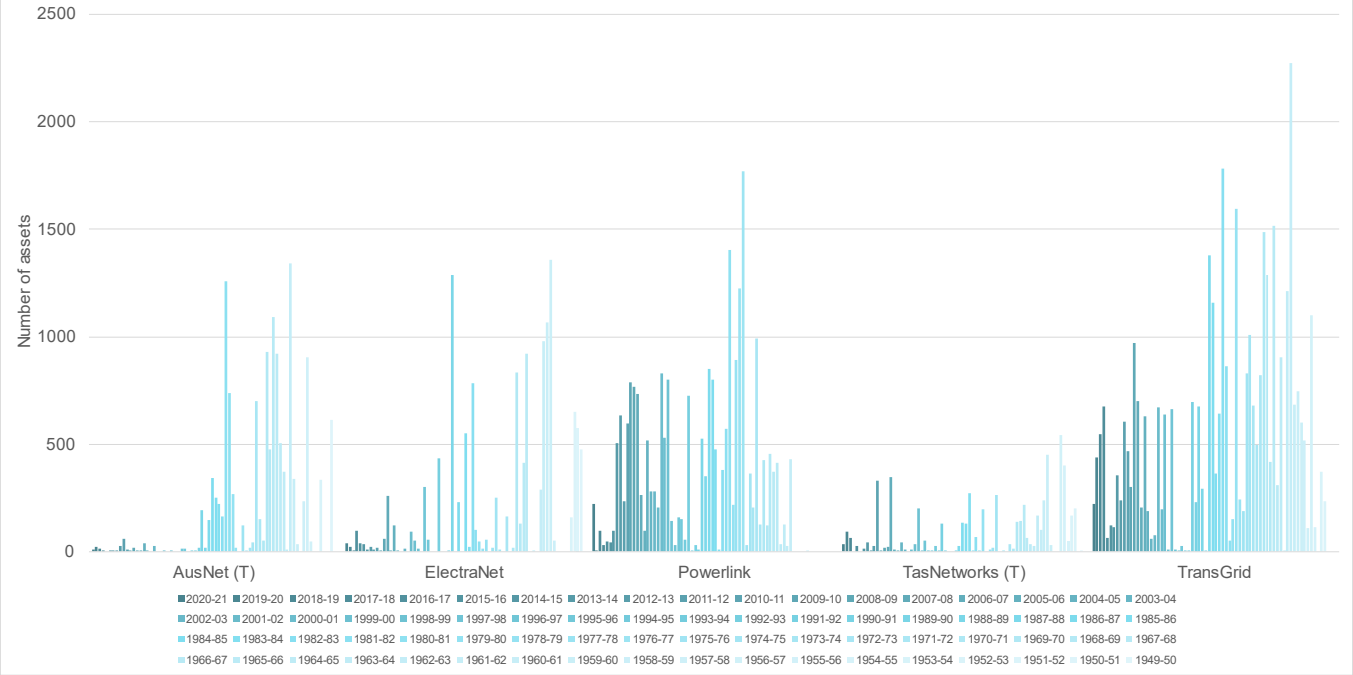
Table 5 Transmission tower assets

	1949-50 and 1972-73		All years	
	No. of transmission tower assets	Proportion of total in NEM	No. of transmission tower assets	Proportion of total in NEM
AusNet (T)	8,209	23%	13,206	14%
ElectraNet	7,933	22%	13,193	14%
Powerlink	2,412	7%	23,533	25%
TasNetworks (T)	2,994	8%	7,140	8%
Transgrid	13,893	39%	37,305	40%
Total	**35,441**	**100%**	**94,377**	**100%**

Source: GHD analysis of "Category Analysis 2020-21 - RIN Response" files published by the AER

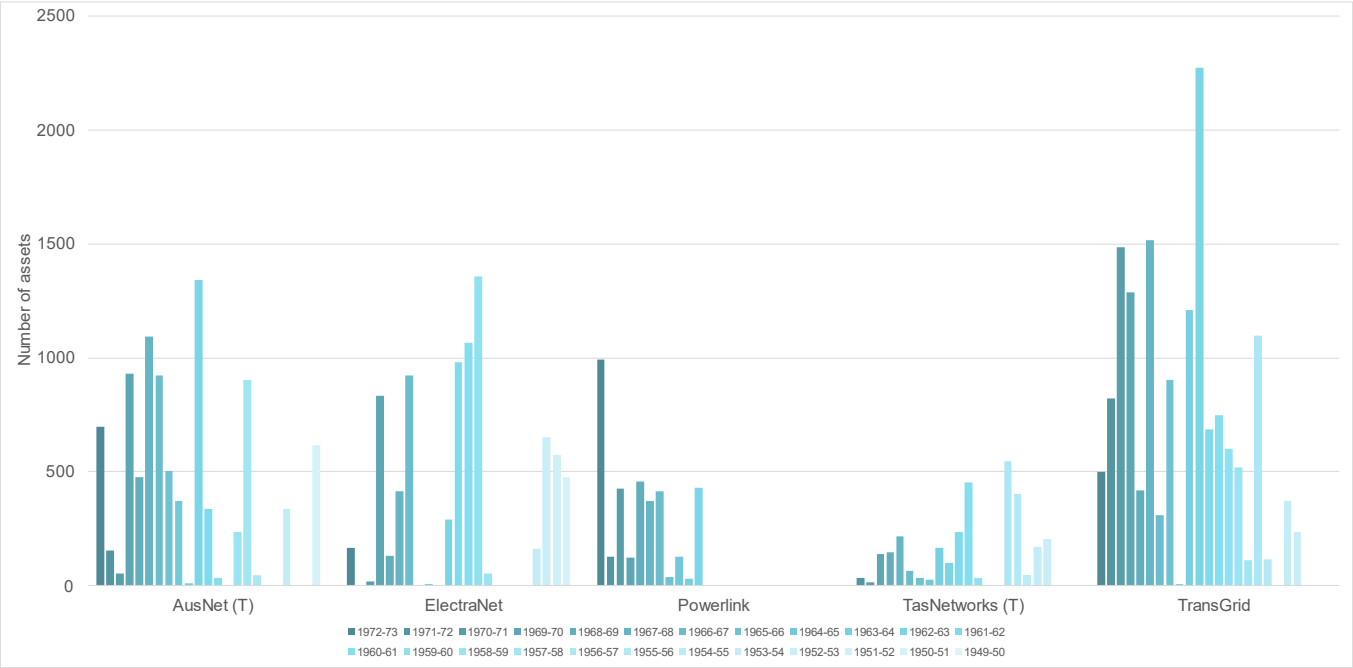
Based on this information and all other factors being equal, we would expect Transgrid's Repex to be higher than other TNSPs. We would also expect Repex for Transgrid, AusNet and Powerlink to increase over the coming regulatory period as the older assets become due for replacement or refurbishment.

Figure 3 Transmission tower assets by decade (1930 to 2020)



Source: GHD analysis of "Category Analysis 2020-21 – RIN Response" files published by the AER

Figure 4 Transmission tower assets by year (1949-50 to 1972-73)



Source: GHD analysis of "Category Analysis 2020-21 – RIN Response" files published by the AER

4.1.3 Substation switchyards

Based on the data collected by the AER, the average age of substation switchyards is in line with that of other TNSPs (Table 6) and the distribution of assets by installation date also appears similar (Figure 5). Consistent with the transmission tower metric outlined above, Transgrid has relatively more of these assets reflecting the relatively larger size of the network and number of connections.

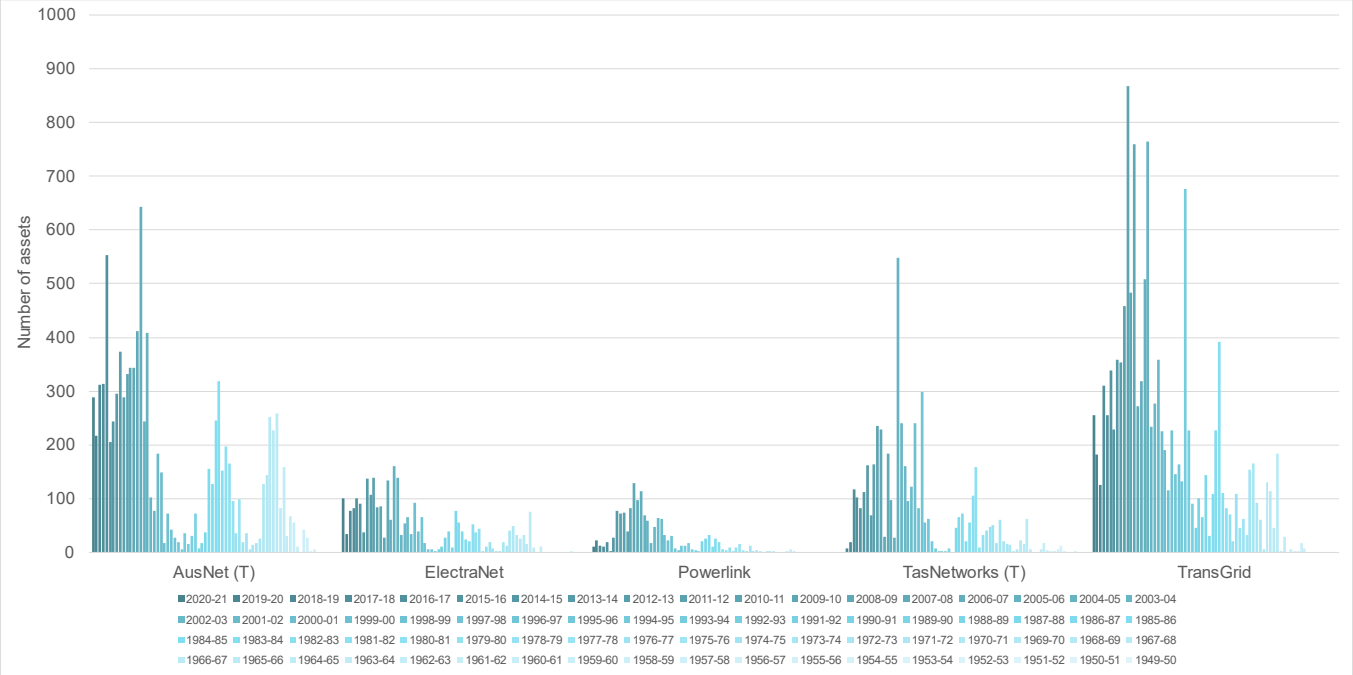
All other factors being equal, we would expect Transgrid's overall Repex on substations would align with other TNSPs.

