E3 Equipment Energy Efficiency

Australian Government

New Zealand Government

# Regulation Impact Statement for Consultation: Distribution Transformers

A joint initiative of Australia, State and Territory and New Zealand Governments

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# Table of Contents

## Table of Illustrations

## Glossary

| | |
|---|---|
| 1P | Single-phase |
| 3P | Three-phase (also called multiple phase) |
| AC | Alternating current |
| AEC | Australian Energy Council |
| AS | Australian standard |
| AS/NZS | Australian and New Zealand (joint) standard |
| BAU | Business as usual |
| CRIS | RIS for Consultation |
| DC | Direct current |
| DELWP | Department of Environment, Land, Water and Planning (Victoria) |
| DISER | Department of Industry, Science energy and Resources (Commonwealth). Renamed in June 2022. |
| DNSP | Distribution Network Service Provider (Australia) |
| DRIS | RIS for Decision (see References E3 2019a) |
| DT | Distribution transformer |
| E3 | Equipment Energy Efficiency |
| EDB | Electricity Distribution Business (New Zealand) |
| EECA | Energy Efficiency and Conservation Authority |
| ETWG | Energy Technology Working Group (of Regulators) |
| EU | European Union |
| FL | Full load |
| GEMS | Greenhouse and Energy Minimum Standards (Act) |
| GWA | George Wilkenfeld and Associates |
| HE | High efficiency |
| Hz | Hertz: cycles per second |
| kV | Kilovolts (Volts x 1,000) |
| kVA | Kilovolt-Amps: power rating (at unity power factor) |
| LRMC | Long run marginal cost |
| MEPS | Minimum energy performance standards |
| MVA | Megavolt-Amps (kVA x 1,000) |
| NL | No load |
| NPV | Net present value |
| PV | Photovoltaics |
| RIS | Regulation Impact Statement |
| SWER | Single wire earth return |
| $U_m$ | Symbol for the highest design voltage (kV) of the system to which the transformer is to be connected |

# Executive Summary

The emissions reductions strategies of the Australian and New Zealand governments involve increasing electrification of energy use in both countries. Electricity networks are expected to become more complex with a wider range and distribution of generators and loads, growing electricity demand from electric vehicles and the replacement of fuels for process heating.

Distribution Transformers (DTs) are critical infrastructure components in the electricity grid, enabling voltage changes between primary and secondary circuits. They typically lose less than 2% of the energy that passes through them, but as they are energised 24 hours a day, even small increases in efficiency result in significant electricity savings. This Consultation Regulation Impact Statement (CRIS) assesses the options for increasing the energy efficiency of DTs in Australia and New Zealand.

Several countries and the European Union have Minimum Energy Performance Standards (MEPS) for transformers. In Australia and New Zealand, MEPS for DTs were introduced in 2004, pre-dating the *Greenhouse and Energy Minimum Standards (GEMS) Act 2012*. They were introduced under State and Territory legislation, and in New Zealand under the Energy Efficiency (Energy Using Products) Regulations 2002.

The current GEMS Determination for DTs was made in October 2012. As with the preceding jurisdictional legislation, the Determination references the MEPS levels in Australian standard AS 2374.1.2-2003 *Power transformers - Minimum Energy Performance Standard (MEPS).* The Determination also references the High Efficiency (HE) criteria in AS 2374 which a product must meet to be classified as a "high power efficiency transformer."

Studies carried out both before and since the Determination was made have recommended increasing the stringency of MEPS for DTs, in line with rising MEPS levels in other economies. These recommendations have not been taken up and the MEPS and HE levels have remained unchanged for 20 years. This CRIS once again assesses the costs and benefits of revising the original MEPS levels. Apart from the rising MEPS levels in other countries, there have been significant changes in the value of the electricity that could be saved and in the avoidance of greenhouse gas emissions from the production of that electricity. This document presents the results of those analyses and makes recommendations about changes to MEPS levels and the scope and types of DTs covered by the regulations.

### The Transformer Market

The DT markets in Australia and New Zealand are highly price-sensitive, and very few buyers or market segments purchase DTs more efficient than the MEPS level. The great majority of sales are to distribution network service providers (DNSPs) and Electricity Distribution Businesses (EDBs) which can pass on the costs of energy losses to electricity retailers, which pass them on in turn to consumers. This chain of split incentives works against the adoption of higher efficiency DTs, even when they have demonstrably lower discounted costs over their service lives, which often exceed 45 years.

The current regulations have been effective in establishing a floor in the energy efficiency of Distribution Transformers. Check tests conducted by the New Zealand Energy Efficiency and Conservation Authority

(EECA) in 2022 concluded that compliance is high, and the reported efficiency values are largely accurate.[1] There are models on the market that qualify as HE, but demand for them is restricted to a handful of electricity distributors, packaged substations and other niche applications. The existing market and regulatory structures do not give purchasers an incentive to prefer DTs with higher efficiency than the MEPS level, even when it would be societally cost-effective. In fact, it is arguable that without MEPS, transformer efficiency might have declined since 2012.

### MEPS levels

The current MEPS and HE levels have not been revised since they were first adopted in 2004. Since that time, transformer MEPS levels in other countries have steadily increased, most recently with the adoption of the Tier 2 levels in the European Union (EU) in July 2021 and higher MEPS levels in the USA in 2024. However, differences in market structures, technical standards and test methods mean that MEPS levels cannot easily be transferred from one country to another.

While the methods and materials for building more efficient transformers are widely available, the societal value of doing so is a matter of costs compared with benefits. This CRIS has modelled three MEPS levels that are more stringent than the current level (which is called MEPS1):

- MEPS2 is based on the existing HE level as specified in AS 2374.1.3:2003;
- MEPS3 is mid-way between MEPS2 and MEPS4; and
- MEPS4 is equivalent to the EU Tier 2 level.

It is recognised that adopting more stringent MEPS levels may drive up the cost of manufacturing DTs and hence the price to buyers. However, this will be exceeded by the benefits in terms of less electricity generated, transformer capacity freed or deferred due to lower peak loads and the value of $CO_2$-e emissions avoided. These conclusions hold true for both Australia and New Zealand and are robust across a range of price and discount rate assumptions.

The modelling compares each MEPS scenario to a ‘business as usual’ (BAU) projection, which takes account of the fact that a significant number of liquid-filled DTs and a high proportion of dry-type DTs already exceed the MEPS1 level. The analysis also models the effects of widening the scope of the regulation from 2,500 to 5,000 kVA capacity and from 24 kV to 36 kV system-highest voltage, as well as including transformers used in step-up applications, i.e. the type of transformers used to connect wind farms, utility-scale photovoltaics (PV) and utility-scale batteries to the grid.

### Energy Savings

Table E1 summarises the projected energy losses and savings from DTs installed in Australia from 2024 to 2051. Widening the scope adds about 8% to the number of DTs covered but increases the coverage of DT losses by 26% because the DT sizes and classes added are larger than the current average rated capacity.

Table E2 illustrates the projected losses from DTs installed in New Zealand from 2024 to 2051. The savings compared to BAU are smaller than for Australia, because of differences in the composition of the NZ DT fleet. The average rated capacity (kVA) of DTs is significantly higher in Australia, which itself leads to higher theoretical efficiency, although differences in actual average loadings may change this result.

[1] Distribution-transformer-testing-results

*Table E1 Projected energy savings 2024-2051, Australia*

| | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 |
|---|---|---|---|---|---|---|---|---|---|
| MEPS Level | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total |
| MEPS1 (BAU) | 126,682 | 32,533 | 159,215 | NA | NA | NA | NA | NA | NA |
| MEPS2 | 114,570 | 30,746 | 145,317 | 12,111 | 1,787 | 13,898 | 9.6% | 5.5% | 8.7% |
| MEPS3 | 102,732 | 25,891 | 128,623 | 23,950 | 6,642 | 30,592 | 18.9% | 20.4% | 19.2% |
| MEPS4 | 91,382 | 24,644 | 116,026 | 35,300 | 7,889 | 43,189 | 27.9% | 24.2% | 27.1% |

Source: Table 27

*Table E2 Projected energy savings 2024-2051, New Zealand*

| | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 |
|---|---|---|---|---|---|---|---|---|---|
| MEPS Level | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total |
| MEPS1 (BAU) | 35,016 | 2,935 | 37,951 | NA | NA | NA | NA | NA | NA |
| MEPS2 | 33,292 | 2,752 | 36,045 | 1,724 | 183 | 1,907 | 4.9% | 6.2% | 5.0% |
| MEPS3 | 29,854 | 2,422 | 32,275 | 5,163 | 513 | 5,676 | 14.7% | 17.5% | 15.0% |
| MEPS4 | 27,320 | 2,200 | 29,520 | 7,697 | 735 | 8,432 | 22.0% | 25.0% | 22.2% |

Source: Table 31

## Costs and Benefits

The projected costs and benefits for Australia are summarised in Tables E3 from the perspective of retail electricity customers, and Table E4 from the perspective of wholesale electricity prices. Progressing from MEPS1 (BAU) to MEPS4 shows the highest net benefit (AUD$M 1,660M) although MEPS3 is not far behind ($M 1,346). However, MEPS4 is projected to lead to much greater increases in DT prices due to higher manufacturing costs, so returning a significantly lower benefit/cost ratio than MEPS3. In all cases, the additional cost of testing and administration is negligible. MEPS3 appears to offer the best balance between costs and benefits. (All prices are expressed in 2024 Australian dollars, i.e. excluding the effects of inflation).

*Table E3 Summary of Projected Costs and Benefits, Australia (Consumer energy and DT prices)*

| | Energy saved $M | $CO_2$-e saved $M | Demand saved $M | Total benefit $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | No $CO_2$-e value B/C |
|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $795 | $30 | $77 | $902 | $395 | $0.3 | $395 | $507 | 2.28 | 2.21 |
| MEPS2 added to scope | $114 | $6 | $14 | $135 | $129 | $0.3 | $129 | $5 | 1.04 | 0.99 |
| MEPS2 total | $909 | $36 | $91 | $1,037 | $524 | $0.6 | $525 | $512 | 1.98 | 1.91 |
| MEPS3 current scope | $1,662 | $64 | $159 | $1,885 | $790 | $0.5 | $790 | $1,095 | 2.39 | 2.30 |
| MEPS3 added to scope | $478 | $26 | $58 | $561 | $310 | $0.3 | $311 | $251 | 1.81 | 1.72 |
| MEPS3 total | $2,139 | $90 | $217 | $2,447 | $1,100 | $0.8 | $1,101 | $1,346 | 2.22 | 2.14 |
| MEPS4 current scope | $2,455 | $95 | $234 | $2,783 | $1,231 | $0.5 | $1,231 | $1,552 | 2.26 | 2.18 |
| MEPS4 added to scope | $567 | $31 | $69 | $667 | $559 | $0.3 | $559 | $108 | 1.19 | 1.14 |
| MEPS4 total | $3,022 | $126 | $303 | $3,450 | $1,790 | $0.8 | $1,790 | $1,660 | 1.93 | 1.86 |

Source: Table 27. $M present values calculated at a discount rate of 7%, compared with BAU (MEPS1). Lower $CO_2$-e prices.

*Table E4 Summary of Projected Costs and Benefits, Australia (Marginal generation costs and producer DT prices)*

| | Energy saved $M | $CO_2$-e saved $M | Demand saved $M | Total benefit $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | No $CO_2$-e value B/C |
|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $449 | $218 | $54 | $720 | $276 | $0.3 | $277 | $444 | 2.60 | 1.90 |
| MEPS2 added to scope | $64 | $31 | $10 | $105 | $90 | $0.3 | $91 | $14 | 1.16 | 0.86 |
| MEPS2 total | $513 | $249 | $64 | $825 | $367 | $0.6 | $367 | $458 | 2.25 | 1.64 |
| MEPS3 current scope | $935 | $454 | $112 | $1,501 | $553 | $0.5 | $553 | $948 | 2.71 | 1.98 |
| MEPS3 added to scope | $263 | $130 | $40 | $433 | $217 | $0.3 | $218 | $216 | 1.99 | 1.48 |
| MEPS3 total | $1,199 | $584 | $152 | $1,935 | $770 | $0.8 | $771 | $1,164 | 2.51 | 1.84 |
| MEPS4 current scope | $1,381 | $670 | $164 | $2,215 | $862 | $0.5 | $862 | $1,353 | 2.57 | 1.87 |
| MEPS4 added to scope | $313 | $154 | $48 | $515 | $391 | $0.3 | $391 | $123 | 1.32 | 0.97 |
| MEPS4 total | $1,694 | $824 | $212 | $2,730 | $1,253 | $0.8 | $1,254 | $1,476 | 2.18 | 1.59 |

Source: Table 29. $M present values calculated at a discount rate of 7%, compared with BAU (MEPS1). Lower $CO_2$-e prices

In all MEPS scenarios, the widening of the scope appears to be cost-effective in its own right, although it reduces the overall benefit/cost (B/C) ratio slightly. The impact of $CO_2$-e emissions values is modest from the consumer perspective, in which energy prices and demand savings dominate, but much higher from the producer perspective, which assumes that the energy saved through reducing transformer losses would have been produced by open-cycle gas turbines (OCGT). For the preferred option (MEPS3) Victoria and Tasmania have the highest average B/C ratios (over 3.5) while the ACT has the lowest (1.8). The B/C ratios for the other jurisdictions are in the range 2.3 to 2.7 (see Appendix C).

The projected costs and benefits for New Zealand are summarised in Table E5. Progressing from MEPS1 (BAU) to MEPS4 shows a benefit of NZ$M 269, and MEPS3 shows a net benefit of NZ$M 155. Even with a greater increase in projected DT prices, MEPS4 seems to be the most cost-effective scenario for New Zealand. (All prices are expressed in 2024 New Zealand dollars, i.e. excluding the effects of inflation).

