AER Benchmarking

A REPORT PREPARED FOR ESSENTIAL ENERGY

April 2018

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AER Benchmarking

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Executive summary

Essential Energy is currently in the process of preparing its Regulatory Proposal to the Australian Energy Regulator (AER) for the forthcoming regulatory control period from 1 July 2019 to 30 June 2024. To inform its annual revenue requirements for the 2019–24 regulatory period, Essential Energy has commissioned Frontier Economics to provide expert advice in relation to the efficiency of its operating expenditures (opex) relative to other DNSPs in the NEM, using a variety of benchmarking techniques.

Recap of AER base year efficiency adjustment for the 2014–19 regulatory control period

In developing its final decision on Essential Energy's proposed base year opex for the 2014–19 regulatory control period, the AER relied heavily on the results of the benchmarking analysis conducted on its behalf by Economic Insights (EI). Based on the findings of EI's benchmarking, the AER determined that Essential Energy's proposed base year opex for the 2014–19 regulatory control period should be reduced by $109.8 million (26.3%)[1].

Table 1: AER's final determination of target base year opex for Essential Energy for the 2014–19 regulatory control period (after OEF adjustments)

	$million 2013–14
Proposed base year opex (A_f^*)	418.0
Target base year opex	308.2
Base year efficiency adjustment (difference between estimated and target opex)	109.8
Percentage base year opex efficiency reduction	26.3%

Source: Table A.1 AER final determinations

Note: OEFs = operating environment factors

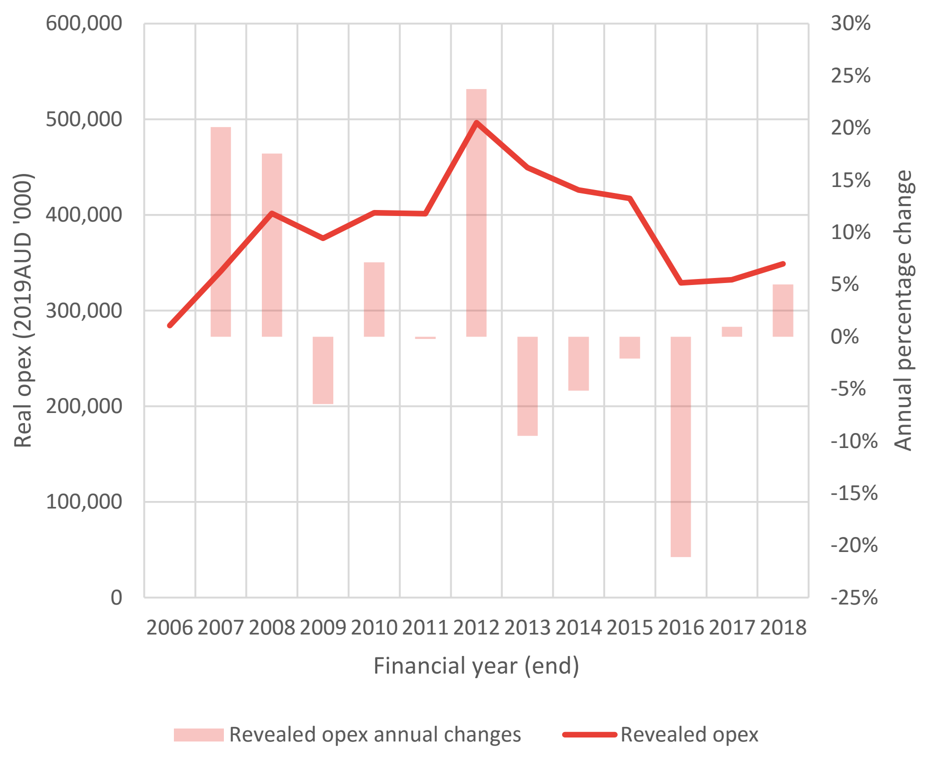
Essential Energy's target base year opex for 2019–24 using the AER's approach for 2014–19

Using the approach that the AER adopted for 2014–19 regulatory control period, we have estimated Essential Energy's target base year opex for 2019–24. As shown

1 The base year for the 2014–19 regulatory control period is 2012-13. The base year opex reported in Table 1 above is for the year 2012-13 in ($2013-14).

in Figure 1 below, Essential Energy has achieved substantial opex reductions since 2012–13.

Figure 1: Essential Energy's revealed opex for 2006 – 2018 (2019AUD '000[2]) and year-on-year percentage changes



Source: Frontier Economics

We demonstrate that, owing to the significant opex reductions that Essential Energy has achieved since 2012–13, Essential Energy's proposed base year opex for the 2019–24[3] regulatory period is lower than the target base year opex estimated under the AERs preferred benchmarking model[4]. As the efficiency adjustment is estimated to be negative (i.e. a negative reduction), this implies that no base year reduction would be required. This is true in the absence of any adjustment for OEFs. Since this conclusion holds prior to any OEF adjustments, it holds even

2 As Essential Energy's proposed base year opex has been provided in 2018-19 dollars, our analysis of Essential Energy's opex in the remainder of this report is also reported in 2018-19 dollars.

3 Essential Energy's proposed base year for the 2019–24 regulatory control period is 2017-18. Essential Energy's proposed base year opex for this period is $348.8m ($2018-19).

4 We note that the efficiency of Essential Energy's base year opex is assessed by directly evaluating the estimated econometric function at the values of the explanatory variables in the base year as discussed in Section 2.2.1.

more strongly if allowance is made for any OEF adjustments in the estimation of Essential Energy's target base year opex.

Table 2: Estimates of efficient base year opex for Essential Energy 2019–24 for the regulatory period – AER's preferred benchmarking model (before OEF adjustments)

	Base year opex: 2014–19	Base year opex: 2019–24
	$million 2013–14	$million 2018–19
	After OEF adjustments	Before OEF adjustments
Proposed base year opex (A_f^*)	418.0	348.8
Target base year opex	308.2	349.4
Base year efficiency adjustment (difference between estimated and target opex)	109.8	-0.6
Percentage base year opex efficiency reduction	26.3%	-0.2%

Source: Table A.1 AER final determinations

Note: OEFs = operating environment factors

Essential Energy's target base year opex for 2019–24 using a variety of alternative approaches

In Figure 2 below we summarise how Essential Energy performs across a range of alternative approaches investigated in this report. Essential Energy's proposed base year opex is represented by the grey vertical line. Essential Energy's target base year opex from each alternative approach is represented by the horizontal bars. The figure shows that Essential Energy's proposed base year opex is equal to or below its target base year opex for the 2019–24 regulatory control period across all the benchmarking models considered in this report, including the AER's preferred benchmarking model, with the exception of one model. As this is true in the absence of any adjustment for OEFs, it holds even more strongly if allowance is made for any OEF adjustments in the estimation of Essential Energy's target base year opex.

Figure 2: Essential Energy's performance across a range of approaches investigated in this report

Source: Frontier Economics

Conclusions and recommendations

We have assessed the efficiency of Essential Energy's proposed base year (financial year 2017–18) opex using a range of benchmarking approaches, including those investigated by EI on behalf of the AER (See Section 2 and Section 3), and other approaches that could feasibly be estimated using the available RIN data (See Section 4). Our conclusions and recommendations for the AER are summarised below.

- **Essential Energy's average efficiency score is a poor indicator of its base year efficiency.** Despite its apparently low average efficiency scores over the 11-year period, Essential Energy's proposed base year opex for the 2019–24 period is lower that its estimated target base year opex. This is owing to the significant opex reductions that Essential Energy has achieved since 2012–13.
- **Benchmarking evidence provides no justification for a base year efficiency adjustment.** Essential Energy's proposed base year opex is below its target base year opex for the 2019–24 regulatory control period across the

vast majority of benchmarking models considered in this report, including the AER's preferred benchmarking model, with the exception of one model. This evidence is compelling, as it is true in the absence of any adjustment for OEFs. It therefore holds even more strongly if allowance is made for any OEF adjustments in the estimation of Essential Energy's target base year opex.

- **There is a strong case for relying on a broad range of evidence.** The AER has hitherto put undue faith in the ability of it, and its advisers, to develop a single benchmarking model (or suite of very closely related models), all derived from the same data and missing the wider review of factors and sense checks that can capture the relative inefficiency of Australian DNSPs with greater reliability. This appears to be an unnecessarily limiting approach for the AER to adopt. We recommend that, in future, the AER rely on a broad range of evidence to determine its target base year opex and efficiency adjustments for Essential Energy, including evidence from any bottom-up benchmarking and engineering assessments, and evidence on other opex factors such as the safety and reliability of the network.
- **There is a need to recognise the limitations of benchmarking analysis at present.** Owing to the lack of data to measure a large number of factors that may drive differences in performance between the DNSPs (such as differences in operating environment), relevant factors have not been adequately captured in any of the approaches presented in this report. Designing a benchmarking methodology that accounts adequately for all of the factors driving the differenced in performance of the DNSPs is extremely challenging – and in our view this is presently not possible to do with the data currently available to the AER. We recommend that the AER attempt to improve the range and quality of data available for benchmarking in the longer term in collaboration with the DNSPs. This could be achieved by creating a working group, in collaboration with the networks, tasked with developing empirical methods that may help it overcome the challenges it faces in regulating a sector within which there is such extensive heterogeneity. This may involve developing, defining and collecting additional measures, or considering methodologies to justify firm-specific adjustments to benchmarked costs, or adjustments to the outcome of benchmarking models.
- **The AER's MTFP and MPFP analysis is not suitable to inform decisions on relative efficiency.** Having reviewed the AER's multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) analysis, we consider that this analysis contains a number of serious shortcomings. We do not consider the MTFP and MPFP results presented in the AER's 2017 annual benchmarking report a suitable basis for informing regulatory decisions on the relative efficiencies of the DNSPs.
- **There is a need to develop a cautious approach in the application of benchmarking results.** While the benchmarking results presented in this

report provide no evidence to suggest that Essential Energy's proposed base year opex for the 2019–24 regulatory period requires an efficiency adjustment, we nevertheless recommend that the AER adopt a conservative approach in the application of its benchmarking analysis should it decide to make base year efficiency adjustments for any of the DNSPs. This can be done in one, or in a combination of ways. For example, the AER could potentially:

- consider lowering its criterion for choosing the target DNSP from the top 5th DNSP to a more conservative target owing to the limitations of the benchmarking approaches that are presently feasible
- consider determining base year allowances on the basis of a weighted average of the DNSPs' proposed base year opex and target base year opex, and/or
- consider splitting the 13 DNSPs into groups or cohorts, determined by evidence on their base year efficiency, and apply different levels of base year opex reductions to each cohort.

1 Introduction

Essential Energy is currently in the process of preparing its Regulatory Proposal to the Australian Energy Regulator (AER) for the forthcoming regulatory control period from 1 July 2019 to 30 June 2024. To inform its annual revenue requirements for the 2019–24 regulatory period, Essential Energy has commissioned Frontier Economics to:

- provide an assessment of the comparative efficiency of Essential Energy's historical opex over the eleven year period from 2006 to 2016, relative to other DNSPs in the NEM;
- provide an assessment of the comparative efficiency of Essential's Energy's proposed base year opex for the 2019–24 regulatory period;
- investigate the use of a variety of benchmarking techniques, including the techniques used by the AER for the 2014–19 period, those used by the AER in the most recent 2017 annual benchmarking report, and a range of reasonable alternative benchmarking techniques that can feasibly be estimated using the RIN data published by the AER;
- comment on whether there are any deficiencies in the benchmarking exercise that has been undertaken by the AER, and the extent to which those deficiencies can be addressed by the AER in the longer-term; and
- comment on how the results from benchmarking should be applied by the AER in the context of the intrinsic challenges in benchmarking the electricity distributors in Australia and the deficiencies of the AER's current benchmarking analysis discussed in this report.

This report outlines our findings in relation to the above. We note that the assessment of operating environment factors (OEFs) is outside the scope of this report. The remainder of this report is structured as follows.

- In Section 2, we replicate the econometric models previously considered by the AER, and assess the efficiency of Essential Energy's proposed base year opex under each of these models.
- In Section 3, we provide our assessment of the AER's MTFP/MPFP analysis.
- In Section 4, we discuss the additional approach investigated by Frontier Economics.
- In Section 5 we outline our conclusions and recommendations for the AER.

2 AER's econometric benchmarking models

On 30 April 2015, the AER released its final decision on Essential Energy's distribution determination for the 2014–19 regulatory control period. In developing its final decision on Essential Energy's proposed base year opex, the AER relied heavily on the comparative benchmarking analysis conducted on the AER's behalf by Economic Insights (EI). Based on the findings of EI's benchmarking, the AER determined that Essential Energy's proposed base year opex for the 2014–19 regulatory control period should be reduced by $109.8[5] million (26.3%).

In this section we estimate Essential Energy's target base year opex for the 2019–24 regulatory period by applying the methodology adopted by the AER in the 2014–19 regulatory period to an updated dataset. We demonstrate that, owing to the significant opex reductions that Essential Energy has achieved since 2012–13, Essential Energy's proposed base year opex for the 2019–24 regulatory control period falls below the estimated target base year opex and hence does not require an efficiency adjustment.

The remainder of this section is structured as follows.

- In Section 2.1, we provide an overview of the AER's approach for the 2014–19 regulatory period, including the breakdown of its approach to determining the $109.8 million (26.3%) reduction to Essential Energy's proposed base year opex for the 2014–19 regulatory control period.
- In Section 2.2, we outline how we obtained our estimate of Essential Energy's target base year opex for 2019–24 using the AER's approach for the 2014–19 regulatory period, as described in Section 2.1.