Table 6 Average age of substation switchyards (years)

TNSP	Substation switchyards
AusNet (T)	22.8
ElectraNet	21.1
Powerlink	18.2
TasNetworks (T)	21.6
Transgrid	**20.7**

Source: GHD analysis of "Category Analysis 2020-21 - RIN Response" files published by the AER

Figure 5 Substation switchyard assets by year (1949-50 to 2020-21)



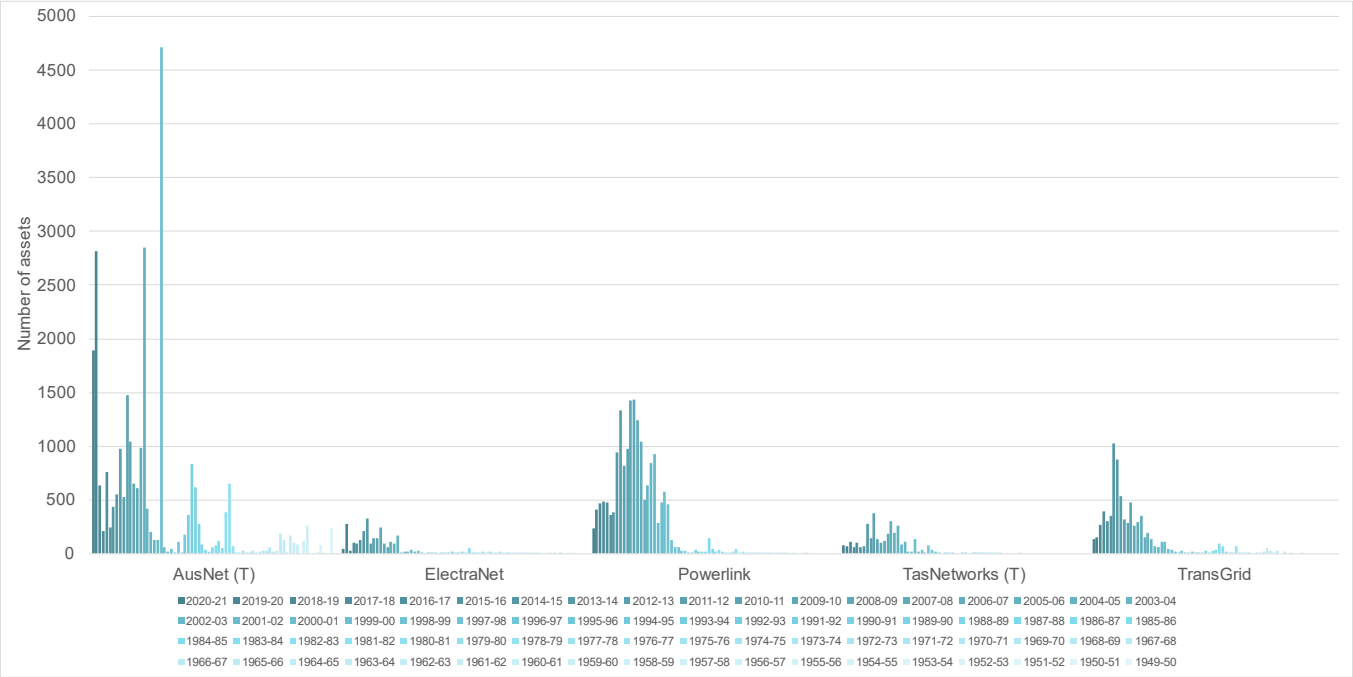
Source: GHD analysis of “Category Analysis 2020-21 - RIN Response" files published by the AER

4.1.4 SCADA, network control and protection

By its nature, digital infrastructure such as SCADA, network control and protection has a shorter replacement life compared to assets classified as transmission lines and substations. The main driver for replacement of digital infrastructure is functionality, accuracy and technology obsolescence rather than asset condition or age.

The introduction of SCADA infrastructure that brought improved visibility and control to Australia’s power system is observable across all of the TNSPs (Figure 6). The distribution of asset age profiles also reflects the shorter replacement cycle for these types of assets.

Figure 6 SCADA, network control and protection assets by year (1949-50 to 2020-21)



Source: GHD analysis of “Category Analysis 2020-21 - RIN Response" files published by the AER

Table 7 Average age of SCADA, network control and protection (years)

TNSP	SCADA, network control and protection
AusNet (T)	17.7
ElectraNet	13.7
Powerlink	13.5
TasNetworks (T)	13.3
Transgrid	**12.8**

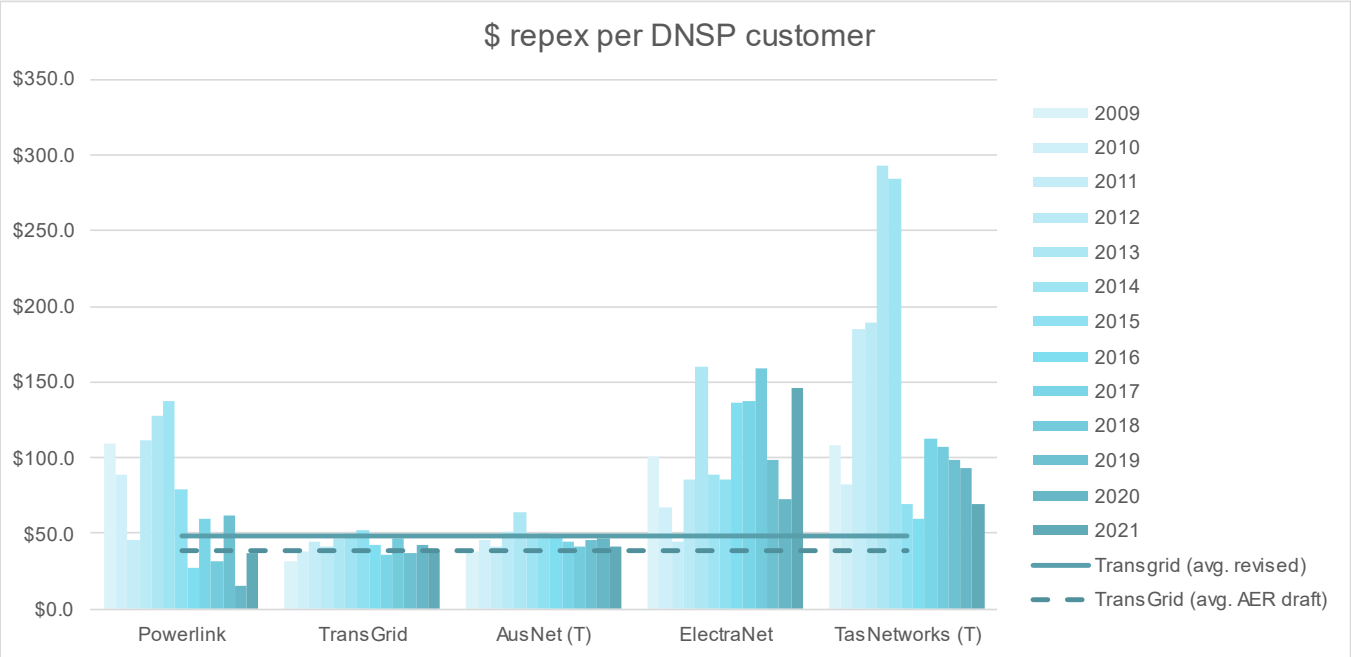
Source: GHD analysis of "Category Analysis 2020-21 - RIN Response" files published by the AER

4.2 Comparison based on customer numbers

Historical network planning design standards and the number and types of end users and generator connections is a good proxy for the complexity of TNSPs network. For this benchmark comparison we consider the replacement expenditure per number of end users (based on number of distribution customers).

