Annual Benchmarking Report

Electricity transmission network service providers

November 2022

AUSTRALIAN ENERGY REGULATOR

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Executive Summary

We report annually on the productivity growth and efficiency of transmission network service providers (TNSPs) in the National Electricity Market (NEM). These service providers operate high voltage transmission lines which transport electricity from generators to distribution networks in urban and regional areas. Transmission network costs typically account for between 5 to 10% of what customers pay for their electricity (with the remainder covering generation costs, distribution, and retailing, as well as environmental policies).

We use economic benchmarking to measure how productively efficient these networks are at delivering electricity transmission services over time and compared with their peers. Where transmission networks become more efficient, customers should benefit through downward pressure on network charges and customer bills. We draw on this analysis when setting the maximum revenues networks can recover from customers.

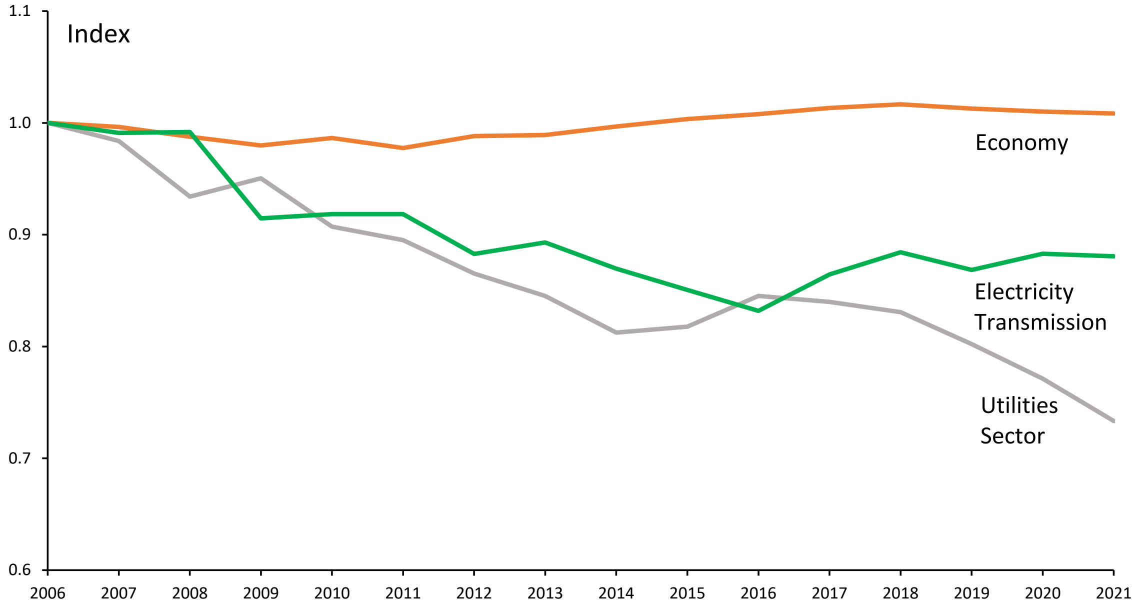
In preparing this benchmarking report, we have taken into account stakeholder views received through our consultation process.

Transmission network productivity reduced slightly over 2021

Electricity transmission productivity as measured by multilateral total factor productivity (TFP) time series analysis decreased by 0.3% over 2021, after a trend of increased productivity since 2016 (see Figure 1). This slight decline was similar to that of the productivity in the overall Australian economy (0.2%) but better than the 5.0% decline in the utilities sector (electricity, gas, water and waste services) over the same period.

The decrease in transmission network productivity in 2021 is primarily due to an increase in the capital input for overhead line capacity, contributing a 0.7 percentage point decrease to the overall TFP decrease. This increase is largely driven by a winter peak in 2021 for some of Transgrid’s existing overhead line assets, rather than any additional investment or increase in the overhead line length. A sensitivity analysis shows the impact of these changes is significant and that TFP growth for 2021 (-0.3%) would have been 0.5% had there been no change in TransGrid’s overhead line input (and capacity) from 2020 and its summer peak was used. The effect of increased overhead line capacity was partially offset by improved network reliability (lower energy not supplied (ENS)) which positively contributed 0.5 percentage points to the growth rate of TFP. Improved reliability is consistent with that experienced by the distribution network service providers.

Figure 1 Electricity transmission, utility sector, and economy TFP, 2006–21



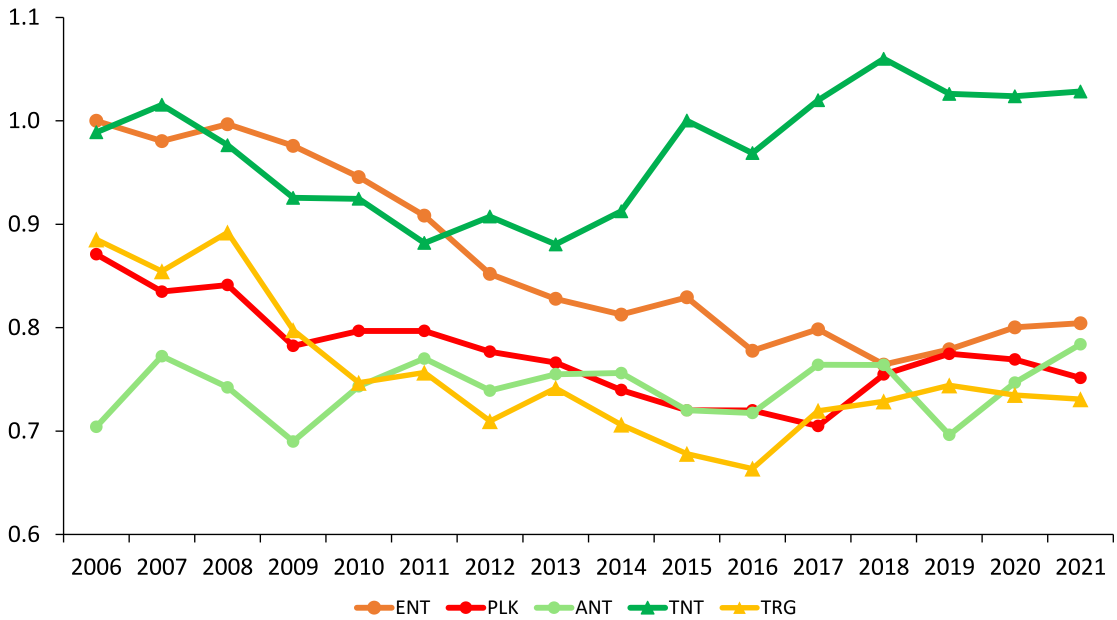
Changes in productivity of TNSPs in the NEM over 2021

There are five transmission networks in the NEM, with one in each state. In 2021, three TNSPs (AusNet, TasNetworks and ElectraNet) improved their productivity as measured by MTFP, with AusNet's improvement being significant at 4.8% compared to that of TasNetworks and ElectraNet at 0.5% (see Figure 2). Two of these TNSPs also recorded productivity improvements over the last two consecutive years (AusNet and ElectraNet). Conversely, TransGrid experienced a slight decrease in productivity in 2021 (0.6%), while Powerlink's productivity decline was more material (2.3%). TasNetworks remained the highest ranked TNSP in terms of productivity measured by MTFP in 2021.

Figure 2 highlights the variability in productivity observed for individual DNSPs from year-to-year and emphasises the importance of considering the changes in productivity in 2021 in the context of longer-term trends.

However, we note that our transmission benchmarking accounts for some but not all possible differences in operating environment factors.

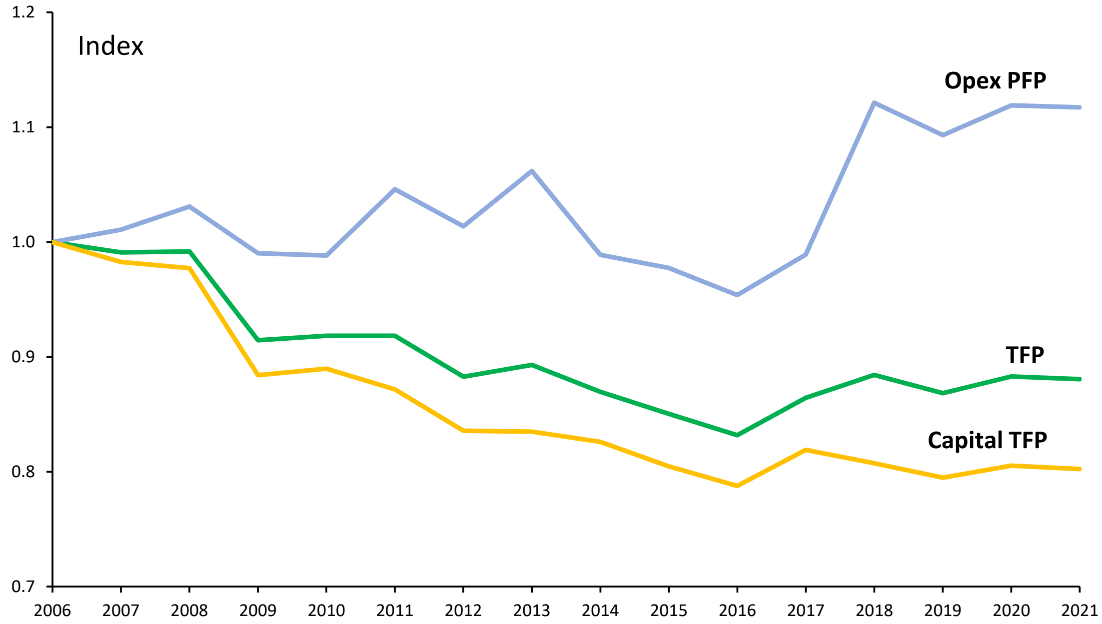
Figure 2 Electricity transmission MTFP indexes by TNSP, 2006–21



The long-term decline in transmission network TFP is driven by declining capital partial factor productivity (PFP)

The productivity of transmission networks has declined at an average annual rate of 0.8% over the last 16 years (see Figure 3). Capital PFP declined at an average annual rate of 1.5% compared to average annual operating expenditure (opex) PFP growth of 0.7% over the same period. The improvement in transmission productivity over the past few years, particularly since 2016, can be linked to reductions in opex and stabilisation of capital inputs (that is, less growth in capital assets compared to earlier years).

Figure 3 Transmission network opex PFP and capex PFP over 2006–21



Updates in this year's report

We operate an ongoing transparent program to review and incrementally refine elements of the benchmarking methodology and data. In this year's report there has only been one relatively small change to the methodology we use and minimal updates to the data other than to add the data for the additional year being updated (2021).

In terms of the benchmarking development work, an independent review of the non-reliability output weights remains important. This did not occur in 2022 following a re-consideration of our priorities in light of resource limitations, however it remains an important development priority that we will progress in 2023–24. Beyond this, the key development issue requiring further examination is the improved measurement (and associated data) of some benchmarking variables, particularly for transformers and overhead line inputs. We consider this a practical way of in part advancing the model development work, including to account for new obligations relating to TNSPs changing operating environment. It will also address measurement and data issues that have been raised in the preparation of this year's and previous year's benchmarking results, and in the context of the AER's Networks Information Requirement Review.

Contents

1 Our benchmarking report

The National Electricity Rules (NER) require the AER to publish network benchmarking results in an annual benchmarking report.[1] This is our ninth annual benchmarking report for TNSPs. This report is informed by expert advice provided by Quantonomics.[2]

National Electricity Rules reporting requirement

6A.31 Annual Benchmarking Report

(a) The AER must prepare and publish a network service provider performance report (an annual benchmarking report), the purpose of which is to describe, in reasonably plain language, the relative efficiency of each Transmission Network Service Provider in providing direct control services over a 12-month period.

Productivity benchmarking is a quantitative or data-driven approach used by governments and TNSPs around the world to measure how efficient firms are at producing outputs over time and compared with their peers.

Our benchmarking report considers the productive efficiency of TNSPs. TNSPs are productively efficient when they produce their goods and services at the least possible cost of inputs given their operating environments and prevailing input prices. We examine the change in productivity in 2021,[3] compared to 2020,[4] and trends in productivity over the full period of our benchmarking analysis (2006–21) as well as shorter time periods.

Our benchmarking report presents results from two types of 'top-down' benchmarking techniques.[5] Each technique uses a different method for relating outputs to inputs to measure and compare TNSP efficiency:

- **Productivity index numbers (PIN)**. These techniques use a mathematical index to measure the relationship between multiple outputs relative to inputs, enabling comparison of productivity levels and trends over time. We use these PIN techniques for our MTFP-based analysis.
- **Partial performance indicators (PPIs)**. These simple ratio methods relate one input to one output.

1 NER, cll. 6A.31(a) and 6A.31(c).

2 The supplementary Quantonomic’s report outlines the full set of results for this year's report, the data we use, the updates and our benchmarking techniques. It can be found on the AER's benchmarking website.

3 This is the financial year 2020–21 (April-March for AusNet and July–June for all the other TNSPs).

4 The 2019–20 financial years (July–June and April–March) (as relevant).

5 Top-down techniques measure a network's overall efficiency, based on high-level data aggregated to reflect a small number of key outputs and key inputs. They generally take into account any synergies and trade-offs that may exist between input components. Alternative bottom-up benchmarking techniques are more resource intensive in that they examine each input component separately. Bottom-up techniques do not take into account potential efficiency trade-offs that may exist between input components of a TNSP’s operations.

Being top-down measures, each benchmarking technique cannot readily incorporate every possible exogenous factor that may affect a TNSP's performance. For example, as further explained in section 2.2, certain factors in a TNSP's operating environment are beyond its control and not all of these have been captured in the benchmarking models. Therefore, the performance measures reflect, but do not precisely represent, the underlying efficiency of TNSPs. For this benchmarking report, our approach is to derive 'raw' benchmarking results and where possible, explain drivers for the performance differences and changes.

The primary benchmarking techniques we use in this report to measure the productivity performance of individual TNSPs in the NEM are MTFP and multilateral partial factor productivity (MPFP) indexes. These indexes allow comparisons of absolute levels and growth rates of the measured productivity. MTFP examines the overall productivity of using all inputs in producing all outputs. MPFP examines the productivity of either opex or capital in isolation.

What is multilateral total factor productivity?

TFP is a technique that measures the productivity of TNSPs over time by measuring the relationship between the inputs used and the outputs delivered. Where a TNSP is able to deliver more outputs for a given level of inputs, this reflects an increase in its productivity. MTFP allows us to extend this to compare productivity levels between networks.

The inputs we measure for TNSPs are:

- Three types of physical capital assets TNSPs invest in to replace, upgrade or expand their networks:
    - Transformers and other capital (quantity proxied by transformer MVA)
    - Overhead lines (quantity proxied by overhead MVAkms)
    - Underground cables (quantity proxied by underground MVAkms)
- Opex to operate and maintain the network.

The non-reliability outputs we measure for TNSPs, and the relative weighting we apply to each non-reliability output, are:

- Circuit line length (52.8%). Line length reflects the distances over which TNSPs transport electricity and is a significant driver of the services a TNSP must provide.
- Ratcheted maximum demand (RMD) (24.7%). TNSPs endeavour to meet the demand for energy from their customers when that demand is greatest. RMD recognises the highest maximum demand the TNSP has had to meet up to in the time period examined.
- Energy delivered (14.9%). Energy throughput is a measure of the amount of electricity that TNSPs deliver to their customers.
- End users (7.6%). The number of end users is a proxy for the complexity of the TNSP's network. Reliability (ENS) is also an output. Reliability measures the extent to which networks are able to maintain a continuous supply of electricity. ENS enters as a negative output and is weighted by the value of customer reliability capped by 2.5% of total revenue.

The November 2014 Economic Insights report referenced in Appendix A details the rationale for the choice of these inputs and outputs. In its August 2017 report, Economic Insights updated the output specification and the weights applied to each output.[6] This output specification is used in this report, with output weights updated in 2020,[7] is consistent with the approach used in the September 2022 Quantonomics report.

In order to assist with the ability to understand these inputs and outputs, as well as how they are used in the benchmarking analysis, we have provided some further detail in relation to these variables.

In terms of the inputs being used in the benchmarking analysis:

- the opex input reflects the costs associated with the labour, materials and services that are purchased in a given year. These costs are deflated by a price index of these inputs to establish a quantity of measure opex inputs
- the capital inputs, such as transformers and overhead lines and underground cables, measures the physical quantity of the assets. This is used as a proxy for annual capital service flow as we assume relatively constant flow of services over the life of an assets, and thus that the annual flow is proportionate to capital stock.