For all MEPS levels, the costs of widening of the scope are marginally greater than the benefits in New Zealand, although when combined with higher MEPS for products currently covered, each MEPS scenario is cost-effective overall. Three emissions price pathways have been modelled for New Zealand. (See Figure 31). Table E5 shows the values for the central pathway, but the outcomes are less sensitive to the emissions value adopted than is the case for Australia. For MEPS3, the adoption of the low emissions price reduces the New Zealand B/C ratio from 2.0 to 1.9, and the high emissions price increases the B/C ratio from 2.0 to 2.1. The great majority of the benefit comes from the value of energy saved and the value of the peak demand and $CO_2$-e emissions savings are about equal.

The cost-effectiveness of the various MEPS levels has been tested across a range of different discount rates and assumptions. All MEPS options are about equally cost-effective under all discount rates because both costs and benefits accrue at roughly equal rates over time. The net benefits remain positive under all assumptions. It is likely that the modelled DT price increase projections are conservative because at present HE products command a price premium, but if all products must meet more stringent MEPS, this may increase price competition at that efficiency level.

*Table E5 Summary of Projected Costs and Benefits, New Zealand (LRMC of generation and producer DT prices)*

| | Energy saved $M | $CO_2$-e saved $M | Demand saved $M | Total benefit $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | No $CO_2$-e value B/C |
|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $58.4 | $13.3 | $15.7 | $87.3 | $61.6 | $0.2 | $61.8 | $25.5 | 1.41 | 1.20 |
| MEPS2 added to scope | $5.7 | $1.3 | $1.5 | $8.5 | $14.8 | $0.2 | $15.0 | -$6.5 | 0.57 | 0.48 |
| MEPS2 total | $64.1 | $14.6 | $17.2 | $95.9 | $76.4 | $0.4 | $76.8 | $19.1 | 1.25 | 1.06 |
| MEPS3 current scope | $187.7 | $42.8 | $50.4 | $280.9 | $118.9 | $0.3 | $119.2 | $161.7 | 2.36 | 2.00 |
| MEPS3 added to scope | $19.0 | $4.3 | $5.1 | $28.5 | $35.6 | $0.2 | $35.7 | -$7.2 | 0.80 | 0.68 |
| MEPS3 total | $206.7 | $47.1 | $55.5 | $309.4 | $154.5 | $0.4 | $154.9 | $154.5 | 2.00 | 1.69 |
| MEPS4 current scope | $280.3 | $63.9 | $75.3 | $419.4 | $137.5 | $0.3 | $137.8 | $281.6 | 3.04 | 2.58 |
| MEPS4 added to scope | $27.3 | $6.2 | $7.3 | $40.8 | $52.9 | $0.2 | $53.1 | -$12.3 | 0.77 | 0.65 |
| MEPS4 total | $307.6 | $70.1 | $82.6 | $460.3 | $190.4 | $0.4 | $190.9 | $269.4 | 2.41 | 2.04 |

Source: Table 31. All $M values are present values calculated using a discount rate of 5%, and compared with BAU (MEPS1). Central $CO_2$-e prices.

## Conclusions

For Australia, MEPS3 for liquid-filled DTs (which account for about 85% of the DT market) and MEPS4 for dry-types offer the highest combined B/C ratios. For New Zealand, with a different DT fleet composition, energy price and emissions profile, MEPS4 offers the highest B/C ratios.

While B/C ratio is one factor in determining the optimum policy option, there are also other considerations. Australia and New Zealand both have local DT manufacturers and there is significant cross-Tasman trade. The Trans-Tasman Mutual Recognition Agreement 1997 (TTMRA) states that products that can legally be sold in Australia or New Zealand can be legally sold in the other country irrespective of differing technical standards. The products must be manufactured in or imported through the complying country. This means that New Zealand and Australia share a common DT market and model range and any inconsistency in regulatory requirements would have unintended implications for market competition, potentially undermining the benefits to the country with the higher MEPS levels.

Considering this, despite the differences in B/C ratios, the optimum option for both countries is MEPS3 for liquid-filled DTs and MEPS4 for dry-types. This provides strong benefits for New Zealand, while ensuring that the countries' regulations remain aligned.

About 80-90% of the liquid-filled DTs sold in Australia and New Zealand are made by four major local manufacturers: Schneider Electric, Tyree and Wilson in Australia and ETEL in New Zealand. These firms are experienced in manufacturing for specific local requirements and clients and should be able to adjust to higher MEPS given sufficient lead time. The same MEPS levels would of course apply to imports, which come mainly from Vietnam, China and Thailand.

While electricity distribution companies use liquid-filled DTs almost exclusively, there is also a market for dry type DTs in commercial and high-rise building, manufacturing and mining, where fire-safety and weight are issues. All of the dry type DTs registered with the regulators are imported and many are already well above MEPS3 level. Therefore, the logical progression for dry type DTs is either to MEPS4, equivalent to EU Tier 2, but still using AS tests (which are based on IEC standards) or perhaps complete adoption of EU Tier 2 together with the European standard test (EN 50708).

Transformers are generally defined in terms of electrical characteristics (number of phases), cooling (liquid-filled, gas-filled or dry) high-side voltage (e.g. 36 kV) and capacity (kVA), rather than intended use ("distribution"). To clarify the scope of the regulations, further definition is needed for some transformer types.

Step-up transformers for wind farms and utility-scale solar PVs and batteries were rare when the current MEPS came into force in 2004. Now several hundred are installed annually in Australia and New Zealand, and step-up transformers are explicitly included in the scope of the EU MEPS regulations (but not the US regulations). The owners of renewable energy projects should be among the market segments most sensitive to transformer efficiency, since they bear the direct cost of losses in terms of energy sales revenue forgone. However, this market is also liable to fragmentation and incentives split between contractors, developers, operators and owners. Therefore, the scope of MEPS should be widened to step-up transformers, if the AC side is 36 kV or less and the capacity 5,000 kVA or less (the upper limit of the new US MEPS regulations).

All energy efficiency testing of transformers involves measurement of energy losses under a range of operating conditions: typically no load (NL) to measure core losses, and full load (FL) or an intermediate loading point to establish the winding losses. Different MEPS regimes use this basic information in different ways to set energy performance standards. AS 2374.1.2, which is referenced in the GEMS Determination and in the New Zealand regulations, specifies the MEPS requirement as the efficiency at 50% load and unity power factor. A 40% load test (as used in Japan) may be more representative of loading levels in actual use, feedback on the feasibility of moving to a 40% test would be appreciated as part of this consultation process.

## Implementation

In Australia, the current GEMS Determination would remain in place until a new Determination comes into force. If Ministers agree to changing the MEPS levels, scope and other technical aspects, then a draft GEMS Determination would be published for comment in due course. This would cover, among other things:

- the target date at which products within the scope must meet the amended MEPS levels and other rules in order to be registered in accordance with the GEMS Act;
- confirmation that up to the target date products can be registered under the rules in the 2012 Determination;
- whether products registered before the target date would have the option of registration under the revised rules.

GEMS Determinations routinely include material that adds to or modifies the application of the standards they reference, or indeed technical content that does not exist in a standard. While it would be efficient in the long run to revise AS2374.1.2 to align with the provisions of an amended Determination, it is not necessary to delay implementation on that account. This is because any amendments required to the standard can be added to the Determination.

In New Zealand, if new regulations were agreed by Cabinet, the Energy Efficiency (Energy Using Products) Regulations 2002 would need to be amended. The regulations should align with the technical requirements of the amended GEMS Determination for MEPS levels and scope. New Zealand may have different transition requirements and a different implementation timeframe, but this should not be earlier than that required in the GEMS Determination.

## Draft Recommendations

The following draft recommendations are presented for consideration by stakeholders. Specific questions relating to these recommendations are in Section 5.

1. The existing GEMS Determination and EUP Regulations covering distribution transformers should be amended as soon as practicable, so that the societal benefits of higher MEPS levels can begin to accrue without delay.

2. The amended Determination and Regulations should cover electricity distribution transformers (DTs) with power ratings from 10 to 5,000 kVA (for single-phase and Single Wire Earth Return [SWER]), 25 to 5,000 kVA (for three-phase), a system high voltage ($U_m$) up to 36 kV and a low side voltage up to 1.2 kV. (The current Determination covers DTs with a maximum power rating of 2,500 kVA system highest voltage up to 24 kV. It does not mention low-side voltage.)

3. The new Determination and Regulations should categorise DTs into the following product classes. (Product classes 1B, 2B, 4B, 6B and 7 expand the scope of the current Determination).

| Product class | Products covered by class |
|---|---|
| 1A | Single-phase or single wire earth return oil immersed type transformer where $U_m$ = 24 kV |
| 1B | Single-phase or single wire earth return oil immersed type transformer where $U_m$ = 36kV |
| 2A | Three-phase, oil immersed type transformer where $U_m$ = 24 kV |
| 2B | Three-phase, oil immersed type transformer where $U_m$ = 36kV |
| 3 | Single-phase or single wire earth return, dry type transformer where $U_m$ = 12 kV. |
| 4A | Single-phase or single wire earth return, dry type transformer where $U_m$ = 24 kV. |
| 4B | Single-phase or single wire earth return, dry type transformer where $U_m$ = 36 kV. |
| 5 | Three-phase, dry type transformer where $U_m$ = 12 kV. |
| 6A | Three-phase, dry type transformer where $U_m$ = 24 kV. |
| 6B | Three-phase, dry type transformer where $U_m$ = 36 kV. |
| 7 | Step-up transformers with system highest voltage up to 36 kV |

4. The amended Determination and Regulations should specify the MEPS and HE levels indicated below for each class of transformer, noting that:

- for liquid-immersed transformers, the new MEPS levels are more stringent than the HE levels in AS 2374.1.2-2003, and the new HE levels are approximately equal to the EU Tier 2 levels;
- for dry type transformers, the new MEPS levels are approximately equal to the EU Tier 2 levels and the new HE levels are as recommended in the 2011 consultation RIS;

| Class | | Class 1A, 2A, 7 $U_m$ =24kV | Class 1A, 2A, 7 $U_m$ =24kV | Class 1B, 2B, 7 $U_m$ = 36 kV | Class 1B, 2B, 7 $U_m$ = 36 kV | Class 3, 5 Dry $U_m$ = 12 kV (a) | Class 3, 5 Dry $U_m$ = 12 kV (a) | Class 4A, 6A Dry $U_m$ = 24 kV (a) | Class 4A, 6A Dry $U_m$ = 24 kV (a) | Class 4B, 6B Dry $U_m$ = 36 kV (a) | Class 4B, 6B Dry $U_m$ = 36 kV (a) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | kVA | MEPS | HE | MEPS | HE | MEPS | HE | MEPS | HE | MEPS | HE |
| 1P, SWER | 10 | 98.58 | 98.74 | 98.30 | 98.42 | 97.53 | 98.20 | 97.32 | 97.90 | 96.87 | 97.50 |
| | 16 | 98.74 | 98.83 | 98.52 | 98.64 | 97.83 | 98.32 | 97.55 | 98.06 | 97.11 | 97.75 |
| | 25 | 98.86 | 98.91 | 98.70 | 98.80 | 98.11 | 98.48 | 97.78 | 98.20 | 97.34 | 97.98 |
| | 50 | 99.05 | 99.10 | 98.90 | 99.00 | 98.50 | 98.78 | 98.10 | 98.50 | 97.74 | 98.33 |
| 3P | 25 | 98.65 | 98.80 | 98.28 | 98.50 | 97.42 | 97.88 | 97.42 | 97.88 | 96.92 | 97.55 |
| | 63 | 98.88 | 98.94 | 98.62 | 98.82 | 98.01 | 98.37 | 98.01 | 98.37 | 97.30 | 97.96 |
| | 100 | 99.05 | 99.10 | 98.76 | 99.00 | 98.28 | 98.61 | 98.28 | 98.61 | 97.58 | 98.25 |
| | 200 | 99.19 | 99.26 | 98.94 | 99.11 | 98.64 | 98.83 | 98.60 | 98.72 | 98.26 | 98.51 |
| | 315 | 99.27 | 99.34 | 99.04 | 99.19 | 98.82 | 98.95 | 98.74 | 98.87 | 98.44 | 98.63 |
| | 500 | 99.34 | 99.42 | 99.13 | 99.26 | 98.97 | 99.08 | 98.87 | 99.01 | 98.62 | 98.79 |
| | 750 | 99.39 | 99.45 | 99.21 | 99.32 | 99.08 | 99.18 | 98.98 | 99.13 | 98.77 | 98.91 |
| | 1000 | 99.42 | 99.46 | 99.27 | 99.37 | 99.14 | 99.26 | 99.04 | 99.19 | 98.87 | 98.99 |
| | 1500 | 99.44 | 99.49 | 99.35 | 99.44 | 99.21 | 99.33 | 99.12 | 99.26 | 98.99 | 99.08 |
| | 2000 | 99.45 | 99.50 | 99.39 | 99.49 | 99.24 | 99.37 | 99.17 | 99.30 | 99.00 | 99.14 |
| | 2500 | 99.45 | 99.51 | 99.40 | 99.50 | 99.27 | 99.39 | 99.20 | 99.33 | 99.00 | 99.19 |
| | 3150 | 99.45 | 99.51 | 99.40 | 99.50 | 99.30 | 99.39 | 99.23 | 99.33 | 99.00 | 99.19 |
| | 5000 | 99.45 | 99.51 | 99.40 | 99.50 | 99.30 | 99.39 | 99.23 | 99.33 | 99.00 | 99.19 |

Note: For intermediate power ratings the efficiency levels shall be calculated by linear interpolation. (a) Alternatively, adopt EU Tier 2 maximum load and no-load losses, as tested in accordance with EN 50708.

5. The amended Determination and Regulations should reference:

- AS/NZS 60076.1:2014 *Power transformers General* and AS 60076.11:2006 *Power transformers Dr type transformers* as the method of test; and
- AS 2374.1.2:2003 *Power Transformers Part 1.2. Minimum Energy Performance Standards (MEPS) requirements for distribution transformers* as the method of determining the efficiency of transformers (except for Sections 2 and 3, which would be superseded by the inclusion of the above table in the Determination and in the New Zealand regulations).