Transgrid's Repex per distribution customer is substantially less than comparator TNSPs (Figure 7) and will continue to be lower than other TNSPs at the revised Repex level proposed by Transgrid.

Figure 7 Replacement expenditure per DNSP customer



Source: GHD analysis of AER, Electricity TNSP Operational performance data - 2006-2021
Note: Transgrid numbers include customers from NSW and the ACT.

4.3 Comparison based on circuit length

The length or size of the network is a key driver for expenditure. We consider three metrics of replacement expenditure:

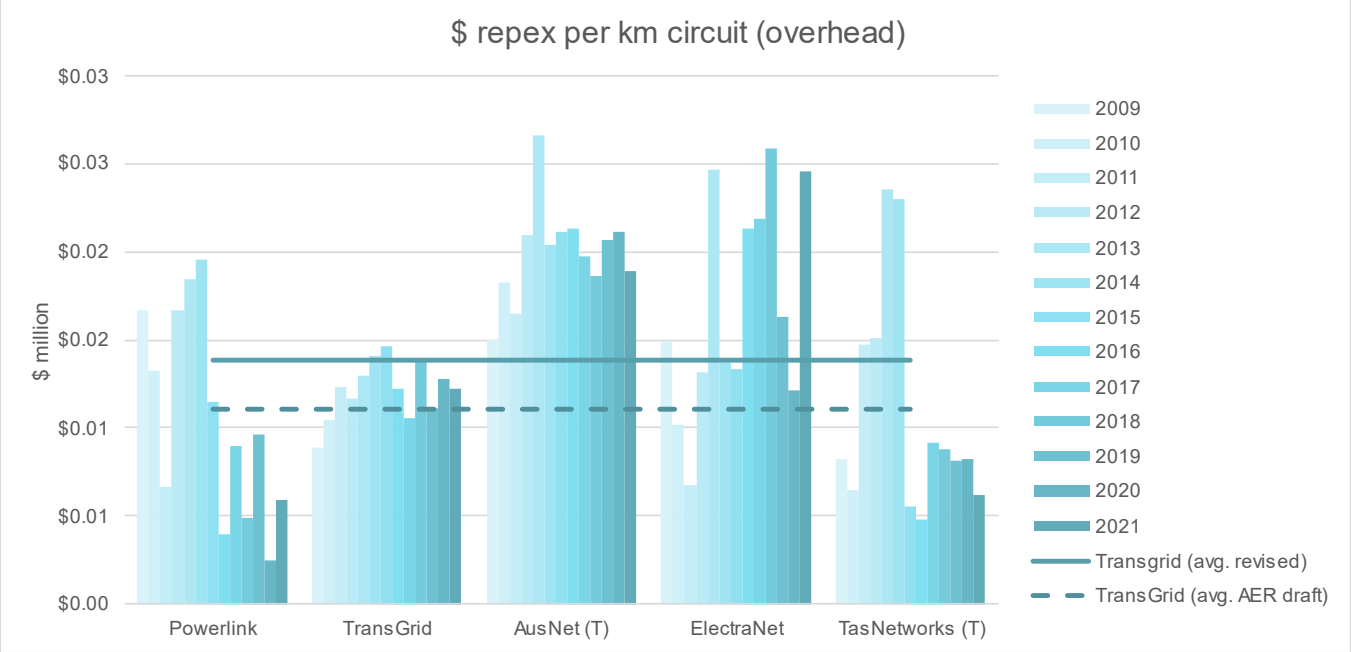
– per km of circuit
– per km of overhead circuit
– per km of underground circuit

On balance, the comparison of overhead circuits is the most representative of the Repex required. The kilometres of overhead lines are much greater for all TNSPs compared with underground cables. These assets are also

relatively older and are more exposed to conditions that deteriorate the asset and therefore be driving the current Repex requirements.

Figure 8 shows Transgrid's proposed replacement is lower than AusNet (T) and ElectraNet and historical expenditure levels by Powerlink and TasNetworks (T). However, it is higher than more recent years of expenditure for Powerlink and TasNetworks (T) and is higher than Transgrid's historical expenditure rate. Of note, Transgrid's expenditure is relatively consistent across the period and around average compared to other TNSPs, which may indicate efforts to smooth investment activities has been more successful than for other TNSPs.

Figure 8 Replacement expenditure per kilometre of circuit (overhead)



Source: GHD analysis of AER, Electricity TNSP Operational performance data - 2006-2021

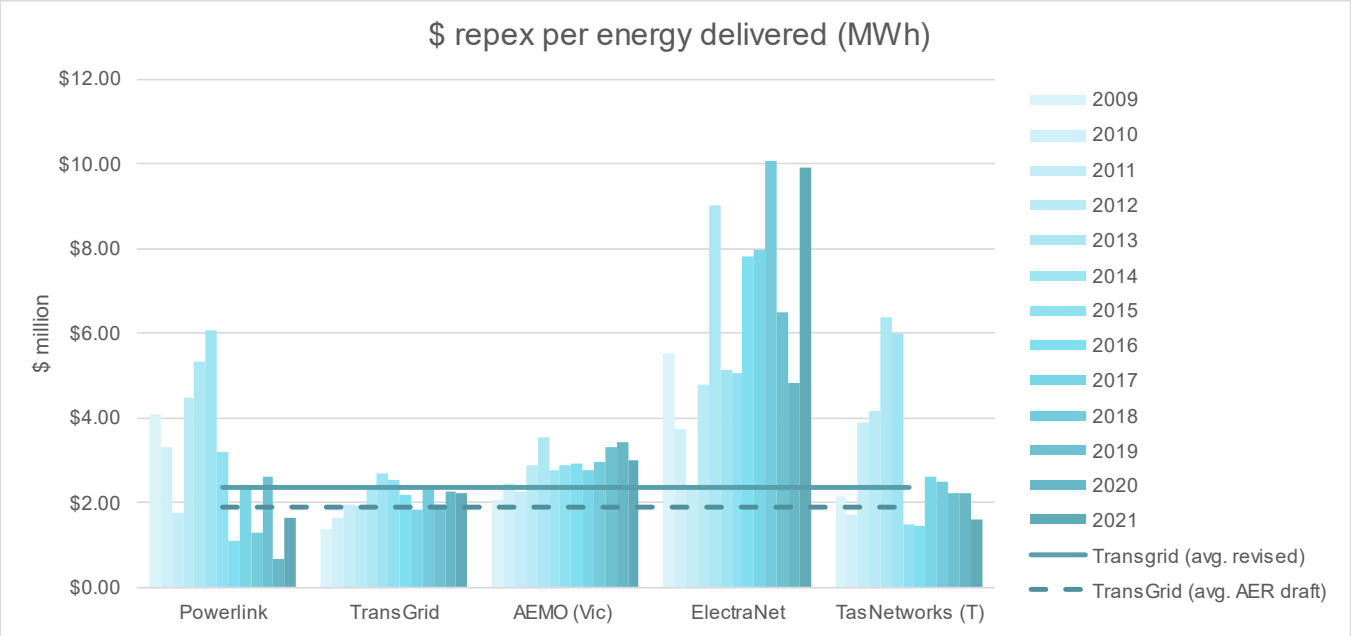
4.4 Comparison based on consumption

4.4.1 Energy delivered

While electricity networks are typically designed to incorporate a level of redundancy, energy delivered can be an indicator of the complexity and relative size of the network, and therefore expenditure required to refurbish and replace assets supporting services.

As shown in Figure 9, Transgrid's Repex based on MWh of energy delivered appears consistently low compared to other TNSPs.