2.1 Overview of AER approach for the 2014–19 regulatory period

The AER's proposed base year efficiency adjustment for the 2014–19 regulatory control period was derived using EI's benchmarking of distribution network service providers (DNSPs) over the 2006–2013 sample period. In this section we provide a detailed overview of the AER's approach. In Section 2.2 we replicate the approach described in this section using updated data to obtain an estimate of Essential Energy's target base year opex for 2019–24.[6]

5 For the year 2012-13 in ($2013-14).

6 Essential Energy's proposed base year for the 2019–24 regulatory control period is 2017-18. Essential Energy's proposed base year opex for this period is $348.8m ($2018-19).

The remainder of this Section is structured as follows.

- In Section 2.1.1, we describe the role of the 'base year' and the 'base-step-trend' approach in the determination of the opex allowances for each year in the regulatory period.
- In Section 2.1.2, we provide a detailed breakdown of the AER's calculation of its base year efficiency adjustment of 26.3%.

2.1.1 Overview of AER's 'base-step-trend' approach

As outlined in the AER's Expenditure Forecast Assessment Guideline,[7] the allowable opex in each year of the upcoming regulatory control period is obtained using a 'base-step-trend' approach.

Under this approach, a nominated year from the previous regulatory period is determined to be the 'base year' from which allowable opex for the upcoming regulatory period is rolled forward for each DNSP. A key step in the AER's approach is to determine the target opex for the regulated utility in the base year. If the DNSP's proposed opex in the base year is assessed as meeting the target efficiency level then the DNSP's proposed opex in the base year will be rolled forward using a rate of change formula. If the DNSP's base year opex is assessed to be materially below the target efficiency level, then it may be adjusted downwards by the assessed amount of inefficiency, before the adjusted target amount is rolled forward using the rate of change formula.

The formula for obtaining the allowable opex in year t can be written as:

$$Opex_t = \left[\left(A_f^* - efficiency\ adjustment \right) \times \prod_{i=1}^{t} (1 + rate\ of\ change_i) \right] \pm step\ changes_t$$

where:

- The expression (A_f^* - *efficiency adjustment*) represents target opex in the base year, where:
  - it is assumed that the base year is $t = 0$
  - A_f^* is the proposed opex in the base year

7 AER Expenditure Forecast Assessment Guideline for Electricity Distribution, AER, November 2013; See: http://www.aer.gov.au/sites/default/files/Expenditure%20Forecast%20Assessment%20Guideline%20-%20Distribution%20-%20FINAL.pdf.

  - *efficiency adjustment* is the adjustment that needs to be applied to proposed opex in the base year to bring it in line with the target opex in the base year.
- $rate\ of\ change_i$ is the rate of change in year i. This is obtained by combining the rates of change in real prices, output and productivity in year i.
- $step\ changes_t$ represents any step changes that may be applied to allowed opex in year t to account for efficient expenditures not captured in the target base year opex or the rate of change.

As can be seen in the formula above, the AER's starting point for determining base year opex is A_f^*, which is the proposed opex in the nominated base year.

The AER's Expenditure Forecast Assessment Guideline states that the 'revealed cost' approach is the AER's preferred approach to assessing base year opex. If proposed opex for the base year reasonably reflects the AER's opex criteria, the AER will set the allowed base year opex equal to proposed opex. On the other hand, should the AER find a material difference between the DNSP's proposed opex in the in the base year and its own estimate of target opex for the base year, it may apply an efficiency adjustment to the DNSP's proposed base year opex. The AER's approach to assessing the target base year opex for Essential Energy in the 2014–19 regulatory control period is outlined in Section 2.1.2 below.

2.1.2 AER's calculation of Essential Energy's efficiency adjustment

In its final decision for Essential Energy for the 2014–19 regulatory control period, the AER determined that Essential Energy's proposed base year opex should be reduced by $109.8 million (26.3%), as summarised in Table 3.

Table 3: AER's final determination of target base year opex for Essential Energy for the 2014–19 regulatory control period (after OEF adjustments)

	$million 2013–14
Proposed base year opex (A_f^*)	418.0
Target base year opex	308.2
Base year efficiency adjustment (difference between estimated and target opex)	109.8
Percentage base year opex efficiency reduction	26.3%

Source: Table A.1 AER final determinations

Note: OEFs = operating environment factors

The AER's approach to determining the base year efficiency adjustment of 26.3% can be described in 9 steps, as summarised in Table 4 below.

Table 4: Breakdown of AER's determination of base year opex efficiency adjustment for Essential Energy for the 2014–19 regulatory control period

Steps in AER's calculation of base year efficiency adjustment of 26.3%		Calculation
Step 1	Essential Energy's raw efficiency score over 2006 – 2013 period – derived from EI preferred model.	54.9%
Step 2	Choice of comparison point (raw efficiency score of top 5th DNSP – AusNet Services)	76.8%
Step 3	Assessment of total operating environment factor (OEF) adjustment for Essential Energy	10.7%
Step 4	Lowering of comparison point to account for OEFs	69.4% = 76.8%/(1+10.7%)
Step 5 [(a)]	Calculation of percentage reduction in average annual opex over estimation period to reach comparison point (i.e. target opex)	20.9% = 1 – (54.9%/69.4%)
Step 6 [(b)]	Calculation of target opex at the middle of the estimation period	$278.8m = (1 – 20.9%) * $352.5m
Step 7 [(c)]	Roll forward target opex in middle of estimation period to base year (2012–13)	$295.7m = $278.8m * (1 + 6.0%)
.Step 8	CPI adjustment of base year target opex from $2012–13 to $2013-14	$308.2m = $295.7m * (1+4.2%)
Step 9 [(d)]	Efficiency adjustment = percentage difference between proposed opex and target opex in base year	26.3% = 1 – ($308.2/$418.0)

Source: Frontier Economics' summary derived from Table 7.4 of AER Final Decision Essential Energy distribution determination for the 2014-19 regulatory control period (Attachment 7 – Operating expenditure).

Notes: (a) In step 5, the AER's percentage reduction in average annual opex over estimation period to reach comparison point (i.e. target opex) is capped to zero. Therefore, the AER does not make an efficiency adjustment for DNSP's with an efficiency score equal to or above the comparison point

(b) In step 6, $352.5m is calculated as the average annual opex over estimation period (2006–13)

(c) In step 7, the AER's growth rate of 0.0604 is the estimated growth rate from the middle of the estimation period and the base year of drivers of opex in the AER's benchmarking model

(d) In Step 9, $418.0 is Essential Energy's proposed base year opex.

Below, we provide a discussion of each of the 9 steps shown in Table 4 above.

Step 1: Raw efficiency scores from EI's benchmarking

EI's raw efficiency scores are obtained from its preferred Cobb-Douglas Stochastic Frontier Analysis (SFA CD) model and are presented in Table 5 below. Essential Energy's raw efficiency score is estimated to be 54.9 per cent over the 2006 – 2013 estimation period. It is important to note that, since EI's SFA CD efficiency scores are time-invariant, they should be interpreted as average efficiency scores over the sample period – they cannot be applied directly to assess the efficiency of proposed opex in the base year.

Table 5: EI's SFA CD efficiency scores: Average over 2006–2013 period

DNSP	Efficiency score
ActewAGL	39.9%
AusNet Services	76.8%
Ausgrid	44.7%
CitiPower	95.0%
Endeavour Energy	59.3%
Energex	61.8%
Ergon Energy	48.2%
Essential Energy	**54.9%**
Jemena	71.8%
Powercor	94.6%
SA Power Networks	84.4%
TasNetworks	73.3%
United Energy	84.3%
Comparison point - top 5th score	**76.8%**

Source: Frontier Economics

Step 2: Choice of comparison point

To determine target base year opex, the comparison point used by the AER was the score of the lowest performing service provider in the top quartile of possible scores (i.e. above 75%), or the top 5th service provider's score in the sample of 13 DNSPs. In Table 5 above, the comparison point using either of these criteria is the efficiency score of AusNet Services. AusNet Services' opex is estimated to be 76.8 per cent efficient based on its performance over the 2006 – 2013 period.

Step 3: Assessment of operating environment factors (OEFs)

As summarised in Table 6 below, the AER provided an adjustment of 10.7% to Essential Energy to account for operating environment factors (OEFs) not accounted for in Economic Insights' SFA CD model.

Material OEF adjustments were made for the following four factors:

- 3.1% for differences in subtransmission configurations
- 1.2% for differences in licence conditions
- 0.5% for differences in occupational health and safety regulations, and
- 0.6% for differences in termite exposure.

The AER also made an adjustment for the total impact of additional factors that did not meet its materiality criterion. A 5.4% adjustment was made for the sum of immaterial OEFs.

Table 6: Summary of OEF adjustments

Factor	OEF adjustment
Subtransmission	3.1%
Licence conditions	1.2%
OH&S regulations	0.5%
Termite Exposure	0.6%
Immaterial factors	5.4%
Total	**10.7%**

Source: AER analysis.
Note: The sum does not match the total due to rounding

The AER's approach to applying these OEF adjustments is described in Step 4.

Step 4: Lowering of comparison point to account for OEFs

In Step 4, the comparison point estimated in Step 3 (76.8%) is lowered by the OEF adjustment in Step 3 (10.7%). This is determined by the following formula:

Adjusted comparison point = comparison point / (1 + OEF)

The adjusted comparison point for Essential Energy in the 2014–19 determination was 69.4% as shown below.

69.4% = 76.8%/(1+10.7%)

Step 5: Calculation of percentage reduction in opex

In Step 5, the percentage reduction in average opex in the middle of the estimation period is obtained using the ratio of Essential Energy's raw efficiency score from Step 1 (54.9%) and the adjusted comparison point from Step 4 (69.4%). It is derived using the following formula:

> Percentage reduction in mid-year opex = 1 – (Essential Energy's raw efficiency score/Adjusted comparison point)

Inserting the relevant scores into the formula produces the percentage reduction for Essential Energy:

> 20.9% = 1 – (54.9%/69.4%)

Step 6: Calculation of target opex in middle of estimation period

In Step 6, the target opex at the midpoint of the 2006 to 2013 estimation period is estimated by applying the percentage reduction calculated in Step 5 (20.9%) to Essential Energy's average annual opex over the period ($352.5m). This is determined by the following formula.

> Mid-period target opex = (1 - Percentage reduction) * Average annual opex over the period

This leads to the AER's target opex for Essential Energy for the middle of the estimation period of $278.8m as shown below:

> $278.8m = (1 – 20.9%) * $352.5m.

Step 7: Roll forward target opex to the base year (2012–13)

In Step 7, the target opex derived in Step 6 ($278.8m) for the middle of the estimation period is rolled forward to the base year, 2012–13, using the AER's estimated growth rates for the drivers of opex in the benchmarking model. This is determined by the following formula:

> Base year target opex = Target opex in middle of estimation period * (1 + estimated growth rate)

The estimated growth rate is determined by changes between the middle of the estimation period and the base year in customer numbers, line length, ratcheted maximum demand and share of undergrounding. These are the drivers of opex in EI's preferred SFA CD model. The total estimated growth rate from EI's model was 6.04 per cent. The AER's estimate of target base year opex was therefore $295.5m, as shown below:

> $295.7m = $278.8m * (1 + 6.04%).

Step 8: CPI adjustment of base year target opex from $2012-13 to $2013-14

In Step 8, the AER's base year target opex from Step 7 ($295.5m) is converted from $2012-13 to $2013-14 values using a CPI adjustment. This is determined by the following formula:

Base year target opex ($2013-14) = Base year target opex ($2012-13) * (1 + CPI adjustment)

The increase in the CPI between 2012–13 and 2013–14 was 4.2%. Hence, the AER's target base year opex ($2013-14) was $308.2, as shown below.

$308.2m = $295.7m * (1+4.2%)

Step 9: Calculation of efficiency adjustment

In Step 9, the AER's base year efficiency adjustment is estimated using the ratio of the base year target opex from Step 8 ($308.2m in $2013-14) and Essential Energy's proposed base year opex of $418.0 in $2013-14. This is obtained using the following formula:

Efficiency adjustment = 1 = (Base year target opex/Base year revealed opex)

The AER's base year efficiency adjustment for Essential Energy was therefore 26.3%, as shown below.

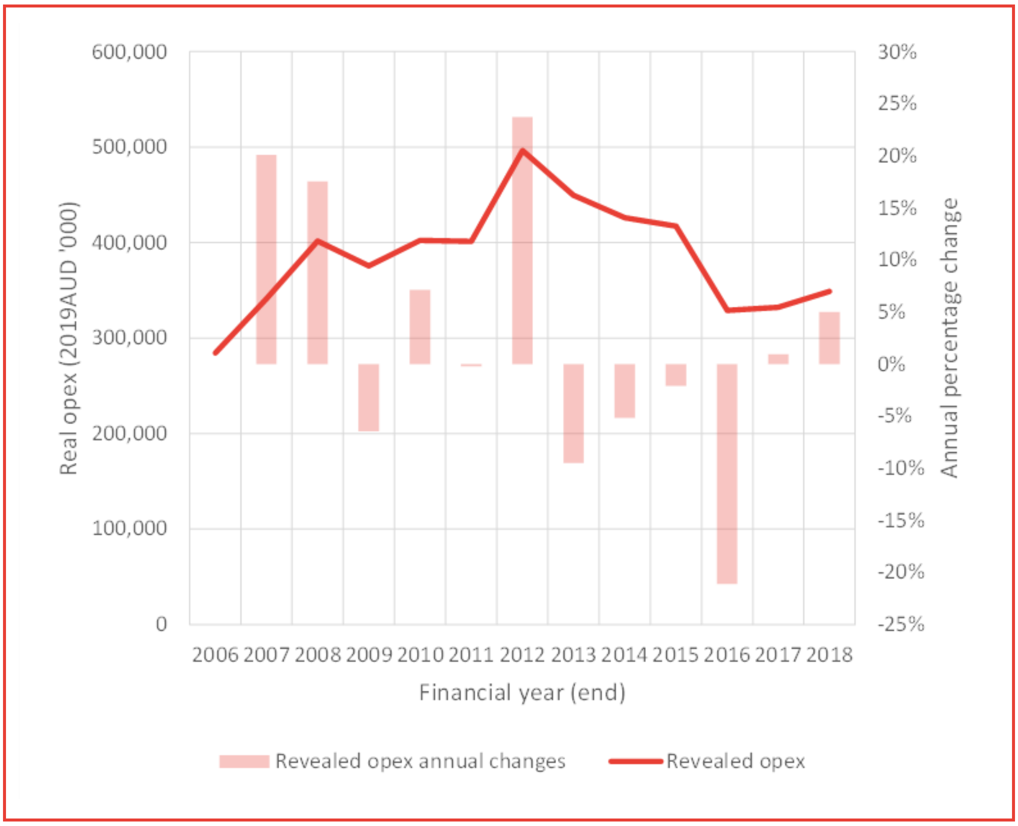
26.3% = 1 – ($308.2/$418.0)

2.2 Essential Energy's target base year opex for 2019–24 using the AER's approach for 2014–19

Using the AER's approach for the previous regulatory period described in Section 2.1.2 above, we estimate Essential Energy's target base year opex for 2019–24. We are advised that Essential Energy's proposed base year for the 2019–24 regulatory control period is 2017-18. Essential Energy's proposed base year opex for this period is $348.8m ($2018-19).