At the start of the benchmarking program, there was general agreement that outputs should be included on a functional rather than billed basis, reflecting that under the building block model approach to regulation there is not typically a direct link between the revenue requirement and how a TNSP structures its prices.[8] It was also noted that the outputs included should reflect services provided to customers, rather than activities undertaken by the TNSP which do not directly affect what the customer receives, even if, given the characteristics of transmission services they are also somewhat removed from the final interface with end users. In terms of the outputs being used in the benchmarking analysis and the services provided:

- energy delivered reflects the energy delivered to the end-user and is the transmission service directly consumed by end users
- end users despite not being a direct output of transmission networks, is a measure of the services and benefits ultimately provided to end users of the distribution networks, regardless of how much they consume, which connect to the transmission networks. It is an indicator of network complexity and connectivity
- circuit length has output related dimensions because it reflects the geographic distribution of end users that TNSPs need to construct networks to connect in order to deliver energy. In combination with end users, it will reflect the impact of different levels of end user density within an area on transmission costs

6 Economic Insights, *Review of Economic Benchmarking of Transmission Network Service Providers - Position Paper*, 9 August 2017, pp. 29–33.

7 AER, *Annual Benchmarking Report 2020 – Electricity transmission network service providers*, November 2020, pp. 3-5.

8 The AER generally sets the revenue requirement and separately prices are set in order to recover this revenue requirement.

- ratcheted maximum demand reflects the (non-coincident) maximum demand from customers on the transmission network. The highest system peak demand observed in the period (up to the year in question) is used to give credit for the provision of capacity to meet higher maximum demand in the earlier years
- reliability (ENS) reflects the extent to which networks are able to maintain a continuous supply of electricity

Appendix A provides reference material about the development and application of our economic benchmarking techniques. Appendix B provides more information about the specific models we use and the data required.

1.1 Updates in this benchmarking report

This benchmarking report uses the methods set out in previous reports, including the minor updates in the 2021 report relating to the opex price index, the reliability index and the annual user cost of capital.[9] Beyond this, for the 2022 report the only update made is in relation to the calculation of the reliability index, where the minimum value of the ENS has been reduced from 1 MWh to 0.2 MWh[10], for current and historical ENS values, reflecting the minimum value for ENS reported for 2021.

1.2 Benchmarking development program

We operate an ongoing transparent program to review and incrementally refine elements of the benchmarking methodology and data.

An important piece of work in this regard is an independent review of the non-reliability output weights. In the 2020 Benchmarking report we corrected an error identified in the non-reliability output weights used in the PIN benchmarking and committed to independently reviewing these weights. We scoped this review and included these details in our 2021 Annual Benchmarking report. However, due to resource availability the independent review did not occur this year. It remains an important development priority and we aim to complete the review in the 2023–24 financial year.

Beyond this, the key issue we think needs further examination, as informed by submissions received from TNSPs, is the improved measurement and associated data of some benchmarking variables, particularly transformer and overhead line inputs. This is connected in part to advancing the development work to review the PIN model specifications to account for new obligations relating to TNSPs changing operating environment (including system strength and inertia requirements), as identified in the 2021 Annual Benchmarking Report for transmission. It is proposed that this work will address measurement and data issues raised in the preparation of this year's, and previous year's, benchmarking results and in the context

9 AER, *Annual Benchmarking Report 2020 – Electricity transmission network service providers*, November 2021, pp. 3-4.

10 Reflecting ElectraNet's 2021 ENS value. This led to a change for Powerlink's 2019 ENS value used for benchmarking, which was 1MWh (instead of zero as actually achieved) but has now been reduced to 0.2 MWh reflecting the lowest non-zero ENS now reported.

of the AER's Networks Information Requirement Review.[11] The measurement and data issues needing greater clarity in definitions include:

- As the overhead lines input is defined in the Economic Benchmarking Regulatory Information Notice (EB RIN), capacities are provided in terms of summer or winter maximum demands, depending on when the peak occurs, and can change from year to year. We have seen this for TransGrid's overhead line capacity in 2021 which changed in part due to a movement from summer to winter peaks for some asset classes.[12] This has also occurred in previous years for TransGrid. These changes in seasonal peaks can substantially influence the productivity results for the industry as a whole and for individual business (as seen in the sensitivity testing set out below).
- A related issue is whether temporary changes in the 'carrying capacity' of an overhead line asset class, resulting in reclassification of voltage classes, requires the associated line length to also be updated. We have seen this for Powerlink's reporting of overhead line input in 2021 where there were changes in the 'carrying capacity' of some asset classes resulting in reclassification but no corresponding changes in the line length of these asset classes.[13] This can also have an impact on the productivity results (as also seen in the sensitivity testing set out below).
- Whether the measurement of capital inputs adequately accounts for differences in the configurations of TNSPs networks. For example, Powerlink has previously raised an issue in relation to Static VAR Compensators (SVCs). It suggested that the transformer input should not include the transformer capacity associated with SVCs because it says this results in double counting as this capacity is included in the overhead line capacity.[14] From initial discussions with TNSPs it seems that this will depend on the purpose for which SVCs have been installed and further work is required to understand the differences between networks and to ensure there is no double counting.
- The way the transformer input is calculated under the EB RIN definition and whether it ensures maximum comparability between TNSPs. This was raised by Powerlink as part of the AER's Networks Information Requirement Review.[15] We agree that it would be useful to examine the measurement of transformer capacity.
- The way the energy delivered output is defined in the EB RIN and whether this should include energy used for pumping as a part of any energy storage solution. This was also raised by Powerlink as part of the AER's Networks Information Requirement Review.[16]

[11] See AER, Network information requirements review.

[12] TransGrid, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received on 7 September 2022.

[13] Powerlink, *Email to the AER – Follow up questions on Powerlink's 2020-21 EB RIN data*. Received 29 August 2022.

[14] Powerlink, *Email to AER – Preliminary Annual Benchmarking Report 2021 – Electricity transmission network service providers – Consultation stage 1*. Received 7 September 2021.

[15] AER, *Network Information Requirements Review, Workshop 1: TNSP Economic Benchmarking, Summary,* July 2022, p. 3.

[16] AER, *Network Information Requirements Review, Workshop 1: TNSP Economic Benchmarking, Summary*, July 2022, p. 2.

1.3 Consultation

In developing this report, we have undertaken consultation with external stakeholders in two stages, consistent with the approach we adopted in previous years. This involved consultation with transmission networks in relation to the preliminary benchmarking results and report prepared by our consultant, Quantonomics, and then further consultation with these networks and other stakeholders in relation to a draft of this year's annual benchmarking report. Minor corrections to the reports and data were submitted by networks and these have been incorporated in the accompanying Quantonomics and final AER report.[17] The following outlines the key issues raised and our responses.[18]

Output specification of TFP / MTFP model

ElectraNet submitted that further consideration needs to be given to the output measures used in our benchmarking analysis, including to account for the changing environment in which TNSPs are operating.[19] Our 2020 Annual Benchmarking Report addressed many of these issues.[20] In relation to changing environment, ElectraNet noted that although it has had substantial investment in *Project Energy Connect* and in increasing system strength and inertia to support renewable energy generation, it considered these investments do not impact the current output measures while cost inputs increase.

We acknowledge that there is change occurring in the transmission environment, particularly driven by increasing connection of renewable generation. This is resulting in new transmission network investment and the need to manage how the transmission system is operated to ensure system strength and reliability requirements are maintained. In this regard, as in last year's report, we have noted the need to consider the impact of these changes on our output specification in our development priorities in section 1.2.

[17] Powerlink, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 29 August 2022; TasNetworks, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 24 August 2022; ElectraNet, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 26 August 2022; AusNet, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 29 August 2022; TransGrid, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 7 September 2022.

[18] It is noted that some of these issues were also addressed in the final report from our consultant, Quantonomics. See Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report, November 2022*.

[19] ElectraNet, Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 2. Received 27 October 2022.

[20] AER, *Annual Benchmarking Report 2020 – Electricity transmission network service providers*, November 2020, pp. 46-50; AER, *Annual Benchmarking Report 2021 – Electricity transmission network service providers*, November 2021, pp. 5-6.

Better explanations of the input and output measures used for benchmarking

AusNet submitted that the Quantonomics and AER reports should have better explanations for the input and output measures used in benchmarking, including what these measures are capturing and why they have the weights they do. It noted that this was particularly the case for the circuit length output as the other outputs are relatively self-explanatory. It considered this would provide greater understanding and the ability of businesses and stakeholders to interpret the benchmarking results.[21]

We agree with AusNet that understanding the basis of the inputs and outputs used in the benchmarking is necessary for it to be useful, including in interpreting the results. Above, a brief description is given for each input and output, and what it is capturing in the TNSP benchmarking analysis. Further detail is provided in Appendix B.2. Further, section 1.2.1 of the Quantonomics report for 2022 includes a discussion of the purposes of the measures used.

Sensitivity analysis of the productivity results

Powerlink submitted that the benchmarking results in the Quantonomics report for 2022, and the AER's 2022 Annual Benchmarking Report for transmission, should contain additional sensitivity analysis and commentary. It considered this would improve the transparency of these reports. It suggested that the sensitivity analysis could cover from an input perspective the changes in TransGrid's reported overhead line capacity in 2021 and from an output perspective the exclusion of reliability (ENS) from the output measure.[22]

We agree with Powerlink that including these sensitivities provides useful additional information to the benchmarking results for this year's reports. As a result, our consultant Quantonomics has included the following sensitivity analysis in its 2022 report[23] and supporting files, and we have also examined these in our report – see section 3.2:

- Testing the sensitivity of the productivity results if there had been no change in TransGrid's overhead line capacity in 2021 associated with moving from summer to winter peaks for some asset classes, as well as the removal of particular line constraints. This has been done by assuming that for relevant asset classes there was no change in the overhead line capacity from 2020 to 2021. The impact on both the industry and TransGrid's productivity has been examined.
- Testing the sensitivity of the productivity results if there was no capacity change in Powerlink's two overhead line classes in 2021 i.e. removing the impact of the reported decline in average capacity for both 132kV and 275kV overhead lines from 2020. This decline to both voltage classes, as reported, is the result of Powerlink's reclassification

21 AusNet, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 29 August 2022.

22 Powerlink, *Email to AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 29 August 2022.

23 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report, November 2022*. ENS sensitivity is reported in chapters 2 and 4, and overhead line capacity sensitivity in Appendix D1 and D2.

of a line from 132 kV to 275kV as it was temporarily energised at 275kV.[24] Powerlink also submitted that this had not resulted in a change to the length of both classes as it has reported length based on a 'constructed basis'.[25] Due to the calculation of MVA km for the overhead line, the change in capacity that is not matched by a change in asset class length has resulted in the input for these two lines being significantly lower in 2021. We consider the voltage class classification needs to be consistently applied to both line length and capacity. This sensitivity has been done by assuming no reclassification and that for both asset classes there was no change in the overhead line capacity from 2020 to 2021. The impact on both industry and Powerlink's productivity has been examined.

- Testing the sensitivity of the productivity results for the impact of changes in the network reliability output (ENS) in 2021. We note in section 3.2 the impact on productivity growth if reliability is not included as an output, and show that reliability had a large and positive contribution to TFP change in 2021. However, we consider that reliability is an important output that should be included in the benchmarking despite the fact it can change significantly from year to year. We also note that due to this variability, the reliability output weight has been capped at 2.5% of total revenue to remove any undue influence.[26]

Improvement measurement and data for benchmarking

Powerlink noted that given the AER's Network Information Requirements Review is already underway, it would welcome the opportunity to work with the AER to ensure:

- measurement issues that have been identified as part of the benchmarking process can be addressed
- data series that better capture the range of services provided by networks can be collected through annual reporting requirements.[27]

As outlined in section 1.2, we agree that these are important development issues and have outlined some of the matters we will consider in this space.

24 Powerlink, *Email to the AER – Follow up questions on Powerlink's 2020-21 EB RIN data*. Received 17 May 2022.

25 Powerlink, *Email to the AER – Follow up questions on Powerlink's 2020-21 EB RIN data*. Received 29 August 2022.

26 This is described in section 1 and in further detail in the supplementary documentation of the Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report, November 2022,* p. 59-60.

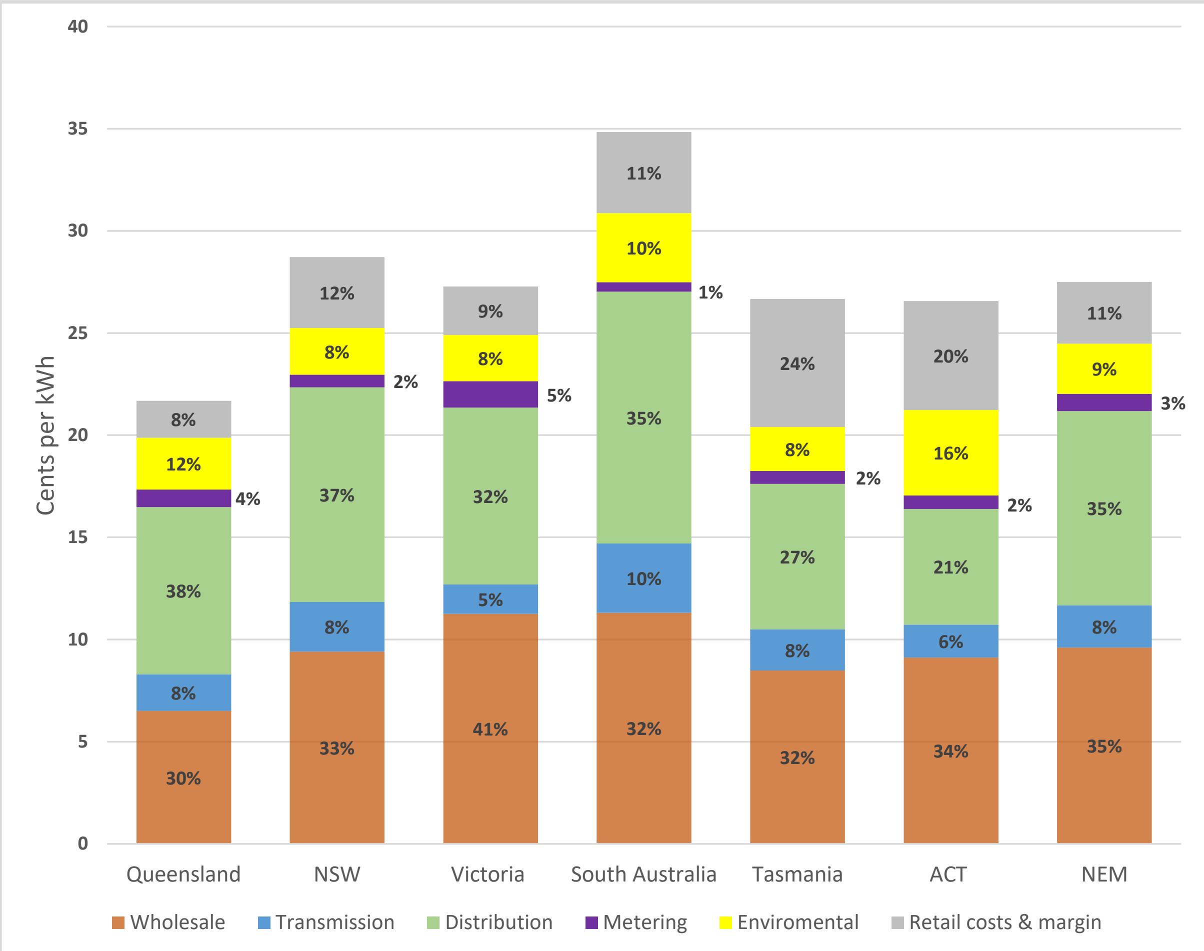
27 Powerlink, *Email to the AER – Preliminary Annual Benchmarking Report 2022 – Electricity transmission network service providers – Consultation stage 1*. Received 29 August 2022.

2 Economic benchmarking and its uses

Electricity networks are 'natural monopolies', which do not face the typical commercial pressures experienced by firms in competitive markets. Unregulated network operators could increase their prices above efficient levels and would face limited pressure to control their operating costs or invest efficiently. As a result, electricity networks are regulated, and economic benchmarking is one tool we use to examine how efficiently they are operating.

Consumers pay for electricity network costs through their retail electricity bills. Transmission network costs typically account for between 5 to 10% of what consumers pay for their electricity while distribution costs account for around one-third of the total bill in most jurisdictions.[28] The remainder covers the costs of generating, and retailing electricity, as well as various regulatory programs related to environmental policies. Figure 4 provides an overview of the typical electricity retail bill.

Figure 4 Network costs as a proportion of retail electricity bills, 2021



Source: AEMC, *Residential electricity price trends 2021, Final Report*, December 2021.

Note: Figures may differ slightly from the source due to rounding.

[28] AEMC, *Residential electricity price trends 2021, Final Report*, December 2021.

Under the National Electricity Law (NEL) and the NER, the AER regulates electricity network revenues with the goal of ensuring that consumers pay no more than necessary for the safe and reliable delivery of electricity services. This is done through a periodic regulatory process (known as revenue determinations or resets) which typically occurs every five years. The electricity network provides the AER with a revenue proposal outlining its forecast expenditures or costs over the following five-year period.