Figure 9 ***Replacement expenditure per energy delivered (MWh)***



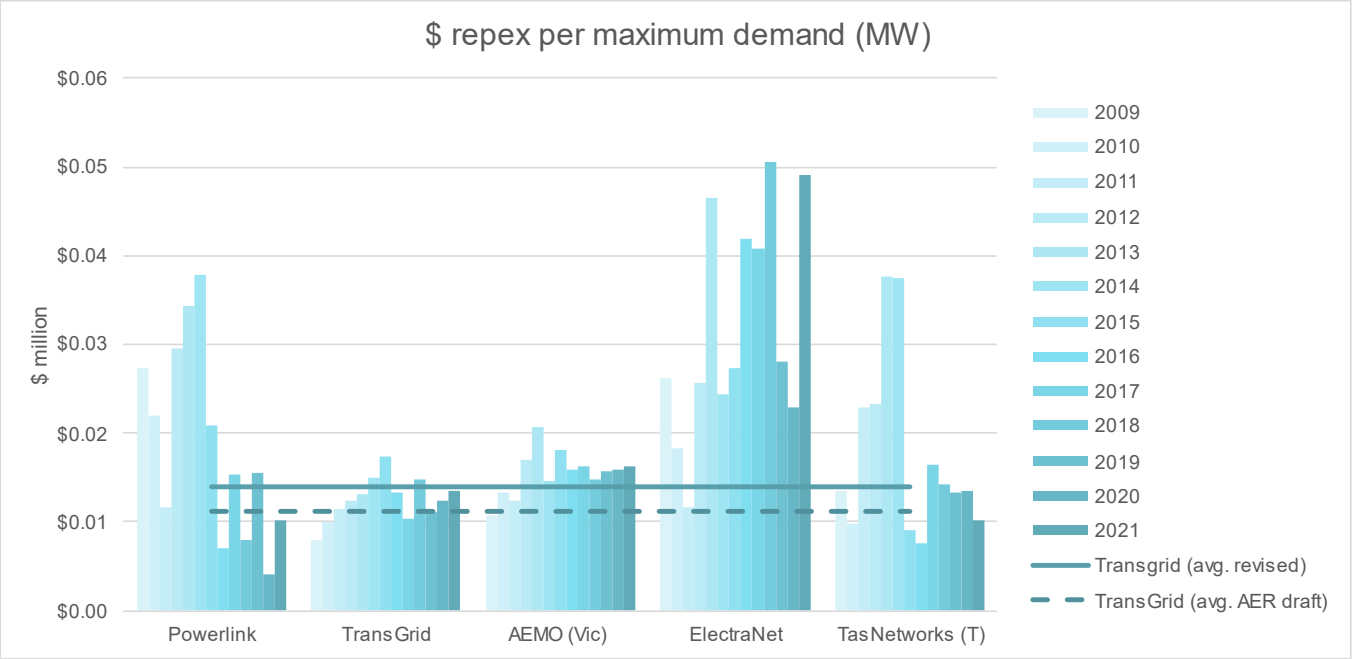
Source: GHD analysis of AER, Electricity TNSP Operational performance data - 2006-2021. Note: Consistent with RIN reporting, AEMO provides the data for Victoria for this metric, where the TNSP is Ausnet (T).

4.4.2 Maximum demand

Maximum demand represents a stress period for electricity networks and is a driver for augmentation expenditure that will eventually need to be upgraded if the forecast exceed the present network capacity. As a benchmark for assessment of Repex, it is relatively weak metric. Any stress on the network resultant from maximum demand is typically very short term in nature and may occur in selected pockets of the network, so is not necessarily a driver of asset conditions more broadly across the network. Further, the lagged effect between maximum demand forecast driving augmentation and replacement requirements means much longer period of analysis is needed to provide meaningful statistics.

Nevertheless, Transgrid's Repex, when benchmarked based on maximum demand, looks relatively low compared to other jurisdictions (Figure 10).

Figure 10 ***Replacement expenditure per maximum demand (MW)***



Source: GHD analysis of AER, Electricity TNSP Operational performance data - 2006-2021. Note: Consistent with RIN reporting, AEMO provides the data for Victoria for this metric, where the TNSP is Ausnet (T).

5. Network performance

The AER Draft Determination notes the following –

> *"Top-down indicators reveal that Transgrid's network performance is improving over time compared against itself and its peers. We commend Transgrid on achieving this improvement, but this result may also suggest that less capex investment in the forecast period is required for Transgrid to maintain its network. Appendix A.1 provides more detail around how we have examined the metrics. In summary, the results indicate that:*
>
> - *Transgrid's assets have the lowest average outage rate among the transmission businesses over the last 5 years. In relative terms, its transformers performance has been around the average, and performance for all other assets has been better than average*
> - *Transgrid's average outage rate has improved substantially in recent years. This suggests that it has invested enough repex over the last two regulatory control periods to improve, rather than maintain, service levels[20]".*

These are high level observations that do not conclude upon the potential impact upon a 20 percent reduction to the program. From a trend perspective a certain level of funding is required to maintain performance and the results of the bottom-up review has potentially clouded this perspective.

> *"Transgrid's forecast of $797.6 million is $30.1 million or 4% higher than current period repex and broadly in line with the long-term trend[21]".*

Putting aside the potential safety implications, when we look at network performance there are a range of service level measures available. These are made up of lagging indicators (i.e., where a consumer impact was actually caused by an asset failure) and leading indicators (where an asset fault occurred that did not cause a customer event).

[20] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure P20
[21] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure P33

GHD has considered RIN response data on supply interruptions as well as assets performance data supplied by Transgrid to consider what insights a range of leading and lagging indicators might provide on Transgrid's network performance and therefore the base levels of Repex that might be required to maintain performance. We present the findings from our review of this information below.

5.1 Lagging indicators

As indicated earlier, reductions in Repex can result in an increasing network risk profile if not mitigated on time and/or to the extent that it satisfies ALARP position. As a consequence, the network carries a higher level of residual risk in terms of likelihood of failure of assets.

Lagging indicators of customer reliability involve observed lost load or supply interruptions. Metrics that relate to reliability of supply were considered based on available data RIN data:

– Loss of supply events
– Average duration of outages.

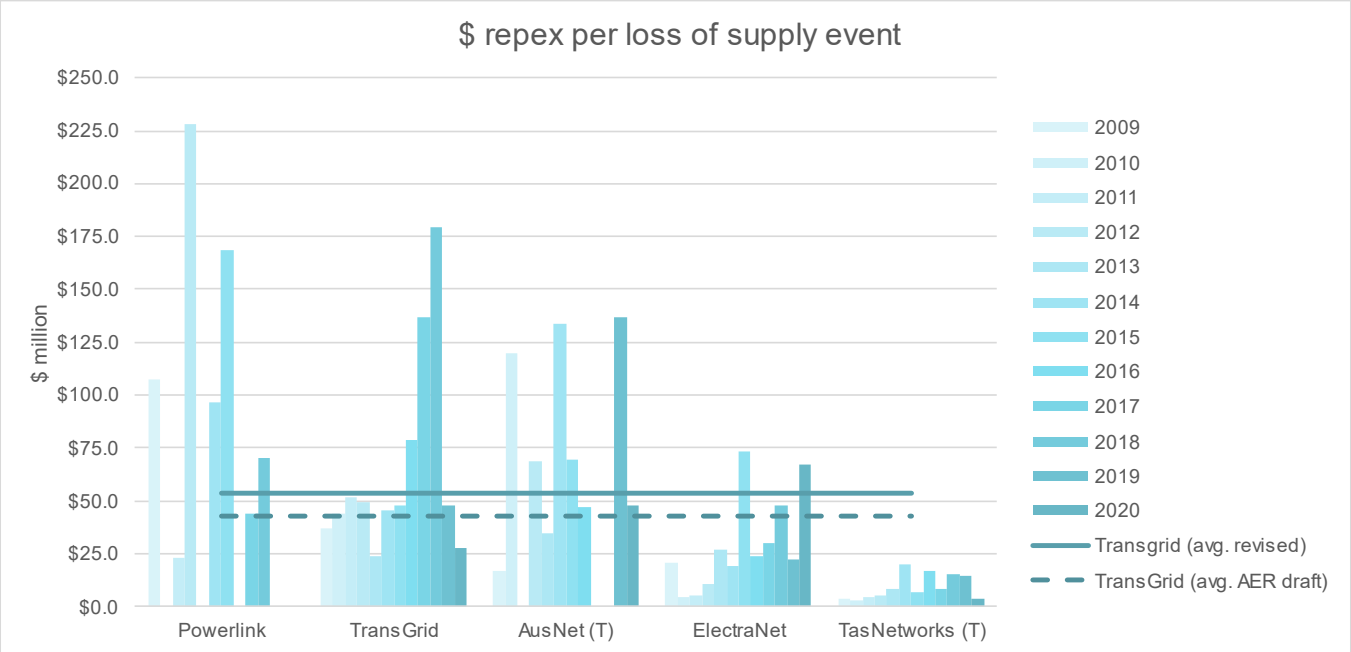
While there are weaknesses in both metrics, only the loss of supply metric is considered for comparison. The average duration of outages is not considered a useful metric for comparing Repex. The average duration of an outage is determined by the nature of the outage and how quickly power can be restored. Restoration is therefore dependent on how strongly the network is configured or designed and also the ability for ground staff and fleet to respond quickly, which is the subject of Opex.

In both cases, Transgrid's performance appears to align with or is better than other TNSPs historically. This could indicate historical levels of expenditure have been effective in managing reliability of supply risks. However, potentially less so than, for example, Powerlink and AusNet, that had several years with no outages.

In considering this metric, it is important to understand the weaknesses. Some loss of supply events and outages are driven by environmental factors beyond the control of the TNSPs (for example, faults caused by animal interference, adverse weather etc). It is also noted that the loss of supply events are relatively infrequent, meaning a single event can significantly alter the benchmarked ratio.

The effectiveness of this metric in predicting future reliability outcomes and including the effect of any reductions in Repex beyond what is prudent is weak. The effect of any reduced expenditure will not be clear until the future.

Figure 11 ***Replacement expenditure per loss of supply event***



Source: GHD analysis of AER, Electricity TNSP Operational performance data - 2006-2021

In addition, the following data provided by Transgrid's enabled analysis of performance as seen by the end user in terms of electricity interruptions:

– Total unsupplied energy (i.e. the lost load for customers)
– Total number of interruptions seen by customer >0.05 system minutes (as per Service Target Performance Incentive Scheme (STPIS) definition)
– Market Impact Component (MIC) parameter (component of STPIS)

In terms of the total unsupplied energy, Transgrid provided data on the annual unsupplied energy for process and non-process events. These are critical measures in terms of impact to the customer. The data distinguishes between process events, which are caused by an issue with the process used by Transgrid (e.g. human error), and non-process events, which are typically asset faults or failures. The non-process events are most reasonably influenced by Repex and therefore relevant to this analysis.