6. For dry type transformers, consideration should be given to accepting for registration models certified as complying with the requirements of Tier 2 of European Commission Regulation (EU) 2019/1783 of 1 October 2019, as compliant with the amended Determination and Regulations.

7. The amended Determination and Regulations should explicitly cover transformers that are intended for use as step-up transformers for wind turbine and utility-scale photovoltaic or battery storage applications, provided that they otherwise fall within scope.

8. The amended Determination and Regulations should exclude the following (noting that by this amendment, gas-filled dry type transformers are included in scope):

(a) instrument transformers; or

(b) auto transformers, that is transformers in which at least two windings have a common part; or

(c) traction transformers mounted on rolling stock; or

(d) starting transformers; or

(e) testing transformers; or

(f) welding transformers; or

(g) three-phase transformers with three or more windings per phase; or

(h) arc-furnace transformers; or

(i) earthing transformers; or

(j) rectifier or converter transformers; or

(k) uninterruptible power supply (ups) transformers; or

(l) transformers with an impedance of more than 8 percent [i.e. removal of 3% lower limit]; or

(m) voltage regulating transformers; or

(n) transformers designed for frequencies other than 50 <u>or 60</u> hertz; or

(o) flameproof transformers.

9. Consideration should be given to requiring permanent marking on the transformer nameplates, so that it is possible to identify every unit in the field against the register.

10. Consideration should be given to requiring the tested no-load loss and full load loss of every unit produced to be permanently marked on the rating plate, or if this is not practicable, then the no-load loss and full load loss as determined in type testing of that model for the purpose of registration.

11. The amended Determination should allow for at least two years between the date of taking effect and the date at which products within its scope must meet the amended MEPS levels and other rules for registration.

12. New Zealand Energy Efficiency (Energy Using Products) Regulations 2002 should be amended so that the provisions for distribution transformers align with the amended GEMS Determination, including the timing of implementation.

### Next Steps

The publication of this Regulation Impact Statement for Consultation marks the beginning of a process which will proceed in the following stages.

1. The Consultation RIS will be circulated to stakeholders as widely as possible, and submissions invited for a period of 8 weeks from its initial publication.
2. E3 will hold information sessions during that period to give an opportunity for stakeholders to ask questions and seek clarification of the CRIS.
3. E3 will review written submissions received up to the closing date. These will be made public, unless the submitter indicates that a submission contains confidential information. Stakeholders may make both a public and a confidential submission if they wish.
4. E3 will review the Consultation RIS in the light of submissions received and if necessary, review the analysis and recommendations accordingly.
5. E3 will prepare a Decision RIS for submission to Commonwealth, State, Territory and New Zealand Energy Ministers.
6. If Ministers (in New Zealand, the Cabinet) decide on a course of action that involves regulatory change, the Commonwealth Minister will oversee preparation of the appropriate GEMS Determination and the New Zealand Cabinet will approve any amendments to the Energy Efficiency (Energy Using Products) Regulations 2002.

### Have your say

The release of this CRIS marks the beginning of a public consultation period. Questions for Stakeholders on pages 69 -71 lists specific questions to which stakeholders are invited to respond. [2] The responses may inform the preparation of a final Decision RIS to be submitted to Ministers.

Submissions and enquiries can be directed to:

Australia: consult.industry.gov.au or GEMSProductReview@DCCEEW.gov.au

New Zealand: star@eeca.govt.nz

Submissions on this document close on: 6 December 2024

It is envisaged that information sessions will be held (by videoconference) in November. Please contact GEMSProductReview@DCCEEW.gov.au to register for the information sessions.

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[2] This Consultation RIS has been prepared in accordance with the *Regulatory Impact Analysis Guide for Ministers' Meetings and National Standard Setting Bodies, June 2023*.

# 1. Background

## Electricity Distribution Transformers

### Context

Distribution Transformers (DTs) are critical infrastructure components in the electricity grid. They are energised 24 hours per day, so their design needs to minimise energy losses. The decarbonisation aspirations in both Australia (greenhouse gas emissions reduction of 43% below 2005 levels by 2030 and net zero by 2050)[3] and New Zealand (greenhouse gas emissions reduction of 50% by 2030 and net zero by 2050)[4] are generating unprecedented changes in trans-Tasman electricity distribution systems.

Governments and industry are gearing up to deal with challenges around reliability and quality of supply that the transition to a low carbon future will require. Australia's electricity consumption is projected to increase by 50% between 2021 and 2050.[5] New Zealand electricity demand is projected to be 60-80% higher in 2050 than in 2022.[6] These increases will be driven by population and economic growth, the electrification of the transport fleet and the replacement of gas in residential and process heating.

The electricity grid has been designed and run as a centralised system, where electricity generators transmit electricity through to consumers in one direction. In future, there will be a move to a more decentralised electricity system, where electricity loads and generation are more mixed, energy flows will be two-way and flexible demand services will optimise grid efficiency. This is likely to lead to greater average loading of DTs, but not necessarily the same level of increase of peak loading. Whether or not the average capacity of new DTs increases in response to changes in electricity demand patterns, losses on all DTs are likely to increase due to greater average loading.

Considerations of impacts on infrastructure planning and investment upgrades are important. DTs have a service life of up to 45 years, so the Minimum Energy Performance Standards (MEPS) requirements of today will have an ongoing impact for decades to come. The purchase and maintenance of DTs is a significant expenditure for electricity network operators (called DNSPs in Australia and EDBs in New Zealand[7]). The timing of any revision of MEPS levels and associated cost impacts will need to be considered, alongside other investment priorities.

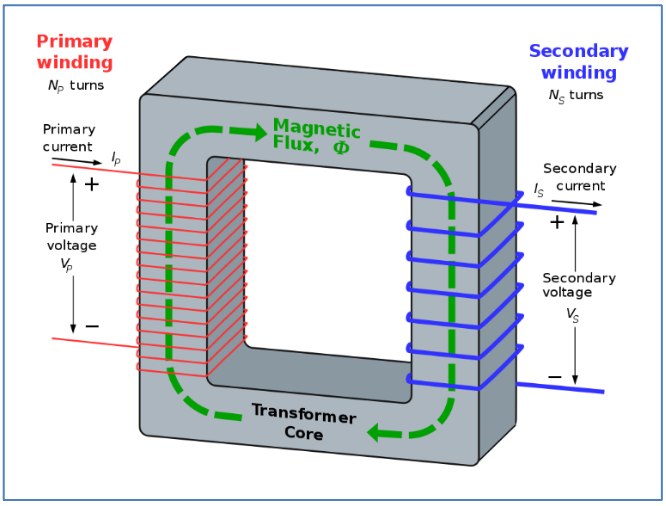
### Transformer Technology

Transformers transfer electrical energy from one electrical circuit to another via magnetic flux in the transformer core, without a direct conductive connection between the two circuits. The voltage and current levels in the two circuits can be differentiated according to the ratio of the number of turns in the primary

[3] Climate Change Authority
[4] Environment NZ
[5] Forecasting AEMO
[6] Transpower
[7] DNSP is Distribution Network Service provider, and EBD is Electricity Distribution Business

and secondary windings (Figure 1). This principle has made transformers indispensable to the operation of alternating current (AC) electric power networks since the first mass-produced designs appeared in Europe and the USA in the 1880s (Hughes, 1983).

*Figure 1 Principles of transformer operation*




Source: wikimedia

The electricity transmission grid generally operates at between 220,000 and 500,000 volts (220 to 500 kV)[8] Near the load centres the energy is transformed down to the 132 to 33 kV sub-transmission level. It is then sent to distribution utility zone substations where it is transformed down to 11-33 kV. Large commercial and manufacturing developments take energy directly from the 11-33 kV network, but most of the energy is conveyed to local street kiosk or pole transformers where it is reduced again to the final supply voltage of 400/230 volts.[9]

Until recently, nearly all of the electrical energy supplied to the grid was generated by fossil fuel or hydro power stations at 11 to 15 kV, and transformed up to transmission voltages. With the development of wind turbines, utility scale solar and other large scale renewable generation and battery storage, energy is generated at much lower voltages (typically 600V for wind) and needs to be stepped up to 11, 22 or 33 kV to be fed into the distribution network.

[8] The higher the voltage, the lower the current for a given amount of energy. As heat losses from the lines are proportional to the square of the current, high voltage transmission reduces energy losses.
[9] The great majority of consumers have historically received single-phase supply at 240V (the new standard is 230V) and in some cases three-phase supply at 415V (now 400 V). With the growth of rooftop PV, local supply voltages can fluctuate significantly during the day and damage equipment if too high.

## Estimated energy losses

There are energy losses at every stage of transformation, both step-up at the point of generation and step-down for distribution. By convention, the distribution sector is defined by voltages of 33 kV or lower, although many DNSPs and EDBs own sub-transmissions networks operating at higher voltages as well.

The total electrical energy loss from public distribution networks in Australia and New Zealand can be estimated from data published by the utilities, their industry associations and regulators, but transformer losses need to be distinguished from line and other losses, including theft. It is estimated that distribution transformer losses are about 5,000 GWh per year in Australia and 1,350 GWh per year in New Zealand. It is not known how changes in electricity demand patterns due to greater distributed generation and the growth of electric vehicle (EV) charging will affect transformer loadings in Australia or New Zealand, but some research indicates that losses could significantly increase (Masoum et al 2011).

Other impacts of EV charging on DTs include the need to upsize DTs due to higher peak loads and reductions in asset life due to the effect of higher operating temperatures and hence faster breakdown of the insulation (Ahmed at al 2021, Diahovchenko at al 2022). Jain and Karimi-Ghartemani (2022) modelled the impact on distribution transformer service life of various levels of EV ownership. With 40% of households having the facilities for home charging of EVs, they estimate an average loss of life of 20,450 hrs (2.4 years).[10] Thus, in addition to higher operating losses, the growing ownership of EVs is likely to increase the capital investment required in the future DT stock, though a combination of larger capacities and shortened service lives. This effect could be ameliorated by management of charging times to avoid peak demand periods.

*Table 1 Estimated energy losses from distribution transformers, Australia and New Zealand 2022*

| | Australia (a) | New Zealand (b) |
|---|---|---|
| Number of DTs in use, 2022 (up to 33 kV) | 787,000 | 193,000 |
| Distribution transformer losses | 5,000 GWh | 1,350 GWh (c) |
| Line and other losses | 6,000 GWh | 1,600 GWh (b) |
| Total distribution losses | 11,000 GWh | 2,900 GWh |
| Energy to distribution customers | 187,000 GWh | 40,000 GWh (b) |
| Transformer loss/distributed energy (d) | 2.6% | 3.2% |

(a) Author analysis of data in Electricity Gas Australia. (b) MBIE (c) Assuming transformer losses are 45% of distribution losses, as in Australia. (d) As % of energy sent to distribution.

Some of the energy sold to high-voltage customers will also be lost from the transformers on their private networks. It is estimated that about 20% of transformers are privately owned.[11] While private transformers

[10] Jain and Karimi-Ghartemani estimate that the loss-of-life could be reduced to 1.6 years with “a centralized recursive controller that periodically sets reactive power references for EVs to supply local reactive power.”

[11] Ellis (2000) estimated that private transformers accounted for about 15% of the total distribution transformer stock in Australia in 2000. This share is likely to have increased since then with changes in electricity market structure and development of large industrial and mining projects.

tend to carry more constant loads and operate nearer to their point of maximum efficiency, their losses could add a further 1,000 GWh per year in Australia and perhaps 170 GWh per year in New Zealand.[12]

## Design and manufacture

Transformers typically pass through over 98% of the electricity from the primary to the secondary circuit. The energy lost is mainly converted to heat, generated by the current flow in the windings resistances and by eddy currents in the core laminations. Some energy is also lost as sound – the familiar “transformer hum”. The heat generated must be removed by a circulating fluid (liquid, air or other gas). In many designs the cooling fluid circulates through external fins where it is dissipated by convection and radiation (Figure 2). In some cases, such as enclosed installations, the natural convective effect must be supplemented with air-circulating fans.

*Figure 2 Typical transformer with external cooling fins*


Source: Eteltransformers

Because transformers are constantly energised, even relatively small increases in efficiency result in significant energy savings. For example, increasing the efficiency of a DT, at any given loading, from 99.10% to 99.25% would reduce the rated energy loss at that loading from 0.90% to 0.75%: a reduction in energy loss of (0.90-0.75)/0.9 = 16.6%.

The main technical avenues for increasing the energy efficiency of DTs are:

- Cores that are of better quality electrical steel and built up from thinner laminations;
- Using wound-core methods of core fabrication rather than laminations;
- Changing the winding metal from aluminium to copper.

There are however technical and commercial barriers to these improvements.

[12] New Zealand has about one fifth the population of Australia, and the industrial/mining share of electricity use is 45% vs 53%. Therefore the equivalent estimate is 1000 x 1/5 x 45/53 = 170 GWh.

- There is a global shortage of high-quality electrical steel. Post-pandemic supply chain disruptions are expected to persist for some years, and at least one major electrical steel supplier to Australia has switched over to supplying the growing electric vehicles (EV) market.
- Thinner laminations are harder to work, involve more labour and may require new equipment for processes such as wound-core fabrication.
- Amorphous metals are used for transformer cores in a number of countries where wound core construction is common, but they are not widely used in Australia because of the difficulty of applying them to laminated core structures. The availability of amorphous magnetic metals for cores is also an issue.
- While less copper is needed to achieve the same conductivity, the metal is much more expensive and more labour-intensive to work.[13] It does not lend itself to the automated production techniques that have kept down the cost of smaller DTs.