As shown in Figure 3 below, Essential Energy has achieved substantial opex reductions since 2012–13.

Figure 3: Essential Energy's revealed opex for 2006 – 2018 (2019AUD '000) and year-on-year percentage changes



Source: Frontier Economics

We demonstrate that, owing to the significant opex reductions that Essential Energy has achieved since 2012–13, Essential Energy's proposed base year opex for the 2019–24 regulatory period is lower than the target base year opex estimated under any of the econometric benchmarking models considered by the AER to date.

Our estimates of the target base year opex and efficiency adjustment for the 2019–24 regulatory period for the AER's preferred model, and for the alternative models the AER has considered, are summarised in Table 7 below. The table shows that Essential Energy's proposed base year opex is below the target base year opex for 2019–24 across all of the econometric benchmarking models considered by the AER to date, including the AER's preferred benchmarking model. Hence, under all these models no efficiency adjustment is required.

In the remainder of this section we provide details of our estimation of Essential Energy's target base year opex and efficiency adjustment for the 2019–24 regulatory control period shown in the above table – the details for the AER's preferred econometric model are shown in Section 2.2.1, and for the other models considered by the AER in Section 2.2.2.

Table 7: Estimates of target base year opex for Essential Energy for the 2019–24 regulatory period – AER's preferred benchmarking model (before OEF adjustments)

	Target base year opex for 2014–19 – as determined by the AER	Estimated target base year opex for 2019–24 – applying AER's approach from previous regulatory period			
		Models considered by the AER			
	SFA CD (AER's preferred model)	SFA CD (AER's preferred model)	SFA TL	LSE CD	LSE TL
	$million 2013–14	$million 2018–19			
Proposed base year opex (A_f^*)	418.0	348.8	348.8	348.8	348.8
Target base year opex	308.2	349.4	384.9	353.0	405.0
Base year efficiency adjustment (difference between proposed and target opex)	109.8	-0.6	-36.0	-4.2	-56.1
Percentage base year opex efficiency reduction	26.3%	-0.2%	-10.3%	-1.2%	-16.1%

Source: Table A.1 AER final determinations for 2014–19 and Frontier Economics' calculations of target base year opex for 2019–2024

Note: If the efficiency adjustment is estimated to be negative (i.e. a negative reduction), this implies that Essential Energy's proposed base year opex is lower than the target base year opex, and no base year reduction would be required.

2.2.1 Estimated target base year opex using the AER's preferred econometric model

The raw efficiency scores estimated from EI's preferred Cobb-Douglas Stochastic Frontier Analysis (SFA CD) model over the updated 2006 – 2016 sample period are presented in Table 8 below. This is step 1 of the 9 steps in the AER's approach discussed in Section 2.1.2.

It can be seen from Table 8 that despite achieving a 4.9% p.a. reduction in opex since 2012–13 (Figure 3 above), Essential Energy's efficiency score estimated by the AER's preferred SFA CD model has improved only by 2.7% since the last regulatory period. This is unsurprising as the SFA CD scores are time-invariant and can be interpreted as average efficiency scores over the 11 year sample period. In order to estimate Essential Energy's target base year opex for the 2019–24 regulatory control period, steps 2 – 9 discussed in Section 2.1.2 need to be carried out.

Table 8: Comparison of EI's SFA CD efficiency scores in 2014 determination and 2017 annual benchmarking report

	SFA CD (2014 determinations)	SFA CD (2016 annual benchmarking report)
ActewAGL	39.9%	44.8%
AusNet Services	76.8%	74.8%
Ausgrid	44.7%	44.6%
CitiPower	95.0%	89.7%
Endeavour Energy	59.3%	57.4%
Energex	61.8%	61.9%
Ergon Energy	48.2%	51.0%
Essential Energy	**54.9%**	**57.5%**
Jemena	71.8%	70.2%
Powercor	94.6%	95.8%
SA Power Networks	84.4%	79.8%
TasNetworks	73.3%	74.6%
United Energy	84.3%	84.5%
Comparison point - top 5th score	**76.8%**	**74.8%**

Source: Frontier Economics

The calculations for steps 2 – 9 of the AER's preferred approach using the updated sample are shown in Table 9. Essential Energy's proposed base year opex for FY18 is \$348.8m[8], which we treat as A_f^* in the AER's base-step-trend formula described in Section 2.1.1.

It can be seen that following the roll-forward of the target opex from the middle of the estimation period to the base year, under the AER's preferred benchmarking model Essential Energy's proposed base year opex is only marginally higher (by 0.6%) than target base year opex before any adjustment for OEFs, and significantly lower (by 10.1%) than the target base year opex after an adjustment for OEFs is applied[9]. As the efficiency adjustment is estimated to be very small (0.06%) even in the absence of any OEF adjustments, this implies that no base year reduction

8 In \$2018-19.

9 Assuming an OEF adjustment of 10.7% as per the AER's previous regulatory determination

would be required. Since this conclusion holds prior to any OEF adjustments, it holds even more strongly if allowance is made for any OEF adjustments in the estimation of Essential Energy's target base year opex.

Table 9: Estimated target base year opex for Essential Energy for the 2019–24 regulatory control period – AER's preferred SFA CD model

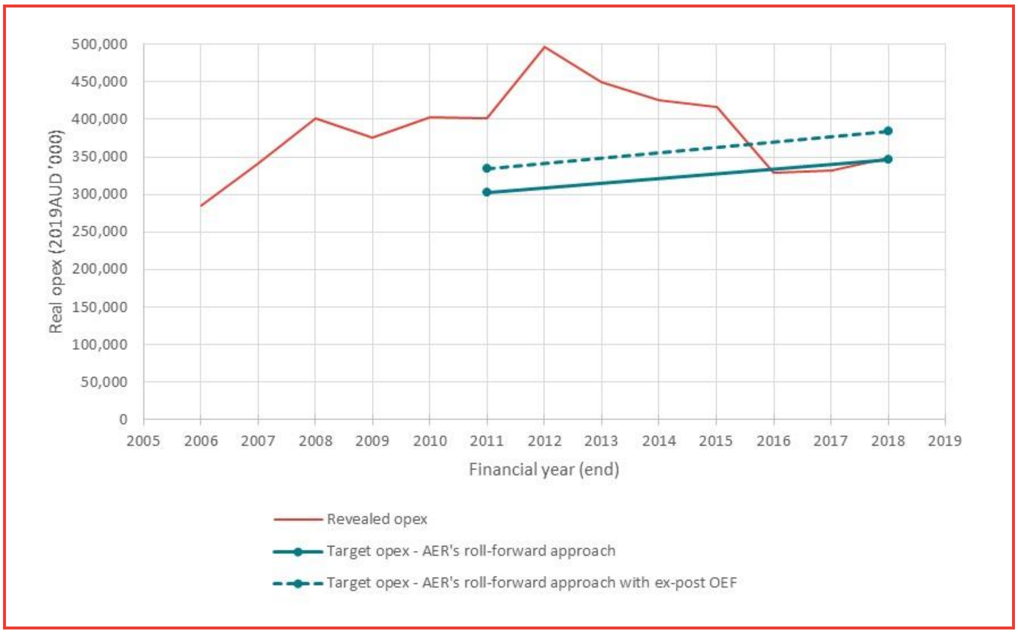
Steps in calculating target opex		Calculation with no ex-post OEF	Calculation with 10.7% ex-post OEF
Step 1	Essential Energy's raw efficiency score over 2006 – 2016 period – derived from EI preferred model.	57.5%	57.5%
Step 2	Choice of comparison point (raw efficiency score of top 5th DNSPs – AusNet Services)	74.8%	74.8%
Step 3	Assessment of total OEF adjustment for Essential Energy	0%	10.7%
Step 4	Lowering of comparison point to account for OEFs	74.8% = 74.8%/(1+0%)	67.6% = 74.8%/(1+10.7%)
Step 5	Calculation of percentage reduction in average annual opex over estimation period to reach comparison point (i.e. target opex)	23.1% = 1 – (57.5%/74.8%)	14.8% = 1 – (57.5%/67.6%)
Step 6	Calculation of target opex at the middle of the period ($2010-11 in $2017-18)	$296.6m = (1 – 23.1%) * $385.6m	$328.4m = (1 – 14.8%) * $385.6m
Step 7	Roll forward target opex in the middle of estimation period to base year (2017–18, $2017-18)	$340.3m = $296.6m * (1 + 14.7%)	$376.7m = $328.4m * (1 + 14.7%)
.Step 8	CPI adjustment of base year target opex from $2017-18 to $2018-19	$346.9 = $340.3m * (1.02)	$384.0 = $376.7m* (1.02)
Step 9	Percentage efficiency adjustment	0.6% = 1 – ($346.9/$348.8)	-10.1% = 1 – ($384.0/$348.8)

Source: Frontier Economics

Note: If the efficiency adjustment is estimated to be negative (i.e. a negative reduction), this implies that Essential Energy's proposed base year opex is lower than the target base year opex, and no base year reduction would be required.

The approach of rolling target opex forward from the middle of the estimation period to the base year is illustrated in Figure 4 below. The solid turquoise line in this figure represents the roll-forward in the absence of any ex-post adjustment for OEFs. The dotted turquoise line represents the roll-forward including an ex-post OEF adjustment of 10.7% as in the AER's previous regulatory determination. It can be seen that Essential Energy's proposed opex in the base year is lower than the target opex after an adjustment is made for OEFs. This implies that no efficiency adjustment to Essential Energy's proposed base year opex is required under the AER's preferred CD SFA benchmarking approach.

Figure 4: Essential Energy's proposed base year opex vs target base year opex (using AER roll-forward)



Source: Frontier Economics

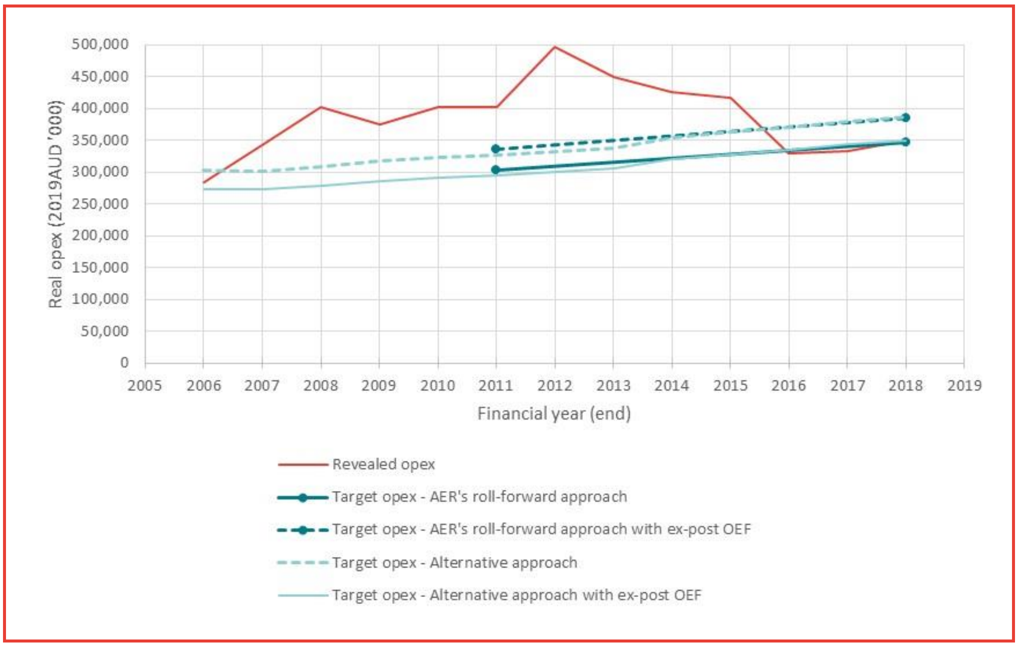
We note that the efficiency of Essential Energy's base year opex can also be assessed by directly evaluating the estimated econometric function at the values of the explanatory variables in the base year. This would be an alternative to the AER roll-forward approach illustrated in Figure 4 above. We compare results from the AER's roll-forward approach with this alternative approach in Table 10 and Figure 5 below.