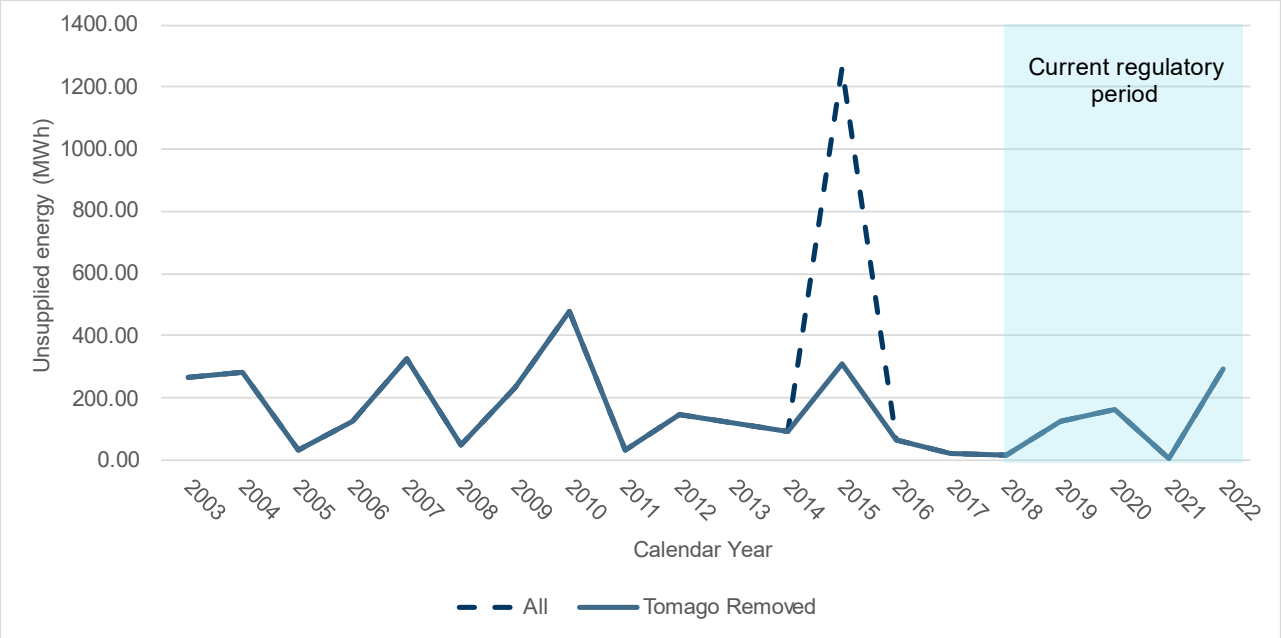
Figure 12 shows the annual unsupplied energy for non-process events. In 2015, there was an abnormally large single event effecting the largest industrial load in Australia (Tomago Aluminium) and can be considered a statistical anomaly. This event is therefore shown as a dotted reference in the figure. The following is noted:

– Performance has been consistent or slightly improved over the period 2003 to 2021 (regardless of the Tomago event). In 2022, the performance trend has been reversed (based on data to September).
– Performance in the current regulatory period shows a reversal of trend. Particularly when available data from 2022 is included, which is the worst performance since 2010 (excluding Tomago)

The current regulatory period coincides with significant increases in distributed and large-scale renewable generation on the network, which are known to make management of networks more challenging.

All other factors being equal, we may expect the reversal of trend to continue as the asset base ages assuming historical levels of Repex.

Figure 12 Annual unsupplied energy (MWh) (non-process events only)



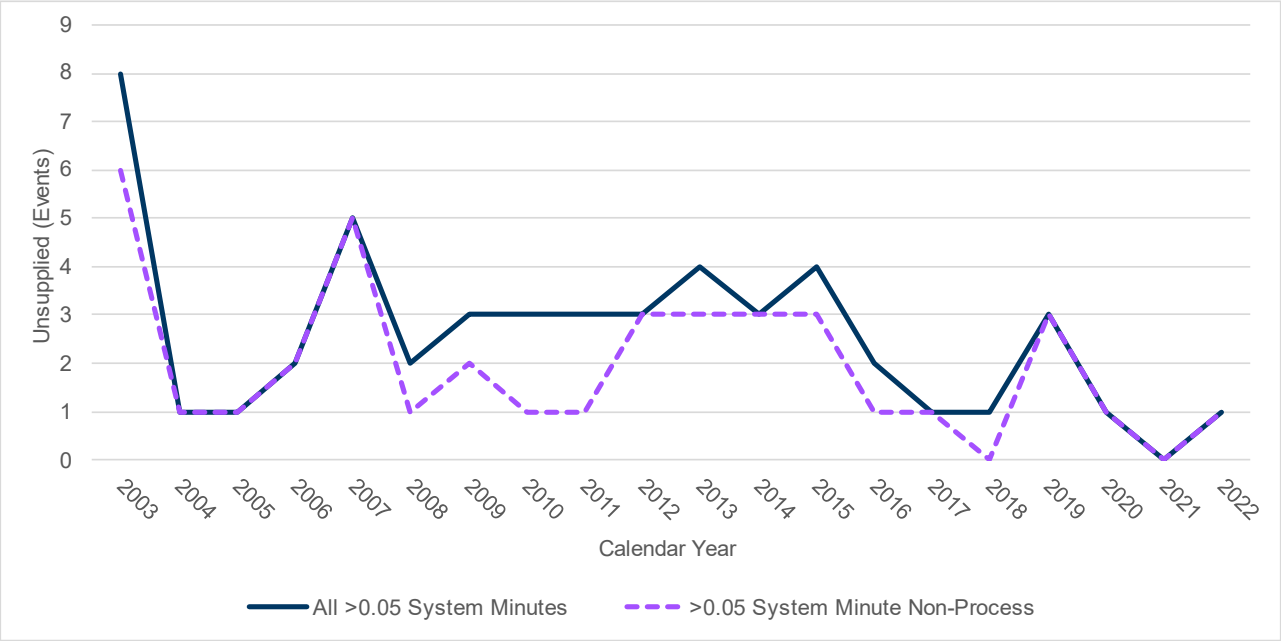
Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 includes months up to September only.

Figure 13 shows the total annual number of energy non-supplied events >0.05 system minutes going back to 2003. The figure indicates data on all events that meet this definition and those events defined as non-process events.

Similar to the overall trend observed for annual unsupplied energy in Figure 12 (above), the trend shows an overall improvement in terms of the number of events (i.e., there are less events). However, it is difficult to draw conclusions from this data as the number of events resulting in loss of load >0.05 system minutes is relatively low. We also note this outcome is consistent with the incentives provided for under the STPIS framework, which

encourages networks to manage assets to keep the frequency and severity of events low. In particular, Opex influences the ability for networks to reduce the severity of outages.

Figure 13 Annual unsupplied events > 0.05 system minutes (all events and non-process events only)



Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 includes months up to September only.

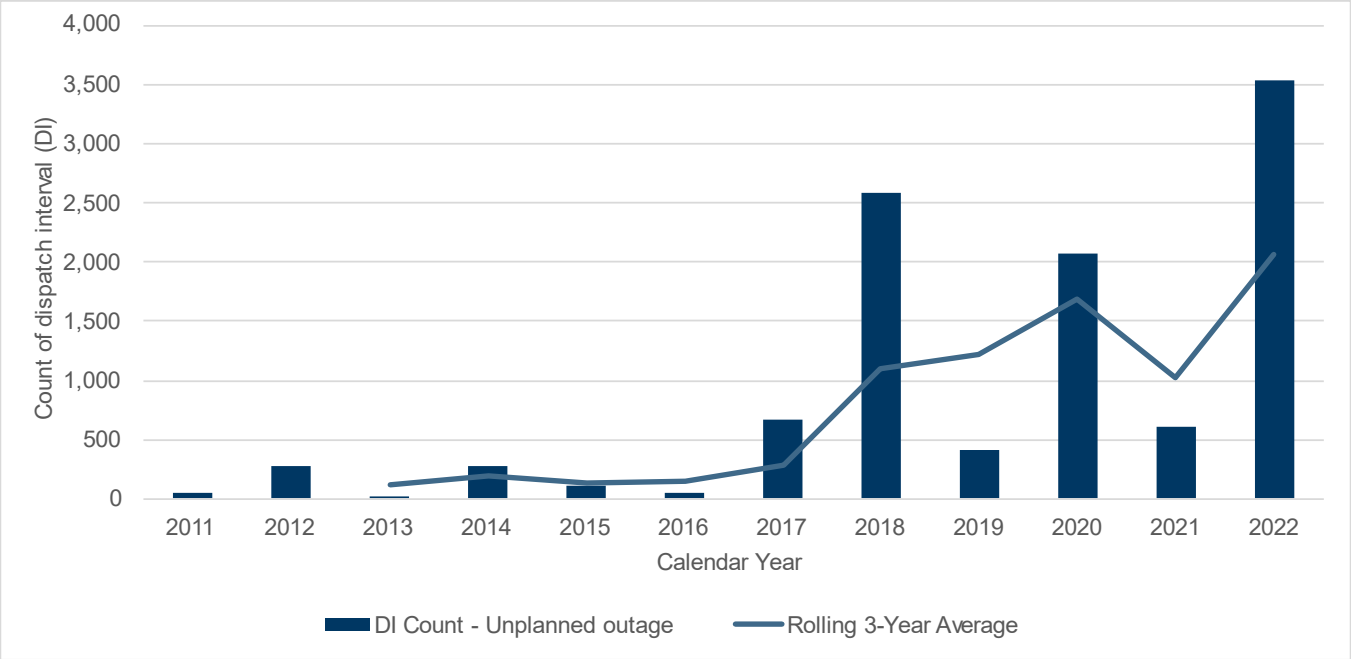
The final lagging indicator considered is the MIC parameter used in STPIS. This parameter shows the impact on the market from Transgrid's outages. Specifically, the MIC counts the number of Dispatch Intervals (DI) when transmission element outages in the network result in binding network outage constraints with a marginal value greater than $10/MWh.