The AER assesses and, where necessary, amends the proposal to ensure it reflects efficient costs. On this basis, the AER then sets the network's revenue allowance for the five-year period, which is the maximum amount the network can recover from their customers.

In 2012, the Australian Energy Market Commission (AEMC) amended the rules to strengthen the AER's power to assess and amend network expenditure proposals.[29] The rule changes were made in response to concerns raised by the AER and other industry participants that restrictions in the NER had resulted in increases in capital and opex allowances of network service providers (NSPs) that were not necessarily efficient and resulted in higher charges for consumers.[30]

The rule changes required the AER to develop a benchmarking program to measure the relative efficiency of all electricity networks in the NEM and to have regard to the benchmarking results when assessing capital expenditure (capex) and opex allowances for network TNSPs. The rules also required the AER to publish the benchmarking results in an annual benchmarking report.[31]

2.1 The uses of economic benchmarking

The AER uses economic benchmarking in various ways when assessing and amending network revenue proposals.[32] We use it to measure the efficiency of network opex, capex and total expenditures, and changes in the efficiency of these expenditures over time. This gives us an additional source of information on the efficiency of historical network opex and capex and the appropriateness of basing forecasts on them.

29 AEMC, *Rule Determination, National Electricity Amendment (Economic Regulation of Network Service Providers) Rule 2012; National Gas Amendment (Price and Revenue Regulation of Gas Services) Rule 2012*, 29 November 2012, p. vii.

30 AEMC, *Rule Determination*, *National Electricity Amendment (Economic Regulation of Network Service Providers) Rule 2012; National Gas Amendment (Price and Revenue Regulation of Gas Services) Rule 2012*, 29 November 2012, p. vii.

31 NER, cll. 6A.31(a) and 6A.31(c).

32 The benchmarking presented in this report is one of a number of factors we consider when making our revenue determinations. For a revenue determination, we examine the efficiency of an individual TNSPs forecast opex and capex. In this report we primarily examine the overall efficiency of transmission networks. Though the efficiency of networks as a whole is relevant to our determinations, we also undertake further analysis when reviewing opex and capex forecasts.

We also use benchmarking to understand the drivers of trends in network efficiency over time and changes in these trends. This can help us understand why network productivity is increasing or decreasing and where best to target our expenditure reviews.[33]

The benchmarking results also provide network owners and investors with useful information on the relative efficiency of the electricity networks they own and invest in. This information, in conjunction with the financial rewards available to businesses under the regulatory framework, and businesses' profit-maximising incentives, can facilitate reforms to improve network efficiency that can lead to lower network costs and retail prices.

Benchmarking also provides government policy makers (who set regulatory standards and obligations for networks) with information about the impacts of regulation on network costs, productivity and ultimately electricity prices. Additionally, benchmarking can provide information that may contribute to the assessment of the success of the regulatory regime over time.

Finally, benchmarking provides consumers with accessible information about the relative efficiency of the electricity networks they rely on. The breakdown of inputs and outputs driving network productivity in particular, allows consumers to clearly see which factors are driving network efficiency and the network cost component of their retail electricity bills. This helps to inform their participation in our regulatory processes and in broader debates about energy policy and regulation.

2.2 Limitations of benchmarking transmission networks

While transmission networks have undertaken cost benchmarking for several years, top-down (whole-of-business) benchmarking of electricity transmission networks is a developing area. We are aware there have been ongoing studies on transmission. For example, European regulators, through the Council of European Economic Regulators have periodically conducted benchmarking studies of electricity and gas transmission system operators in Europe since 2005.[34] There has been greater use of TNSP benchmarking by economic regulators since 2014, but we consider that transmission benchmarking is still less developed than distribution benchmarking. The small number of electricity transmission networks in Australia (five) also makes efficiency comparisons at the aggregate level difficult.

When undertaking economic benchmarking, it is important to recognise that TNSPs operate in different environments and subsequently there is diversity amongst TNSPs. Certain factors arising from a TNSPs operating environment are beyond its control. These 'operating environment factors' may influence a TNSPs costs and, therefore, its benchmarking performance. The benchmarking techniques presented in this report capture key operating environment factors. For example, the MTFP analysis includes as outputs a TNSPs circuit length, number of end users, ratcheted maximum demand and energy throughput, and by doing so we also allow for key network density measures, including throughput per kilometre

33 AER, *Explanatory Statement - Expenditure Forecast Assessment Guideline*, November 2013, pp. 78–79.

34 Economic Insights, *Economic Benchmarking Results for the Australian Energy Regulator's 2021 TNSP Annual Benchmarking Report*, November 2021, pp. 3-4.

and maximum demand per customer. However, not all operating environment factors can be captured in the models. The small number of electricity transmission networks in Australia (five) also makes efficiency comparisons at the aggregate expenditure level difficult.

However, we consider the benchmarking analysis presented in this report is reasoned and comprehensive. We have consulted with industry participants to refine our transmission benchmarking as part of our ongoing development work program and, as outlined in section 1.2, will continue to do so.[35] We have also collected data on all major inputs and outputs for TNSPs, and we consider that the dataset used is robust.

[35] In 2017, we reviewed the output specifications of our transmission benchmarking models. Among the issues we considered were the measure of customer connections and the weighting of network reliability. A more detailed description of the updated TNSP benchmarking specifications, stakeholder comments and our rationale for the changes can be found here.

3 The productivity of the electricity transmission industry as a whole

Key points

- Electricity transmission industry productivity as measured by MTFP for time series analysis decreased slightly by 0.3% over 2021.
- An increase in the capital input for overhead line capacity, combined with an increase in opex input and a fall in the output measure of Energy throughput (GWh) were the main drivers for the productivity decrease over 2021. These were partially offset by improvement in network reliability and reduction in transformer capacity.
- The slight decrease in electricity transmission industry productivity over 2021 was similar to the slight decline (0.2%) in productivity in the overall Australian economy over the same period and was better than the 5.0% decline for the utilities sector.
- Transmission industry TFP has decreased over the period 2006–21, with the long-term decline in capital partial factor productivity (PFP) largely driving this result.
- An improvement in transmission productivity from 2016 to 2020 can be linked to reductions in opex as reflected by improved opex PFP. In 2021, the trend of declining opex was not observed and the increase in opex inputs contributed to the decline in TFP.

We present below TFP results for the electricity transmission industry over the 2006–21 period and for the 12-month period 2021. We also set out the input and output drivers, and their contribution to the industry-wide productivity change in 2021, as well as the major input and output contributions to the change in productivity for each TNSP level. The variability in productivity from year-to-year can be seen in the results below and emphasises the importance of considering the changes in productivity in 2021 in the context of longer-term trends.

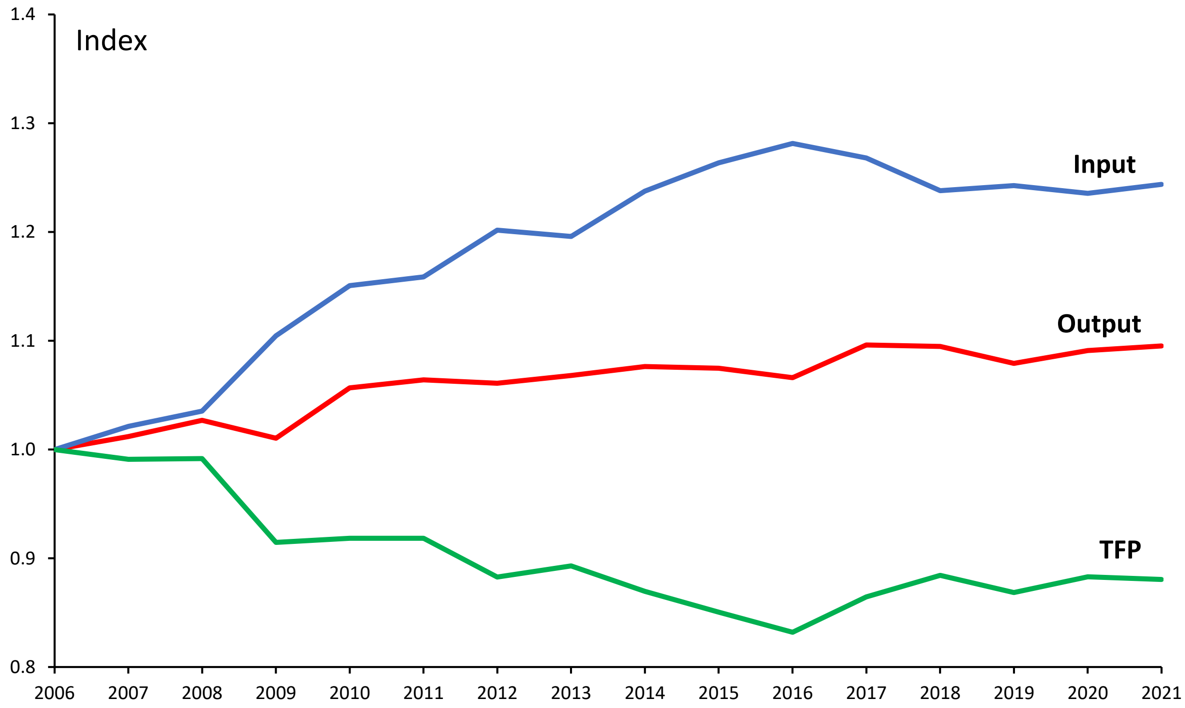
3.1 Transmission industry productivity over time

Figure 5 presents TFP for the electricity transmission industry over the period 2006–21. Over this 16-year period, input use grew faster (1.5% per year on average) than outputs (0.6% per year on average). This resulted in a decline in long-term TFP by 0.8% per annum on average.[36] There was an improvement in transmission industry productivity in 2017, 2018 and 2020, while there were declines in 2019 and 2021. Transmission productivity in these years were only slightly below the 2018 and 2020 levels. In 2021, the decline in productivity

[36] This is based on logarithmic endpoint-to-endpoint growth, using logarithmic difference method to calculate the annual average rate of growth. We have followed the Quantonomics report to report log-difference annual growth rates by periodical percentage change in productivity indexes. As for individual inputs and outputs, as well as partial performance indicators, we have referred to the percentage change calculation for both annual and periodical rate of change.

(by 0.3%) was the result of an increase in input growth (0.7%) which exceeded the growth in outputs (0.4%).

Figure 5 Transmission industry input, output and TFP indices, 2006–21



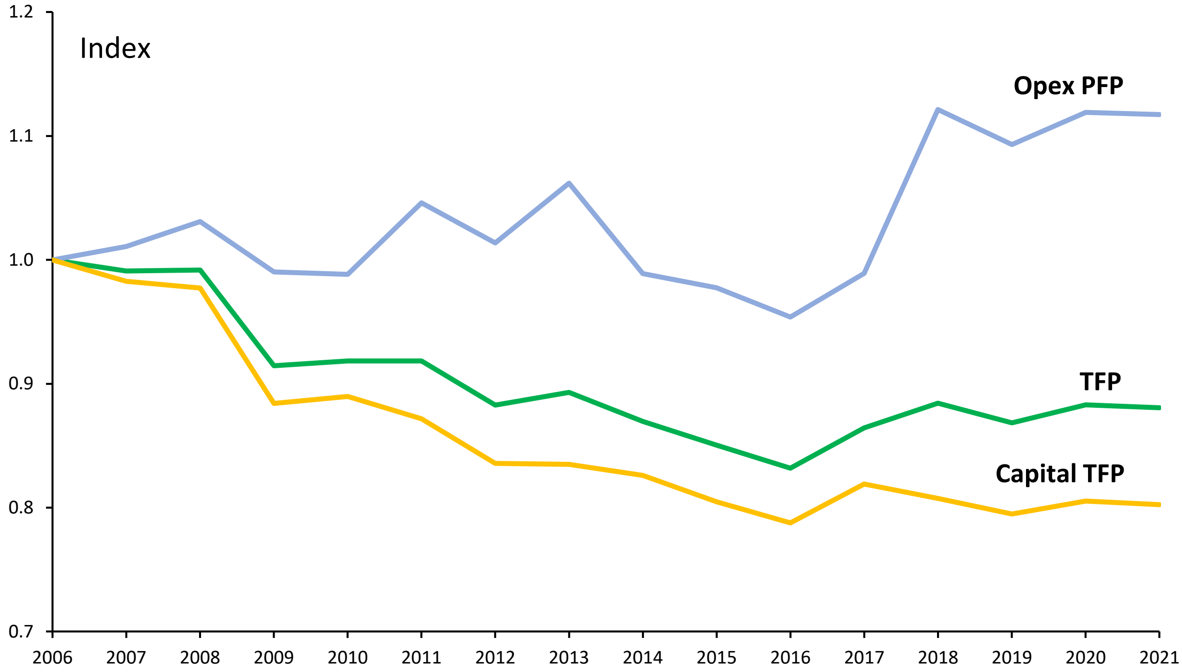
Source: Quantonomics.

Figure 6 shows that the long-term decline in capital PFP is largely driving this long-term reduction in transmission network productivity. Over the last 16 years (2006–21), capital PFP declined at average annual rate of 1.5% compared to opex PFP which grew at an average annual rate of 0.7%. The improvement in transmission productivity from 2016 can be primarily linked to the increase in opex PFP, although stabilisation of capital PFP also contributed to the improvement (that is, less growth in capital assets compared to earlier years). Figure 6 shows that opex PFP increased significantly over 2017 and 2018 and capital PFP fluctuated but increased in 2017 and 2020. In 2021, opex PFP fell by 0.1% and capital PFP by 0.4% to contributing to the decline of 0.3% growth in TFP.

Figure 7 compares the TFP of the electricity transmission industry over time relative to estimates of the overall Australian economy and utilities sector[37] productivity. Over the past 16 years, declining productivity in the electricity transmission industry was broadly consistent with the utilities sector, although the average annual rate of decline of 0.8% was not as low as the decline in average annual growth reported for the utilities sector which of 2.1%. In contrast, the Australian market economy's productivity grew slightly over the 2006–21 period with an average annual growth of 0.1%, noting that in 2021 TFP for the economy fell by 0.2%.

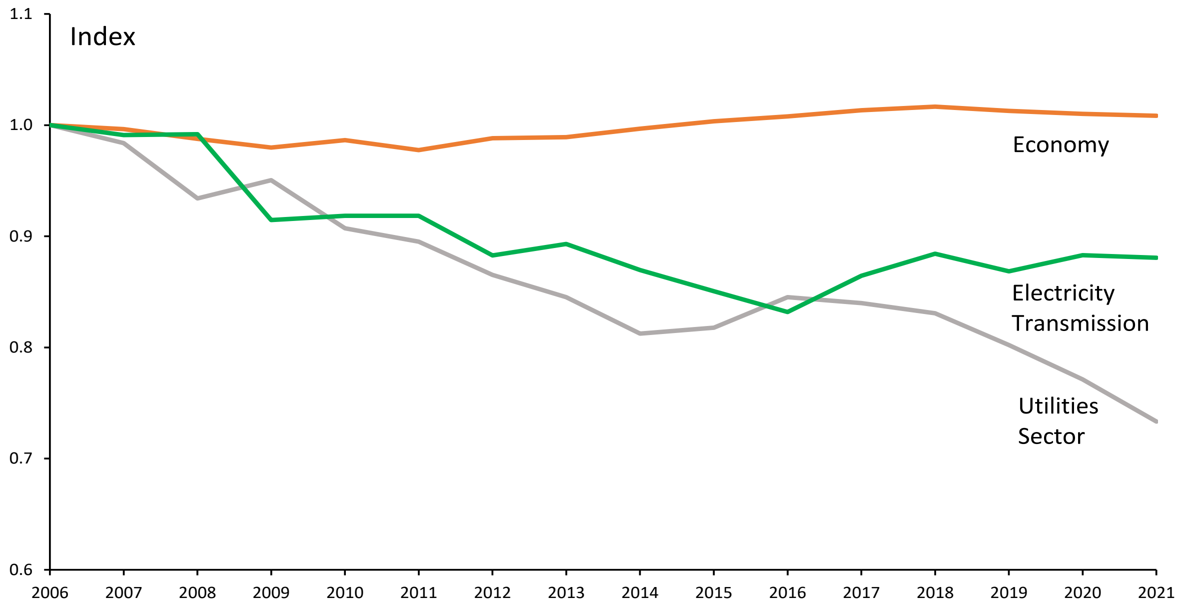
[37] Electricity, gas, water and waste services (EGWWS).

Figure 6 Transmission industry opex PFP and capex PFP, 2006–21



Source: Quantonomics.