Table 10: AER roll-forward approach vs alternative approach

	AER's roll-forward approach		Alternative approach	
	Calculation with no ex-post OEF	Calculation with 10.7% ex-post OEF	Calculation with no ex-post OEF	Calculation with 10.7% ex-post OEF
Proposed base year opex (A_f^*)	348.8	348.8	348.8	348.8
Target base year opex	346.9	384.0	349.4	386.8
Base year efficiency adjustment (difference between proposed and target opex)	1.9	-35.2	-0.6	-37.9
Percentage base year opex efficiency reduction	0.6%	-10.1%	-0.2%	-10.9%

Source: Frontier Economics

Figure 5: AER roll-forward approach vs alternative approach



Source: Frontier Economics

It can be seen from Table 10 and Figure 5 above that both approaches provide similar results. However, the advantage of the alternative approach of evaluating the estimated econometric function at the values of the explanatory variables is that it can be applied directly to alternative econometric functional forms such as TL SFA and LSE. By contrast, the AER's approach to rolling forward the target opex from the middle of the estimation period to the base year cannot be applied directly to the TL functional form since it is non-linear in logarithms and hence the elasticities are not constant. In the remainder of our report, we have Estimated Essential Energy's target opex in the base year by directly evaluating the estimated econometric functions at the values of the explanatory variables in the base year. As this approach facilitates comparisons across all alternative econometric models, it is our preferred approach.

2.2.2 Estimated target base year opex using alternative econometric models considered by the AER

In addition to its preferred SFA CD model, the AER has investigated several alternative econometric models in its annual benchmarking reports and in the previous regulatory determination for Essential Energy, namely:

- LSE CD: Least Square Estimation (LSE) using a Cobb-Douglas (CD) functional form
- LSE TL: Least Square Estimation using a Translog (TL) functional form, and
- SFA TL: Stochastic Frontier Analysis using a Translog functional form.

The estimated time-invariant efficiency scores over the 2006 – 2016 period from these alternative approaches are presented in Table 11. The table also presents the estimated base year efficiency adjustment for Essential Energy according to each of these models.

Despite its apparently low <u>average</u> efficiency scores over the 11-year period, Essential Energy's proposed base year opex is lower that its estimated target base year opex across all these models. This is owing to the significant opex reductions that Essential Energy has achieved since 2012–13.

In conclusion, neither the AER's preferred model, nor the alternative models it has investigated, provide any evidence to suggest that Essential Energy's base year opex for the 2019–24 regulatory period requires an efficiency adjustment. Since this conclusion holds prior to any OEF adjustments, it holds even more strongly if allowance is made for any OEF adjustments in the estimation of Essential Energy's target base year opex.

Table 11: Efficiency scores for EI's SFA CD model and other alternative models investigated by EI

	SFA CD	SFA TL	LSE CD	LSE TL
ActewAGL	44.8%	41.4%	44.1%	39.9%
AusNet Services	74.8%	74.0%	74.8%	71.7%
Ausgrid	44.6%	61.9%	42.2%	47.6%
CitiPower	89.7%	94.9%	86.9%	82.5%
Endeavour Energy	57.4%	64.3%	55.5%	59.2%
Energex	61.9%	77.1%	60.9%	66.3%
Ergon Energy	51.0%	57.4%	52.8%	52.6%
Essential Energy	**57.5%**	**64.6%**	**63.4%**	**66.9%**
Jemena	70.2%	70.2%	65.4%	55.7%
Powercor	95.8%	96.3%	100.0%	100.0%
SA Power Networks	79.8%	87.5%	80.6%	83.9%
TasNetworks	74.6%	66.7%	76.7%	70.3%
United Energy	84.5%	94.2%	80.0%	71.7%
Target score				
Top 5th score	74.8%	77.1%	76.7%	71.7%
Essential Energy				
Target opex (2019AUD '000)	349.4	384.9	353.0	405.0
Revealed opex (2019AUD '000)	348.8	348.8	348.8	348.8
Percentage base year opex efficiency reduction – (No allowance for OEFs)	-0.2%	-10.3%	-1.2%	-16.1%

Source: Frontier Economics

Notes:

1. *If the efficiency adjustment is estimated to be negative (i.e. a negative reduction), this implies that Essential Energy's proposed base year opex is lower than the target base year opex, and no base year reduction would be required.*
2. *The AER does not present results for the TL SFA model in its annual benchmarking reports. However, the AER has considered this approach in the past. We discuss the TL SFA results further in Section 4.3.*

3 AER's MTFP/MPFP analysis

In its annual benchmarking reports, the AER also presents results for multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) measures of productivity. Having reviewed the MTFP and MPFP analysis undertaken by EI on behalf of the AER, we consider that this analysis contains a number of serious shortcomings. In the remainder of this section, we outline the following issues with EI's analysis.

- EI's MTFP and MPFP scores are highly sensitive to the output weights used in constructing the indices.
- EI's output weights are derived using outdated RIN data and have not been updated since 2014.
- There are a number of issues with EI's econometric methodology used to derive its output weights.

Owing to these errors in approach, we believe that the results contained in the AER's 2017 annual benchmarking report are entirely unsuitable to be used in support of regulatory decisions on the relative efficiencies of the DSNPs.

3.1 The AER's MTFP and MPFP scores are highly sensitive to the output weights used

The AER's MTFP and MPFP indices are ratios of DNSP outputs to inputs over time. The AER's preferred specification includes the following output and input variables.

- **The AER's five output variables** are energy, ratcheted maximum demand, customer numbers, circuit length, and reliability. The same output variables are used to calculate the MTFP, Opex MPFP and Capital MPFP indices.
- **The AER's four input variables** include real opex, overhead lines (MVAkms), underground cables (MVAkms), and distribution transformer capacity (MVA) plus the sum of single stage and the second stage of two-stage zone substation level transformer capacity (MVA). Whereas the MTFP input index includes all four inputs, the Opex MPFP index and Capital MPFP index include only the opex and capital inputs, respectively.

In order to operationalise its productivity index methodology, the AER estimates output weights for each of the outputs in its output index. These weights, also referred to as 'output shares', are summarised in Table 12.

As shown in Table 12, the AER's output index specification includes: customer numbers (with a 45.8% share), circuit length (with a 23.8% share), ratcheted maximum demand (with a 17.6% share), energy (with a 12.8% share), and reliability. The weight for reliability is based on AEMO's current estimate of the value of consumer reliability (VCR). The AER's weights for the output variables other than reliability are derived econometrically using a Leontief cost function, as described in Section 3.3 below.

Table 12: AER output shares

	2006–2013 EI's weights	Approach
Customer numbers	45.8%	Weights are econometrically derived
Circuit length	23.8%	
Ratcheted maximum demand	17.6%	
Energy	12.8%	
Reliability	Weight based on current AEMO VCRs	

Source: AER

Note: The same output variables and output weights are used to calculate the MTFP, Opex MPFP, and Capital MPFP indices.

In Figure 6 and Figure 7 we demonstrate how sensitive the AER's MTFP results are to changing the output weights on customer numbers and circuit length. This is illustrated as follows.

- **Figure 6 shows that the MTFP scores of urban DNSPs increase as a higher weight is given to customer numbers.** In Figure 6, MTFP scores[10] are plotted on the Y axis and the output weight given to customer numbers is plotted on the X axis. It can be seen that the MTFP scores of DNSPs operating in more urban environments (such as CitiPower and United) trend upwards as a higher weight is given to customer numbers. Conversely, the MTFP scores of the more rural DNSPs (such as Ergon Energy and Essential Energy) decline as a higher weight is given to customer numbers.
- **Figure 7 shows that the MTFP scores of rural DNSPs increase as a higher weight is given to circuit length.** In Figure 7, MTFP scores are plotted on the Y axis and the output weight given to circuit length is plotted on the X axis. It can be seen that the MTFP scores of DNSPs operating in more rural environments (such as Ergon Energy and Essential Energy) trend upwards as a higher weight is given to circuit length. Conversely, the MTFP scores of the more urban DNSPs (such as CitiPower and United) decline as a higher weight is given to circuit length.

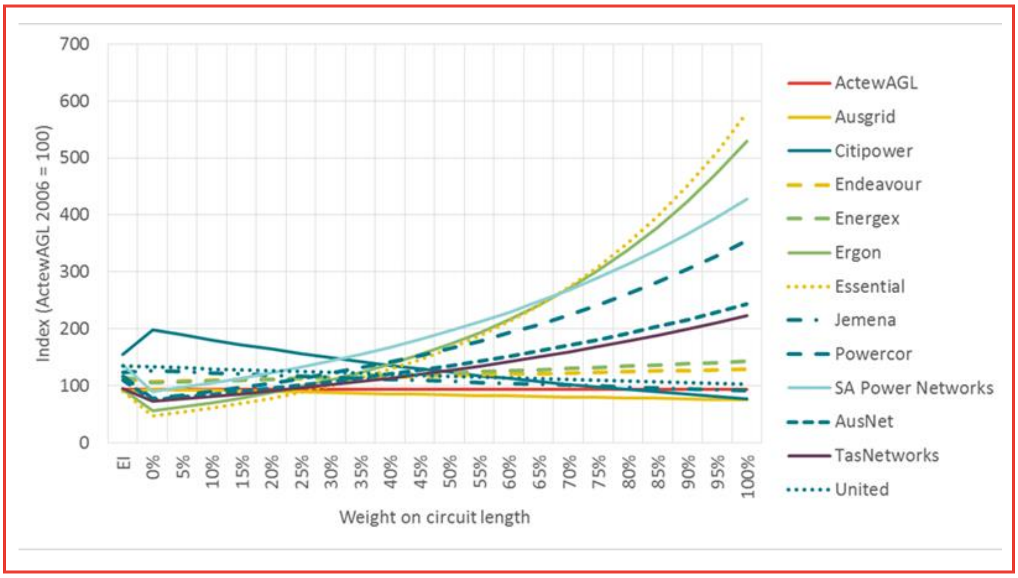
10 We show the average MTFP scores from 2006 - 2016

Figure 6: Average MTFP – sensitivity to customer numbers weight

Source: Frontier Economics

Note: In this figure, we progressively increase the output weight given to customer numbers, while splitting the remaining output weight equally amongst the remaining output variables. For example, at the left of the chart, if the weight given to customer numbers is 10%, then the weight assigned to circuit length, ratcheted maximum demand and energy delivered is 30% each. At the right of the chart, if the weight assigned to customer numbers is 100%, then the weight given to circuit length, ratcheted maximum demand and energy delivered is 0% each. EI's output weights shown (see Table 12) are plotted at the extreme left of this chart to provide a reference point for the possible alternative sets of weights presented to the right of the chart.

Figure 7: Average MTFP – sensitivity to circuit length weight



Source: Frontier Economics

Note: In this figure, we progressively increase the output weight given to circuit length, while splitting the remaining output weight equally amongst the remaining output variables. For example, at the left of the chart, if the weight given to circuit length is 10%, then the weight assigned to customer numbers, ratcheted maximum demand and energy delivered is 30% each. At the right of the chart, if the weight assigned to circuit length is 100%, then the weight given to customer numbers, ratcheted maximum demand and *energy delivered is 0% each. EI's output weights (see Table 12) are plotted at the extreme left of this chart to provide a reference point for the possible alternative sets of weights presented to the right of the chart.*

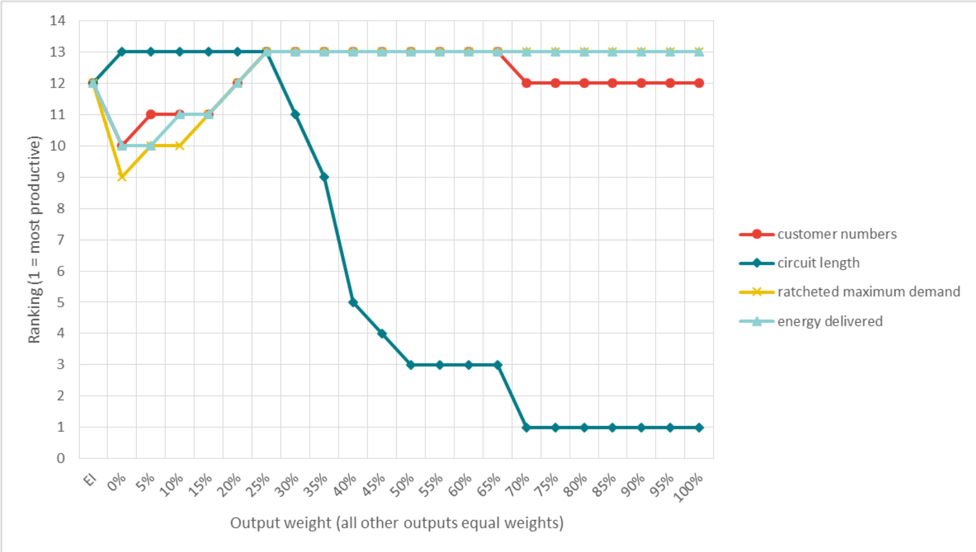
It is clear from Figure 6 and Figure 7 that Essential Energy's MTFP scores and rankings increase as higher weight is given to circuit length, and decrease as a higher weight is given to customer numbers.

In Figure 8, we summarise how Essential Energy's MTFP ranking changes with different combinations of output weights for all four output variables. In this figure, Essential Energy's MTFP ranking is plotted on the Y-axis. On the X-axis we show the output weight assigned to each of the four output variables represented by the turquoise (circuit length), red (customer numbers), yellow (ratcheted maximum demand) and light blue (energy delivered) lines, while equally splitting the output weight assigned to each of the remaining three output variables. As in Figure 6 and Figure 7 above, we progressively increase the output weight assigned to each of the four output variables in turn, while equally splitting the weight assigned to the remaining three output variables.

The following three examples facilitate an interpretation of Figure 8.

- To the bottom right of Figure 8 it can be seen from the turquoise line that if a 70% weight is assigned to circuit length, and the remaining three output variables are assigned a weight of 10% each, Essential Energy would rank 1st under the AER's MTFP model.
- Similarly, at the top right of Figure 8 it can be seen from the red line that if a 70% weight is assigned to customer numbers, and the remaining three output variables are assigned a weight of 10% each, Essential Energy would rank 12th under the AER's MTFP model.
- In another example, if instead of assigning a 45% weight to customer numbers (similar to EI's weight), a weight of 45% were attached to circuit length, Essential Energy's MTFP rank would improve from 12th to 4th.