Typically, STPIS considers both planned and unplanned outages attributable to the network. However, for this analysis, we consider only unplanned outages as these are the outages that are likely to be influenced by Repex.[22]

Figure 14 shows the MIC results attributable to unplanned outages for Transgrid over the period 2011 to 2022. An upward trend is observed in the parameter indicating the severity of outages as measured by market impact has been increasing. This trend runs counter to the trends observed in unsupplied energy and annual unsupplied events (discussed above). It is also not aligned to the trends observed for fault outages (discussed in section 5.2 below), which are relatively constant or reducing over the same period. However, unplanned outage MIC performance is demonstrating that network performance isn't generally improving as indicated by the AER.

[22] Note: DI counts relating to planned outages vary year by year based on the capital works and maintenance program, rather than reflecting asset failures.

Figure 14 Unplanned Market Penalty Trend



Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 includes months up to September only.

5.2 Leading indicators

The leading indicators for network performance and customer reliability are asset failures that do not result in customer outages. Repex is specifically focused on the prudent replacement of assets that maximises the life of the asset and avoids reactive post-failure-based replacements that risk service levels, safety and environmental consequences. Where asset failures are increasing overtime, this can be an indicator that there is insufficient Repex to maintain current service levels, suggesting an underlying change in the risk-profile of the network assts.

We have considered the following Transgrid data to understand trends in leading indicators for network performance:

– Transmission line and cable fault outage rates
– Transformer fault outage rates
– Reactive Plant fault outage rates

The fault outage data uses the definition adopted by the AER for the STPIS. Fault outages are unexpected outages without prior notice to AEMO. These outages are typically protection trips due to electrical faults. These outages are distinguished from forced outages, which are also unexpected outages that are typically taken in response to equipment alarms, but where less than 24 hours' notice is given to AEMO prior to the outage taking place.[23]

Only fault outages are considered as a leading indicator and not forced outages, because the trend of forced outages is influenced by Transgrid's operational processes (which is more relevant to Opex than Repex). More specifically, an increasing volume of forced outages in response to equipment alarms are taken with a notice period to AEMO exceeding 24 hours (where prudent) to avoid capture in the relevant STPIS forced outage measures.

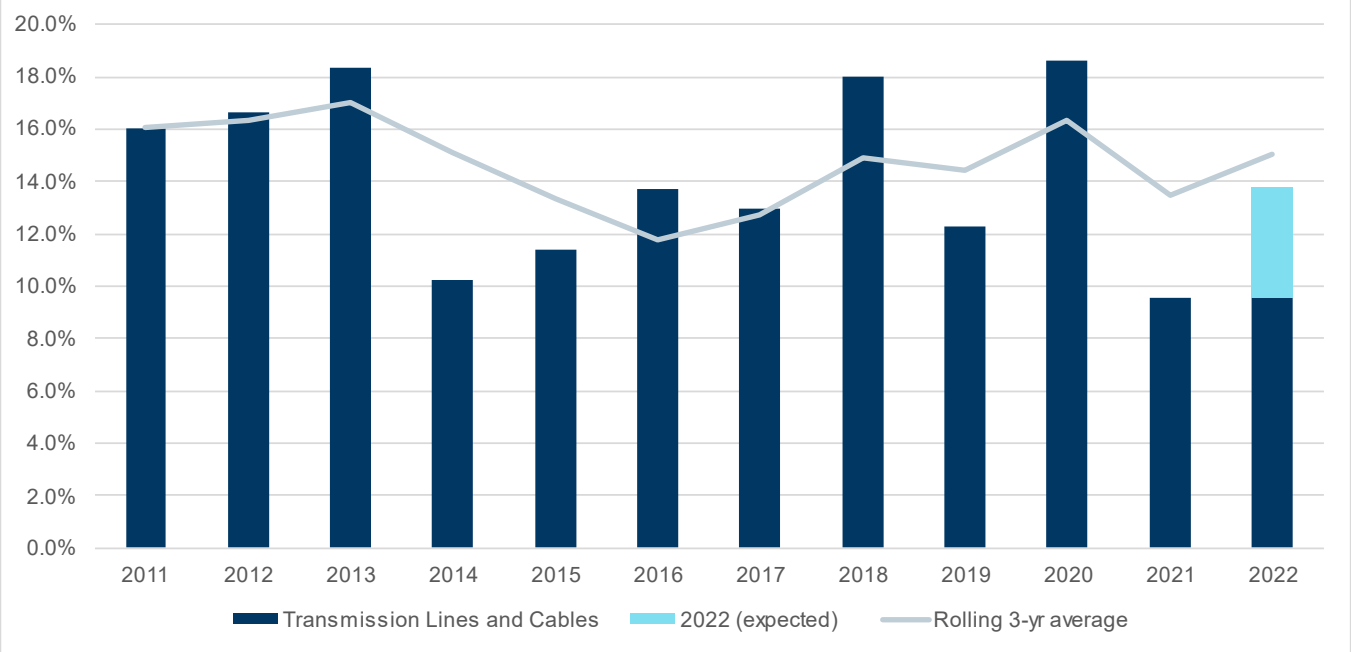
Data on transmission line and cable fault outage rates suggests is presented in Figure 15. The 3-year rolling average shown suggests a relatively consistent rate over the ten-year analysis period. Fault outage rates for transformers and reactive power plant (shown in Figure 16 and Figure 17) indicate a falling rate of outages, particularly in the most recent years.

[23] Full details on the descriptions are available in the AER's Electricity transmission network service provider Service Target Performance Incentive Scheme (STPIS) guideline. refer to Version 5 (corrected), October 2015.

While it is not clear over which period the AER has conducted its analysis, some of the more recent periods (without 2022) data support it's observation of improved outcomes. However, if the transmission line and cables are given a weighting that reflects their contribution to Repex, then we suggest the overall trend is more likely to have been stable or only slightly improved outcomes.

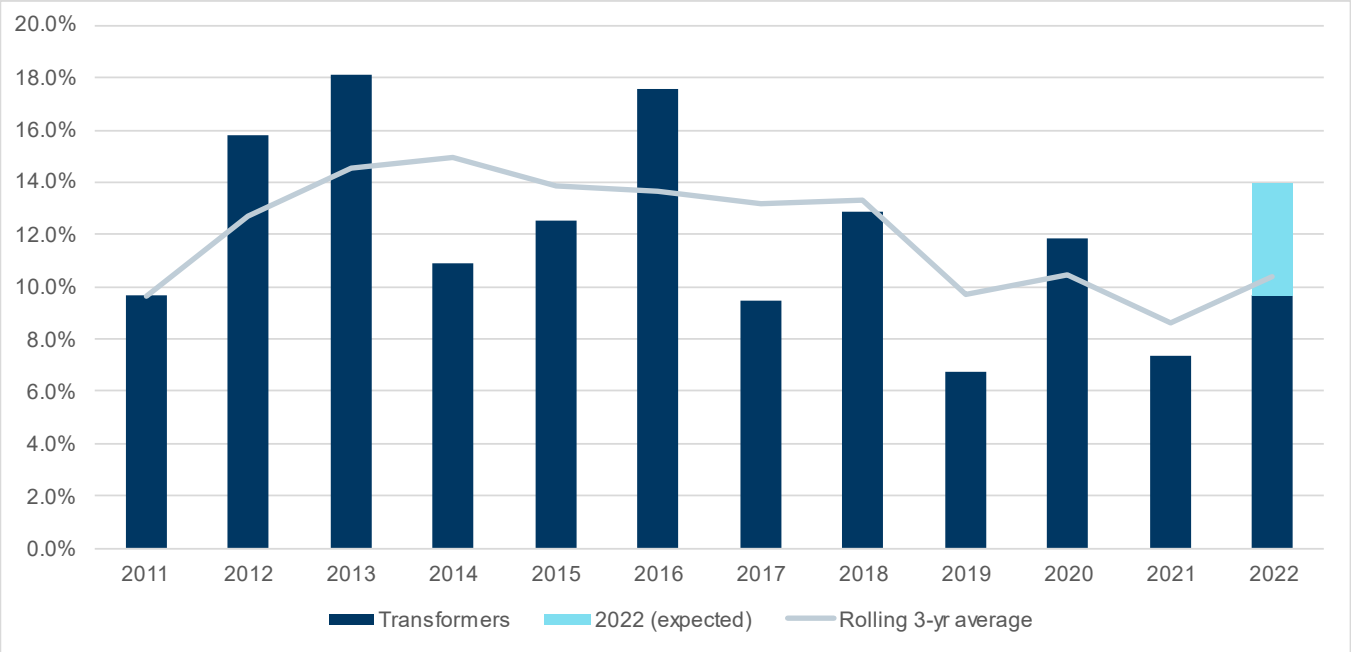
We note there is some limitation in drawing conclusions based on this high-level analysis on transmission network equipment as the analysis does not consider the distribution of the outages on the equipment, either with respect to age, manufacturer, location or use, all of which can play a role in the outage rate for individual assets.