Figure 7 Electricity transmission industry, utilities sector, and economy productivity indexes, 2006–21



Source: Quantonomics; Australian Bureau of Statistics

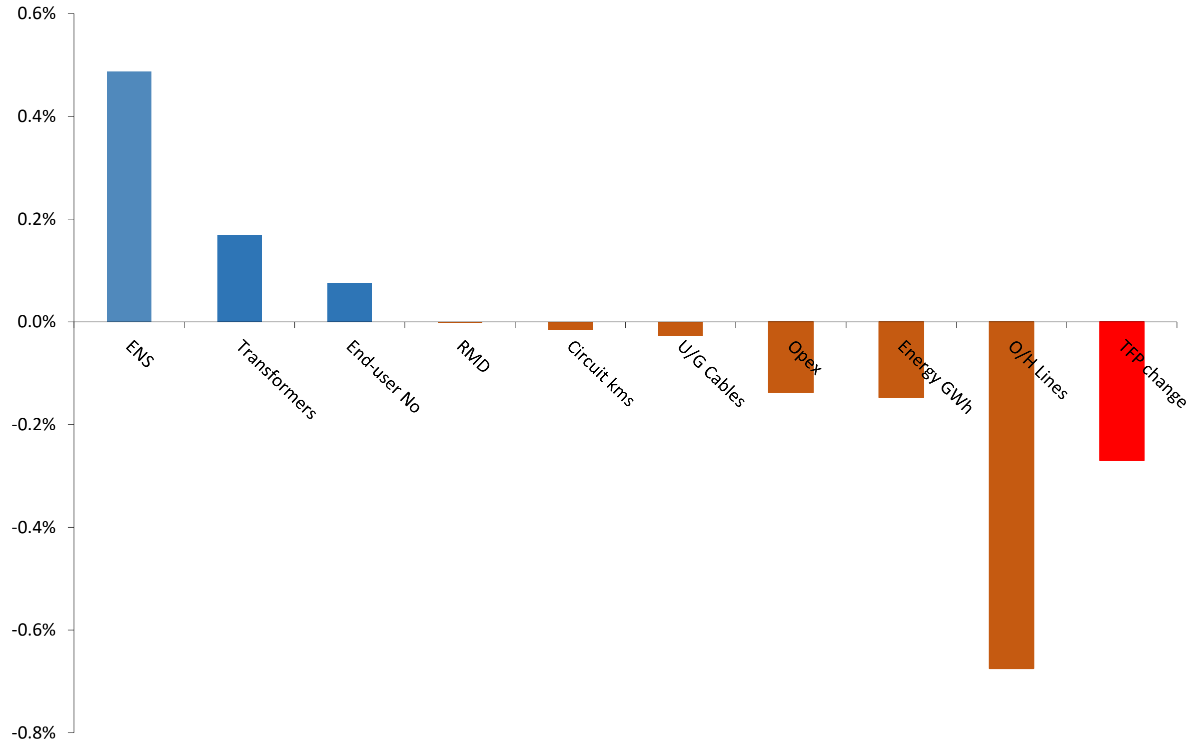
Note: The productivity of the Australian market economy and the utility industry is from the ABS indices within 5260.0.55.002 Estimates of Industry Multifactor Productivity, Australia, Table 1: Gross value added based multifactor productivity indexes (a). We have rebased the ABS indices to 1 in 2006.

3.2 Transmission industry productivity over 2021

Transmission industry TFP decreased by 0.3% over 2021.

Figure 8 shows the drivers of change in electricity transmission productivity over 2021 by showing the contributions of each output and each input to the change in TFP. The contributions appear from the most positive on the left to the most negative on the right. If all the positive (blue bars) and negative contributions (orange bars) in Figure 8 are added together, they sum to the TFP change given by the red bar on the right of the figure.

Figure 8 Transmission industry output and input percentage point contributions to annual TFP change, 2021



Source: Quantonomics.

Figure 8 shows that the primary driver of decreased productivity for the transmission industry in 2021 was the increase in overhead line capital input. This in isolation contributed a 0.7 percentage point decrease to the growth rate of TFP. The increase in overhead lines input was largely driven by an increase in TransGrid's overhead lines in one asset class which was due to both a change from summer to winter ratings (a variation in measurement of capacity reflecting when the maximum demand occurred[38]) and removal of particular line constraints (see section 3.2.1 for further discussion). A sensitivity analysis shows that the impact of these changes is significant and that industry TFP growth for 2021 (-0.3%) would have been 0.5% had there been no change in TransGrid's overhead line input (and capacity) from 2020 and its summer ratings were used.[39] As discussed in section 1.2, the variability in overhead line inputs depending on whether summer or winter ratings are used is one issue we consider should be examined in relation to improving the measurement of inputs.

Other drivers of reduced transmission industry TFP in 2021 included the reduction in the output for energy throughput (GWh) and the increase in the opex input, both negatively contributing 0.1 percentage points, respectively.

Partially offsetting the negative contributions to productivity change in 2021, was improved network reliability (reduction in ENS). This in isolation positively contributed 0.5 percentage points to the growth rate of TFP. ENS enters the total output index as a negative output such that a reduction in ENS represents an improvement in reliability and a higher level of service for end users. Conversely, an increase in ENS reduces total output as end users are inconvenienced more by not having supply over a wider area and/or for a longer period. In 2021, reliability improved as there was a reduction in ENS. The growth of TFP for the transmission industry in 2021 excluding ENS was significantly lower than when ENS is included (-0.8% and -0.3%, respectively).[40] The drivers of this change in reliability at a TNSP level are discussed below and reflect the improved reliability performance of four of the five TNSPs, with large improvements in network reliability for AusNet, ElectraNet and TransGrid. Powerlink was the only network to report a decrease in network reliability (i.e. an increase in ENS) for 2021.

In addition to improved network reliability, minor positive contributions to transmission industry TFP in 2021 included a reduction in transformer capacity and an increase in end-user numbers, contributing 0.2 and 0.1 percentage points, respectively.

3.2.1 Individual TNSP contributions to productivity growth over 2021

Table 1 presents the industry's and each TNSPs TFP growth in 2021, and decomposition into the individual input and output contributions that were most material to this growth. In this light, we have focused on ENS, transformers, opex, overhead lines, and energy throughput contributions given their materiality in driving TFP growth in 2021.

38 Under our benchmarking information requirements, the overhead line input takes account of both the length of lines and the overall 'carrying capacity' of the lines. In relation to the carrying capacities, TNSP's must provide these in terms of summer maximum demands for summer peaking assets and winter maximum demands for winter peaking assets. If the TNSP's peak has changed, the peak rating in a given year should be applied e.g. if there is a change from summer to winter in a given year the winter rating should be applied.

39 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report*, November 2022, pp. 66-67.

40 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report*, November 2022, p. 10.

Table 1 Selected input and output contributions to TFP growth rates by TNSP, 2021

	Annual change in TFP (%)	Energy not supplied (ppts)	Transformers (ppts)	Opex (ppts)	Overhead lines (ppts)	Energy Throughput (ppts)
Transmission industry	-0.3	0.5	0.2	-0.1	-0.7	-0.1
AusNet	4.8	2.0	0.1	2.4	0.0	0.3
ElectraNet	0.9	2.6	-1.9	0.5	-0.1	-0.3
TasNetworks	0.4	1.5	0.3	-2.2	0.0	0.6
TransGrid	-0.8	2.0	0.3	-0.7	-2.0	-0.3
Powerlink	-1.9	-1.9	0.6	-0.8	0.4	-0.4

Source: Quantonomics

The productivity of three TNSPs as measured by TFP growth improved in 2021 (AusNet, ElectraNet and TasNetworks) while that of two TNSPs (Powerlink and TransGrid) declined. The productivity of AusNet, ElectraNet, and TasNetworks grew over 2021 by 4.8%, 0.9% and 0.4%, respectively.

A reduction in opex was a key driver of AusNet's TFP growth in 2021 of 4.8%, making a positive 2.4 percentage point contribution. AusNet reported a reduction in opex of 9.4% in 2021 compared to its level in 2020. This was driven by a range of factors including reductions in network operating activities as an outcome of outsourcing, slower vegetation management mobilisation due to wet weather and lower corporate costs.[41] AusNet also reported a significant improvement in reliability, with ENS decreasing in 2021 by 93.6% relative to its level in 2020. This was because AusNet did not have significant outage events in 2021 as compared to the previous years (2019 and 2020).[42] As a result, ENS made the second largest positive contribution to AusNet's TFP change at 2.0 percentage points.

ElectraNet's TFP productivity growth in 2021 of 0.9% was largely driven by improved reliability (reduced ENS), which made the largest positive contribution of 2.6 percentage points. ElectraNet experienced improved weather conditions, resulting in a reduced number of connection point supply interruptions in 2021 compared to 2020.[43] The positive contribution of improved reliability was partly offset by an increase in the transformers input, which has a negative contribution of 1.9 percentage points. This was due to the addition of six transformers (6 MVA) to ElectraNet's network.[44]

TasNetworks' productivity as measured by TFP increased slightly in 2021 by 0.4%. Improved reliability made the largest contribution of 1.5 percentage points to TasNetworks' TFP

41 AusNet, *Email to the AER – follow up questions on AusNet's 2020-21 EB RIN data*. Received 31 March 2022.

42 AusNet, *Email to the AER – follow up questions on AusNet's 2020-21 EB RIN data.* Received 14 September 2022.

43 ElectraNet, *Email to the AER – follow up questions on ElectraNet's 2020-21 EB RIN data*. Received 19 May 2022.

44 ElectraNet, *Email to the AER – follow up questions on ElectraNet's 2020-21 EB RIN data*. Received 12 April 2022.

change. This was due to a reduction in the duration and frequency of outage events in 2021 for TasNetworks compared to 2020, when its ENS was impacted by extreme weather events.[45] An increase in energy throughput (GWh) also has a positive contribution of 0.6 percentage points to TasNetworks' TFP change. This was driven by an increase in consumption by directly connected customers largely for the 11 and 6.6 kV voltage levels.[46] Offsetting the positive contributions, was an increase in opex which was the only negative contribution (-2.2 percentage points) to TasNetworks' productivity in 2021. TasNetworks reported that this was due to increases in operational costs for field operations and maintenance and asset management support driven by an increase in preventative maintenance activities in 2021.[47]

TransGrid's productivity as measured by TFP declined in 2021 by 0.8%. The increase in the capital input for overhead lines was the largest negative contribution of 2.0 percentage points to TransGrid's TFP change. As discussed in section 1.2 and above, TransGrid reported that the increase in overhead line capacity was linked to seasonal capacity, which for an asset class changed from summer to winter capacity for 2021, and the removal of particular line constraints in this asset class.[48] Overhead capacity is measured as MVA kilometres, and the increase in the input for this asset class is driven by the higher winter peak, and capacity, given the constant kilometres of overhead lines. Therefore, which while an increase in the input, it also reflects greater utilisation of the existing assets in this class. A sensitivity analysis for the overhead line capacity input shows that had there been no change in TransGrid's overhead line input (and capacity) from 2020, and its summer peak was used, TransGrid's TFP growth in 2021 would have been an increase of 1.2% instead of a decline of 0.8%.[49]

Increases in opex also led to TransGrid's productivity decline, negatively contributing 0.7 percentage points. This was driven by increases in operational costs for the 2023–28 revenue proposal, insurance premiums, human resource and health, safety and environment training and information technology related costs.[50] Offsetting these negative contributions was an improvement in reliability (i.e. reduction in ENS) which has the largest positive contribution (2.0 percentage points) to TransGrid's productivity. TransGrid noted that seven loss of supply events occurred over 2020 with the largest event resulting in 145 MWh of unsupplied energy, compared to the five events over 2021 with the largest event reported as

[45] TasNetworks, *Email to the AER – follow up questions on TasNetworks' 2020-21 EB RIN data*. Received 15 September 2022.

[46] TasNetworks, *Email to the AER – follow up questions on TasNetworks' 2020-21 EB RIN data*. Received 11 April 2022.

[47] TasNetworks, *Email to the AER – follow up questions on TasNetworks' 2020-21 EB RIN data*. Received 13 April 2022.

[48] TransGrid, *Email to the AER – follow up questions on TransGrid's 2020-21 EB RIN data*. Received 11 April 2022.

[49] Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report*, November 2022, pp. 66-67.

[50] TransGrid, *Email to the AER – follow up questions on TransGrid's 2020-21 EB RIN data*. Received 11 April 2022.

a loss of 3 MWh.[51] Lower transformer input also made a positive contribution of 0.3 percentage points.

Powerlink's productivity as measured by TFP declined in 2021 by 1.9%. A decrease in network reliability (i.e. increase in ENS) has the largest negative contribution of 1.9 percentage points to Powerlink's TFP change. Powerlink was the only TNSP to report a decrease in network reliability over 2021, with an increase in ENS to 160.85 MWh from 4.58 MWh in 2020. Powerlink reported that the significant increase in ENS was due to a single event in 2021.[52] The growth of TFP for Powerlink in 2021 excluding ENS is significantly improved compared to when ENS is included (-0.1% and -1.9%, respectively).[53] An increase in opex also has a negative contribution of 0.8 percentage points to Powerlink's TFP change in 2021. Powerlink reported that this was due to increases in operational costs related to field maintenance, refurbishments (of higher insulator replacement activities), insurance premiums and grid support.[54]

Partially offsetting the negative contributions to Powerlink's decline in productivity was a reduction in transformers and overhead line inputs. These positively contributed to Powerlink's TFP change by 0.6 and 0.4 percentage points respectively. Powerlink reported that the reduction in transformer inputs was due to a failure of a large transformer (375 MVA) and its removal from service and connection of a new generator (132 kV) at one of its 275/132kV substations, which changed the ratio of transformer capacity subgroups.[55] The decrease in overhead lines inputs was due to a failure in a 275kV cable, resulting in the temporary use of a 132kV line energised at 275kV.[56]

In terms of this change in overhead line capacity, Powerlink reported a reduction in the weighted average capacity for both the 132 and 275kV asset classes in 2021 compared to 2020 as a result of the reclassification of asset voltage classes. It also submitted that no change to the length of the 132 kV line was required as reported length for the 132 and 275kV lines was on an 'as constructed basis.[57] Due to the calculation of MVA km for the overhead line being based on actual operating voltage[58], the change in voltage class capacity is not matched by a change in voltage class length resulting in the input for these

51 TransGrid, *Email to the AER – follow up questions on TransGrid's 2020-21 EB RIN data.* Received 19 September 2022.

52 Powerlink, *Email to the AER – follow up questions on Powerlink's 2020-21 EB RIN data*. Received 14 September 2022.

53 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report*, November 2022, p. 38.

54 Powerlink, *Email to the AER – follow up questions on Powerlink's 2020-21 EB RIN data*. Received 14 April 2022.

55 Powerlink, *Email to the AER – follow up questions on Powerlink's 2020-21 EB RIN data*. Received 14 April 2022.

56 Powerlink note that the transmission network between Townsville and Cairns has some circuits that are rated for 275kV operation but are normally energised at 132kV. Powerlink, *Email to the AER – follow up questions on Powerlink's 2020-21 EB RIN data*. Received 14 April 2022.

57 Powerlink, *Email to the AER – follow up questions on Powerlink's 2020-21 EB RIN data*. Received 29 August 2022.

58 Powerlink 2020-21 EB RIN Basis of Preparation – Public, p. 32.

two voltage levels being lower in 2021. Our view is that both capacity and length for overhead lines should be matched in the asset classes reported. For this reason, a sensitivity analysis of Powerlink's overhead line capacity measures is included in the accompanying Quantonomics report.[59] This sensitivity analysis assumes no reclassification and no change in capacity rating for the two lines from the 2020 values while using the line lengths as reported. The results show a further decline of TFP growth in 2021 for Powerlink, from -1.9% to -2.3%, and slightly decline for the industry from -0.3% to -0.4%.

Four TNSPs (AusNet, ElectraNet, TransGrid and TasNetworks) achieved productivity change in 2021 at a rate that is greater than the average annual over the 2006–21 period (-0.8%). The full set of input and output contributions to TFP for the industry over the 2006–21 and 2020–21 periods can be found in the Quantonomics report.[60]

[59] Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Annual Benchmarking Report,* November 2022, pp. 67-69.

[60] Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Annual Benchmarking Report,* November 2022, pp. 9-21.

4 Relative efficiency of individual transmission networks

Key points

- TasNetworks continued to be the highest ranking TNSP as measured by MTFP in 2021 and had small productivity growth in 2021. TasNetworks has remained the top ranked TNSP since 2012, but we note that our transmission benchmarking does not account for all possible differences in operating environment factors.
- Three TNSPs (Ausnet, TasNetworks and ElectraNet) improved their productivity in 2021. In particular, AusNet's productivity increased significantly in 2021, following a decline in 2019, and is the highest it has been since 2006. ElectraNet's 2021 performance improved its productivity to the highest level since 2015.
- TransGrid's productivity was lower in 2021 compared to 2020, but significantly higher than its 2016 level. Powerlink's productivity was also lower in 2021 and similar to its 2018 level.
- The productivity of ElectraNet, Powerlink and TransGrid has deteriorated over the 2006–21 period.