Figure 8: Ranking of Essential Energy based on average MTFP



Source: Frontier Economics

Note: Essential Energy's MTFP ranking using EI's output weights (see Table 12) is plotted at the extreme left of this chart. It can be seen that Essential Energy ranks 12th out of 13 DNSPs when EI's output weights are used, but its ranking improves dramatically when more weight is given to circuit length.

Therefore, while Essential Energy ranks 12th according to the AER's MTFP results presented in its 2017 annual benchmarking report (based on an output weight of 46% assigned to customer numbers), Figure 8 shows that its ranking would be higher than estimated by the AER in all cases where circuit length is given a weight of higher than 30%.[11] If circuit length were assigned a weight between 50% and 65%, Essential Energy's MTFP ranking would improve to 3rd out of 13 DNSPs. If circuit length were assigned a weight of above 70%, Essential Energy's MTFP would rank first among the 13 DNSPs.

Given how sensitive the AER's DNSP MTFP rankings are to the relative weights assigned to customer numbers and circuit length, we recommend that the AER consider using different sets of weights for rural and urban DNSPs, to reflect the fact that these two outputs impose different costs on rural and urban DNSPs. Given how sensitive the relative DNSP ranking are to changes in output weights, and the fact that the importance of different cost drivers are likely to differ between rural and urban DNSPs, we do not consider the AER's MTFP and MPFP results presented in the AER's 2017 annual benchmarking report a suitable basis for informing regulatory decisions on the relative efficiencies of the DNSPs.

11 In the simplified example where the residual output weight is split equally amongst the remaining three output variables.

3.2 EI's output weights are derived using outdated RIN data and have not been updated since 2014

In estimating the output weights shown in Table 12 in Section 3.1, EI has not used the most up to date RIN data available. This is unusual in the context of regulatory work, where typically the most up to date information will be used in any analysis, unless there are concerns over the quality/veracity of such information. No such concerns have been expressed by the AER.

The output weights presented in Table 12, which form the basis of the AER's latest 2017 annual benchmarking report, have been calculated using RIN data published in 2014. The latest RIN data revisions made by the DNSPs, and the three additional years of data that were available to the AER at the time of writing the 2017 annual benchmarking report have not been incorporated.

We have attempted to reproduce the AER's econometric output weightings using the latest available information. However, in doing so, we found a number of serious shortcomings in the econometric methodology adopted by the EI, which we discuss further in Section 3.3 below.

Box 1: Summary of data revisions incorporated in last two annual benchmarking reports

Data revisions incorporated in 2017 annual benchmarking report:

> "Data revisions have mainly focused on further refinements to estimated MVA factors for lines and cables. ActewAGL has revised the rating of its underground 132kV cables for the entire time period. Ergon Energy has revised ratings for some of its high voltage overheads lines for 2016. We backcast these revised ratings to 2012 to provide a consistent time series. Corrections have also been made to the MVA rating of ENX's high voltage cables and TND has revised the total MVA quantity of its distribution transformers, the latter mainly affecting the early years of the reporting period. Some minor changes have been made to RAB values in line with changes in guidelines and price determinations. In line with previous practice, CitiPower and Powercor data are based on the Cost Allocation Methodologies (CAMs) that applied in 2014 rather than their recently revised CAMs.
>
> In previous economic benchmarking of NSPs we have assumed a composition of operating expenditure (opex) of 62.6 per cent labour costs and 37.4 per cent non–labour costs. In response to debate about the currency of this estimated split and its appropriateness, the AER has sought data from DNSPs on the composition of their opex. Across all DNSPs, the proportion of labour (from in–house labour, field services contracts and non–field services contracts) was found to be 59.7 per cent, after adjustments by the AER to ensure consistent reporting. While this is quite close to the proportion we have previously used, we use the updated proportion in this report. As part of the same data collection exercise, the AER also gathered data on redundancy payments for all DNSPs in all of the 11 years covered in the current analysis." [12]

Data revisions incorporated in 2016 annual benchmarking report:

> "Data revisions have mainly focused on further refinements to estimated MVA factors for lines and cables. In some cases where DNSPs have provided revised MVA factors for 2015, these have also been applied to earlier years (eg AusNet Distribution). Some refinements have also been made to methods used to calculate line and cable lengths. Some changes have been made to RAB values in line with changes in guidelines and price determinations. These refinements and changes have generally had quite minor impacts on the economic benchmarking results. We have also decided to include the CAM change for ActewAGL." [13]

Source: AER (2017) Annual Benchmarking Report and EI (2016) DNSP MTFP memo.

12 AER (Nov 2017), *Annual Benchmarking Report: Electricity Distribution Network Service Providers*. Section 1.2

13 Economic Insights (Nov 2016), *Memo on DNSP multilateral total factor productivity results – 4 November 2016*, p. 2.

3.3 There are a number of issues with EI's econometric methodology used to derive its output weights

The AER's output weights shown in Table 12 are derived econometrically by estimating Leontief cost functions. As discussed in Section 3.2, the estimations have not been updated since 2014, when they were estimated by EI using data for the 8 year sample period 2006 – 2013.

For each DNSP, EI estimates a separate Leontief cost function for each of the four input variables in EI's input index (the denominator of the MTFP calculation). The four input variables are:

- real opex
- overhead lines (MVAkms)
- underground cables (MVAkms), and
- distribution transformer capacity (MVA) plus the sum of single stage and the second stage of two-stage zone substation level transformer (MVA).

For each DNSP, each of the four input variables is separately regressed against EI's four output variables in Table 9 above (energy, ratcheted maximum demand, customer numbers, and circuit length) and a time trend; i.e. 52 regressions in total (13 DNSPs x 4 inputs).

Algebraically, the Leontief model estimated by EI separately for each DNSP and each input can be written as:

$$x_i^t = \sum_{j=1}^{4} (a_{ij})^2 y_j^t (1 + b_i t)$$

where x_i^t, $i = 1, \ldots 4$ represents the value of the i^{th} input at time t, and $y_j^t, j = 1, \ldots 4$ represents the value of the j^{th} output at time t. The coefficient a_{ij} in this model has been squared to ensure that an increase in any of the outputs has a non-negative impact on inputs.

We can see from the specification above that there are 5 parameters that need to be estimated in each of the 52 regressions. Once the 52 Leontief cost functions have been estimated, an output cost share can be estimated for each output j and for each DNSP and year as described in the following paragraph.

The expression $(a_{ij})^2 y_j^t (1 + b_i t)$ in the formula above can be interpreted as the amount of input i required to produce y_j^t units of output j. If w_i^t is the input price for input i at time t, then the input cost of input i in producing y_j^t units of output j is $w_i^t (a_{ij})^2 y_j^t (1 + b_i t)$. This can be estimated for each DNSP, each input and each output by substituting the estimated values of the parameters in the Leontief cost function, i.e. by $w_i^t\left(\widehat{a_{ij}}\right)^2 y_j^t(1+\widehat{b_i}t)$. Summing across the four inputs and normalising then leads to an estimate of the share that each output contributes to the total cost of inputs:

$$h_j^t = \frac{\sum_{i=1}^{4} w_i^t\left(\widehat{a_{ij}}\right)^2 y_j^t(1+\widehat{b_i}t)}{\sum_{j=1}^{4}\left[\sum_{i=1}^{4} w_i^t\left(\widehat{a_{ij}}\right)^2 y_j^t(1+\widehat{b_i}t)\right]}$$

Finally, the output cost shares used in the MTFP analysis are derived by taking a weighted average of the DNSP and year specific cost shares, where each cost share is weighted by the corresponding cost as predicted by the estimated regressions.

EI's methodology described above has a number of serious shortcomings.

- Each of EI's 52 regressions is estimated on a sample of only 8 data points (one data point for each year from 2006 to 2013). As there are 5 parameters estimated in each regression with 8 only data points, EI's analysis suffers from a lack of degrees of freedom.
- Since the regressions are non-linear in the parameters, the estimates will be biased. While the bias would become negligible in large samples, with only 8 observations the bias could be substantial. Moreover, the usual statistics for evaluating the significance of the parameters will not have the usual properties.
- The estimates of the input-output ratios $\left(a_{ij}\right)^2$ depend on the base year selected for the time trend. Hence, it is possible that for one choice of base year the estimated input-output ratio is constrained to be zero, while for another choice of base year it is positive. It is a weakness of EI's specification that the estimated coefficients could depend on the choice of base year.
- Despite estimating output shares separately for each DNSP and each input, EI eventually uses a single weighted average output cost share for each output variable. Therefore, EI's approach to estimating its output weights is inconsistent with the way these weights are used, as output weights are allowed to differ by DNSPs during the estimation, but a common set of weights is then used to derive the MTFP/MPFPs. EI's rationale for doing so is unclear to us.

Owing to the shortcoming described above, we believe that the MTFP and MPFP results contained in the AER's 2017 annual benchmarking report are entirely unsuitable to be used to support regulatory decisions on the relative efficiencies of the DSNPs.

4 Additional approaches investigated by Frontier Economics

As outlined in Section 2.1.2, the AER's efficiency adjustment for Essential Energy in the previous regulatory period was estimated using a single benchmarking model, the SFA CD model. In our view, it would not be appropriate for a regulator to rely on a single approach and a single number to characterise the efficiency of a particular business. Rather, the efficiency of businesses might more appropriately be characterised by a range of numbers.

We note that overseas regulators who have decades of experience in economic benchmarking, such as Ofgem in Great Britain and Bundesnetzagentur in Germany, use a number of different approaches to mitigate the risk that regulatory decisions are influenced excessively by model errors associated with a single model. Understanding the dangers of relying on a single econometric model to determine efficiency scores for benchmarking purposes, these regulators rely on a range of approaches when benchmarking businesses. In our view, any model aimed at determining efficiency scores for regulated businesses is subject to a range of assumptions and data issues, and the estimated efficiency scores are sensitive to how these issues are handled. In order to understand how sensitive the benchmarking results are to alternative approaches and model specifications, we estimate Essential Energy's efficiency scores and target base year opex these using a range of different approaches including the following.

- In Section 4 we show how sensitive the AER's preferred CD SFA results are to splitting the sample of DNSPs into separate urban and rural sub-samples.
- In Section 4.2 we investigate statistically whether the sample of Australian DNSPs can validly be pooled with the DNSPs in New Zealand and Ontario. We also show how the AER's preferred CD SFA results change when the DNSPs in Ontario and New Zealand are excluded from the sample.
- In Section 4.3 we show the results from our estimation of the translog SFA (SFA TL) specification, which the AER has considered and rejected in the past. We argue that the AER's reasons for rejecting this model are not relevant in the current context; and
- In Section 4.4 we show the results from the use of Data Envelopment Analysis (DEA).

In undertaking this exercise, we emphasise that we do not claim that the models presented in this section are the 'right' models, and that the AER should use these as 'preferred' models to set allowances at this reset. Rather, we recommend that the AER consider a range of benchmarking evidence when determining its target base year opex for the DNSPs. We propose that the evidence presented in this report should be used as a starting point for discussion and consultation with all 13 DNSPs.

Our sensitivity analysis is discussed in the remainder of this section.

4.1 Splitting of rural and urban samples

The CD SFA benchmarking model relied on by the AER implicitly takes account of customer density in a fairly simplistic way: the model includes the logarithms of customer numbers and circuit length. This is algebraically equivalent to including the logarithms of customer density (number of customers per kilometre of circuit length) and circuit length. However, this does not account for the fact that the impact of different costs drivers on cost (e.g. elasticities) might differ across networks with different customer densities. Denser networks are likely to be able to serve a given number of customers with fewer assets than more sparsely populated networks, and are also likely to have lower operating costs.

To investigate whether there are differences in the elasticities between denser and less dense networks, we split the sample into DNSPs with less than 20 customers per km of circuit length[14] (designated as rural), and more than 20 customers per kilometre of circuit length (designated as urban). To test whether these two subsets of DNSPs have the same elasticities, we modified EI's preferred model by interacting all the variables with a rural dummy variable. This allows all the coefficients to differ between the rural and urban subsamples.

A statistical test of whether the coefficients are different between rural and urban DNSPs can be carried out by testing whether the 5 coefficients on the interacted variables are jointly significantly different from zero. This is referred as a test of poolability. The estimation results and the poolability test details are shown in Table 13. The model has been estimated using data for the period 2006 – 2016.

The poolability test rejects the hypothesis that the rural and urban subsamples have the same coefficients at the 3% level of significance. This indicates that the impact of cost drivers on costs differ between rural and urban utilities. Although some of these differences are not statistically significant individually, they are jointly significant, and some of the differences are very significant from a business point of view. For example, while for urban DNSPs the elasticity of opex with respect to circuit length is 0.076, for rural DNSPs the elasticity is 0.076 + 0.191 = 0.267. Similarly, there is a large difference between the urban and rural elasticities with respect to customer numbers, with an elasticity of 0.883 for urban DNSPs and 0.883 – 0.224 = 0.659 for rural DNSPs.

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14 The number of customers and circuit length used in determining customer density were taken as the average number of customers and the average circuit length over the 2006 – 2016 period.

As we illustrated in Section 3.1, the efficiency ranking of a DNSP can be very sensitive to the weights attached to different cost drivers. The fact that EI's benchmarking exercise does not take into account material differences in the way different cost drivers impact on DNSPs facing different operating environments makes it imperative that EI's benchmarking results not be applied in a mechanistic manner.