Other major developments in DT technology in recent years involve the cooling liquid. The fluid used in traditional liquid-filled transformers is mineral oil obtained from petroleum oil distillation. Such oil is very flammable and is not easily bio-degradable. In recent years vegetable-based oils (natural esters such as soy and linseed) have been used, as well as synthetic esters and silicone oils. While these fluids are more expensive, they are less flammable, tolerate higher operating temperatures and are less environmentally damaging. DT efficiency does not seem to be affected by this change in oil types. Where both mineral oil (ONAN) and ester (KNAN) variants of a given DT model are registered with the AU/NZ regulators the suppliers claim identical energy efficiencies.

Another area of development has been manufacturing techniques. The smaller and more standardised the transformer, the greater the potential for automation. Robot-assisted manufacture is used for some SWER (single wire earth return) models, and units up to 500 kVA are made on production lines. Larger units are in general still mainly hand-assembled by highly skilled labour because of their size and weight and greater demand for customisation, but core winding machines are now being used extensively.

Apart from its design, materials and manufacture the efficiency of each DT over its service life depends on both physical maintenance (e.g. filtering and topping up liquid coolant on a regular basis) and on the loading levels (and hence the operational temperature of the insulation over the transformer lifetime). The test procedure for DT energy efficiency should therefore be done at load levels well-matched to expected average loading.

## MEPS in Australia and New Zealand

MEPS for DTs were introduced in 2004, following a regulatory impact analysis in 2002 (GWA 2002). As the MEPS pre-dated the GEMS Act 2012, they were implemented in Australia via State and Territory legislation, and in New Zealand via the Energy Efficiency (Energy Using Products) Regulations 2002.

The current GEMS Determination for DTs was made in October 2012. As with the preceding jurisdictional legislation, the Determination references the MEPS levels in AS 2374.1.2-2003 *Power transformers - Minimum Energy Performance Standard (MEPS).* The Determination also references the High Efficiency (HE)

[13] At the end of June 2024 the London Metals Exchange quoted USD 2,510/tonne for aluminium and USD 9,570/tonne for copper.

level in AS 2374.1.2, which a product must meet in order to be lawfully classified as a "high power efficiency transformer." The MEPS and HE levels in AS 2374.1.2 are detailed in Appendix B of this CRIS.

In November 2021 the E3 Committee published a Public Consultation Paper on the following options:

- Allow the Determination to expire;
- Renewing the Determination with minimal changes; and
- Increasing the MEPS and Scope (E3 2021).

At the time, it was thought that the Determination was due to sunset on 1 April 2023 unless it was renewed. The Review concluded that: "If no further information is received from stakeholders, the review is likely to recommend that a full analysis is undertaken to determine the costs and benefits of increasing the MEPS and expanding the scope." In the event, there was no negative response from stakeholders, although response was limited.[14]

Several studies, carried out both before and since the Determination was made, have recommended increasing the stringency of MEPS for DTs, in line with rising DT MEPS levels in other economies, notably the USA and the European Union. The CRIS prepared for the E3 program in 2011 stated that in light of available DT technology, the MEPS and HE were no longer challenging and there was room to increase the requirements (E3 2011). A 2014 report by Deloitte also recommended a move to higher MEPS levels (Deloitte 2014). These recommendations have not been taken up and the MEPS and HE levels have remained unchanged for nearly 20 years.

## International Standards

Several countries and the European Union have MEPS for transformers (Table 2). These differ with regard to a number of key aspects.

**Scope.** e.g. Australian and New Zealand MEPS cover transformers up to 2,500 kVA rated power and 24kV, whereas the EU places no limit on coverage.

**Test standards.** Each country and region uses a unique test standard. While these are technically similar in that the main quantities measured are no-load (core) losses and load (copper) losses, the differences are such that a product tested to one standard cannot be guaranteed to return the same results under a different test standard (SEAD 2013b). The relative merits of retaining or changing the test procedure in the current Determination are discussed in Section 4.

**Energy Performance Metric**s. This is the measure of energy performance. The most common metric is efficiency at 50% load, although 100% and 40% are also used. Some countries specify MEPS in terms of minimum efficiency at the rating point while others use maximum losses in kW or a formula (e.g. the EU Peak Efficiency Index (PEI) which also includes any energy used for cooling).

[14] Industry stakeholders interviewed were unaware of this consultation, which received only two responses addressing DTs: from the Energy Efficiency Council (21 December 2021) which "supports increasing the MEPS and expanding the determination scope" and GWA (3 December 2021) which stated: "We support the recommendations foreshadowed in the *Public Consultation Paper: Review of the GEMS Power Transformer Determination*:
• a full analysis to determine the costs and benefits of increasing the MEPS and labelling requirements.
• the current determination to be retained in the meantime."

**MEPS levels.** These are the target values which the energy performance metric must attain in order to comply: the *minimum* permissible efficiency or the *maximum* permissible energy loss under the specified test conditions. In some cases separate values apply to no-load losses and load losses (e.g. China) while in others it is the combined loss. In nearly all cases the MEPS level becomes more stringent (higher efficiency or lower loss per kVA) with increasing capacity and maximum kV rating, to reflect the physical characteristics of transformer construction.

**Classifications.** MEPS levels may be differentiated by other criteria in addition to capacity. Most countries apply different MEPS values to liquid-immersed and dry type transformers of the same capacity. Australia and New Zealand further differentiate single-phase from three-phase types. The EU applies different MEPS to "medium power" transformers (up to 3,150 kVA and 24kV) and "large power" (over 3,150 kVA).

*Table 2 Countries with MEPS for Distribution Transformers*

| Country or Region | Energy performance metric | Standard |
|---|---|---|
| Australia and New Zealand | Efficiency at 50% load | AS 2374.1.2 - 2003 |
| Brazil | Max no-load and load losses at 100 % load | ABNT NBR 5356; 5440 |
| Canada | Efficiency at 50% load | CSA C802.1 |
| China | Max no-load and load losses at 100% load | JB/T 10317-02 GB 20052-2013 |
| EU | For <= 3,150 kVA): Max no-load and load losses at 100% load<br>For >3150 kVA: Peak Efficiency Index (PEI) | EN50588-1:2014; PEI calculated according to EU Eco-design-regulation No. 548/2014. |
| India | Max total losses at 50% and at 100% load | IS 1180:2014 & Government of India Gazette 2968 |
| Israel | Max total losses at 100% load | IS 5484 |
| Japan | Total losses at 40% or 50% load | Top runner |
| Mexico | Efficiency at 50% load | NOM-002- SEDE-1997 |
| Korea | Efficiency at 50% load | KS C4306, C4316 and C4317 |
| USA | Efficiency at 50% load | 10 CFR 431 |
| Vietnam | Efficiency at 50% load | TCVN 8525:2015 |

Source: Das, B. and Milledge, R. (2022)

**Intended application.** The EU further distinguishes pole-mount transformers from other types, whereas in Australia and New Zealand the transformer is rated on its own, irrespective of whether it is finally supplied in a pole-mounting configuration (with appropriate casing and brackets), for floor level or kiosk application or as part of a complete ready-to-connect substation, with enclosure and switchgear.

All MEPS rules note exceptions and clarifications. For example, the EU states:

> "The directive does not apply to transformers solely designed and implemented for the following purpose:

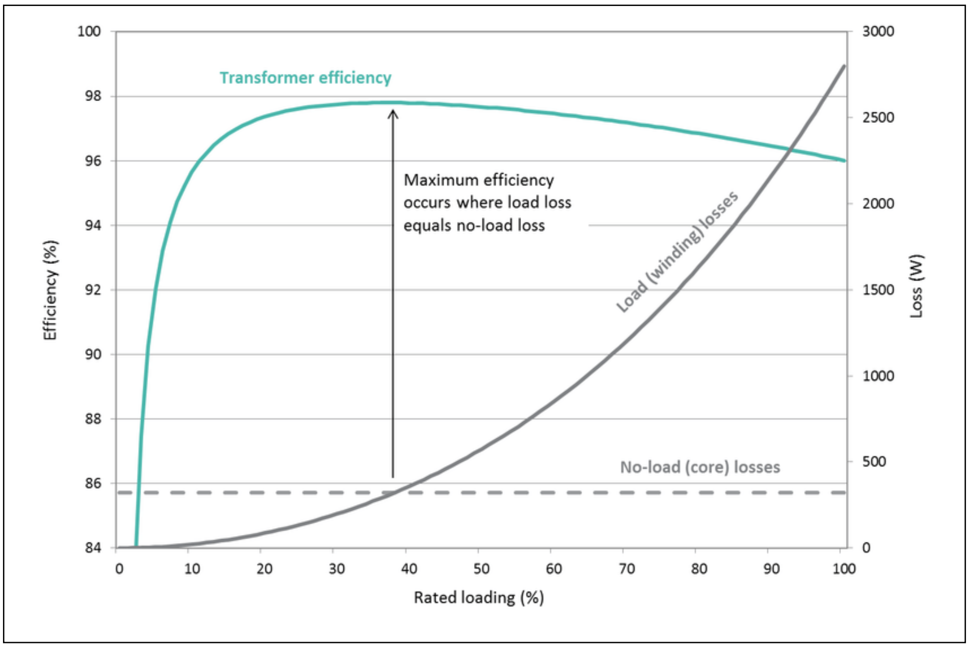
…(b) transformers specifically designed and intended to provide a DC power supply to electronic or rectifier loads. *This exemption does not include transformers that are intended to provide an AC supply from DC sources such as transformers for wind turbine and photovoltaic applications or transformers designed for DC transmission and distribution applications*" (EU 2019; emphasis added).

In Australia and New Zealand, renewable generation step-up transformers are not explicitly addressed by the current GEMS Determination or AS 2374.1.2.

## Effect of Loading

According to AS 2374, the efficiency of a given transformer is the electrical energy output divided by the electrical input at 50% loading. For example, a transformer rated at 500 kVA is tested at a load of 250 kW at a power factor of 1. A transformer's core losses are constant so long as it is connected to power, but the winding losses increase as the square of the current (Figure 3).

*Figure 3 Typical transformer loss curve*



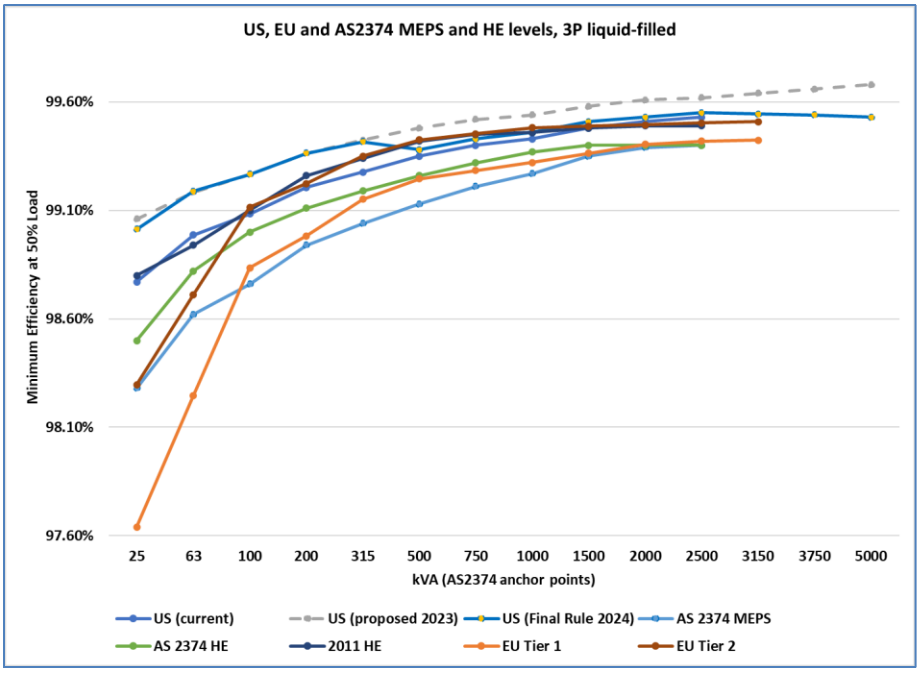

The maximum efficiency occurs at the loading point where core and winding losses are equal. This may be a loading other than 50%. However, as long as a DT meets the MEPS level specified for its configuration and capacity at 50% loading it complies with the GEMS Determination and Energy Using Product (EUP) Regulations, even if it is more efficient at a different point. Over time, manufacturers tend to design DTs to meet statutory requirements including MEPS, so it is likely that most AU/NZ-made DTs do in fact achieve peak efficiency at 50% load.

The actual efficiency in use rarely matches the rated efficiency. Loadings vary considerably during the day, especially for utility-owned transformers, which can go from very low overnight loads to fully loaded (or even over-loaded for short periods) during peak demand periods. Efficiency falls off steeply at low loads, but so does the energy throughput and hence energy loss. The fall in efficiency is less severe as loadings increase. Transformers in manufacturing and mining applications often carry a more constant and predictable load than those on public networks, so their selection can be better optimised for the load.

## Comparison with current MEPS

The many differences in scope, tests and performance metrics complicate the comparison of MEPS levels across countries and regions. Figure 4 illustrates the current MEPS (the lowest line) and HE levels (middle line) for 3-phase liquid-immersed DTs. The current USA (middle line) and EU Tier 1 (second lowest line) and 2 MEPS levels (second highest line). It also shows the higher “2011 HE” levels (third highest line) proposed in the analyses (E3 2011 and Deloitte 2014). The recent increases in US MEPS levels is the top line. Figure 5 (on the next page) illustrates the corresponding MEPS levels for single-phase transformers, which account for a far greater share of the DT fleet in the US than in Australia.