Below we present the economic benchmarking results that we use to measure and compare the productivity of individual TNSPs over the period 2006–21 and for the 2021 regulatory year. We also provide our key observations on the reasons for changes in the relative productivity of each TNSP in the NEM. In particular:

- section 4.1 presents the results of the panel data MTFP benchmarking, which relates total inputs to total outputs and provides a measure of overall network efficiency relative to other networks. MTFP is the headline technique we use to measure and compare the relative productivity of individual TNSPs. This is supported by the corresponding partial productivity measures of opex and capital inputs.
- section 4.2 presents the PPIs, which provide a general indication of comparative performance in delivering one type of output.

Being a top-down analysis, the results discussed in this chapter, particularly the MTFP results, are only indicative of the TNSPs relative performance. While the analysis accounts for some factors that are beyond a TNSPs control, such as network density and some system structure factors, additional operating environment factors can affect a TNSPs costs and benchmarking performance. At this stage, and as noted in section 2.2, our transmission benchmarking analysis does not incorporate additional operating environment factors beyond the network density differences, which are incorporated via the output specification.

4.1 MTFP productivity results for TNSPs

Figure 9 presents the relative productivity levels of TNSPs as measured by MTFP over the 2006–21 period.[61] It shows a general clustering of four TNSPs below TasNetworks, which has been the outlier since around 2013 and 2014. In this regard we note that our transmission benchmarking does not account for all possible differences in operating environment factors.

Figure 9 also shows that three TNSPs recorded increases in productivity in 2021 (AusNet, TasNetworks and ElectraNet). Powerlink recorded the highest decline in productivity over the same period (-2.3%), primarily driven by a decrease in reliability due to the significant increase in ENS as a result of a single outage event for an extended duration (as noted in section 3.2.1).[62] TransGrid also experienced a slight decline in productivity over 2021 (-0.6%) and remained the lowest ranked TNSP as measured by MTFP (see also Table 2).

TasNetworks' productivity in 2021 is higher than at the start of the period in 2006, despite it declining since 2018. TasNetworks' productivity declined from 2006 to 2013 before trending up from 2014. The positive trend from 2015 likely reflects efficiencies resulting from the merger of Tasmanian distribution and transmission networks.[63] TasNetworks has remained the most productive TNSP since 2012. It is followed by ElectraNet and in a reasonably tight cluster, the other TNSPs.

The productivity of ElectraNet, TransGrid and Powerlink as measured by MTFP has generally fallen over the 16-year period as shown in Figure 9 and in each case is lower in 2021 than it was in 2006. ElectraNet's productivity increased in 2021, whereas the productivity for TransGrid and Powerlink decreased in 2021.

TransGrid's productivity improved over the period 2017 to 2019, before declining slightly in 2020 and 2021, while Powerlink's productivity improved in 2018, 2019 but declined in 2020 and 2021. ElectraNet's productivity has improved over the last three years (2019, 2020 and 2021).

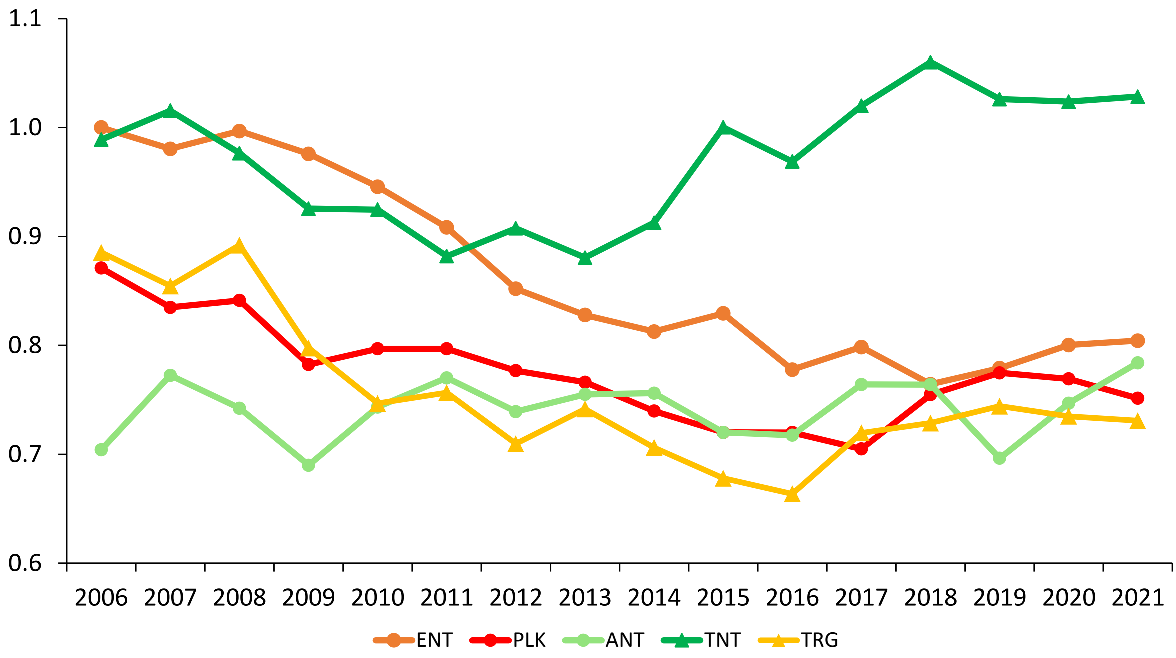
AusNet's productivity as measured by MTFP is 11.4% higher in 2021 than it was in 2006. Its MTFP performance improved in 2020 and 2021 following a significant decline in 2019 (due to a single network outage event). Over the period 2012 to 2018 AusNet's productivity was relatively stable with slight increases.

61 2006 is set as the base (i.e. index = 1.00).

62 Powerlink, *Email to the AER – follow up questions on Powerlink's 2020-21 EB RIN data*. Received on 14 September 2022.

63 TasNetworks was formed on 1 July 2014 from a merger between Aurora and Transend.

Figure 9 Electricity transmission MTFP indexes by TNSP, 2006–21



Source: Quantonomics.

Table 2 presents the MTFP rankings for individual TNSPs in 2020 and 2021, the change in rankings between 2020 and 2021, and the annual growth in productivity (as reflected by the change in their MTFP productivity scores) between 2020 and 2021.[64] It shows that TasNetworks and ElectraNet maintained their first and second rankings, while AusNet improved its ranking from fourth in 2020 to third in 2021. Powerlink ranking fell from third to fourth in 2021 and TransGrid remained in fifth ranking.

Table 2 TNSP MTFP scores, rankings and growth rate, 2020 and 2021

	Rank (2021)	Rank (2020)	MTFP Score (2021)	MTFP Score (2020)	Change between 2020 and 2021
TasNetworks	1	1	1.03	1.02	0.5%
ElectraNet	2	2	0.80	0.80	0.5%
AusNet	3↑	4	0.78	0.75	4.8%
Powerlink	4↓	3	0.75	0.77	-2.3%
TransGrid	5	5	0.73	0.73	-0.6%

Source: Quantonomics

In addition to MTFP, we also present the results of two MPFP models:

64 The rankings in this table are indicative only because, as outlined earlier, there may be other operating environment variables not captured in the MTFP model.

- Opex MPFP, which considers the productivity of the TNSPs' opex.
- Capital MPFP, which considers the productivity of the TNSPs' use of overhead lines, underground cables and transformers.

These partial productivity measures assist in interpreting the MTFP results by examining the contribution of opex and capital assets to overall productivity. They use the same output specification as MTFP but provide more detail on the contribution of the individual components of capital and opex to changes in productivity. However, they do not account for synergies between capital and opex like the MTFP model. As noted in section 1 these partial measures provide a way of gaining insight into the factors driving MTFP trends.

Figure 10 and Figure 11 present capital MPFP and opex MPFP results respectively for all TNSPs over the 2006–21 period.[65] AusNet achieved positive growth in 2021 in both capital MPFP and opex MPFP (2.7% and 13.9%, respectively). This is consistent with its overall 4.8% growth in MTFP in 2021. TasNetworks achieved a mixed outcome with positive growth in capital MPFP (3.0%) and a decline in their opex MPFP over 2021 (-7.9%). Conversely, ElectraNet achieved positive growth in opex MPFP (3.6%) but its capital MPFP declined over 2021 (-0.9%). Both Powerlink and TransGrid has negative growth in capital MPFP (-1.2% and -0.6%, respectively) and opex MPFP (-5.3% and -1.0%, respectively) consistent with their overall -2.3% and -0.6% growth in MTFP in 2021, respectively.

Figure 10 shows that capital productivity declined since 2006 for all TNSPs (by 18 to 27% in total between 2006 and 2021) except for AusNet where it remained broadly stable, increasing by 2.3% over the 16-year period. For all four TNSPs with declining capital MPFP, the average rate of decline was lower in the more recent period 2012 to 2021 than in the period from 2006 to 2012.

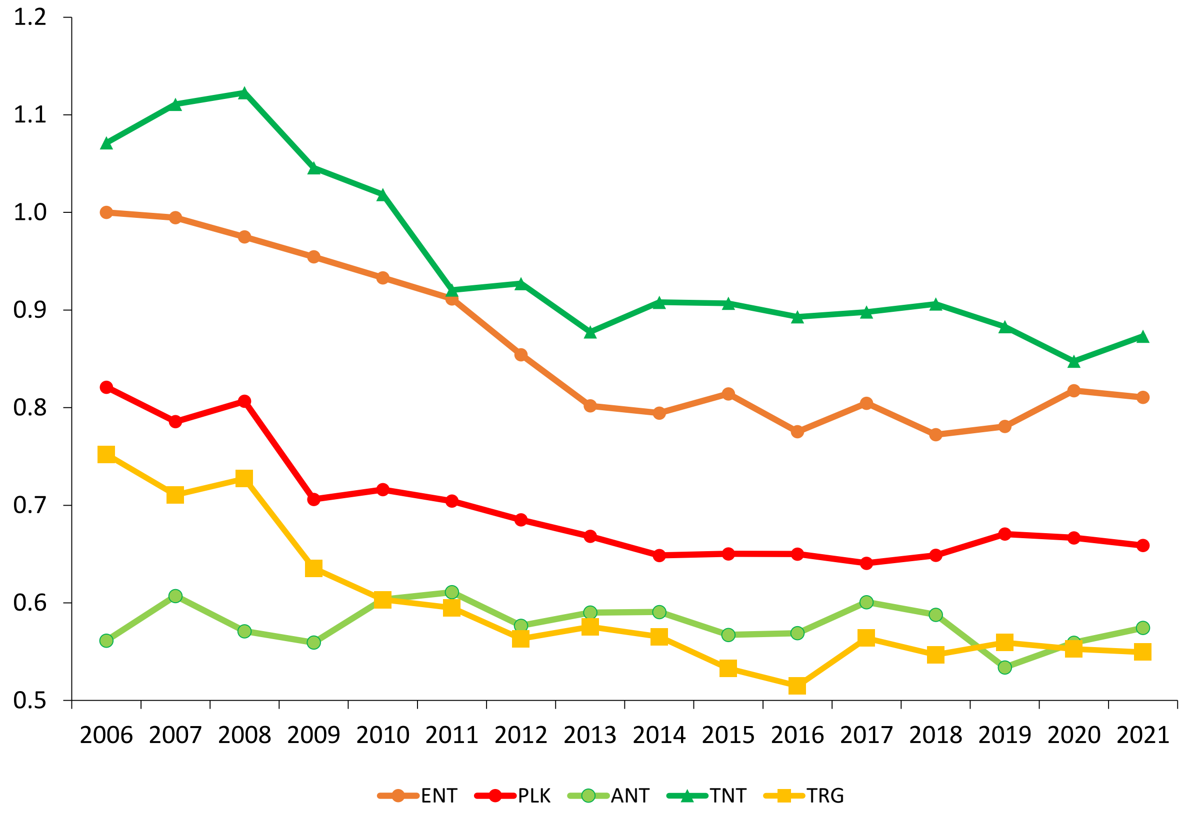
The slow and consistent decline in capital MPFP over time for those TNSPs other than AusNet is due to network capacity growing more than outputs as measured by customers, demand, line length and energy consumption. Although MTFP and MPFP models do not capture all operating environment factors, this continues to be a cause for concern.

TasNetworks has remained the highest ranked TNSP in terms of capital MPFP since 2006. We note that TasNetworks operates a relatively lower voltage transmission network compared to other TNSPs. Generally, TNSPs have networks with voltage class at 132kV and above, but the majority of TasNetworks transmission network is of 110kV and 220kV.

Figure 11 shows that in terms of opex MPFP over the 16-year period to 2021 AusNet, TasNetworks and TransGrid remained relatively higher performers and Powerlink and ElectraNet relatively lower performers. Despite recording the lowest opex MPFP at the start of the period, TasNetworks joined the higher performing TNSPs in 2015, with opex MPFP in 2021 higher than the 2006 level by 86.5%.

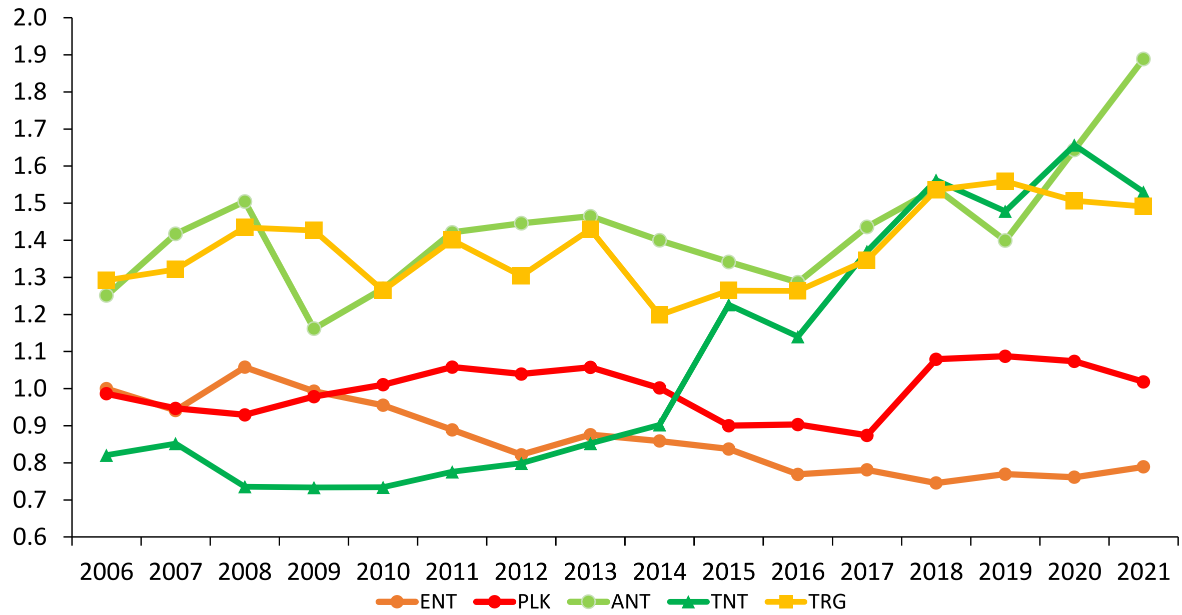
[65] ElectraNet in 2006 is set as the base (i.e., index = 1.00).

Figure 10 Capital MPFP index, 2006–21 ($2021)



Source: Quantonomics

Figure 11 Opex MPFP index, 2006–21 ($2021)



Source: Quantonomics

4.2 Partial performance indicator results of TNSPs

PPIs provide a simple representation of the input costs used to produce particular outputs. The PPIs used here support the MTFP analysis by providing a general indication of comparative performance in delivering one type of output. However, PPIs do not take interrelationships between outputs into account. Therefore, PPIs are most useful when used in conjunction with other top-down benchmarking techniques, such as MTFP.

The inputs we use are the TNSPs' total costs, made up of opex and asset costs. Asset cost is the sum of annual depreciation and return on the TNSPs' regulatory asset base, and benchmark tax liability under the building block model approach.[66] This measure has the advantage of reflecting the total cost of assets for which customers are billed on an annual basis, using the average return on capital over the period. This accounts for variations in the return on capital across TNSPs and over time.

The outputs we use are the number of end users, circuit line length, maximum demand served and energy transported (see Appendix B for further details). We examine each of these outputs below.