Table 13: Test for poolability of rural and urban DNSPs in EI's preferred SFA CD model

Model with variables interacted with rural dummy	Parameter estimates
Log (customer numbers)	0.883***
Log (circuit length)	0.076
Log (ratcheted maximum demand)	0.066
Log (share of underground cables)	-0.138***
Time trend	0.016***
Log (customer numbers) * rural dummy	-0.224
Log (circuit length) * rural dummy	0.191*
Log (ratcheted maximum demand) * rural dummy	-0.033
Log (share of underground cables) * rural dummy	-0.026
Time trend * rural dummy	0.009***
Constant	-22.361***
Country dummies	
New Zealand	0.031
Ontario	0.284***
Variance parameters	
mu	0.402***
sigma_u	0.171
sigma_v	0.104
Poolability test	
Test statistic (Chi-squared)	12.432
Degrees of freedom	5
p-value of test statistic	0.029
Test rejected?	Yes, at 3% significance level
N	748

Source: Frontier Economics

*Note: *** denotes significance at 1%, ** significance at 5%, and * significance at 10%.*

Additional approaches investigated by Frontier Economics

Given that the pooling of rural and urban DNSPs in EI's preferred model does not pass the poolability test, we have also estimated EI's model on separate urban and rural subsamples. Estimates for these models are shown in the last two columns of Table 14. For comparison, we have also included in Table 14 the estimates of EI's preferred SFA CD model (the first column of estimates) and the model estimated for the poolability test above (second column of estimates in Table 14).

Table 14: Comparison of models capturing rural versus urban differences

	EI's SFA CD model	Interaction with rural dummy	SFA CD - urban DNSPs	SFA CD - rural DNSPs
Log (customer numbers)	0.769***	0.883***	0.861***	0.624***
Log (circuit length)	0.097**	0.076	0.068	0.321***
Log (ratcheted maximum demand)	0.131**	0.066	0.079	0.031
Log (share of underground cables)	-0.144***	-0.138***	-0.123**	-0.131**
Time trend	0.018***	0.016***	0.016***	0.024***
Log (customer numbers) * rural dummy		-0.224		
Log (circuit length) * rural dummy		0.191*		
Log (ratcheted maximum demand) * rural dummy		-0.033		
Log (share of underground cables) * rural dummy		-0.026		
Time trend * rural dummy		0.009***		
Constant	-27.832***	-22.361***	-22.269***	-38.774***
Country dummies				
New Zealand	0.092	0.031	0.034	0.131
Ontario	0.251***	0.284***	0.213**	0.537***
Variance parameters				
mu	0.392***	0.402***	0.414***	0.204
sigma_u	0.179	0.171	0.172	0.196
sigma_v	0.105	0.104	0.097	0.114
Measures of fit				
LLF	511.912	518.721	348.605	176.353
AIC	-1001.825	-1003.441	-675.211	-330.705
BIC	-951.033	-924.946	-629.720	-290.489
N	748	748	462	286

Source: Frontier Economics

*Note: *** denotes significance at 1%, ** significance at 5%, and * significance at 10%.*

In Table 15 we present the efficiency scores and target base year opex resulting from the estimated models shown in Table 14. It can be seen that for Essential Energy, the impact on the raw efficiency score and the target base year opex of allowing costs drivers to have different weights for rural versus urban DNSPs has a very substantial impact on the target score and on the target base year opex. Compared to EI's preferred model, the model with rural dummy interactions leads to a 17% increase in target base year opex, and the separate urban and rural models to a 25% increase.

Table 15: Efficiency scores for models capturing rural versus urban differences

	EI's preferred SFA CD model	Interaction with rural dummy	Combination of urban & rural models[15]
ActewAGL (U)	44.8%	44.7%	46.3%
AusNet Services (R)	74.8%	67.2%	71.1%
Ausgrid (U)	44.6%	47.4%	47.0%
CitiPower (U)	89.7%	91.5%	94.5%
Endeavour Energy (U)	57.4%	59.1%	59.1%
Energex (U)	61.9%	65.0%	64.4%
Ergon Energy (R)	51.0%	54.3%	59.3%
Essential Energy (R)	**57.5%**	**63.5%**	**69.3%**
Jemena (U)	70.2%	72.4%	73.6%
Powercor (R)	95.8%	92.3%	96.6%
SA Power Networks (R)	79.8%	74.0%	81.7%
TasNetworks (R)	74.6%	68.9%	72.3%
United Energy (U)	84.5%	88.7%	88.8%
Target score			
Top 5th score	74.8%	72.4%	73.6%
Essential Energy – base year			
Target opex (2019AUD '000)	349.4	408.1	437.4
Revealed opex (2019AUD '000)	348.8	348.8	348.8
Percentage base year opex efficiency reduction – (No allowance for OEFs)	-0.2%	-17.0%	-25.4%

Source: Frontier Economics

15 To determine the 5th top ranked DNSP and target score for the separate urban and rural regressions, we merged the raw efficiency scores derived from the separate models.

4.2 The use of international data: Can data be pooled across countries?

In EI's estimation of its preferred SFA CD econometric model, the Australian data sample is embedded within a much larger sample comprising data from New Zealand and Ontario. The aim of using the larger dataset is to increase the variation in the data to enable more robust estimation of the model's parameters. As shown in Table 16 below, the Australian DNSPs account for only 19% of the estimation sample. The New Zealand DNSPs account for 26%, and the Ontarian DNSPs account for 54%, more than half of the sample.

Table 16: Number of companies in EI's sample

	Australia	New Zealand	Ontario
Number of companies	13	18	37
Proportion of EI's sample	19.1%	26.5%	54.4%

Source: EI dataset

This raises the question whether the impact of the different cost drivers on opex in these 3 jurisdictions is similar enough to enable these datasets to be pooled. In Table 17 we present the estimation results for EI's preferred model specification when estimated using each of the three country subsamples separately, as well as using the pooled sample.[16] It can be seen that the parameter estimates for EI's pooled model are more similar to the estimates for Ontario alone, than to the estimates for Australia or New Zealand. This would suggest that there may be material differences between the cost drivers in different countries.

We can test statistically whether the impact of cost drivers on opex is similar enough across countries for the pooling of the samples to be justified. Poolability requires that there are no statistically significant differences between the values of the main parameters in the model across the sub-samples. To conduct the poolability test we re-estimated EI's preferred model with the addition of dummy variables that could pick up any differences between the countries in the values of the elasticities on the four main drivers of costs (customer numbers, circuit length,

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16 EI initially attempted to benchmark the Australian DNSP using only Australian data but found that the sample of 104 observations available at the time did not produce robust econometric estimates. Since then, three additional years of data have become available, improving the robustness of the estimates using only Australian data.

ratcheted maximum demand and share of underground cables) as well as the time trends

Table 17: Comparison of models with different datasets

	AUS+NZ+ ONT data	AUS data only	NZ data only	ONT data only
Log (customer numbers)	0.769***	0.559*	0.538***	0.911***
Log (circuit length)	0.097**	0.186*	0.231*	0.058
Log (ratcheted maximum demand)	0.131**	0.321	0.199	0.054
Log (share of underground cables)	-0.144***	-0.030	-0.120	-0.174***
Time trend	0.018***	0.017***	0.022***	0.016***
Constant	-27.832***	-24.434***	-34.151***	-22.067***
Country dummies				
New Zealand	0.092			
Ontario	0.251***			
Variance parameters				
mu	0.392***	0.256	0.129	0.433***
sigma_u	0.179	0.293	0.230	0.133
sigma_v	0.105	0.115	0.114	0.094
N	748	143	198	407

Source: Frontier Economics

*Note: *** denotes significance at 1%, ** significance at 5%, and * significance at 10%.*

For example, to test whether the Ontarian data is poolable with the Australian and New Zealand we created a dummy variable for Ontario and interacted this with each of the five variables of interest. The coefficients on these so-called 'interaction' terms are estimates of the differences between the parameter values for Ontario and the corresponding parameter value for the combined Australia/New Zealand sample. We also test whether the New Zealand sample is poolable with the Australian sample if Ontario is excluded from the dataset.

Table 18 shows the results of these estimations and tests. The first column of estimates is EI's model on the pooled sample without any interactions, the middle column tests the poolability of the Ontarian data with the Australia/New Zealand sample, and the last column tests whether the New Zealand sample is poolable with the Australian sample in the absence of Ontarian data.

The last few rows in the table show the results of the poolability tests. The tests indicate that the Ontario sample is statistically not poolable with the Australian/New Zealand sample, but that the Australian and New Zealand samples can be pooled.

Table 18: Tests for poolability of international data in EI's preferred SFA CD model

	EI's preferred model, all data, no interactions	Is ONT poolable with AUS+NZ?	Is NZ poolable with AUS?
Log (customer numbers)	0.769***	0.529***	0.576*
Log (circuit length)	0.097**	0.191***	0.189**
Log (ratcheted maximum demand)	0.131**	0.239**	0.307
Log (share of underground cables)	-0.144***	-0.080	-0.020
Time trend	0.018***	0.020***	0.016***
Log (customer numbers) * country dummy		0.397***	-0.024
Log (circuit length) * country dummy		-0.134	0.018
Log (ratcheted maximum demand) * country dummy		-0.201	-0.095
Log (share of underground cables) * country dummy		-0.083	-0.126
Time trend * country dummy		-0.005	0.005
Constant	-27.832***	-30.976***	-23.627***
Country dummies			
New Zealand	0.092	-0.063	-11.079
Ontario	0.251***	9.294	
Variance parameters			
mu	0.392***	0.406***	0.163
sigma_u	0.179	0.171	0.276
sigma_v	0.105	0.104	0.114
Measure of fit			
LLF	511.912	518.343	204.061
AIC	-1001.825	-1004.687	-378.122
BIC	-951.033	-930.808	-320.644
Poolability test			
Test statistics (Chi-squared)		13.077	4.064
Degrees of freedom of test statistics		5	5
p-value of test statistics		0.023	0.540
Test rejected?		Yes, at 3% significance level	No
N	748	748	341

Source: Frontier Economics

*Note: *** denotes significance at 1%, ** significance at 5%, and * significance at 10%.*

Which countries are included in the estimation sample can have a material impact on the estimation of a DNSP's efficiency score and target opex. In Table 19 we show the efficiency scores of the Australian DNSPs for several of the models and datasets discussed in the above paragraphs, and the corresponding estimates of target opex for Essential Energy. The table shows that across the different samples and models, Essential Energy's target opex varies from $339.6m to $358.3m (in 2019 dollars).

Table 19: Efficiency scores and target opex for different datasets and models

	EI's preferred model, all data, no interactions	AUSNZONT data - interactions with ONT dummy	AUSNZ pooled data	AUS only data
ActewAGL	44.8%	48.1%	50.9%	47.2%
AusNet Services	74.8%	72.4%	76.1%	74.4%
Ausgrid	44.6%	42.4%	45.3%	51.8%
CitiPower	89.7%	88.4%	95.2%	94.3%
Endeavour Energy	57.4%	58.3%	62.3%	67.5%
Energex	61.9%	60.8%	65.0%	72.4%
Ergon Energy	51.0%	54.5%	56.6%	55.2%
Essential Energy	**57.5%**	**58.1%**	**60.1%**	**57.9%**
Jemena	70.2%	66.4%	70.8%	66.5%
Powercor	95.8%	94.4%	97.2%	95.9%
SA Power Networks	79.8%	84.5%	89.3%	93.1%
TasNetworks	74.6%	78.3%	82.6%	75.3%
United Energy	84.5%	76.8%	82.3%	82.3%
Target score				
Top 5th score	74.8%	76.8%	82.3%	75.3%
Essential Energy – base year				
Target opex (2019AUD '000)	349.4	352.1	339.6	358.3
Revealed opex (2019AUD '000)	348.8	348.8	348.8	348.8
Percentage base year opex efficiency reduction – (No allowance for OEFs)	-0.2%	-0.9%	+2.6%	-2.7%

Source: Frontier Economics

4.3 The SFA translog model

EI has presented compelling reasons why the translog functional form should be preferred over the Cobb-Douglas model.

> "The translog model is a much more comprehensive way of dealing with potential second–order non–linearity, because it allows for this effect on all variables in the model, not just one hand–picked variable."; See also comment on page 44: "Because we get little difference in results between the more flexible translog LSE model and the somewhat more rigid Cobb–Douglas SFA model, we are confident the SFA model is accurately modelling the included DNSPs."[17]

The translog functional form has also been preferred in the AER's TNSP benchmarking analysis.

However, in its previous benchmarking of Australian DNSPs EI dismissed the SFA translog (TL) model, on the grounds that this model results in some elasticities having the 'wrong' sign. We believe that EI's objections are unwarranted since these violations are typically very minor and statistically highly insignificant.

In its Nov 2014 report,[18] EI rejected the SFA TL model on account of the violation of so-called monotonicity conditions, i.e. the requirement that an increase in any output involves an increase in cost. The AER found that monotonicity was satisfied for the LSE TL model, but that 7 of the Australian DNSPs had monotonicity violations for the SFA TL model. The AER therefore concluded that the SFA TL model does not produce robust and reliable results, and it has not been considered since then.

EI has not published information on whether the SFA TL model estimated on the latest data violated monotonicity conditions. Our analysis of the violations of monotonicity in the SFA TL model estimated on the updated dataset indicates that:

- the monotonicity violations are small (the most negative elasticity is -0.11); and
- the monotonicity violations are statistically highly insignificant (the smallest p-value 0.17). In other words, they are statistically not significantly different from 0, and convincingly so.

As the violations of the monotonicity condition are very mild and statistically not significantly different from 0, we recommend that the AER include the SFA TL model in its toolkit of models.

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17 Economic Insights (Nov 2014), *Economic Benchmarking of NSW and ACT DNSP Opex*, p. 35.

18 See comment in Economic Insights (Nov 2014), Economic Benchmarking of NSW and ACT DNSP Opex, p. 32- 33.

We also note that the LSE TL model, when estimated on the updated dataset, has some monotonicity violations, though these are also small and statistically insignificant. Yet EI has included the LSE TL model as one of the models in its 2017 DNSP benchmarking report.