*Figure 4 US, EU and AS 2374 MEPS and HE levels (Oil filled, 3P)*



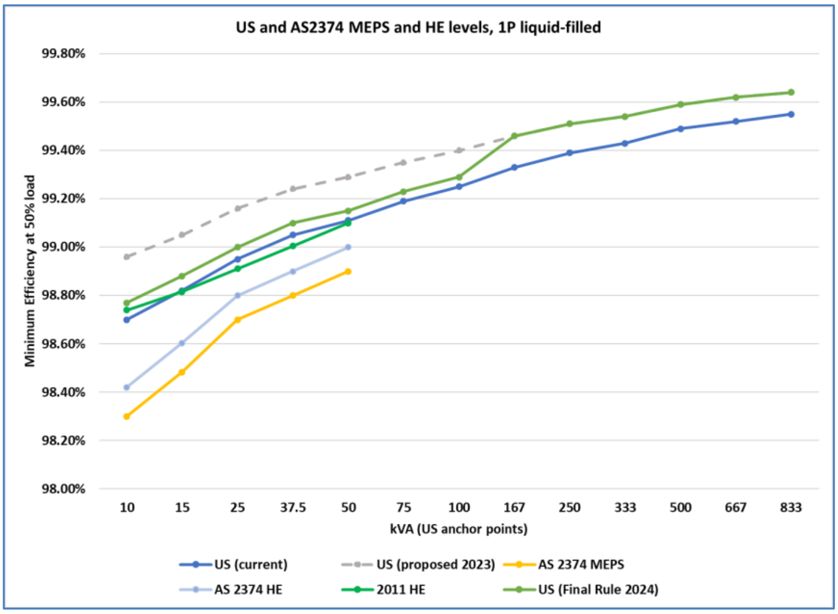

The USA first implemented MEPS for DTs in January 2007, and increased the MEPS levels from January 2016. In January 2023 the US Department of Energy published a notice of intention to further increase the MEPS levels (DOE 2023). After receiving submissions from industry, the DOE issued final standards in April 2024 which were less stringent than those originally proposed for some product classes, notably liquid-filled transformers of 250 kVA and above (DOE 2024).

The rule proposed by the DOE in January 2023 would have required almost 90% of transformers to have amorphous metal cores, whereas the final rule will allow 75% of distribution transformer cores to use grain-oriented electrical steel, which is manufactured in the USA. [15]

Industry stakeholders in Australia have advised that efficiency values at 60Hz (e.g. as used in the USA and Canada) should not be compared with the results at 50Hz. This is primarily because of the slightly increased core losses due to eddy currents at the higher frequency. While DT construction and testing methods are similar and DTs designed for 60Hz markets could be used in 50Hz markets without modification, they may need to be retested to prove MEPS compliance.

The EU, where 50Hz is the standard, adopted a first MEPS level (Tier 1) in July 2015 and a higher MEPS level (Tier 2) in July 2021.[16] In September 2023 the EU began a process to review the Tier 2 levels and potentially introduce a more stringent 'Tier 3.' This is not supported by European transformer manufacturers, who argue that moving beyond the current levels would not be cost-effective (Eurelectric 2023).

*Figure 5 US and AS 2374 MEPS and HE levels (Oil filled, 1P)*




[15] https://tinyurl.com/28f234bp

[16] It is difficult to line up MEPS levels precisely, partly because of differing "anchor points" – the discrete kVA values at which minimum efficiencies are specified (e.g. 25 kVA, 63 kVA, 100 kVA etc). For DTs with a rating that does not match an anchor point, the MEPS level is calculated by linear interpolation between the two adjacent anchor points. A graph that follows the US anchor points, for example, will be slightly different from one that follows the AS2374 anchor points in Figure 4.

## The Transformer Market

### Manufacturers and Importers

The register of distribution transformer models complying with MEPS listed 18 suppliers at April 2024.[17] Four of these manufacture liquid-immersed DTs in Australia or New Zealand. (A fifth company, TMC Australia, has a transformer manufacturing plant in Brunswick, Melbourne, but has no DT models registered).[18]

ETEL Limited manufactures in Auckland, and sells products in New Zealand, Australia and the Pacific. Since 2009 ETEL has been wholly owned by Unison Group, the fifth largest electricity network company in New Zealand. It has 290 employees.

Schneider Electric is a global conglomerate headquartered in France. It acquired ASET (Australian Standard Electrical Transformers) at Benalla, Victoria in 2004. It employs 190-250 people at the site. Exports from Australia are minimal.

Tyree manufactures transformers at Mittagong, NSW, and exports to New Zealand and the Pacific. It employs about 300 people. In 2023 it established a small DT manufacturing facility in Auckland.

Wilson Transformer Company Pty Ltd is Australia's largest manufacturer of power and distribution transformers, with manufacturing facilities at Glen Waverley and Wodonga, Victoria. It has about 225 employees and has several facilities in other countries.

These companies all manufacture power transformers (above 33 kV and 3,150 kVA) as well as distribution transformers. Some also make step-up transformers for wind and solar farms and supply a small number of imported DTs for special applications.

ABB Australia Pty Limited is part of the global ABB Group, headquartered in Switzerland, whose power grids business was majority acquired by Hitachi Energy in 2020. ABB Australia manufactures power transformers at Moorebank in Sydney but has closed down its DT manufacturing facilities in Australia and New Zealand. It imports DTs from other ABB factories in Vietnam and China.

Other major importers of liquid-immersed DTs are POWINS, which imports CCT brand DTs from Thailand, and QTC Energy (Thailand).

There are no locally made dry type DTs on the register. The main suppliers are GE Waveform (importing from China), Grant Transformers (Turkey/China), Siemens Energy (Germany, China), GEAFOL (Germany) and ABB Power (South Korea).

It is difficult to establish the import share of the DT market because the import statistical categories straddle both power and distribution transformers. However, it is estimated that 80-90% of liquid-immersed DTs supplied in both Australia and New Zealand are locally made.

The DT market is highly price competitive. Local manufacturers have the advantages of long-standing relationships with DNSPs and EDBs, shorter order times and lower freight costs, although they face higher labour and material costs. There have been dumping cases initiated by local manufacturers, but these have targeted power transformers rather than DTs (DIIS 2020).

[17] Energyrating
[18] https://www.tmc.com.au/

## Model Range

At April 2024 there were 277 models of DTs registered: 94 with the Energy Efficiency and Conservation Authority (EECA) and the rest with the Australian GEMS regulator (Table 3). In some cases both 22kV and 11 kV variants of the same basic model are registered, with identical kVA ratings and power efficiency values. In other cases there are multiple listings of the same model to reflect different configurations (pole- and pad-mount) and the specifications of various DNSPs and EDBs, which differ in details such as fixing brackets and external cabinets and finishes, but are otherwise technically identical. Taking this into account, there are 181 unique models (Table 4).

There is at least one model available at each of the standard capacities recognised in AS 2374, but the most are clustered at 50, 500, 1000 and 1500 kVA (see Figure 6). As most DTs are purchased by electricity distribution companies, this clustering reflects buyer preference for rationalising their network designs and stock inventories. About three quarters of the unique models are rated 11 kV and a quarter 22kV.

*Table 3 Registered distribution transformer models by type and energy efficiency, 2024*

| Models | Liquid filled - Single phase | Liquid filled- Three phase | Liquid filled- All Liquid | Dry type | All types | HE % |
|---|---|---|---|---|---|---|
| New Zealand registered | 17 | 74 | 91 | 3 | 94 | |
| High efficiency | | | 7 | 3 | 10 | 11% |
| Standard efficiency | | | 84 | 0 | 84 | 89% |
| Australian registered | 6 | 164 | 170 | 13 | 183 | |
| High efficiency | | | 135 | 10 | 145 | 79% |
| Standard efficiency | | | 35 | 3 | 38 | 21% |
| All registered models | 23 | 238 | 261 | 16 | 277 | |
| High efficiency | | | 142 | 13 | 155 | 56% |
| Standard efficiency | | | 119 | 3 | 122 | 44% |
| HE/total models | | | 54% | 82% | 56% | |

Source: Author analysis of register on Energyrating April 2024

*Table 4 Unique distribution transformer models by type and energy efficiency, 2024*

| Models | Liquid filled - Single phase | Liquid filled- Three phase | Liquid filled- All Liquid | Dry type | All types | Unique % |
|---|---|---|---|---|---|---|
| New Zealand registered | 17 | 49 | 66 | 3 | 69 | 82% |
| Australia registered | 6 | 97 | 103 | 9 | 112 | 61% |
| All models | 23 | 146 | 169 | 12 | 181 | 65% |
| Unique/total models | 100% | 61% | 65% | 75% | 65% | |

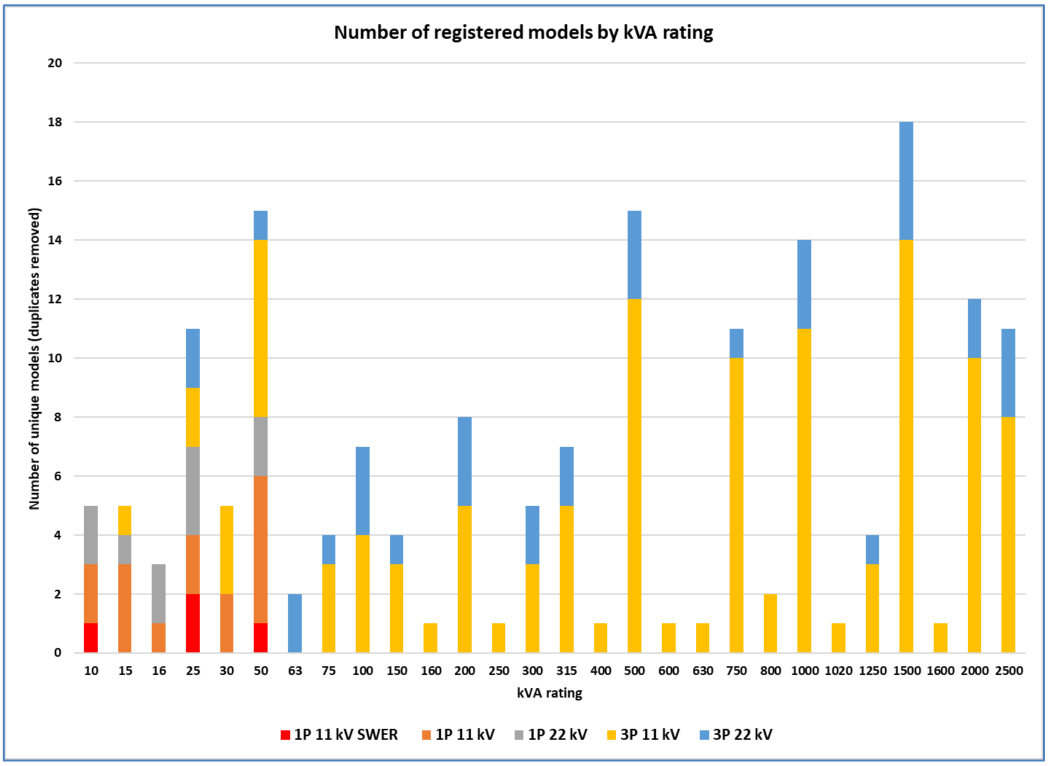
Source: Author analysis of register on Energyrating April 2024

All registered models claim to meet MEPS, otherwise they could not be registered. It is possible that other DTs within the scope of the regulations are being supplied untested and unregistered. This would be contrary to the GEMS Act, which applies to all product "supplied" in Australia including direct imports by mining and manufacturing companies. However, it is not contrary to the New Zealand regulations, which only cover "sale, lease, hire or hire purchase". It is understood that this gap in coverage is being reviewed by the New Zealand Government[19].

The models on the register can be divided into two energy efficiency grades:

A. Those meeting the MEPS for their configuration and kVA rating (designated as MEPS1) but not the HE level (designated as MEPS2). About 46% of liquid-immersed DT models are in this group, and 18% of dry type models;
B. Those meeting the current HE level for their configuration and kVA rating. About 54% of liquid-immersed DT models are in this group, and 82% of dry type models (Table 3).

*Figure 6 Number of distribution transformer models registered by capacity, 2024*




Source: Author analysis of register on Energyrating April 2024

The margin by which DTs exceed MEPS or HE is an important indication of the likely benefits of lifting MEPS levels. These are detailed in Appendix C, Table 26. The closer that DTs are to a specific efficiency level already, the less the benefit from mandating that level.

[19] Energy efficient products and services | Ministry of Business, Innovation & Employment (mbie.govt.nz)

Table 5 indicates some of the key differences between DTs registered in New Zealand and in Australia (manufacturers tend to register in the country of manufacture). The average capacity of three-phase liquid-filled transformers (GEMS Class 2) registered in Australia is much higher than in New Zealand (1,071 kVA vs 317 kVA). This would be a major factor in the higher average energy efficiency for that class (99.28% vs 99.00%) because efficiency increases with capacity, all else being equal.

It should be noted that these are "model-weighted" average efficiencies. If the larger DTs sell in greater numbers, then the "sales-weighted" average kVA will be greater than model-weighted average. Similarly, if the annual sales of less efficient models were higher than the sales of more efficient models, than the sales-weighted average would be slightly lower than the model-weighted average. Both of these factors appear to be the case on the basis of the limited sales data available, and this has been taken into account in cost-benefit modelling (see Appendix C).

*Table 5 Key model-weighted characteristics of distribution transformers registered in Australia and New Zealand, April 2024*

| Models | 1P KVA | 3P KVA | Dry type KVA | All types KVA | 1P efficienc y | 3P efficienc y | Dry type efficiency | All types efficiency |
|---|---|---|---|---|---|---|---|---|
| New Zealand registered | 28 | 317 | 800 | 267 | 98.70 | 99.00 | 99.17 | 98.94 |
| Australia registered | 29 | 107 1 | 1306 | 1034 | 98.85 | 99.28 | 99.22 | 99.25 |
| All models | 29 | 818 | 1179 | 742 | 98.74 | 99.19 | 99.21 | 99.13 |

Source: Author analysis of 181 unique models registered on Energyrating April 2024,

## Energy efficiency in the purchase decision

About 80-85% of DTs are purchased by utilities which are regulated with regard to their revenues and return on capital. An analysis commissioned by the Australian Energy Regulator (AER) found that transformers accounted for about 29% of electricity distribution industry costs in Australia. It noted that the total capacity of DNSP transformers increased by nearly 41% between 2006 and 2020, well ahead of the growth in peak demand or energy sales (AER 2021).