4.2.1 Total cost per end user

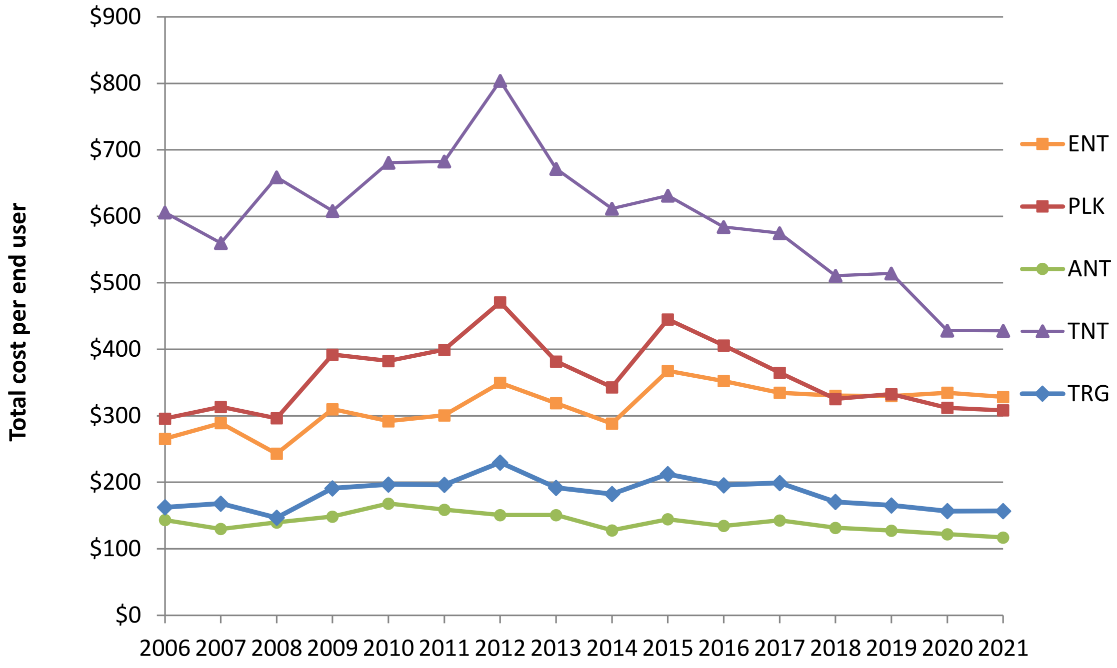
We present total cost per end user in Figure 12.[67] AusNet maintained the lowest total costs per end user in 2021. Conversely, TasNetworks continued to have the highest total costs per end user of all TNSPs, although its total cost per end user reduced significantly in 2020 which it maintained in 2021. Four of the five TNSPs (AusNet, ElectraNet, Powerlink and TasNetworks) recorded a modest decline in total cost per end user in 2021, AusNet has the largest decrease of 4.2%. TransGrid recorded a slight increase of 0.1% in 2021.

Total costs per end user for AusNet, TasNetworks and TransGrid are lower in 2021 than they were in 2006 (-18.4%, -29.4% and -3.4%, respectively). The opposite is the case for ElectraNet and Powerlink where total costs per end user are higher in 2021 than they were in 2006 (23.7% and 4.2%, respectively). This may be due to these TNSPs' costs (and mainly their asset costs, reflecting the growth in their regulatory asset bases) increasing faster than the increase in end users.

66 We have applied to the PPI calculations the same annual user cost of capital approach we applied to MTFP and MPFP analysis. As noted earlier, we have updated the calculation of the annual user cost of capital in 2020 and 2021 to reflect the AER's Rate of Return Instrument 2018. In previous years the annual user cost of capital calculations broadly reflected the 2013 rate of return guideline. See: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/rate-of-return-instrument-2018/final-decision.

67 This, and all PPI's presented below, are in dollar values as at the end of June quarter 2021.

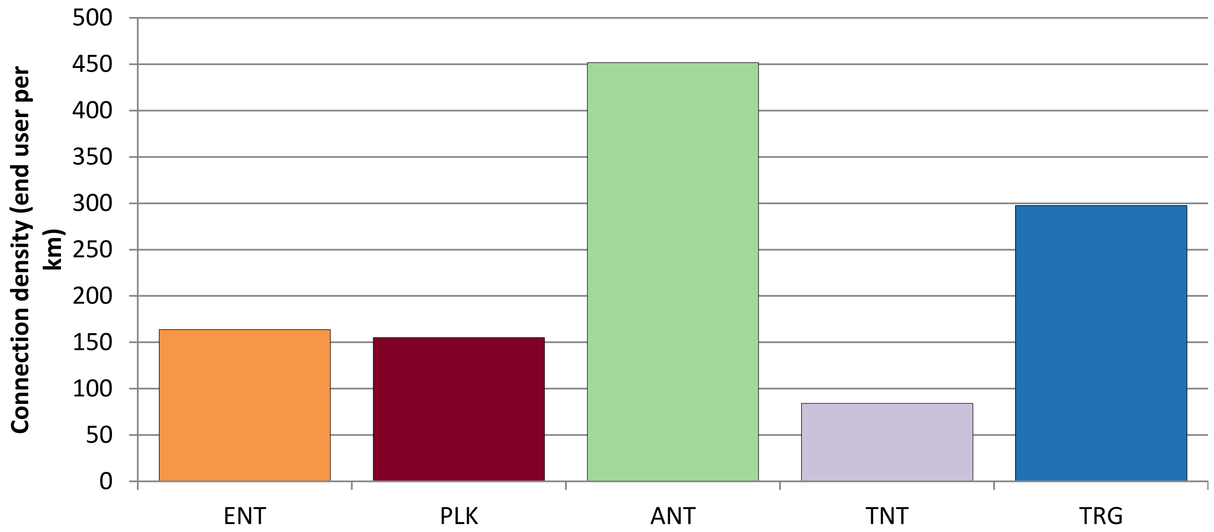
Figure 12 TNSP cost per end user, 2006–21 ($2021)



Source: Economic Benchmarking RINs; AER analysis.

We note the total cost per end user PPI potentially favours TNSPs with denser transmission networks (where density is measured in terms of end users per circuit kilometre). This is because denser transmission networks tend to have more customers per kilometre and hence are required to build and maintain fewer lines per end user connection point. The average connection density of TNSPs over 2017–21 is presented in Figure 13. This shows that AusNet has the highest average connection density, followed by TransGrid, ElectraNet, Powerlink and TasNetworks respectively. This is broadly consistent with the cost per end user rankings in Figure 12.

Figure 13 TNSP connection density (end user per circuit km, 2017–21 average)



Source: Economic Benchmarking RINs; AER analysis.

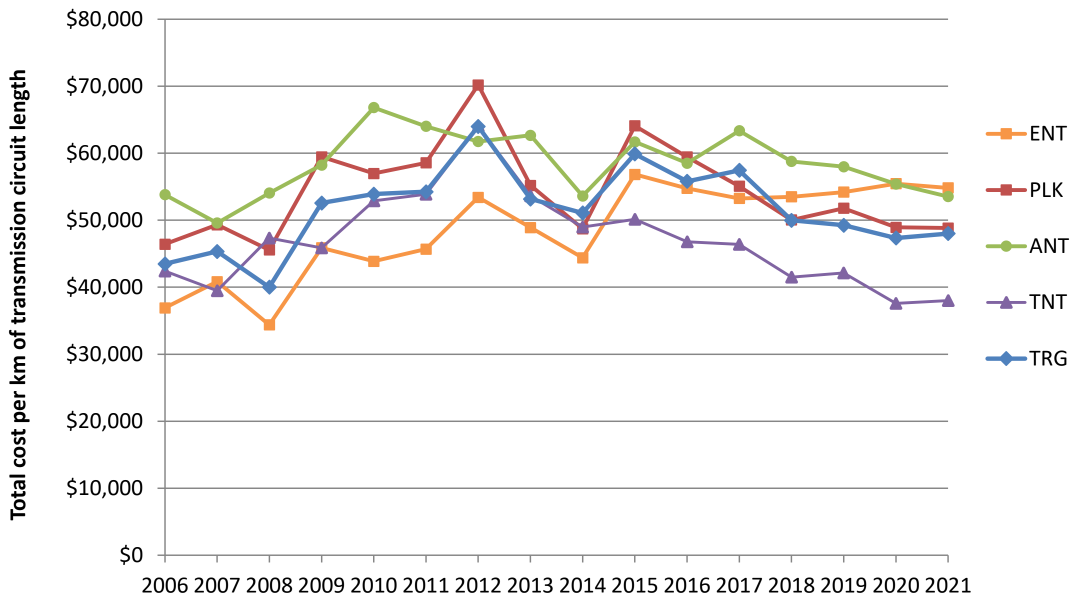
4.2.2 Total cost per km of transmission circuit length

In Figure 14 we can see that TasNetworks has the lowest cost per kilometre of circuit length in 2021, while ElectraNet has the highest cost per kilometre of circuit length (slightly above AusNet).

ElectraNet, Powerlink and TransGrid experienced growth in total costs per kilometre of transmission circuit length between 2006 and 2021. This is due to increases in annual user cost exceeding the growth in transmission circuit length. The largest increase in cost per kilometre of circuit length over this period was by ElectraNet (48.5%), followed by TransGrid (10.4%) and Powerlink (5.2%). TasNetworks and AusNet's cost per kilometre of circuit length in 2021 were 10.3% and 0.5% lower than their 2006 levels, respectively.

Since 2014 the difference in cost per km of transmission circuit length between the highest and lowest ranking TNSPs has widened, largely as a result of a sharp decline in costs by TasNetworks. For the other TNSPs, there was a step up in 2015 followed by a steady decline, such that in 2021 Powerlink and TransGrid's total cost per kilometre of transmission circuit length is at or below its 2014 level. In 2021, the difference between ElectraNet (highest cost per km of transmission circuit length) and TasNetworks (lowest cost per km of transmission circuit length) was $16 811 ($2021) whereas in 2014 the difference between AusNet (highest cost per km of transmission circuit length) and ElectraNet (lowest cost per km of transmission circuit length) was $9 227 ($2021).

Figure 14 TNSP total cost per km of transmission circuit length ($2021), 2006–21



Source: Economic Benchmarking RINs; AER analysis.

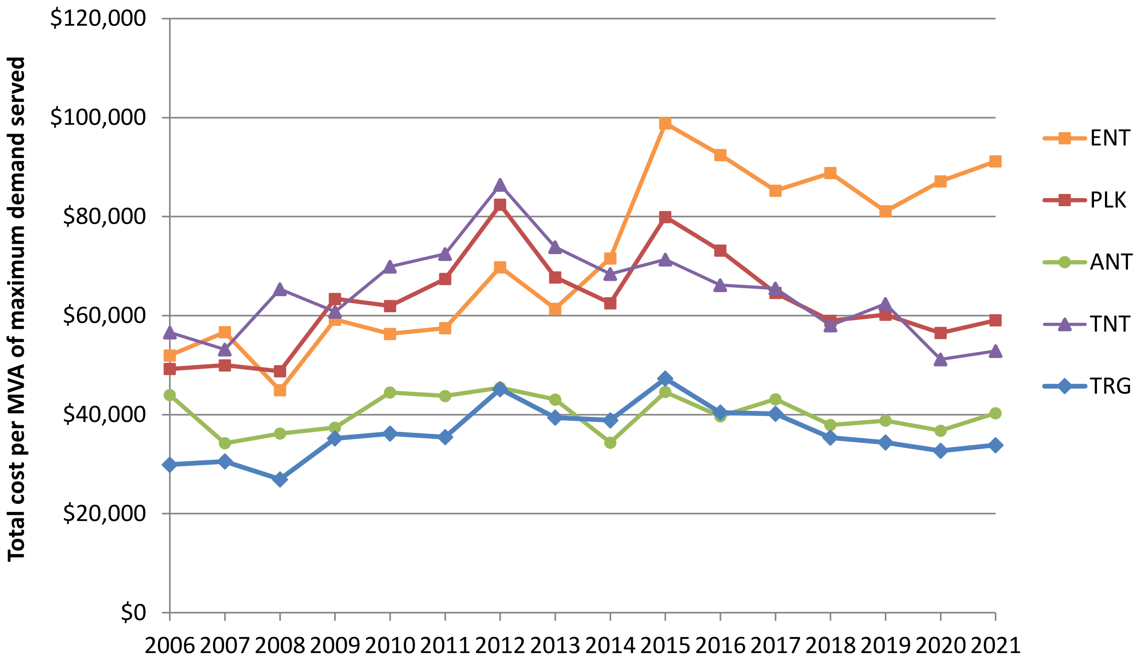
4.2.3 Total cost per Mega Volt Amp (MVA) of non-coincident maximum demand

Figure 15 shows TNSPs total costs per MVA of non-coincident maximum demand.

ElectraNet reported the highest cost per MVA of maximum demand in 2021. This follows large growth between 2013 and 2015 because of a substantial drop in maximum demand without an offsetting decrease in its total costs. ElectraNet's costs per MVA of maximum demand increased in the latest 12-month period by 4.6% (from $87 148/MVA ($2021) in 2020 to $91 168/MVA ($2021) in 2021), following a fall in 2019. Its costs per MVA in 2021 are approximately two and a half times greater than the two best performing networks, TransGrid ($33 840/MVA, ($2021)) and AusNet ($40 308/MVA, ($2021)).

Since 2006 three TNSPs have reported growth in total costs per MVA of maximum demand (ElectraNet, Powerlink and TransGrid). ElectraNet's total costs per MVA of maximum demand, largely due to the surge between 2013 and 2015, increased by 75.4% between 2006 and 2021. On the other hand, TransGrid and Powerlink have experienced a relatively smaller increase in total cost per MVA of maximum demand over the 2006–21 period (13.2% and 20.0% respectively) with all TNSPs showing steady reductions in recent years prior to 2021. Over the 2006–21 period, AusNet's costs have decreased by 8.3% to $40 308/MVA ($2021) and those of TasNetworks have decreased by 6.6% to $52 846/MVA ($2021).

Figure 15 TNSP total cost per MVA of maximum demand served ($2021), 2006–21



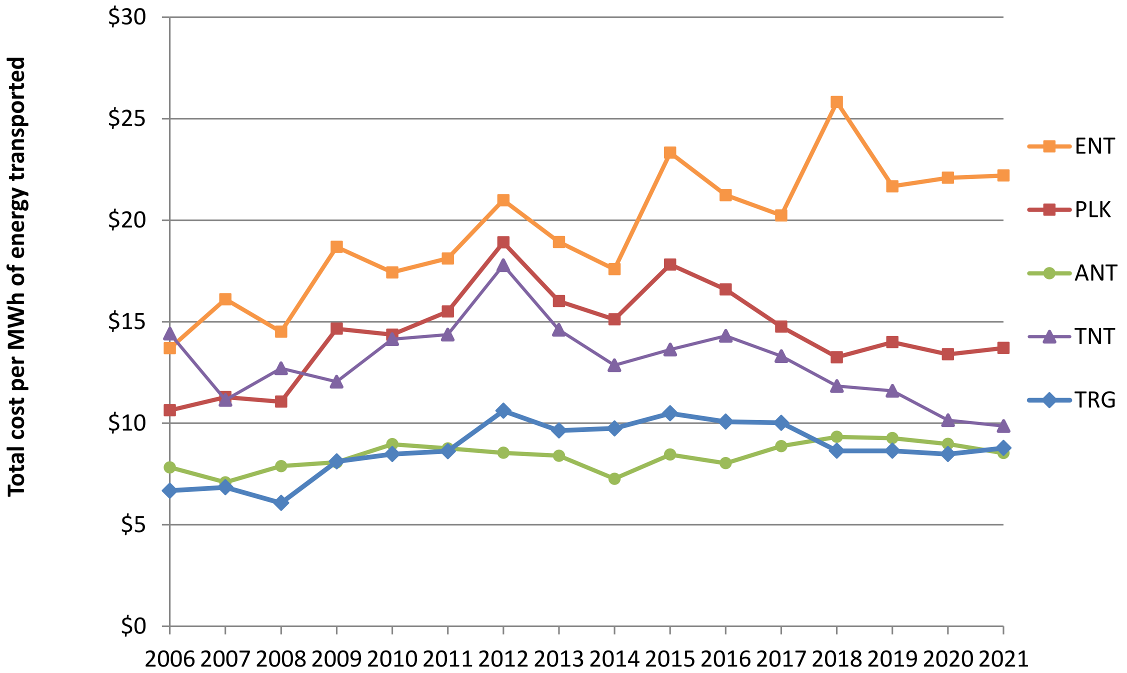
Source: Economic Benchmarking RINs; AER analysis.

4.2.4 Total cost per MWh of energy transported

As can be seen in Figure 16, ElectraNet recorded the highest cost per MWh of energy transported in 2021 at $22.20/MWh. ElectraNet's costs were two and a half times greater than the two best performing networks TransGrid ($8.78/MWh, ($2021)) and AusNet ($8.53/MWh, ($2021)).

Costs per MWh of energy transported have risen over the 2006–21 period for most TNSPs, except for TasNetworks. ElectraNet's costs per MWh of energy transported have risen by 62.1% over the 2006–21 period, whereas TransGrid, Powerlink and AusNet's costs have increased by 31.5%, 28.8% and 9.0% respectively. TasNetworks, on the other hand, experienced a decrease of 31.6% in costs per MWh of energy transported over the same period. ElectraNet's increase in costs per MWh has resulted in an increase in the gap between TNSPs since around 2014 and 2015.