There are also reasons why monotonicity may not be as important a criterion in the current context as the AER suggests:

- We are not interested in predicting how opex changes if there is a small change in only one of the outputs; we are interested in getting the best estimates of the efficiency scores of the DNSP.
- Since there is high correlation between the 3 scale variables (customer numbers, circuit length and ratcheted maximum demand), the elasticities for individual outputs are not estimated precisely.
- The outputs, particularly customer numbers and circuit length, tend to increase together over time.
- Cross-sectionally, a DNSP tends to be larger or smaller than another on all 3 scales measures.
- Hence, it would be more appropriate to examine what happens when all 3 outputs increase by 1% together rather than looking at individual outputs one by one. Using this criterion there is no issue in regard to 'monotonicity': a 1% increase in all the outputs leads to a close to 1% increase in opex in all cases.

Using the SFA TL rather than the SFA CD functional form for the benchmarking model can have substantial impacts on the efficiency scores and target opex of DNSPs. In Table 11 in Section 2.2.2 we presented estimates for the SFA CD and SFA TL models estimated using the updated dataset.

We reproduce these results in Table 20, and note the differences for Essential Energy between the two models – the raw efficiency score improves from 57.5% to 64.6% when using the SFA TL, and the target opex increases from $349.4m to $384.9m ($2019). Given the materiality of these differences, and EI's own theoretical reasons for preferring the SFA TL specification over the SFA CD specification, we believe it is totally inappropriate for the AER to rely almost exclusively on the SFA CD model for its benchmarking of DNSPs.

Table 20: Efficiency scores and target opex from SFA CD and SFA TL analysis

	SFA CD	SFA TL
ActewAGL	44.8%	41.4%
AusNet Services	74.8%	74.0%
Ausgrid	44.6%	61.9%
CitiPower	89.7%	94.9%
Endeavour Energy	57.4%	64.3%
Energex	61.9%	77.1%
Ergon Energy	51.0%	57.4%
Essential Energy	**57.5%**	**64.6%**
Jemena	70.2%	70.2%
Powercor	95.8%	96.3%
SA Power Networks	79.8%	87.5%
TasNetworks	74.6%	66.7%
United Energy	84.5%	94.2%
Target score		
Top 5th score	74.8%	77.1%
Essential Energy – base year		
Target opex (2019AUD '000)	349.4	384.9
Revealed opex (2019AUD '000)	348.8	348.8
Percentage base year opex efficiency reduction – (No allowance for OEFs)	-0.2%	-10.3%

Source: Frontier Economics

4.4 Data envelopment analysis

The AER's Expenditure Forecast Assessment Guideline in 2013 indicated that the AER intended to apply three main techniques when undertaking economic benchmarking: Multilateral Total Factor Productivity analysis, econometric analysis (such as SFA), and data envelopment analysis (DEA). In its regulatory decisions and annual benchmarking reports to date, the AER has presented results for the first two approaches, but has not presented any DEA results. In the Draft Decision for Networks NSW for the 2014–19 period, (Attachment 7, p.7-55), the AER simply dismisses the use of DEA outright stating that SFA is a "superior technique to DEA". We find this surprising because:

- The Expenditure Forecast Assessment Guideline did not indicate that DEA would not be applied if it became feasible to apply SFA.
- The AER appeals to a conceptual argument by EI about the relative strengths and weaknesses of SFA and DEA (i.e. it did not appeal to new empirical

evidence that became available after the publishing of the Guideline to justify its view). This conceptual argument should have been available to the AER at the time it developed the Guideline, yet it did indicate then that it believed SFA to be a superior technique.

- The AER may reasonably come to a view that DEA has weaknesses, and even that it may be less preferable than other techniques. But, having signalled in the Guideline that it intended to apply DEA, it seems odd that the AER did not even present any DEA results before dismissing the technique in favour of another technique, which, as we have shown above, suffers from its own significant limitations.

We recognise the need to be aware that DEA scores can require careful interpretation, bearing in mind the following features of DEA:

  - efficiency scores in the variable returns to scale (VRS) version of DEA efficiency scores are always weakly greater than the constant returns to scale (CRS) efficiency scores
  - adding more inputs and/or outputs will weakly improve all efficiency scores
  - adding more utilities will weakly worsen all efficiency scores
  - an outlier with extremely low cost may give rise to very low measured efficiency scores for other utilities in the sample.

However, we still regard DEA as a helpful tool in understanding the performance of different utilities, since by varying the model specification, including assumptions over scale, it allows one to build up a picture of each utility, such as which variables may be influencing the measured efficiency of a utility. This can aid the regulator in understanding which utilities are similar in their output mix, and consequently which utilities it should consider close peers to one another.

To facilitate comparison with EI's preferred SFA CD model, we specify a basic DEA model that is analogous to EI's SFA CD model as follows:

  - there is one input (real opex)
  - we consider four outputs (customer numbers, circuit length, ratcheted maximum demand, and proportion of overhead lines). Note that we use the proportion of overhead lines rather than the proportion of underground cables since DEA assumes a positive relationship between inputs and outputs.
  - all variables are evaluated as the annual average over the sample period (this is analogous with EI's SFA CD model which generates time-invariant efficiency scores)
  - we impose the CRS assumption (which is consistent with EI's empirical finding of close to constant returns to scale in the SFA CD model).

We have also estimated the same DEA model allowing for variable returns to scale (VRS). These two models were estimated using both the full international sample of DNSPs (denoted AUSNZONT) as well as only the Australian DNSPs (denoted AUS). The results of these four estimations are presented in Table 21 below.

Table 21: DEA efficiency scores

	CRS - AUSNZONT	CRS - AUS	VRS - AUSNZONT	VRS - AUS
ActewAGL	50.3%	71.9%	50.6%	88.4%
AusNet Services	77.1%	77.7%	82.6%	83.6%
Ausgrid	48.0%	48.1%	100.0%	100.0%
CitiPower	100.0%	100.0%	100.0%	100.0%
Endeavour Energy	63.9%	64.6%	95.4%	100.0%
Energex	67.5%	67.7%	100.0%	100.0%
Ergon Energy	75.8%	89.4%	100.0%	100.0%
Essential Energy	**85.8%**	**100.0%**	**100.0%**	**100.0%**
Jemena	74.8%	95.9%	82.5%	99.3%
Powercor	100.0%	100.0%	100.0%	100.0%
SA Power Networks	99.6%	100.0%	100.0%	100.0%
TasNetworks	80.5%	100.0%	95.5%	100.0%
United Energy	87.2%	87.3%	100.0%	100.0%
Top 5th score	85.8%	100.0%	100.0%	100.0%

Source: Frontier Economics

Note: The AUSNZONT *dataset includes all of the international sample, the* AUS *dataset includes only the Australian DNSPs. In both cases, the variables are the average annual values across the sample period.*

The results in Table 21 show that:

- DEA estimated on the full international sample based on a CRS specification places two Australian DNSPs on the efficient frontier – CitiPower and Powercor. We note that DEA scores from this specification for the Australian DNSPs are in many cases substantially higher than EI's SFA CD scores.
- DEA estimated on the full international assuming VRS instead of CRS moves six more Australian DNSPs to the efficient frontier – Ausgrid, Energex, Ergon Energy, Essential Energy, SA Power Networks and United Energy. This means that once returns to scale are taken into account, the DEA method fails to find more efficient peers for eight out of thirteen Australian DNSPs. Note that this is not the case for NZ and Ontarian DNSPs. This suggests that in extending the sample to include international firms the AER/EI failed to add any firms that are comparable to, and more efficient than, these eight Australian DNSPs.

- DEA scores based on the Australian sample alone are higher than the DEA scores based on the full international sample. This is to be expected as it is a property of DEA adding more firms will weakly worsen all efficiency DEA scores. The following results for the Australia-only sample need to be interpreted with this in mind.
  - DEA estimated on the Australia-only sample based for the CRS specification places three more Australian firms on the frontier compared to the CRS results for the international sample – Essential Energy, SA Power Networks and TasNetworks.
  - DEA estimated on the Australia-only sample based for the VRS specification places almost all Australian firms to the frontier compared to the VRS results for the international sample. While we do not consider these results to be plausible as estimates of efficiency scores, it could be interpreted as evidence that for most of the Australian DNSPs there are no comparable, more efficient, Australian DNSPs that can be considered as efficient peers.

5 Conclusions and recommendations

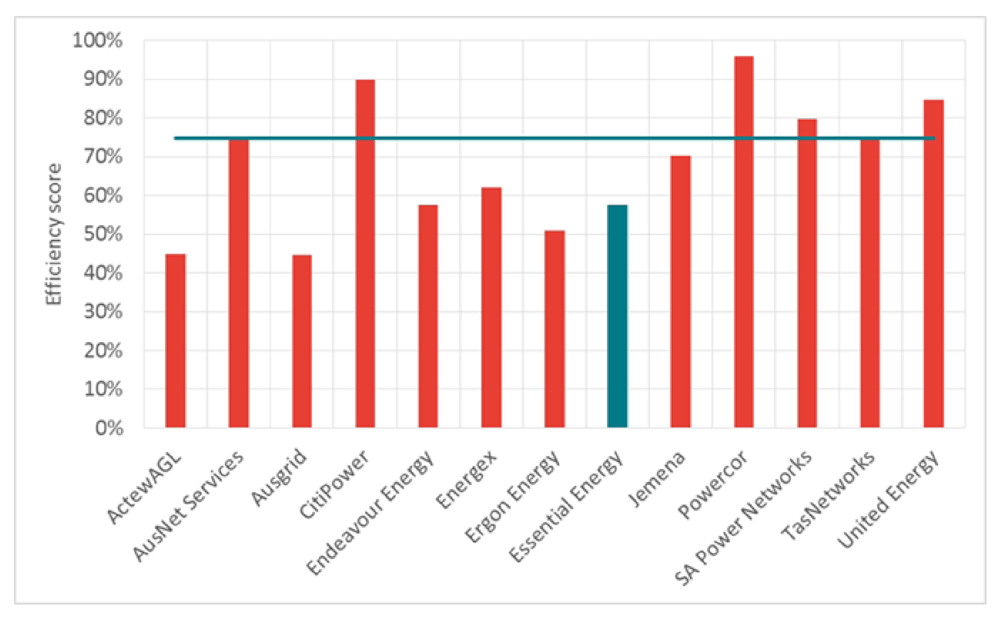
We have assessed the efficiency of Essential Energy's proposed base year (FY2018) opex using a range of benchmarking approaches, including those investigated by EI on behalf of the AER (See Section 2 and Section 3), and other approaches that could feasibly be estimated using the available RIN data (See Section 4). Our conclusions and recommendations for the AER are presented in the remainder of this section, which is structured as follows.

- In Section 5.1 we show that despite its apparently low average efficiency scores over the 11-year period (Figure 1), Essential Energy's proposed base year opex is lower that its estimated target base year opex. Essential Energy's average efficiency score is therefore a poor indicator of its base year efficiency.
- In Section 5.2 we show that neither the AER's preferred model, nor the alternative models investigated in this report, provide any evidence to suggest that Essential Energy's base year opex for the 2019–24 regulatory period requires an efficiency adjustment.
- In Section 5.3 we outline why it is important for the AER to consider a wider range of evidence when considering the case for an efficiency adjustment. It can be seen that Essential Energy's efficiency score and target base year opex is highly sensitive to changes in model specification, changes in the sample of comparator firms, and changes in modelling approach.
- In Section 5.4 we outline the known limitations of the benchmarking approaches investigated in this report.
- In Section 5.5 we discuss how the present limitations can be overcome by a work programme undertaken by the regulator/industry to develop a richer set of cost driver variables and cost adjustments.
- In Section 5.6 we outline different ways in which the AER could adopt a cautious approach in the application of benchmarking results.

5.1 Poor relationship between average efficiency scores and base year efficiency

The raw efficiency scores estimated using EI's preferred SFA CD model over the 2006 – 2016 sample period are presented in Figure 9 below. Essential Energy's raw efficiency score is estimated to be 57.5 per cent over the 2006 to 2016 period. Since EI's SFA CD efficiency scores are time-invariant, they can be interpreted as average efficiency scores over the sample period.

Figure 9: Efficiency scores estimated using AER's preferred benchmarking model

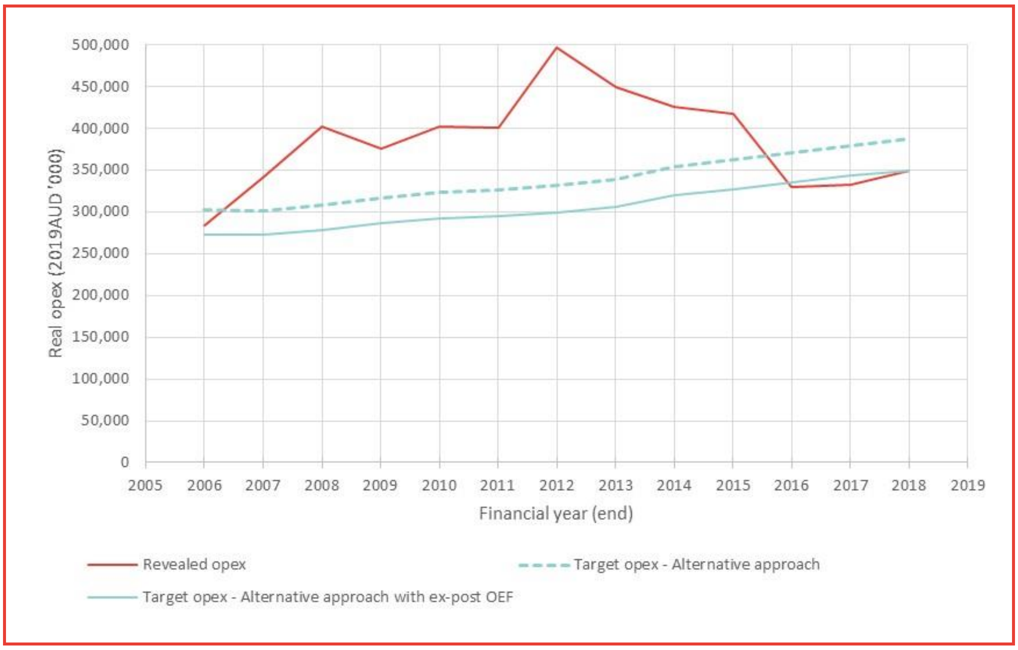


Source: Frontier Economics

In order to estimate Essential Energy's target base year opex for the 2019–24 regulatory control period, the alternative approach to estimate target opex in the base year is illustrated in Figure 10. This shows that, despite its apparently low average efficiency scores over the 11-year period, Essential Energy's proposed base year opex is lower that its estimated target base year opex. This is owing to the significant opex reductions that Essential Energy has achieved since 2012–13. It can therefore be concluded that the AER's preferred model provides no evidence to suggest that Essential Energy's base year opex for the 2019–24 regulatory period requires an efficiency adjustment.