There are 16 major DNSPs in Australia: 14 regulated by the AER and two by the Western Australian Economic Regulation Authority. New Zealand has 29 Electricity Distribution Businesses (EDBs) of which 16 are price-quality regulated and 13 are only subject to information disclosure regulation. On the basis of population difference alone, this suggests that the average Australian DNSP serves more than nine times as many customers as the average New Zealand EDB.

Each electricity distributor has a different network structure due to its particular history of accumulating smaller networks, and each maintains a set of technical specifications for the DT types it regularly purchases. These cover many factors, including:

- High and low side (primary and secondary) kV;
- kVA capacity;

- Filling fluid, if liquid-immersed;
- Physical characteristics (weight, dimensions, cooling arrangements, fixing and lifting brackets etc.);
- Durability (minimum service life, or specific finishes and dust and liquid incursion ratings);
- Minimum energy efficiency or maximum losses.

Discussions with stakeholders indicate that most electricity distributors only require that transformers meet the MEPS level, except for some Victorian DNSPs, which specify the HE level. In general, manufacturers do not see a commercial or marketing advantage in designating products as HE, even those that meet the HE criterion. What then account for the relatively high proportion of locally made models that meet HE (see Table 3).

The driver of the demand for HE models is the need to limit heat losses from DTs installed in kiosks and other enclosed locations. This avoids the energy and noise associated with cooling fans and reduces transformer hum. Transformer manufacturers are increasingly supplying complete pad-mount substations, with switchboards and enclosures, ready to be installed on a concrete slab and operational within 48 hrs, compared with several months for traditional on-site construction methods. A HE DT can make the substation design more cost-effective, even if the DT itself costs more. This cost dynamic does not apply to pole-mount transformers, which continue to lag in their efficiency.

The incentive for DNSPs themselves to specify the HE level is weak. Their revenues are regulated according to their capital base and their operating expenses, but not the energy losses on their networks. The costs of losses are passed on to the energy retailers using the network, who recover them in turn from customers. One indication of the lack of incentive is the fact that the one DT manufacturer owned by a distribution company has no HE models registered at all.

Many DNSPs now outsource their DT purchase and installation functions to contractors, who bid on an overall price. It is estimated that over 90% of DNSP purchases in NSW are now made via contractors. Unless the DNSP specifies HE – which most do not – the contractor has every incentive to purchase the cheapest DT that meets the specifications. In this respect the DNSP transformer market has come to resemble the private transformer market, where the developers of residential and commercial buildings and their electrical systems contractors are primarily driven by first cost. In both cases there are split incentives. The capital costs of the transformers and the cost of the losses are borne by different parties.

The only market segments that directly face the costs of losses are isolated networks where the same organisation generates and consumes energy, and renewable generation operators. In isolated systems the cost of generation fuel or purchased electricity is usually high, so losses are expensive, and the operator usually has the technical, analytical and financial capacity to assess the DT options and choose the most cost-effective.

With utility-scale renewable generation systems such as wind farms and PV, the operator is usually paid according to the energy delivered at the point of transmission connection (typically at 33kV or 66 kV), so losses on the step-up DTs on their side of the connection represent a financial loss. However, there are often several parties involved in the financing, design and contracting chain, and transformer efficiency is not always a primary consideration, given additional technical requirements related to harmonics and eddy currents.

# 2. The Problem and Options to Address It

## The Problem

The value which DNSPs place on energy losses, and hence the value of transformer efficiency, depends on the commercial and regulatory incentives. Up to the 1990s all Australian DNSPs were part of publicly owned utilities integrating generation, transmission, distribution and retailing. Increasing technical efficiency across the supply chain could be realised as either lower energy prices to electricity consumers or higher commercial returns, both of which were of value to the public sector owners.

Transformer purchase criteria included both capital costs and the capitalised value of energy losses over the service life, so higher price transformers were preferred if their efficiency was high enough. The restructuring of the electricity markets in both Australia and New Zealand changed the incentives. The DNSPs in Victoria, South Australia and the ACT were sold to private companies in the 1990s, and NSW followed in the 2000s. New Zealand EDBs followed a similar trajectory after they were split from retail companies following the passage of the Electricity Industry Reform Act 1998 (although a larger percentage remain consumer owned).

Whatever the benefits of electricity sector restructure, one of the costs has been the weakening of incentives for distributors to purchase equipment with a higher capital cost, even if greater energy-efficiency makes it cost-effective over its operating life. In this regard the behaviour of energy utilities represents a market failure which can most effectively be rectified by government intervention in the market. This was demonstrated in the RIS that preceded the introduction of the current GEMS determination (E3 2011). The conditions of the market have not changed and the rationale for government intervention remains. There is as much evidence of split incentives as in 2011 when the previous RIS was prepared.

The existing market and regulatory structures do not give distributors an incentive to prefer DTs with higher efficiency than the MEPS levels, even when it would be societally cost-effective. In fact, it is arguable that without MEPS transformer efficiency might actually have declined.

It is apparent that the current regulations have been effective in establishing a floor in energy efficiency. Recent check tests have concluded that compliance is very high, and the claimed efficiency values are largely accurate. The fact that there is a significant number of liquid-filled models which exceed MEPS and meet the current HE level is due largely to the shift in some market segments to packaged substations rather than separate DT sales. Outside those segments the market continues to prefer MEPS only rather than HE products.

## Options Considered

### No change in Regulations

This is the baseline option against which other options will be compared. The existing GEMS determination would remain in place in Australia and the existing EUP regulation in New Zealand. There would be no additional testing or administrative costs beyond those incurred under “business as usual”.

The existing market conditions would also remain in place. Some progress towards greater DT energy efficiency would continue due to market trends such as packaged kiosk substations, but not in configurations such as pole-mount DTs. The current MEPS levels ("MEPS1") have not changed for nearly 20 years, and if they were retained they would remain in place for a further indefinite period at a time when DT MEPS levels in comparable economies are increasing and total DT losses in Australia and New Zealand are rising.

## Raising the MEPS level

There are several possible approaches to selecting more stringent MEPS levels for analysis.

- The HE levels in AS 2374.1.2-2003 and in the current Determination. HE levels are included in GEMS Determinations for several other products as well, with the dual objective of offering a commercial incentive for suppliers to move beyond MEPS and as an early indication to industry of future MEPS levels. The 2011 RIS recommended the adoption of these HE levels (with some modification for units of 1500 kVA and above) as the revised MEPS levels.
- The MEPS levels used in comparable economies, such as the European Union, the USA and Canada. These levels were analysed by Blackburn (2007) and the 2011 RIS. At the time, no other MEPS levels were higher than the AS 2374.1.2 HE levels. (More stringent "HE" levels were published in some cases, but those were not mandatory). The MEPS levels and regulatory trajectories in other jurisdictions have now exceeded the AS 2374.1.2 HE levels (Figure 4, Figure 5). Comparisons with international MEPS levels need to be carefully considered, because the scope, methods of test and the calculation of efficiency are slightly different from AS 2374.
- Some other efficiency level. While the existing AS 2374 HE levels and other countries' MEPS levels are useful precedents, there is no inherent bar to adopting different MEPS levels, should that be feasible and cost-effective. After all, the great majority of the Australian and New Zealand market (a least for liquid-filled DTs) is supplied by local manufacturers and the present MEPS levels are unique to Australia and New Zealand.

A combination of these approaches is also possible, to suit different segments of the DT market.

It is a matter for consideration whether increasing the stringency of MEPS requirements should be accompanied by a still more demanding HE requirement, or whether the HE designation can be abandoned on the grounds that MEPS has been shown to be the primary policy driver for efficiency improvements.

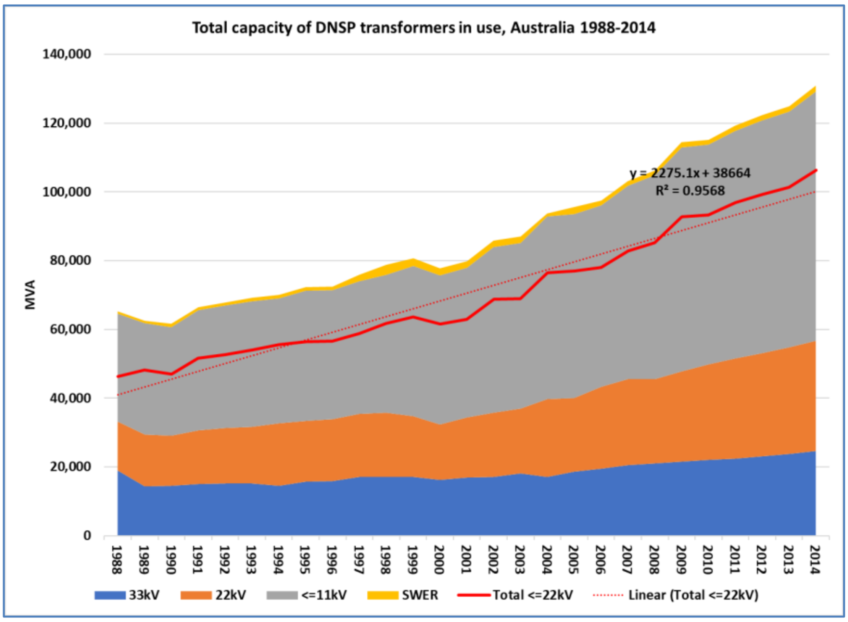
## Widening the Scope of the Determination

The current GEMS Determination covers "power transformers…with power ratings from 10 kVA to 2500 kVA and a system highest voltage up to 24kV". It adds a note that "this subsection reflects the scope specified in clause 1.1 of AS 2374.1.2-2003."

There is no compelling reason why the scope should be limited to these values, and indeed there are in some internal contradictions in this definition.

The electricity distribution industry classifies as 'distribution transformers' all transformers with one winding operating at a voltage up to 1000 V and the other winding up to and including 33 kV. 33kV DTs account for about 1.3-1.5% of DTs by number, but 19-20% by capacity (Figure 7) albeit a somewhat lower share of losses, because 33 kV units are higher in the network hierarchy, more heavily loaded on average and so operate closer to their maximum efficiency for more of the time than the lower voltage DTs downstream of them.

*Figure 7 Total capacity of Distribution Transformers by voltage levels, Australia 1988-2014*




Source: Derived by author from AER data

The industry uses the term ‘power transformer’ to refer to transformers used in generation, sub-transmission and transmission, with voltage ratings of 66 kV and above and capacities in the tens up to hundreds of MVA. Therefore, extending MEPS regulation coverage for ‘distribution transformers’ up to 36 kV would be consistent with the practice of both the electricity distribution industry and the transformer industry.[20]

With regard to capacity, the European Union classifies transformers up to and including 3,150 kVA as ‘medium power’ and larger units as ‘large power’ and applies different methods of efficiency calculation to each category. There is no upper capacity limit on the EU MEPS regulations for large power transformers.

Until recently, the upper limit of US DT efficiency regulations was 2,500 kVA for both liquid-immersed and dry type units. In April 2024 the Department of Energy published a new rule raising the upper limit to 5,000 kVA (CFR 2024), citing both the EU example and Canadian regulations that cover dry type transformers up to 7,500 kVA.

Expanding the scope of MEPS has been supported by the Standards Australia committee responsible for AS 2374.1.2, which in March 2009 agreed in principle to include:

- 33 kV transformers (as used in wind farms and other renewable energy generation) pending further consultation with the sector;

[20] The existing MEPS regulations cover DT voltages up to 24 kV, the system maximum voltage for 22kV networks. Similarly, 36kV is the system maximum voltage for 33 kV networks.

- efficiency values for transformers up to 3,150 kVA for 11kV, 22kV and 33 kV networks; and
- the marking of transformers as MEPS compliant (RIS 2011).

Interviews with industry as part of the research for the CRIS indicated no objection to expanding the scope to 33 kV and 3,150 kVA, or including step-up transformers that fell within that scope. Australian and New Zealand manufacturers offer DTs up to 4,000 kVA and 33 kV. It has since become apparent that a higher upper limit of 5,000 kVA (as adopted in the US) would be needed in order to cover step-up transformers in terrestrial wind farms, where individual turbine capacities are now around 5,000 kVA (off-shore wind turbines are much larger and typically feed into the grid at 66kV, so they would remain out of scope). As testing and administrative costs are related to the number of units while potential benefits are related to power, this expansion is potentially cost-effective.

Coverage could also be extended to certain types of transformers explicitly excluded by the present regulations. Blackburn (2007) recommended that the following categories, currently excluded, should be covered in order to prevent distortions in the market (lettering refers to exclusions in the current Determination):

> (a) “transformers other than those designed for 11 or 22 kV networks”. This clause could be invoked to exclude transformers installed in micro-grids isolated from the public network, or DC to AC step-up transformers in wind turbines, for example, if the network linking the turbines to the point of connection operated at voltages other than 11 and 22 kV (or 33 kV, if included in the scope). To remove all ambiguity, the rules should state that such transformers are covered, as is the case in the EU.
>
> (m) “transformers with impedance less than 3% or more than 8%”. Transformers with impedance down to 1% are now available and there is no technical reason why they should be excluded. The 2024 US regulations specify that impedance ranges down to 1% are considered ‘normal‘ (CFR 2024, p87) The lower limit should be removed, but the upper limit retained.
>
> (o) “transformers designed for frequencies other than 50 Hz.” Transformers designed for 60Hz markets such as North America could easily be used in 50Hz markets without modification, so the exclusion should be limited to frequencies other than 50 Hz *or 60 Hz*. However, if such models become available on the local market their efficiency would need to be assessed at 50 Hz using AS 2374.1.2 to maintain competitive neutrality.
>
> (p) “gas-filled transformers” (as distinct from liquid-filled and dry type, which are covered). These are increasingly popular in inner-city installations where fire risk is high, and there is no technical reason why they should be excluded.