Figure 16 TNSP total cost per MWh of energy transported ($2021), 2006–21



Source: Economic Benchmarking RINs, AER analysis.

4.3 Explaining differences between the MTFP and PPI results

In previous Annual Benchmarking Reports for transmission we have received feedback that the differences in the MTFP and PPI benchmarking results do not make sense. For example, AusNet noted that in three out of the four PPIs, it had either the lowest or second-lowest costs, but this is in contrast to the MTFP results where it ranks fourth.[68] While AusNet's MTFP performance improved in 2021, and it is now ranked third, we consider it is useful to provide a conceptual explanation of these differences.

We note that we use the top-down economic benchmarking for different purposes from the PPI analysis. The MTFP / MPFP benchmarking approach examines the efficiency in the use of inputs to produce total outputs where the TNSPs are multiple-input users and multiple-output producers. In contrast, the PPI analysis considers the efficiency of the input costs (i.e. total cost, opex and capital cost) used to deliver a particular output. We have used MTFP analysis as our primary tool to examine the overall efficiency and productivity of TNSPs while using the MPFP and PPI analysis as supporting tools to reveal potential sources of inefficiencies.

The MPFP and PPI analysis are partial as they examine a single input or output in isolation rather than a combination of inputs or outputs. Depending on the output considered, PPIs may favour TNSPs with certain network characteristics and thus need to be normalised for

68 AusNet, *Submission to the AER's 2021 draft Annual Benchmarking Report*, 20 October 2020, pp. 1-2.

density factors. We have found that PPIs measured in terms of circuit length tend to favour TNSPs with lower customer/connection density and PPIs measured on end user (or maximum demand, energy transported) tend to favour TNSPs with higher end user/demand/energy densities.

In terms of measurement, they differ in the following aspects:

- Using MTFP / MPFP, five outputs are measured and aggregated by output weighting based on cost share. As MTFP / MPFP measures a weighted average output quantity, it accounts for the combination of the five outputs rather than a single output at a time as under the PPIs. Under the PPIs, the per-unit cost is only measured in terms of one output. While AusNet is measured as having relatively low cost in terms of end user, maximum demand and energy transported PPI, it is found to incur the highest cost in terms of circuit length. When considering all the outputs together, AusNet's relative position changes depending on the weighting allocated to circuit length relative to other outputs. Under the corrected output weights, as updated in the 2020 Annual Benchmarking Report, the weight applied to circuit length is 52.8% of gross revenue. Ausnet considers this weight is too high and that it has an outsized impact on the results.[69] This issue of output weights will be subject to an independent review as outlined in section 1.2.
- Under the MTFP / MPFP analysis four inputs (i.e., opex, overhead lines, underground cables, transformers) are measured in terms of physical quantity. In contrast, the PPI analysis considers input costs (instead of quantities) and measures the opex and annual user cost of capital in real dollar value. The cost measure differs from the input quantity measure, particularly in relation to capital.[70] As the annual user cost of capital is measured as the sum of return on capital and depreciation, for TNSPs with the same physical quantity of capital inputs in place, their annual user cost of capital can differ substantially due to differences in asset valuation and prices actually paid, investment cycles and asset lives.

For the above reasons, we do not expect the MTFP / MPFP and PPI analyses to present the same or similar results. The use of the PPI analysis is to provide further insights into the efficiency performance of TNSPs.

We also note that our Annual Benchmarking Reports present cost-based PPI analysis rather than RAB-based PPI analysis. As with the annual user cost of capital measure, RAB values can differ substantially across TNSPs due to differences in asset valuation and prices, as well as asset age and lives.

69 Using the output quantity index from the MTFP analysis, AusNet's total cost per unit of total output is below the average for the other four TNSPs.

70 We consider that opex input prices and opportunity costs of capital can be expected to be similar between TNSPs.

Shortened forms

Shortened form	Description
AEMC	Australian Energy Market Commission
AER	Australian Energy Regulator
ANT	AusNet Services (transmission)
Capex	Capital expenditure
ENT	ElectraNet
MW	Megawatt
MVA	Mega Volt Amp
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
Opex	Operating expenditure
PLK	Powerlink
RAB	Regulatory asset base
RIN	Regulatory Information Notice
STPIS	Service target performance incentive scheme
TNSP	Transmission network service provider
TNT	TasNetworks (Transmission)
TRG	TransGrid

Glossary

Term	Description
Efficiency	A TNSPs benchmarking results relative to other TNSPs reflect that network's relative efficiency, specifically their cost efficiency. TNSPs are cost efficient when they produce services at least possible cost given their operating environments and prevailing input prices.
Inputs	Inputs are the resources TNSPs use to provide services.
MPFP	Multilateral partial factor productivity is a PIN technique that measures the relationship between total output and one input. It allows both partial productivity levels and growth rates to be compared between entities (networks).
MTFP	Multilateral total factor productivity is a PIN technique that measures the relationship between total output and total input. It allows both total productivity levels and growth rates to be compared between entities (networks). In this year's annual benchmarking report, we also apply the method to time-series TFP analysis at the industry level and for individual TNSP to better capture large ENS changes.
Prescribed transmission services	Prescribed transmission services are the services that are shared across the users of transmission networks. These capture the services that TNSPs must provide under legislation.
OEFs	Operating environment factors are factors beyond a TNSPs control that can affect its costs and benchmarking performance.
Opex	Operation and maintenance expenditure
Outputs	Outputs are quantitative or qualitative measures that represent the services TNSPs provide.
PIN	Productivity index number techniques determine the relationship between inputs and outputs using a mathematical index.
PPI	Partial performance indicator are simple techniques that measure the relationship between one input and one output.
Ratcheted maximum demand	Ratcheted maximum demand is the highest value of maximum demand for each TNSP, observed in the time period up to the year in question. It recognises capacity that has been used to satisfy demand and gives the TNSP credit for this capacity in subsequent years, even though annual maximum demand may be lower in subsequent years.
TFP	Total factor productivity is a PIN technique that measures the relationship between total output and total input over time. It allows total productivity changes over time or growth rates to be compared across networks. This method was used in previous annual benchmarking reports (up to 2019) to examine productivity change over time at the TNSP level and the industry level.
VCR	Value of Customer Reliability. VCR represents a customer's willingness to pay for the reliable supply of electricity.

A References and further reading

This benchmarking report is informed by several sources. This includes ACCC / AER research and expert advice provided by Quantonomics, and previously by Economic Insights as set out below.

Quantonomics publications

The following publication explains in detail how Quantonomics developed and applied the economic benchmarking techniques we used:

- Quantonomics Report – Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report, November 2022.

Economic Insights publications

The following publications explain in detail how Economic Insights, our previous consultant, developed and applied the economic benchmarking techniques we used:

- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy* Regulator's *2021 TNSP Benchmarking Report*, November 2021 (link)
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2020 TNSP Benchmarking Report*, 15 October 2020 (link)
- Economic Insights, AER Memo Revised 2019 TNSP EB Results, 24 August 2020
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2019 TNSP Benchmarking Report*, September 2019 (link)
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2018 TNSP Benchmarking Report*, November 2018 (link)
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2017 TNSP* Benchmarking *Report*, November 2017 (link)
- Economic Insights, *Memorandum – TNSP MTFP Results*, November 2016 (link).
- Economic Insights*, Memorandum – TNSP MTFP Results*, 13 November 2015 (link).
- Economic Insights, *Economic Benchmarking Assessment of Operating Expenditure for NSW and Tasmanian Electricity TNSPs*, 10 November 2014 (link).
- Economic Insights, *AER Response to HoustonKemp for TransGrid determination*, 4 March 2015 (link)
- Economic Insights, Economic *Benchmarking of Electricity Network Service Providers*, 25 June 2013 (link).

AER 2017 TNSP Benchmarking Review

All documents related to the AER's 2017 TNSP Benchmarking Review can be found on line here.

ACCC/AER publications

These publications provide a comprehensive overview of the benchmarking approaches used by overseas regulators:

- ACCC/AER, *Benchmarking Opex and Capex in Energy Networks – Working Paper no. 6*, May 2012 (link).
- ACCC/AER, *Regulatory* Practices *in Other Countries – Benchmarking opex and capex in energy networks*, May 2012 (link).
- WIK Consult, Cost Benchmarking in Energy Regulation in European Countries, 14 December 2011.

AER transmission determinations

The AER uses economic benchmarking to inform its regulatory determination decisions. A full list of these decisions to date can be found on the AER's website here.

B Benchmarking models and data

This appendix contains further information on our economic benchmarking models, and the output and input data used in the benchmarking techniques.

B.1 Benchmarking techniques

This report presents results from two types of 'top-down' benchmarking techniques:

- Productivity index numbers (PIN). These techniques use a mathematical index to measure the relationship between outputs relative to inputs:
  - TFP relates total inputs to total outputs and provides a measure of overall productivity growth for a single entity (a network or the whole industry). It allows total productivity growth rates to be compared for different periods of time for the one entity. It also allows total factor productivity growth rates to be compared across networks but does not allow productivity levels to be compared across networks. It can be used to decompose productivity change into its constituent input and output parts.
  - MTFP relates total inputs to total outputs and provides a measure of overall network efficiency relative to other networks. It thus allows total productivity levels to be compared between networks and over time when it is applied to combined time-series and cross-section (or 'panel') data.
  - MPFP is a partial efficiency measure which uses the same output specification as MTFP but separately examines the productivity of opex and capital against total output. It allows partial productivity levels to be compared between networks.
- Partial Performance Indicators (PPIs). These techniques, also partial efficiency measures, relate one input to one output (contrasting with the above techniques that relate one or all inputs to total outputs). PPIs measure the average amount of an input (such as total cost) used to produce one unit of a given output (such as total end users, megawatts of maximum electricity demand or kilometres of circuit line length).

B.2 Benchmarking data

The inputs and outputs used in the benchmarking techniques for this report are described below. The inputs represent the resources (such as capital and labour) a TNSP uses to provide electricity transmission services. The outputs represent the electricity services delivered (such as the line length and how much electricity they transport).

Data for each of these input and output categories are provided each year by the TNSPs in response to EB RINs. The EB RINs require all TNSPs to provide a consistent set of data which is verified by the TNSPs chief executive officer and independently audited. We separately test and validate the data. The complete data sets for all inputs and outputs from

2006 to 2021, along with the Basis of Preparation provided by each TNSP, are published on our website.[71]

An overview of the inputs and outputs are in box 1 below.

Box 1: Categories of inputs and outputs used in TNSP benchmarking

Outputs

Outputs are measures that represent the services the TNSPs provide. The outputs we use to measure service provision are:

- Energy throughput (GWh)
- Ratcheted maximum demand (RMD)
- Circuit length (Circuit kms)
- End–user numbers (End User nos)
- (minus) Energy not supplied (ENS) (weight based on AER’s 2021 estimates of the value of customer reliability (VCR) capped at a maximum absolute value of 2.5% of total revenue).

Inputs

TNSPs use a mix of physical assets and operational spending to deliver services.

- Capital stock (assets) include:
  - Overhead lines (quantity proxied by overhead MVAkms) (O/H lines)
  - Underground cables (quantity proxied by underground MVAkms) (U/G cables)
  - Transformers and other capital (quantity proxied by transformer MVA) (Trfs)
- Operating expenditure (expenditure TNSPs spend to operate and maintain their assets) (opex).

B.2.1 Outputs

Outputs are measures that represent the services the TNSPs provide. TNSPs exist to provide customers with access to a safe and reliable supply of electricity. We explain the outputs we use in more detail in this section.

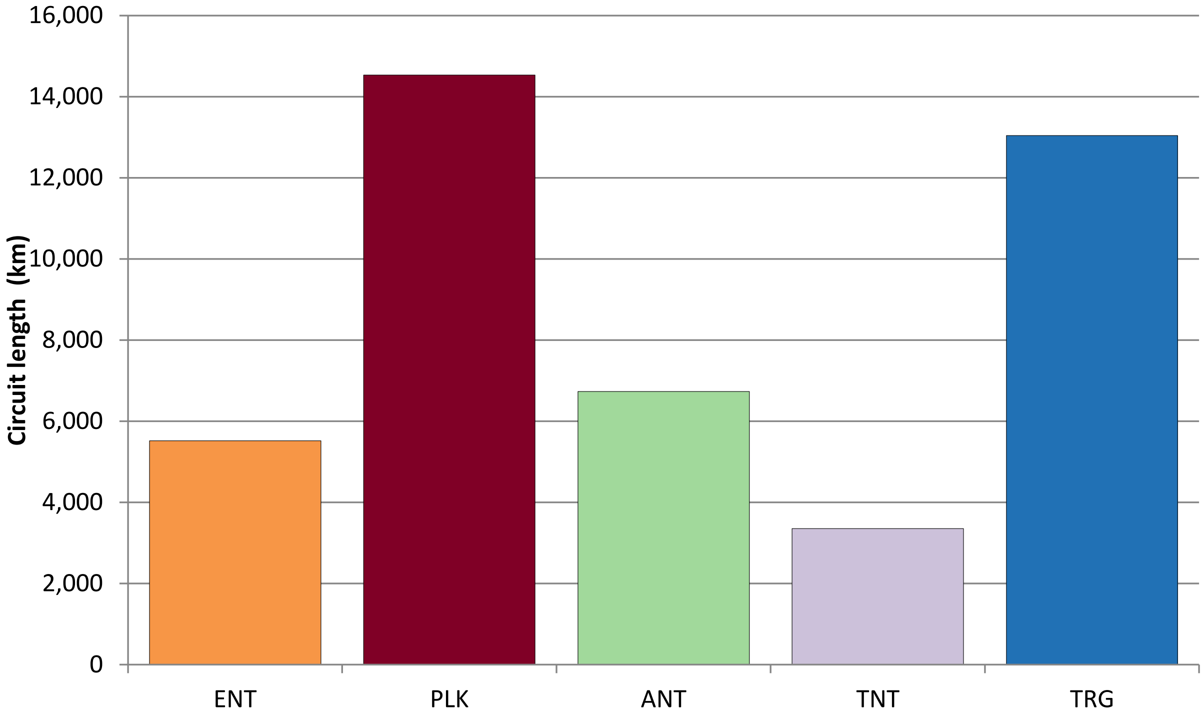
Circuit length

Circuit length reflects the distances over which TNSPs deliver electricity to downstream users from generators, which are typically over thousands of kilometres. We measure line length in terms of circuit line length. This is the length in kilometres of lines, measured as the length of each circuit span between poles and/or towers and underground. This represents the distance over which transmission networks are required to transport electricity.

71 This dataset is available at www.aer.gov.au/networks-pipelines/performance-reporting.

We use circuit length because, in addition to measuring network size, it also approximates the line length dimension of system capacity. System capacity represents the amount of network a TNSP must install and maintain to supply DNSPs, which in turn supply consumers with the quantity of electricity demanded at the places where they are located. Figure B.1 shows each TNSP's circuit length in 2021.

Figure B.1 Circuit length by TNSP in 2021 (km)

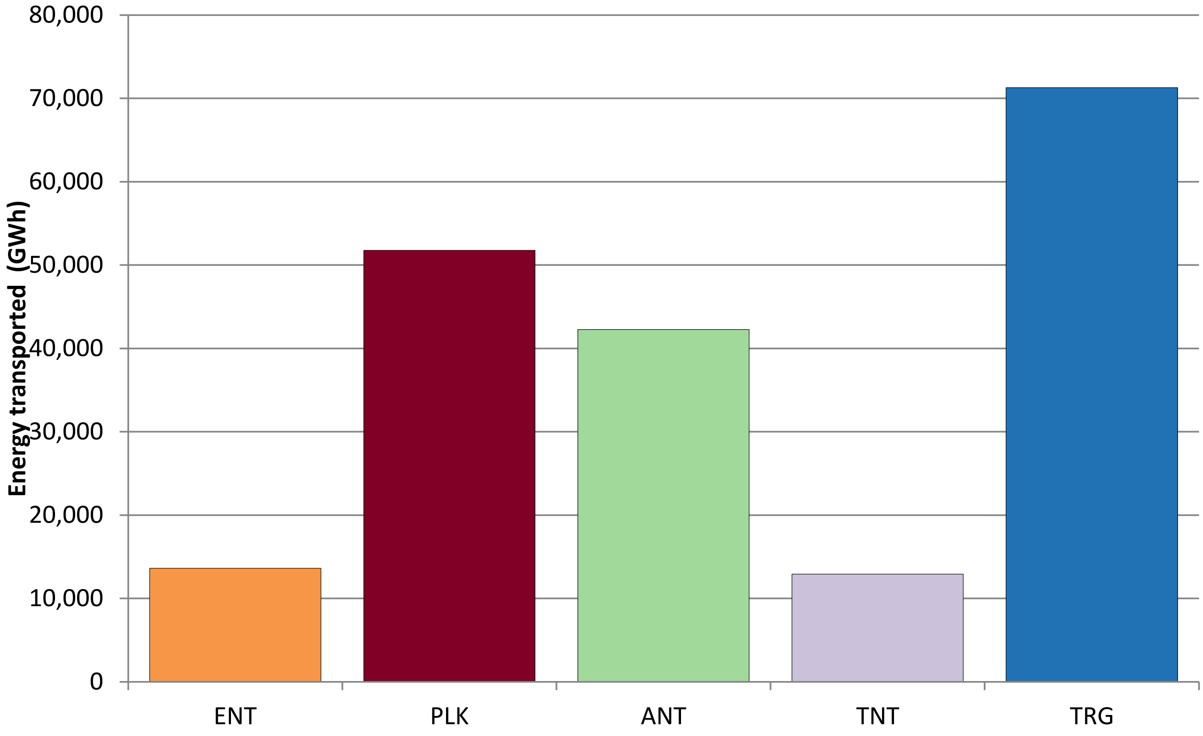


Source: Economic Benchmarking RINs.