This illustrates that the estimated average efficiency scores over the 2006 – 2016 period are a poor indicator of the efficiency of base year opex.

Figure 10: Essential Energy's proposed opex (2019AUD '000) and target opex (alternative approach) with and without ex-post OEF adjustment



Source: Frontier Economics

5.2 No justification for a base year efficiency adjustment

In Figure 11 below we summarise how Essential Energy performs across a range of approaches investigated in this report. Essential Energy's proposed base year opex is represented by the grey vertical line. Essential Energy's target base year opex from each alternative approach is represented by the bars. The figure shows that Essential Energy's proposed base year opex is below its target base year opex for the 2019–24 regulatory control period across the majority of the benchmarking models considered in this report, including the AER's preferred benchmarking model.

Hence, neither the AER's preferred model, nor the alternative models investigated in this report (except one), provide any evidence to suggest that Essential Energy's base year opex for the 2019–24 regulatory period requires an efficiency adjustment.

Since this conclusion holds prior to any OEF adjustments, it holds even more strongly if allowance is made for OEF adjustments in the estimation of Essential Energy's target base year opex.

Figure 11: Essential Energy's performance across a range of approaches investigated in this report

Source: Frontier Economics

5.3 Case for relying on a broad range of evidence

The AER has put undue faith in the ability of its advisers to develop a single benchmarking model (or suite of very closely related models) that can capture the relative inefficiency of Australian DNSPs with great precision. This appears to be an unnecessarily restrictive approach for the AER to adopt. We recommend that, in future, the AER rely on a broad range of evidence to determine its target base year opex and efficiency adjustments for Essential Energy, including evidence from any bottom-up benchmarking and engineering assessments, and evidence on other opex factors such as the safety and reliability of the network.

Table 22 below shows Essential Energy's efficiency scores and target base year opex estimated using a range of benchmarking approaches, including those investigated by EI on behalf of AER (See Section 2 and Section 3), and other approaches that could feasibly be estimated using the available RIN data (See Section 4). It can be seen that Essential Energy's efficiency score and target base year opex is highly sensitive to changes in model specification, changes in the sample of comparator firms, and changes in modelling approach.

- Across the range of models shown, the estimated target base year opex for Essential Energy ranges from $339.6m to $437.4m.
- Essential Energy's raw efficiency score ranges from as low as 57.5% to as high as 100%.
- The estimated top 5th score ranges from 71.7% to 100%.
- The target DNSP (the top 5th service provider's in the sample of 13 DNSPs) is different under different approaches. Under some approaches, we note that Essential Energy would be identified as the target DNSP.

Table 22: Essential Energy's performance across a range of approaches investigated in this report

	Proposed opex (2019AUD '000)	Target opex (2019AUD '000)	Percentage base year opex efficiency reduction	Essential Energy's estimated efficiency score	Estimated target score
SFA CD on AUSNZ data only	348,844	339,608	2.6%	60.1%	82.3%
DEA CRS on AUS data only	348,844	348,844	0.0%	100.0%	100.0%
DEA CRS	348,844	348,844	0.0%	85.8%	85.8%
SFA CD	348,844	349,405	-0.2%	57.5%	74.8%
SFA CD with interaction with ONT dummy	348,844	352,111	-0.9%	58.1%	76.8%
LSE CD	348,844	352,997	-1.2%	63.4%	76.7%
SFA CD on AUS data only	348,844	358,290	-2.7%	57.9%	75.3%
SFA TL	348,844	384,866	-10.3%	64.6%	77.1%
LSE TL	348,844	404,966	-16.1%	66.9%	71.7%
SFA CD with interaction with rural dummy	348,844	408,066	-17.0%	63.5%	72.4%
SFA CD urban/rural combined	348,844	437,380	-25.4%	69.3%	73.6%

Source: Frontier Economics

Given the sensitivity of the DNSPs' efficiency scores and target scores to the alternative approaches outlined in this report, we recommend that the AER consider a range of evidence on benchmarking and not mechanistically apply the results from any single approach. Moreover, it would not be appropriate for the AER to mechanistically apply the steps described in Table 4 in Section 2.1.2 to the alternative range of efficiency scores presented in Table 22 using the top 5th score as the comparison score. It can be seen, for example, that the top 5th score estimated using DEA is 100%.

We emphasise strongly that the approaches considered in this report do not account adequately for all the material differences between the DNSPs. The feasible alternative approaches that we were able to investigate have been restricted by the data that is presently available to us. We discuss these shortcomings in more detail in Section 5.4.

We note that the models presented in this report do not account for possibly large genuine differences in operating environment between DNSPs, as we have provided no adjustment for OEFs. Our aim in presenting this analysis is to demonstrate that the AER's benchmarking results for the Australian DNSPs are quite sensitive to minor modifications to EI's preferred model, and highly sensitive to alternative approaches. We also show that alternative techniques such as DEA, despite requiring careful interpretation, are feasible for assessing relative efficiencies, and should not be disregarded by the AER.

We recommend that the approaches considered in this report be used as a basis for constructive engagement between the AER and the DNSPs aimed at improving the AER's benchmarking approach over the longer term.

5.4 Need to recognise the limitations of benchmarking analysis at present

No two network businesses are exactly the same. Differences in perceived performance can arise from a number of potential sources including underlying differences in:

- core cost drivers (e.g. customer numbers, circuit length, demand);
- input costs (e.g. labour rates, local taxes);
- operating environment (e.g. climate, topography, soil properties, vegetation, and the urban/rural nature of certain areas);
- past (legacy) configuration decisions and planning constraints; and
- current managerial and operating efficiency.

Some of these factors, such as the core cost drivers, are straightforward to measure and account for. Cost driver variables such as customer numbers and circuit length are provided in the AER's RIN data and included in the AER's model and the alternative approaches investigated in this report. Other factors, such as differences in operating environment and the effects of past/present differences in technical/planning standards are far more challenging to account for in a benchmarking model. Importantly, when determining efficiency adjustments in regulatory proceedings, it is only excess cost owing to the last type of underlying difference in the above list – differences in current managerial and operating efficiency – that should be taken into account. Differences in performance due to the other factors mentioned above should not be used to justify the imposition of efficiency adjustments.

Further complications arise when attempting to benchmark operators in different countries, as the AER has attempted to do by including comparator DNSPs from New Zealand and Ontario in its model. There could be material differences in a number of additional areas to those identified above, including:

- legislative framework (e.g. employment, environmental, planning, tax, procurement and health and safety law)
- regulatory arrangements (e.g. data collection processes, incentive frameworks, scope of licensed activities, boundary/interface with other businesses)
- cost of capital and other financing arrangements (which may affect planning and design decisions)
- differences in design standards, types of equipment and assets used, and the costs of those types of assets (e.g. including differences in transport costs); and
- exchange rates.

Designing a benchmarking methodology that accounts adequately for all of these factors is extremely challenging – and in our view this is presently not possible to do with the data currently available to the AER. We note that owing to the lack of data to measure a large number of factors outlined above, they have not been adequately captured in any of the approaches presented in this report.

5.5 Need to undertake a work program by the regulator/industry to develop a richer set of cost driver variables and cost adjustments

The benchmarking work undertaken to date has been restricted by the data that is available. While we have been able to investigate the sensitivity of the AER's benchmarking results to changes in model specification, changes in the sample of comparator firms and changes in approach, we have not been able to investigate the inclusion of additional/alternative cost driver variables in our analysis, owing to a lack of reliable data available on additional variables. In particular, we have not been able to account for the vast differences in the operating environment of the different DNSPs.

We attempted to incorporate RIN data reported by the DNSPs on vegetation management costs, the number of poles, the number of spans, and rural proportion in our analysis. However, it became evident from an examination of the information available that there are inconsistencies (some of them material) in the way different DNSPs report RIN data on these variables. Inconsistent reporting can confound the results of benchmarking analysis, and considerable effort needs to be made by both the regulator and the industry to improve the consistency of the RIN data.

We recommend that the AER attempt to improve the data available for benchmarking in the longer term in collaboration with the DNSPs. This could be facilitated through the collection of additional variables and ensuring data are reported in a consistent manner across DNSPs. This could be achieved by creating a working group, in collaboration with the networks, tasked with developing, defining and collecting additional measures, or considering methodologies to justify firm-specific adjustments to benchmarked costs, or adjustments to the outcome of benchmarking models.

In our experience, the achievement of high quality, consistent data is an incremental and iterative process that requires ongoing engagement between the regulator and the businesses.

5.6 The AER's MTFP and MPFP analysis is not suitable to inform decisions on relative efficiency

Having reviewed the AER's for multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) analysis, we consider that this analysis contains a number of serious shortcomings.

In particular, we note that EI's MTFP and MPFP scores are highly sensitive to the output weights used in constructing the indices. For example, while Essential Energy ranks 12th according to the AER's MTFP results presented in its 2017 annual benchmarking report (based on an output weight of 46% assigned to customer numbers), we demonstrate that its ranking would be higher than estimated by the AER in all cases where circuit length is given a weight of higher than 30%.[19] If circuit length were assigned a weight between 50% and 65%, Essential Energy's MTFP ranking would improve to 3rd out of 13 DNSPs. If circuit length were assigned a weight of above 70%, Essential Energy's MTFP would rank first among the 13 DNSPs.

Given how sensitive the AER's DNSP MTFP rankings are to the relative weights assigned to customer numbers and circuit length, we recommend that the AER consider using different sets of weights for rural and urban DNSPs, to reflect the fact that these two outputs impose different costs on rural and urban DNSPs. Given how sensitive the relative DNSP ranking are to changes in output weights, and the fact that the importance of different cost drivers is likely to differ between

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19 In the simplified example where the residual output weight is split equally amongst the remaining three output variables.

rural and urban DNSPs, we do not consider the MTFP and MPFP results presented in the AER's 2017 annual benchmarking report a suitable basis for informing regulatory decisions on the relative efficiencies of the DNSPs.

5.7 Need to develop a cautious approach in the application of benchmarking results

We recommend that the AER apply the results from any benchmarking analysis with an appropriate degree of caution, recognising the significant practical challenges involved in performing benchmarking analysis, and taking account of issues relating to RIN data reporting and consistency. Owing to the limitations of even the best and most reliable benchmarking analyses, the great majority of overseas regulators do not impose the outcome of their benchmarking directly or mechanistically as reductions to allowed costs. Most will make allowances for data errors, the range of results derived from different models, and the imperfect assessment of different circumstances. Some examples of how overseas regulators apply the results from benchmarking analysis are presented below.

- Ofgem, in its recently completed RIIO-ED1 investigation has made use of an interpolation procedure where final allowances are made up of 25% of the firms' submitted costs and 75% of its benchmarking models.
- Ofgem in its previous electricity regulatory price review, varied its approach to determining the 'target' DNSPs on the basis of its view of the robustness of different benchmarking models. For example, a higher upper quartile target was used for its benchmarking of 'indirect' costs (such as overhead costs and network planning, which were considered less prone to year-to-year volatility and hence easier to benchmark). On the contrary, a lower upper third target was used for its benchmarking of network operating costs (which were considered both volatile and less fully explained by the available cost drivers).
- The Ontario Energy Board (as we discuss below) uses its benchmarking to inform on relatively modest differences in 'stretch factors' for the firms it regulates, with the best performers provided with a stretch factor of 0.0% per annum, and the worst performers with a stretch factor of 0.6% per annum.
- Ofwat (the regulator of water companies in England and Wales) has in the past used its benchmarking to split the water and sewerage companies into five efficiency bands that each received the same moderated efficiency discount subject to a glide path.
- The regulator in Norway moderates the results of its benchmarking by setting allowed cost in line with 40% of the firms' submitted costs, and 60% of the 'efficient' benchmarked costs derived from its model.

While the benchmarking results presented in this report provide no evidence to suggest that Essential Energy's base year opex for the 2019–24 regulatory period requires an efficiency adjustment, we nevertheless recommend that the AER adopt a conservative application of its benchmarking analysis should it decide to make base year efficiency adjustments for any of the DNSPs. This can be done in one, or in a combination of ways. For example, the AER could potentially:

- consider lowering its criterion for choosing the target DNSP from the top 5th DNSP to a more conservative target owing to the limitations of the benchmarking approaches that are presently feasible
- consider determining base year allowances on the basis of a weighted average of the DNSPs' proposed base year opex and target base year opex; and/or
- consider splitting the 13 DNSPs into groups or cohorts, determined by evidence on their base year efficiency, and apply different levels of base year opex reductions to each cohort.

The examples above are different ways for the AER to recognise that there are many reasons why the efficiency estimates derived from its benchmarking analysis are not be a perfectly accurate representation of the relative efficiencies across the DNSPs.

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