While there may be no technical reasons for continuing to exclude these categories, it was not possible to obtain an indication of the number of such models on the market and their average sales. If the volume of sales per model is low, then the testing and administrative costs per unit sold might be high enough to significantly offset the benefits. Further information is sought from stakeholders (see Section 5).

## Criteria for Option Preference

The assessment of the preferred option includes both qualitative and quantitative criteria. The main quantified metrics are the projected costs and benefits of adopting more stringent MEPS levels, expressed as net present values (NPV) using a suitable discount rate. This will give net benefits (benefits minus costs) and benefit/cost (B/C) ratios for each option. Where more than one option offers a positive net benefit and a positive B/C ratio, the one with the highest net benefit is preferred (PMC 2020).

The qualitative impacts to be considered include:

- Technical feasibility
- Impacts on suppliers and competition;
- Trans-Tasman alignment and impacts on local manufacturing; and
- Impacts on users.

Both quantitative and qualitative impacts are covered in the following chapters.

# 3. Projected Costs, Benefits and Impacts

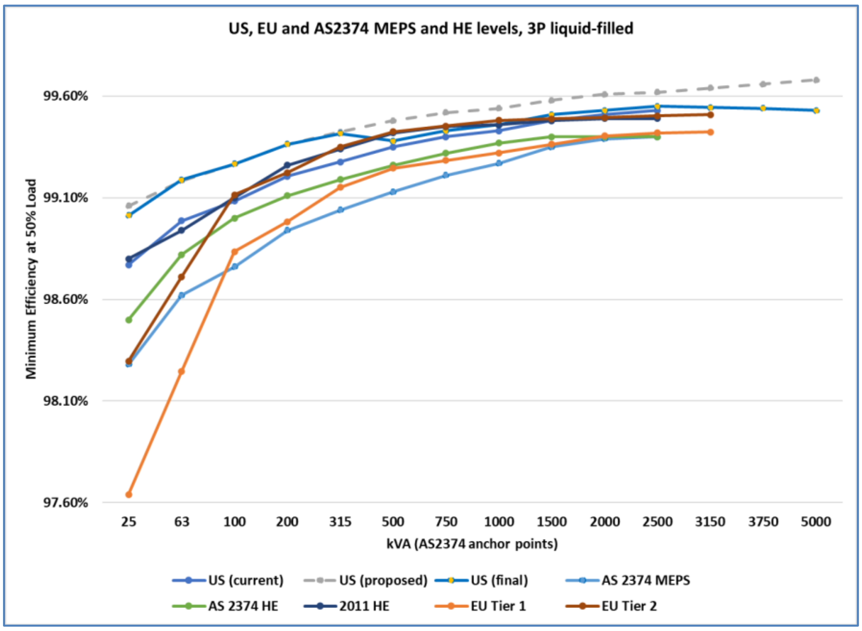
## MEPS & HEPS levels considered

Three sets of potential MEPS levels are analysed for liquid-filled DTs (in order of stringency):

- MEPS2: The existing HE levels in AS 2374.1.2, modified for products rated 1500 kVA and above.[21] MEPS 2 roughly corresponds to EU Tier 1;
- MEPS3: Intermediate between MEPS2 and MEPS4;
- MEPS4: roughly equivalent to EU Tier 2.[22]

The levels are illustrated in Figure 8, which highlights the relaxation from current HE levels proposed in the 2011 RIS in the flattening of the curve above 1000 kVA. It also shows how the 2024 US MEPS levels were modified (for DTs larger than 315 kVA) from the levels proposed by DOE in January 2023, for reasons that will be discussed later. It is assumed that in each case the method of test continues to be AS/NZS 60076.1 and the energy efficiency is calculated in accordance AS 2374.1.2, so avoiding the complications of different methods of test and anchor points (the effects of straight-line interpolations between anchoring kVA values, which differ between MEPS regimes).

*Figure 8 MEPS and HE levels analysed in this CRIS*




[21] The 2011 RIS recommended that MEPS2 levels for liquid-immersed DTs of 1500 kVA and above should be less stringent than the existing HE levels, on the basis of advice from industry.

[22] MEPS4 is based on the HEPS2 level in the 2011 RIS. In regard to EU Tier 2, U4E (2021) advocates that the EU Tier 2 levels should be made more stringent for units up to 250 kVA and for 1,000 kVA and above, arguing that the present levels are based on commercial rather than technical considerations.

Only two MEPS levels have been modelled for dry type DTs: MEPS2 and MEPS4. As the majority of dry type models already pass MEPS2 and as all dry type DTs are imported, it is logical to consider the application of EU Tier 2 (MEPS4) for those products rather than MEPS3, which would be a specific Australian and New Zealand MEPS. Therefore, the scenarios labelled as 'MEPS3' are actually MEPS3 for liquid-filled and MEPS4 for dry-types.

## Projected Benefits

## Energy savings

The method of modelling projected energy savings from each MEPS level is detailed in Appendix C. It takes account of the fact that a significant number of liquid-filled DTs and a high proportion of dry type DTs already meet the MEPS2 level. It is also assumed that all the DT types that would be added to the scope would already be at the equivalent of MEPS1, even though there is no MEPS for those models and as they are not registered there is no readily available information on their present efficiency. If this is lower than MEPS1 then there would be more savings from moving to a higher MEPS level.

Figure 9 illustrates the projected losses from DTs installed in Australia from 2024 onward, and the savings are summarised in Table 6. The trend lines begin to diverge in 2026, after the assumed announcement of new MEPS levels at the end of 2025. Widening the scope adds about 7% to the number of DTs covered, but increases the coverage of DT losses by 23-40% because the types added are much larger. Figure 10 illustrates the projected losses from DTs installed in New Zealand from 2024 onward, and the savings are summarised in Table 7. The relative savings compared to BAU are smaller than for Australia because of differences in the composition of the NZ DT fleet.

*Table 6 Projected energy savings 2024-2051, Australia*

| | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 |
|---|---|---|---|---|---|---|---|---|---|
| MEPS Level | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total |
| BAU | 126,682 | 32,533 | 159,215 | NA | NA | NA | NA | NA | NA |
| MEPS2 | 114,570 | 30,746 | 145,317 | 12,111 | 1,787 | 13,898 | 9.6% | 5.5% | 8.7% |
| MEPS3 | 102,732 | 25,891 | 128,623 | 23,950 | 6,642 | 30,592 | 18.9% | 20.4% | 19.2% |
| MEPS4 | 91,382 | 24,644 | 116,026 | 35,300 | 7,889 | 43,189 | 27.9% | 24.2% | 27.1% |

Source: Table 27

*Table 7 Projected energy savings 2024-2051, New Zealand*

| | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh losses 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | GWh saved 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 | Reduction in losses 2024-2051 |
|---|---|---|---|---|---|---|---|---|---|
| MEPS Level | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total | Current Scope | Added Scope | Total |
| BAU | 35,016 | 2,935 | 37,951 | NA | NA | NA | NA | NA | NA |
| MEPS2 | 33,292 | 2,752 | 36,045 | 1,724 | 183 | 1,907 | 4.9% | 6.2% | 5.0% |
| MEPS3 | 29,854 | 2,422 | 32,275 | 5,163 | 513 | 5,676 | 14.7% | 17.5% | 15.0% |
| MEPS4 | 27,320 | 2,200 | 29,520 | 7,697 | 735 | 8,432 | 22.0% | 25.0% | 22.2% |

Source: Table 31

*Figure 9 Projected energy losses from Distribution Transformers installed from 2024, Australia,*

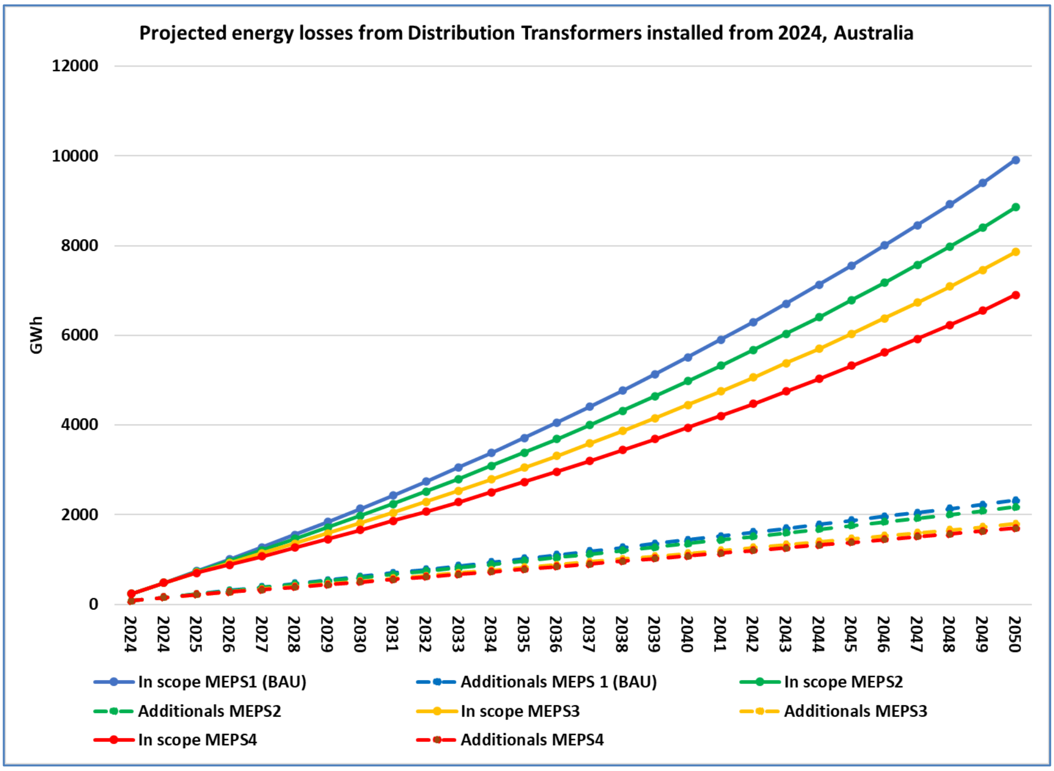
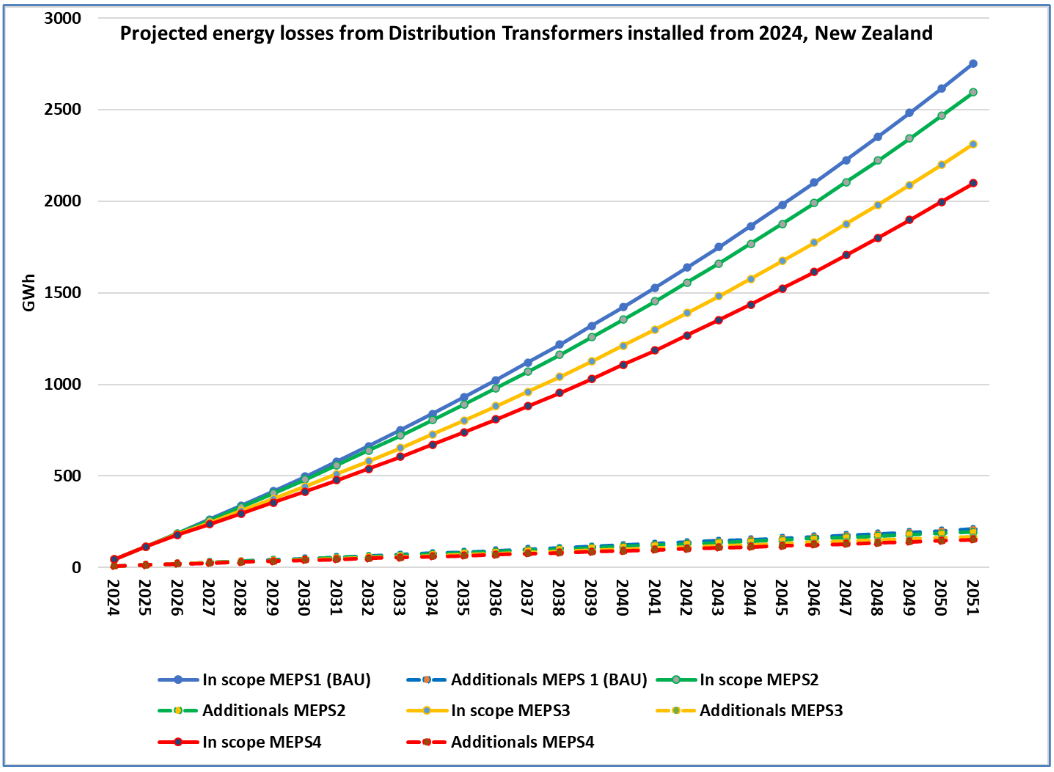



*Figure 10 Projected energy losses from Distribution Transformers installed after 2022, New Zealand*



## Modelling assumptions

Once the energy saved through adoption of a particular MEPS level is calculated, monetary values are assigned to those savings. There are several components of value and various options for quantifying them. This provides a means of testing the sensitivity of the projected benefits to a range of input assumptions.

The cost-benefit modelling takes into account the capital costs and lifetime operating costs of all the distribution transformers that are expected to be purchased in Australia and New Zealand from 2024 to 2051. The assumptions are detailed in Appendix C.

It is assumed that MEPS levels are announced at the end of 2024 and take effect at the end of 2026; i.e. a lead time of over two and a half years from the date of this Consultation RIS. The primary benefit is the net present value (NPV) of the projected energy saved by the reduction in losses from new DTs due to more stringent MEPS, compared with the Business as Usual (BAU) case, in which the current MEPS are maintained.

The value of energy saved is calculated at both consumer and producer prices for Australia, and at long run marginal cost (LRMC) of production in New Zealand, reflecting the different methodologies adopted for assessing E3 program measures in the two countries. The average reduction in electricity demand is calculated from the energy saved and assigned a separate monetary value. The greenhouse gas emissions reductions associated with energy savings are also calculated and assigned monetary values in each country.