Energy transported

Energy transported is the total volume of electricity throughput that is transported over time through the transmission network, measured in gigawatt hours (GWh). We use it because energy throughput is the TNSP service directly consumed by end–customers. Therefore, it reflects a key service provided to customers. However, if there is sufficient capacity to meet current energy throughput levels, changes in throughput are unlikely to have a significant impact on a TNSP's costs. Figure B.2 shows each TNSP's energy transported in 2021.

Figure B.2 Energy transported by TNSP in 2021 (GWh)



Source: Economic Benchmarking RINs

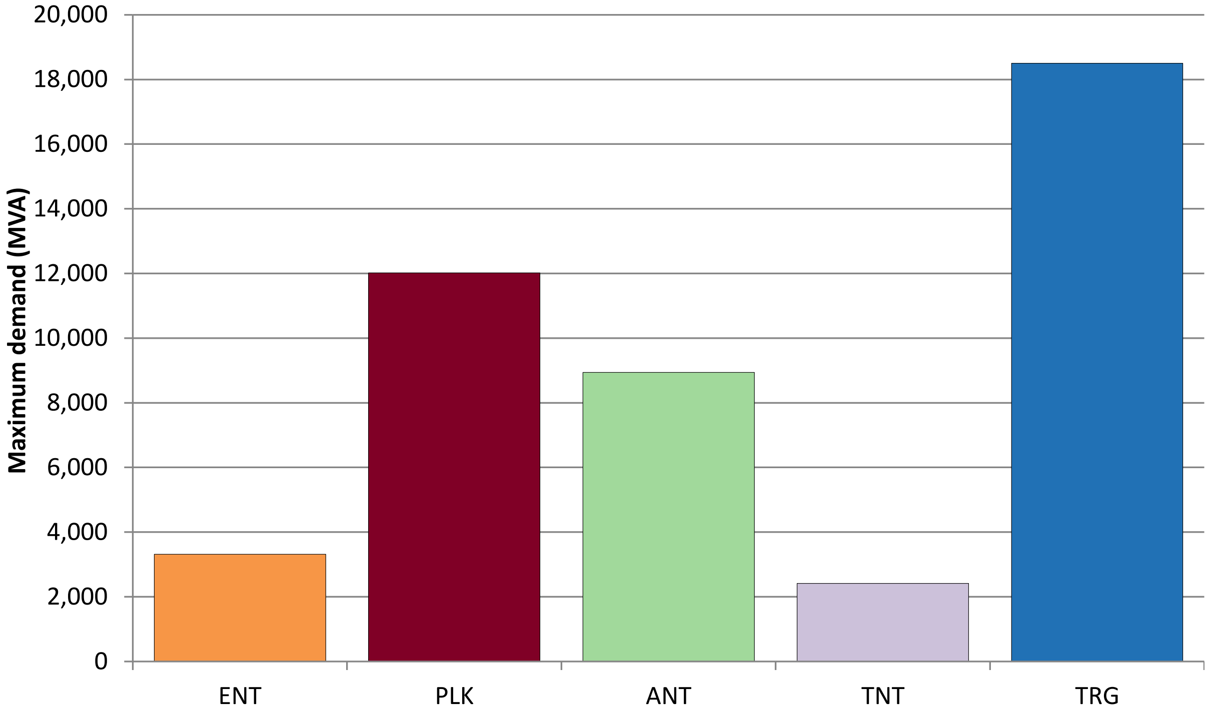
Maximum demand

TNSPs are required to meet and manage the demand of their customers. This means they must build and operate their networks with sufficient capacity to meet the expected peak demand for electricity. Maximum demand is a measure of the overall peak in demand experienced by the network. The maximum demand measure we use is non-coincident summated raw system annual maximum demand, at the transmission connection point.

The economic benchmarking techniques use 'ratcheted' maximum demand as an output rather than observed maximum demand. Ratcheted maximum demand is the highest value of peak demand observed in the benchmarking period up to the year in question for each TNSP.[72] It recognises capacity that has been used to satisfy demand and gives the TNSP credit for this capacity in subsequent years, even though annual maximum demand may be lower in subsequent years. Figure B.3 shows each TNSP's maximum demand in 2021.

72 For example, in 2021 ElectraNet's maximum demand was 3,317 MVA, while its ratcheted maximum demand occurred in 2013 and was 4,403 MVA.

Figure B.3 Maximum demand in 2021 (MVA)



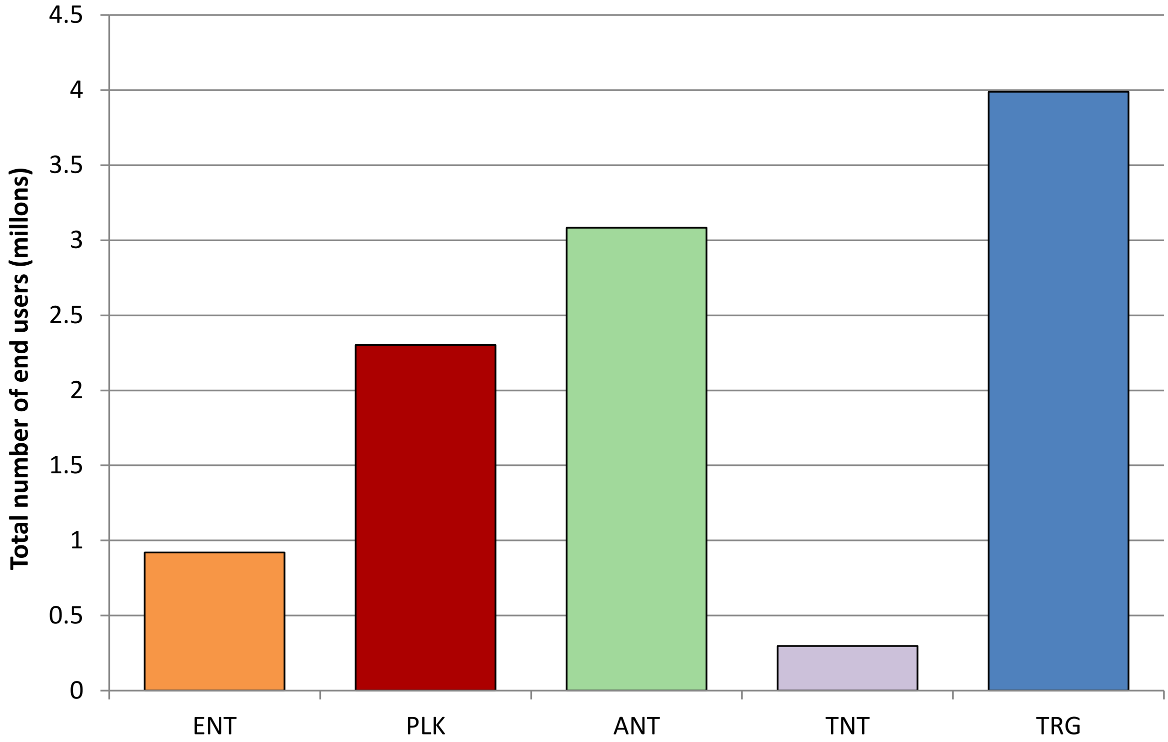
Source: Economic Benchmarking RINs.

End user numbers

The end user number output measures the number of customers for which TNSPs are required to provide a service. This is used to represent the size and complexity of the transmission network. Specifically, the greater the number of end users, the more complex the task facing the TNSP and the larger the market the TNSP serves. More complex networks will typically be more asset-intensive. Figure B.4 presents the number of end users serviced by each of the TNSPs in 2021.

As expected, the size of the network aligns with the population in each state. NSW is the largest network, with TransGrid providing services for 4.0 million end users in NSW, followed by Victoria, with AusNet servicing over 3.1 million end users. Tasmania has the smallest network, with TasNetworks servicing around 298,000 end users in 2021.

Figure B.4 End user numbers for 2021 (millions)



Source: Economic Benchmarking RINs.

Total outputs

Table B.1 presents the average network outputs over the most recent five-year period from 2017 to 2021 for TNSPs, with the exception of reliability.

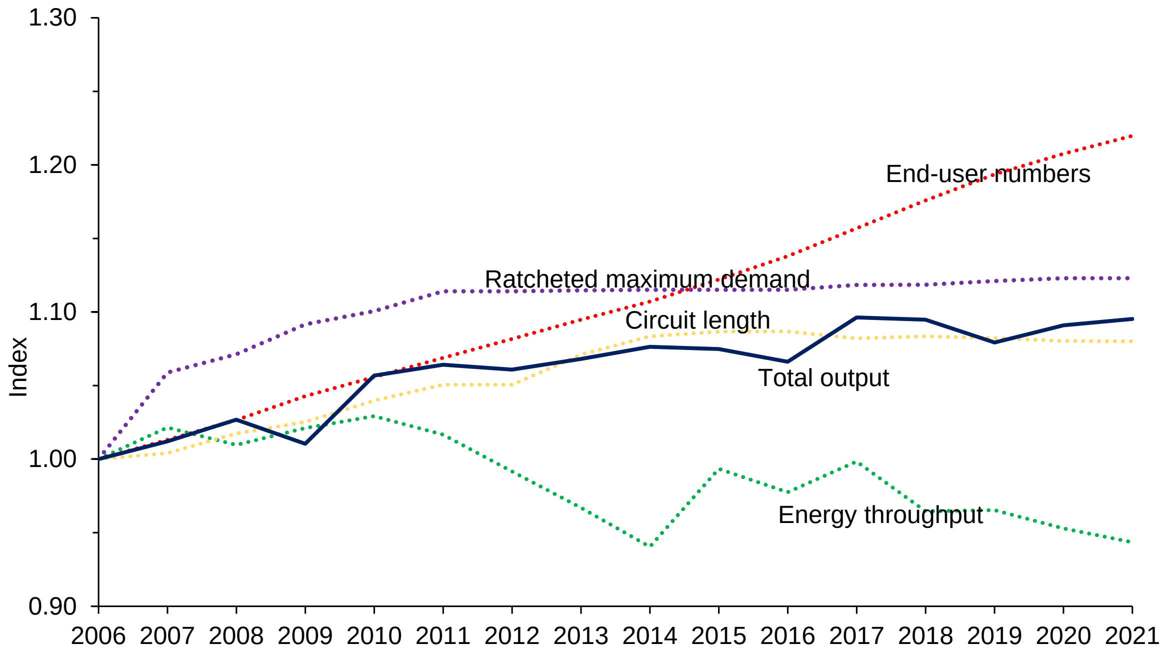
Table B.1 TNSP outputs 2017–2021 average

	Circuit line length (km)	Energy transported (MWh)	Maximum demand (MVA)	Number of end users
ElectraNet	5,518	13,446,970	3,458	902,868
Powerlink	14,530	53,545,617	12,361	2,254,280
AusNet	6,655	42,764,171	9,780	3,006,548
TasNetworks	3,471	12,613,537	2,465	291,528
TransGrid	13,062	73,860,000	18,660	3,886,674

Source: Economic Benchmarking RINs.

Figure B.5 presents indexes of the key industry outputs over the 2006–21 period (with the exception of reliability) along with the total output index.

Figure B.5 Components of total output 2006–21



Source: Quantonomics

B.2.2 Inputs

The inputs used in this report are assets and opex. TNSPs use a mix of assets and opex to deliver services. Electricity assets can provide useful service over several decades. However, benchmarking studies typically focus on a shorter period of time.

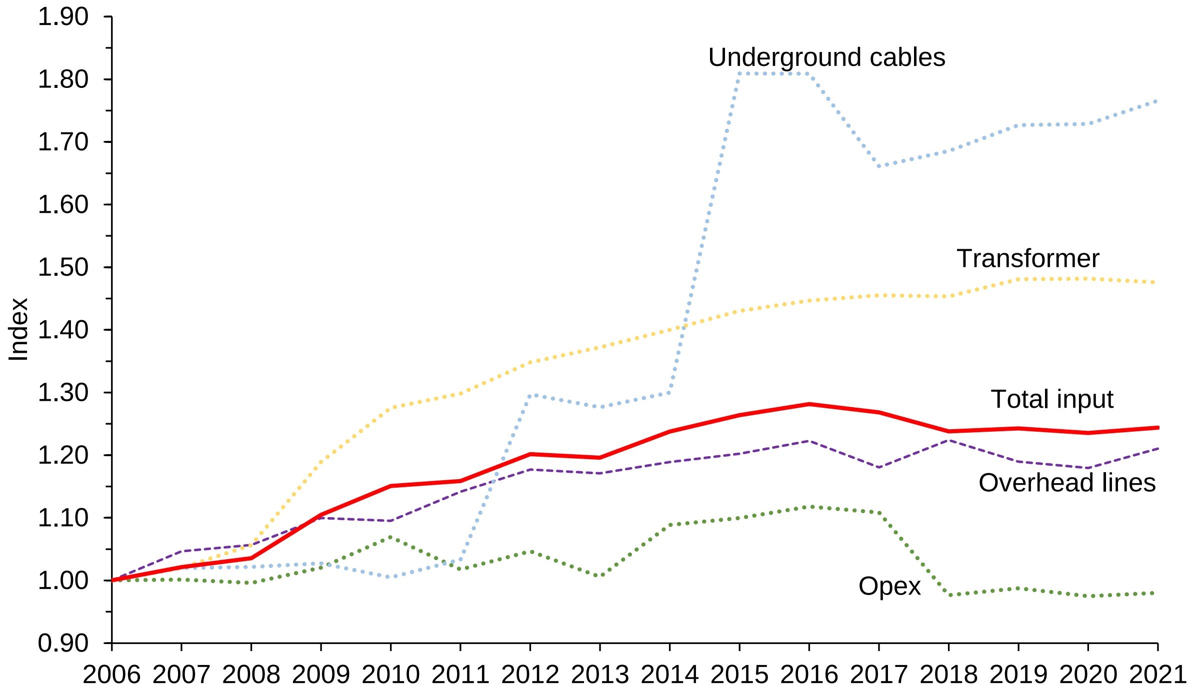
The two inputs we use in our MTFP technique are:

- Operating expenditure (opex). This is the expenditure TNSPs spend on operating and maintaining their assets. We use the observed opex spent on prescribed transmission services. Nominal opex is deflated by an index of labour and other relevant prices to obtain a measure of the quantity of opex inputs.
- Capital stock (assets). TNSPs use physical assets to provide services and invest in them to replace, upgrade or expand their networks. We split capital into overhead lines, underground cables and transformers.
  - For our MTFP analysis we use physical measures of capital inputs. Using physical values for capital inputs has the advantage of best reflecting the physical depreciation profile of TNSP assets.[73]
  - For the PPIs we use the real value of the regulatory asset base as the proxy for assets to derive the real annual cost of using those assets.

Figure B.6 presents the change in industry input over the 2006–21 period.

[73] Economic Insights, *Memorandum – TNSP MTFP Results*, 31 July 2014, p. 5.

Figure B.6 Factors contributing to total inputs, 2006–21



Source: Quantonomics

Table B.2 presents measures of the cost of network inputs relevant to opex and assets for all TNSPs. We have presented the average annual network costs over the most recent five years in this table to moderate the effect of any one-off fluctuations in cost.

Table B.2 Average annual costs for network inputs for 2017–21 ($'000, 2021)

	Opex	Capex	RAB	Depreciation
ElectraNet	99,181	142,723	2,440,438	118,948
Powerlink	214,187	148,528	6,819,477	299,843
AusNet	85,824	154,314	3,111,036	183,613
TasNetworks	31,339	49,340	1,444,417	62,628
TransGrid	168,690	222,972	6,478,387	284,847

Source: Economic Benchmarking RINs.

C Map of the National Electricity Market

This benchmarking report examines the efficiency of the five TNSPs in the NEM. The NEM connects electricity generators and customers from Queensland through to New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania. Figure C.1 illustrates the network areas for which the TNSPs are responsible.

Figure C.1 Electricity transmission networks within the NEM