Figure 15 Transmission line and cable fault outage rates



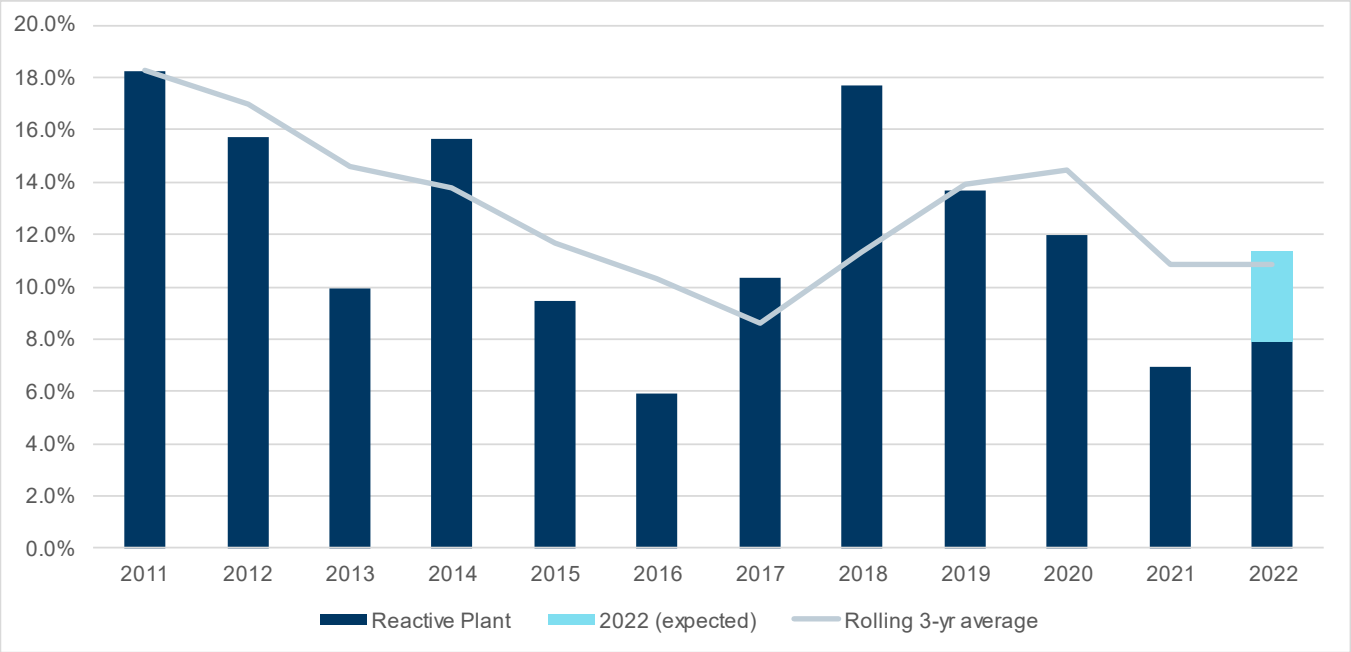
Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 reflects real data for the months up to September (dark blue) and projected outcomes based on the year to date trend for 2022 for remaining months (light blue).

Figure 16 Transformer fault outage rates



Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 reflects real data for the months up to September (dark blue) and projected outcomes based on the year to date trend for 2022 for remaining months (light blue).

Figure 17 Reactive Plant fault outage rates



Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 reflects real data for the months up to September (dark blue) and projected outcomes based on the year to date trend for 2022 for remaining months (light blue).

6. Safety related Repex

A proportion of Repex is associated with bushfire, worker and public safety risk. This does not necessarily correlate with network performance analysis.

The following data were available from Transgrid:

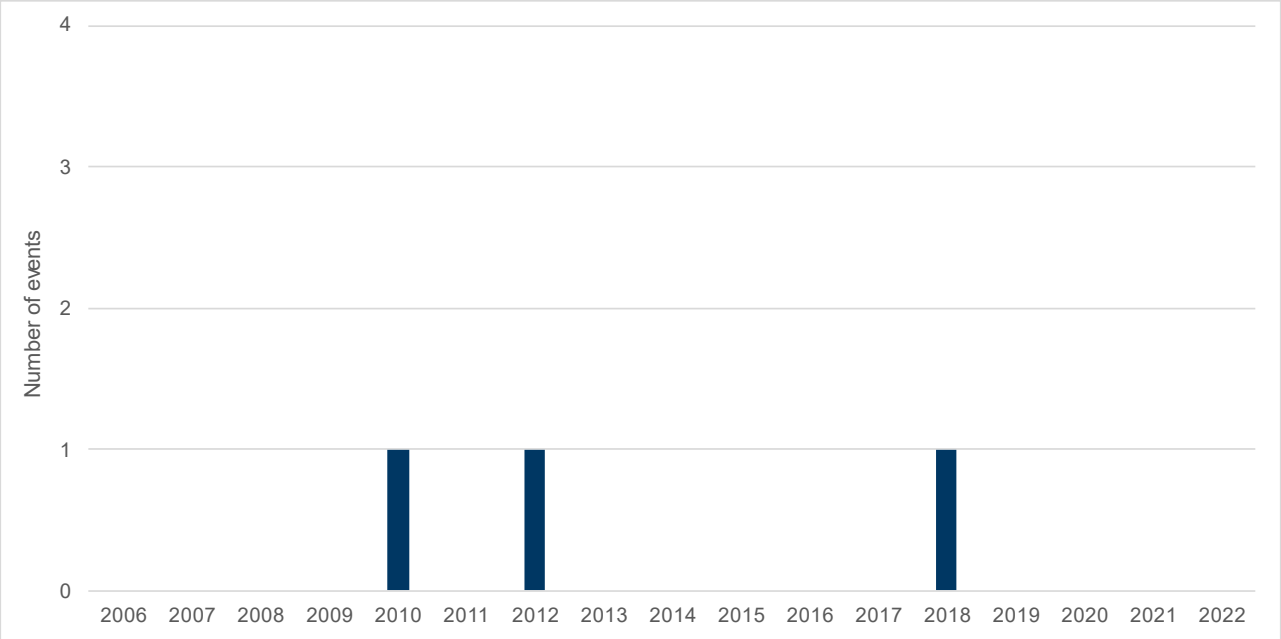
– Bushfire starts
– Dangerous asset failures

Figure 18 shows that Transgrid are maintaining its bushfire start performance long term. There have been three events in the last ten years. Two of the events related to conductor drop[24] and the third event in January 2018 occurred when a transmission line de-energised as it had been arching causing a ground fire. Given community expectations around bushfire avoidance (zero tolerance), we would expect this performance to continue to be actively managed going forward.

Changes in trends of dangerous asset failures can be indicative of the effectiveness of Repex. Data recorded by Transgrid for this metric is shown in Figure 19. Data shows the total number of events has increased in the most recent years. However, it's noted that there are very few events in any one year – on average there are 6 events per year and 2020 had the highest number of events in the ten year period with 9 events. Conductor drop is a consistent contributor to the dangerous asset failures.

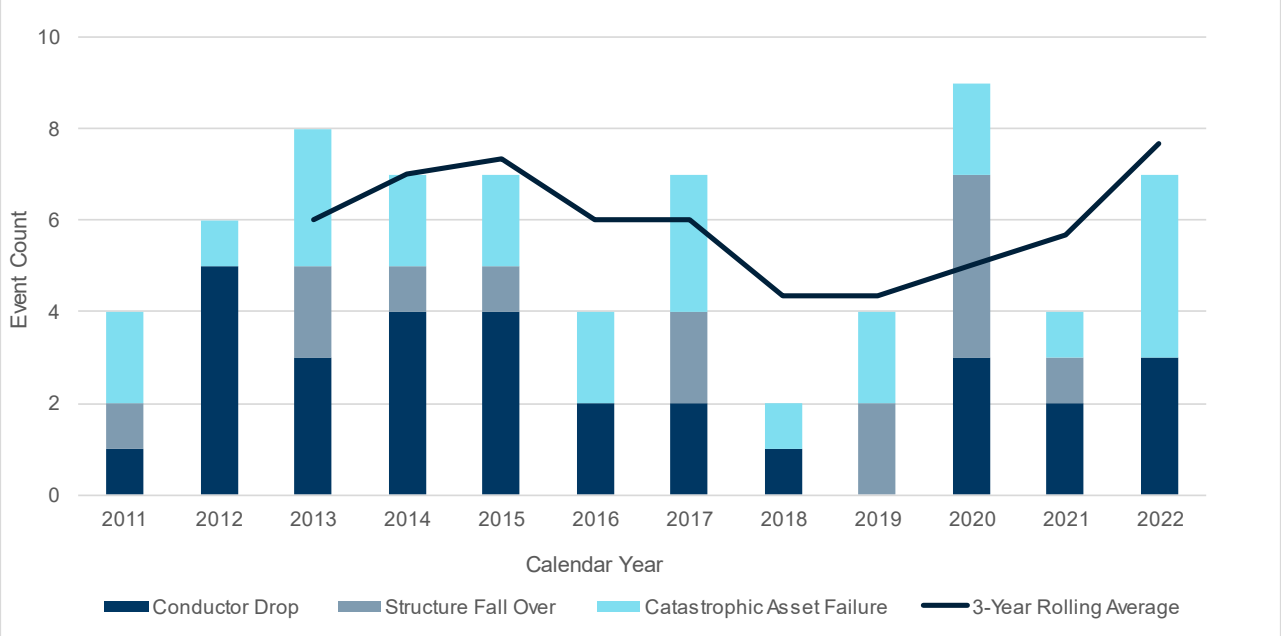
[24] In March 2010 the fire was caused by a white phase conductor on the ground and in December 2021, a conductor failure led to a small crop fire that was extinguished by the Rural Fire Service.

Figure 18 ***Non-vegetation Fire Starts (annual)***



Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 includes months up to September only.

Figure 19 ***Dangerous asset failures***



Source: Data supplied by Transgrid on 5 October 2022. Data for 2022 includes months up to September only.

7. Summary of findings and conclusion

The AER have completed a top-down and bottom-up assessment of the Repex program included in the 2023-28 Revenue Proposal. Their top-down view indicates that it is "*broadly in line with the long-term trend*[25]*".* Their bottom-up review results in a 20 percent reduction to the Repex program. These two perspectives do not reconcile, and our analysis indicates that the reduction would bring a number of metrics towards the bottom of the range of historical outcomes for TNSPs.

Comparisons of Repex based on customer numbers, energy delivered and maximum demand show Transgrid's historical expenditure is the lowest of the TNSPs. Transgrid's revised Repex forecast brings it into line with the historic expenditure rates of other TNSPs with regards to these metrics, while the AER's draft decision would reduce Transgrid's ratios further.

Table 8 brings together data presented in section 5 of this report and highlights this finding. It is also noted that the AER's draft determination would result in average expenditure below the historic levels allowed for the Transgrid network, which may alter the networks performance in the coming years.

Table 8 Benchmark comparison results – average for 2009 to 2021 (historic) and proposed

Comparator	Per customer	Per km overhead circuit	Per MW maximum demand	Per MWh delivered
Historic				
Powerlink	$71.78	$0.011	$0.019	$2.92
TransGrid	**$42.23**	**$0.012**	**$0.013**	**$2.10**
AusNet (T)	$46.61	$0.020	$0.016	$2.87
ElectraNet	$106.48	$0.017	$0.032	$6.37
TasNetworks (T)	$134.97	$0.011	$0.018	$2.95
Proposed				
AER draft determination	$38.71 (below Transgrid historic)	$0.011 (below Transgrid historic)	$0.011 (below Transgrid historic)	$1.89 (below Transgrid historic)
TransGrid (revised)	$48.38	$0.014	$0.014	$2.36

Our benchmark analysis also considers the age of Transgrid's network assets compared with other TNSPs. Our observation that Transgrid has a relatively old network, with a relatively low estimated residual service life across the various categories of transmission network assets contrasts to the finding made by the AER in their Draft Determination –

> *"Transgrid's assets are on average the second youngest of the transmission businesses in the National Electricity Market (NEM) after Powerlink Queensland. They are also second youngest in most of the Regulatory Information Notice (RIN) asset categories*[26]*"*

Our analysis relies on the same underlying data used by the AER – the Economic Benchmarking RIN Responses from TNSPs for 2020-21 and reports data as presented in RIN responses (i.e., no calculations). While we have not been able to reconcile the difference based on public information,[27] we find that for:

– Transmission towers (a proxy for all transmission line assets), all TNSPs have asset bases with a heavy distribution of towers constructed between the 1950s and 1970s that should be coming up for replacement. Transgrid and Ausnet being the most effected.

– Substations and SCADA, network control and protection the assets are more closely distributed towards the younger side for all TNSPs compared with transmission towers. This reflects the shorter lives of these assets

[25] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure p. 33
[26] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure P20
[27] It is possible a weighted approach has been taken by the AER in their analysis or has used non-public data.

and the emergence of new technologies. Transgrid's asset base does not appear significantly different to that of other TNSPs for these categories (except for AusNet which is affected by the AMI roll-out in Victoria).

Given that transmission line assets represent the largest proportion of Repex, the above suggest we would expect to see an increase in the allowed Repex that reflects the lumpy nature of historical transmission line investment which is now due for replacement and the fact that Transgrid owns the largest quantum of higher voltage assets (i.e. ≥ 330 kV) compared with other TNSPs.

Repex is primarily concerned with replacement or refurbishment of assets that might fail and cause risks to power system security, customer reliability or network safety. The AER provides a high-level overview in their Draft Determination to support their decision making -

> *"Top-down indicators reveal that Transgrid's network performance is improving over time compared against itself and its peers. We commend Transgrid on achieving this improvement, but this result may also suggest that less capex investment in the forecast period is required for Transgrid to maintain its network. Appendix A.1 provides more detail around how we have examined the metrics. In summary, the results indicate that:*
>
> - *Transgrid's assets are on average the second youngest of the transmission businesses in the National Electricity Market (NEM) after Powerlink Queensland. They are also second youngest in most of the Regulatory Information Notice (RIN) asset categories*
> - *Transgrid's assets have the lowest average outage rate among the transmission businesses over the last 5 years. In relative terms, its transformers performance has been around the average, and performance for all other assets has been better than average*
> - *Transgrid's average outage rate has improved substantially in recent years. This suggests that it has invested enough repex over the last two regulatory control periods to improve, rather than maintain, service levels[28]".*

Our review of leading and lagging network performance indicators that speak to the potential requirement for additional Repex above the historic levels or reductions if the performance is above minimum standards, suggests a complex picture:

- Lagging indices of annual unserved energy and non-process outages leading to >5 system minimum losses have remained constant or slightly reduced over the period going back to 2003. In the most recent 10-year period from 2011 onwards, these indices have been flat. It is noted that these metrics may be weak indicators of Repex requirements as the response times to outages are heavily influenced by Opex.
- The leading index of outages of transmission lines and cables have remained constant. Given this is the largest contributor to Repex, it is a strong indicator that the historic expenditure levels have been appropriate to maintain performance.
- Other leading indices that consider smaller Repex contributors – transformers and reactive plant – indicate slightly improved outcomes over the period. Only fault outages are considered and forced outage are not as the trend of forced outages is influenced by Transgrid's operational processes. More specifically, an increasing volume of forced outages in response to equipment alarms are taken with a notice period to AEMO exceeding 24 hours (where prudent) to avoid capture in the relevant STPIS forced outage measure.
- The MIC parameter provides additional insights to the above trends. Analysis of this metric for unplanned outages, which are most likely to be influenced by Repex, is that the severity of outages as measured by market affects has been increasing over the period 2011 to 2022. Unplanned outage MIC performance is indicating network performance issues rather than improvement.

The market impact performance parameter is an important metric in understanding the complexity of the relationship between Repex, outages and overall economic effects. The current regulatory period and the most recent years of data coincide with a rapid increase in distributed and large-scale renewables.

Collectively the observations on leading and lagging indicators present mixed results rather than a clear indication of improved performance. Even if network performance was improving this doesn't prove that a reduction in Repex is appropriate.

[28] AER – Draft Decision Transgrid Transmission Determination 2023 to 2028 Attachment 5 Capital expenditure p. 20

A 20 percent reduction to the Repex program might not immediately impact performance, but over time could contribute to degraded performance.
A proportion of Repex is associated with bushfire, worker and public safety risk. Recent Revenue Proposals for Electranet and Ausnet show a great deal of variation over time. Repex relating to mitigating bushfire, worker and public safety risks may be driven by life cycle risks, events or incidents rather than being driven by asset age as a single factor.

Data provided by Transgrid shows a strong performance in terms of bushfire starts. Given the community tolerance for bushfires is very low, we suggest continued expenditure to maintain this performance is appropriate. Dangerous asset failure data was also considered. Noting there are very few events in any one year (average of 6 per year across the analysis period), this data shows the total number of events has increase in the most recent years.

In conclusion, once the age of assets is considered, the data considered in GHD's analysis suggests an increasing role for network management, meaning that historical levels of Repex would need to be at least maintained.

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