The quantified costs comprise:

1. the NPV of the estimated increases in DT prices as a result of the move to higher MEPS levels, which would involve more expensive materials and construction methods;
2. the NPV of testing and other compliance costs borne by suppliers beyond BAU;
3. the NPV of additional GEMS registration fees borne by suppliers in Australia beyond BAU (there are no fees to register products in New Zealand).

It is assumed that cost components 1, 2 and 3 above are passed on from suppliers to buyers. It is assumed that component 3 covers the regulators' administration costs, including an allowance for occasional check testing, so it represents an internal transfer within the program rather than an additional cost.

***Value of electricity saved***

When buyers purchase a more energy-efficient item of electrical equipment (either through an informed choice, or because the efficiency options are restricted by MEPS) they bear any increases in product price and benefit directly from avoiding the purchase of some of the energy they would otherwise need to obtain.

In the case of a distribution transformer acquired by a utility, the utility purchases the DT essentially on behalf of all users, and passes on the cost to the electricity retailers that use its network, along with all other legitimately incurred costs including a return on capital. The utility regulator reviews the costs and sets a revenue cap accordingly.

Any cost increment due to the purchase of a more efficient DT is passed on to the electricity retailers, who pass them on (with appropriate margin) to the customers. By the same token, customers pay the retailers for energy purchases on their behalf, including the share of energy that is lost from distribution transformers and not delivered. It is assumed that competition between retailers ensures that the value of energy saved through lower DT losses are passed on indirectly, but still accrues ultimately to the customer.

One approach to valuing the electricity saved is therefore based on the prices faced by customers. The Australian weighted average retail price in 2024 (30.5 c/kWh, or $305/MWh) is calculated from AEMC (2021) and Alviss (2022) and the projected real price trend (excluding future inflation) is shown in Figure 28 in Appendix C.

The alternative approach is to base the value of energy saved on the Long Run Marginal Cost (LRMC) of generation. Whatever the composition of the generation mix, each additional kWh at the margin will need to be generated by an identified technology. For New Zealand this is expected to be wind, while in Australia it is expected to be open cycle gas turbine (OCGT). The Australian LRMC projections developed for this analysis are consistent with the latest CSIRO estimates (CSIRO 2024). The projected trends in LRMC of electricity are shown in Figure 28.

***$CO_2$-e emissions avoided***

The projected emissions-intensity for electricity supplied in each Australian jurisdiction and in New Zealand is shown in Figure 30. There is only one projected intensity profile for New Zealand, but for Australia there are two sets for each State and Territory: an average intensity based on the projected generation mix, and a marginal intensity relevant to OCGT generation.

Once the quantity of emissions is calculated, the following options for valuing emissions are modelled:

- For Australia, the lower carbon price trend is taken from the Decision RIS for a proposal to increase residential building energy efficiency improvements in the National Construction Code (ACIL Allen 2022). The higher carbon price trend is the value of emissions reductions for national energy objective planning purposes adopted by the Australian Energy Market Commission in 2024 (AEMC 2024);
- For New Zealand, the Central, Low and High emissions price trends are supplied by EECA.

The emissions price trends are illustrated in Figure 31, Appendix C.

The combination of the average $CO_2$-e intensity and the lower carbon price projections assigns the lowest value to the emissions reductions from energy savings in Australia, and combination of the marginal intensity and higher carbon price projections assigns the highest value (the other two combinations will be between these extremes). Both options are presented, to illustrate the sensitivity of the calculated benefits to the value placed on emissions reductions.

There is only one emissions intensity scenario for New Zealand but three price trends, giving three value combinations.

***Reductions in electricity demand***

The projected reductions in energy use compared with BAU are translated to reductions in demand by assuming that they are evenly distributed throughout the year (the same method and value as Deloitte 2014). This underestimates the likely reduction in *peak* demand, but projecting this would require information on the typical hourly and seasonal loading profiles of all, or at least a representative sample, of DTs. These demand reductions are valued as follows:

- For New Zealand, network costs avoided are valued *in each year* at $222 for each kW reduction in load below BAU (advised by EECA).

- For Australia, network costs avoided are based on the one-time reduction in load growth avoided in each year due to the addition of each new cohort of more energy efficient DTs. This is multiplied by marginal $/kW costs for each jurisdiction (the same method and values as E3 2019).

## Projected Costs

Any regulatory intervention in the market for an energy-using product carries the following costs:

- The costs of testing the products to establish performance and compliance with the regulation.
- The costs to government of administering the regulations, including maintaining a publicly accessible register of compliant products, market monitoring and verifying compliance through check testing from time to time;
- The costs of manufacturing more energy-efficient products than would be the case in the absence of the regulatory change.

## Testing, Registration and Administration

New models are introduced regularly even in the BAU case, so the historical average number of annual tests and registrations forms the baseline for calculation of additional costs. If the same test and MEPS metric is retained, current models whose existing tests indicate that they meet the new MEPS levels need not be retested. Newly introduced models would need testing, at an estimated cost of AUD 3,000 per test undertaken in Australia and NZD 3,300 per test undertaken in New Zealand. If the scope of coverage is widened, then all of the newly included models will need testing (unless the supplier has already determined their efficiency in accordance with the prescribed test standard) and registration.

Testing costs are borne by the supplier in the first instance, but then passed on to the buyer (as is the case at present). In Australia the supplier pays a registration fee of $780 per model or model family to the GEMS Regulator; registrations with the New Zealand regulator incur no fee. The GEMS Regulator meets the costs of administration, including the occasional check test, out of the fee income. In New Zealand the cost of administration and check testing are borne by EECA (i.e. the taxpayer).

## Costs of efficiency improvements

The largest cost segment by far is the design, materials and manufacturing costs associated with building more energy-efficient products. This can be expressed either as a percentage increase in price to consumers or as a Price/Efficiency (P/E) ratio. For DTs, the P/E calculation is based on the change in the energy loss (at standard rating conditions) needed to comply with the more stringent MEPS. For example, if a 10% reduction in losses leads to a 10% increase in price, the P/E ratio is 1. If a 10% reduction in losses leads to a 20% increase in price, the P/E ratio is 2.0 and so on.

As the DT market is cost-sensitive and highly competitive, suppliers have been reluctant to disclose production and component costs, but in some cases have stated the percentages by which higher MEPS levels would increase prices. Estimates were also given in the 2011 RIS (E3 2011) and Deloitte (2014). On the basis of this information, two sets of price increases have been modelled (Table 8). In the central cost assumptions MEPS3 is tested with the Medium price rise and MEPS4 with the High price rise.

It is assumed that the proportional price impact increases with the size of the DT, because the fixed cost share is lower and the share of variable material, labour and transport costs – the factors most linked to product efficiency – are higher. While P/E ratios are not used as inputs, they are calculated from the outputs and are also reported.

The absolute increase in cost depends on the starting point. A function relating unit cost to DT type and kVA rating has been developed and verified against the relatively few actual prices disclosed (in confidence) by the electricity distributors consulted.

*Table 8 Assumed increase in retail prices under various MEPS scenarios*

| Capacity kVA | Medium price rises - MEPS2 | Medium price rises - MEPS3 | High price rises - MEPS2 | High price rises - MEPS4 |
|---|---|---|---|---|
| <1500 | 2% | 7% | 6% | 10% |
| 1500-2000 | 3% | 10% | 8% | 15% |
| >2000 | 5% | 17% | 10% | 30% |

When the value of energy savings is calculated at the LRMC of electricity production in New Zealand, or the OCGT production cost in Australia, this is roughly equivalent to the producer price rather than the consumer price. Accordingly, the projected change in DT costs should also be estimated as a producer price rather than consumer price. For consumer electrical products, the ratio of producer to consumer price is typically about 0.5, as used in the RIS for refrigerated display cabinets (E3 2017). The difference goes to wholesalers and retailers. However, the DT market involves fewer intermediaries between supplier and purchaser, so the cost of production to the supplier represents a higher ratio of the final price. A ratio of 0.7 has been used. This increases the dollar impost associated with each scenario (compared with a ratio of 0.5) so represents a conservative assumption.

## Benefit/Cost Analysis

## Australia

The values of estimated costs and benefits under consumer energy prices, projected average $CO_2$-intensity trends for generation (declining steeply as fossil fuels are phased out) and lower $CO_2$-e value assumptions are summarised in Table 9. They are calculated separately for each state and territory and summed for Australia (separate state and territory values are given in Table 32 onward).

Progressing from MEPS1 (BAU) to MEPS4 gives the highest national net benefit (A$M 1,660 compared with $M 1,346 for MEPS3 and $M 512 for MEPS2). However, MEPS3 has a higher benefit/cost ratio than MEPS4 (2.22 compared with 1.93) due to lower increases in projected transformer prices. In all cases the additional cost of testing and administration is negligible compared with the rise in transformer prices. All prices are expressed in 2024 Australian dollars, i.e. ignoring the effects of inflation.

*Table 9 Summary of Projected Costs and Benefits, Australia (Consumer energy and DT prices)*

| | Energy saved $M | CO2-e saved $M | Demand saved $M | Total benefit $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio |
|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $795 | $30 | $77 | $902 | $395 | $0.3 | $395 | $507 | 2.28 |
| MEPS2 added to scope | $114 | $6 | $14 | $135 | $129 | $0.3 | $129 | $5 | 1.04 |
| MEPS2 total | $909 | $36 | $91 | $1,037 | $524 | $0.6 | $525 | $512 | 1.98 |
| MEPS3 current scope | $1,662 | $64 | $159 | $1,885 | $790 | $0.5 | $790 | $1,095 | 2.39 |
| MEPS3 added to scope | $478 | $26 | $58 | $561 | $310 | $0.3 | $311 | $251 | 1.81 |
| MEPS3 total | $2,139 | $90 | $217 | $2,447 | $1,100 | $0.8 | $1,101 | $1,346 | 2.22 |
| MEPS4 current scope | $2,455 | $95 | $234 | $2,783 | $1,231 | $0.5 | $1,231 | $1,552 | 2.26 |
| MEPS4 added to scope | $567 | $31 | $69 | $667 | $559 | $0.3 | $559 | $108 | 1.19 |
| MEPS4 total | $3,022 | $126 | $303 | $3,450 | $1,790 | $0.8 | $1,790 | $1,660 | 1.93 |

Source: Table 27. $M present values calculated at a discount rate of 7%, compared with BAU (MEPS1). Lower $CO_2$-e prices.

Table 10 summarises the outcomes calculated using producer rather than consumer prices for both energy and transformers, and assumes that any reduction in transformer losses would avoid the use of gas as the marginal generation fuel. This is clearly an extreme assumption, since in future a growing share of the transformer losses avoided will occur at times when there is no fossil fuel generation on the grid, so the emissions saved will be closer to the average than the margin (this is the basis of the calculations in Table 9). The value of energy saved is significantly lower than in Table 9 and the value of demand saved is slightly lower, because the capital costs of transformer capacity avoided is valued at producer rather than consumer prices. Although the price per tonne of $CO_2$-e is the same as in Table 9, the $CO_2$-e benefits are higher in Table 10 because the emissions intensity of marginal generation (OCGT) is much higher than the average intensity. As a result, the B/C ratios calculated using producer prices are somewhat higher than those calculated using consumer prices. In both cases, the Net Present Values are comparable, and MEPS3 has a higher B/C ratio than either MEPS2 or MEPS4.

*Table 10 Summary of Projected Costs and Benefits, Australia (Marginal generation costs and producer DT prices)*

| | Energy saved $M | $CO_2$-e saved $M | Demand saved $M | Total benefit $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio |
|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $449 | $218 | $54 | $720 | $276 | $0.3 | $277 | $444 | 2.60 |
| MEPS2 added to scope | $64 | $31 | $10 | $105 | $90 | $0.3 | $91 | $14 | 1.16 |
| MEPS2 total | $513 | $249 | $64 | $825 | $367 | $0.6 | $367 | $458 | 2.25 |
| MEPS3 current scope | $935 | $454 | $112 | $1,501 | $553 | $0.5 | $553 | $948 | 2.71 |
| MEPS3 added to scope | $263 | $130 | $40 | $433 | $217 | $0.3 | $218 | $216 | 1.99 |
| MEPS3 total | $1,199 | $584 | $152 | $1,935 | $770 | $0.8 | $771 | $1,164 | 2.51 |
| MEPS4 current scope | $1,381 | $670 | $164 | $2,215 | $862 | $0.5 | $862 | $1,353 | 2.57 |
| MEPS4 added to scope | $313 | $154 | $48 | $515 | $391 | $0.3 | $391 | $123 | 1.32 |
| MEPS4 total | $1,694 | $824 | $212 | $2,730 | $1,253 | $0.8 | $1,254 | $1,476 | 2.18 |

Source: Table 29. $M present values calculated at a discount rate of 7%, compared with BAU (MEPS1). Lower CO2-e prices

In both the retail and producer price calculations the majority of the benefit comes from the value of electricity saved. Emission and demand reductions account for about 4% of the cost savings under retail prices, but up to 29% under producer prices. In all MEPS scenarios, the widening of the scope to 36kV and

5,000 kVA appears to be cost-effective in its own right, although the scope expansion reduces the overall B/C ratio slightly.

## New Zealand

The value of the projected costs and benefits under the central cost assumptions is summarised in Table 11. Progressing from MEPS1 (BAU) to MEPS4 shows the highest net benefits (NZ$M 269) with MEPS3 next (NZ$ 155). The benefits of MEPS2 are small (NZ$ 19). In all cases the additional cost of testing and administration is negligible compared with the rise in transformer prices. All prices are expressed in 2024 New Zealand dollars, i.e. ignoring the effects of inflation. The pattern of costs and benefits varies significantly from Australia, due to the differing composition of the DT fleet and sales, generation costs, CO2-intensities and $CO_2$ values, and the discount rates used.

Emission and demand reductions are roughly equal, and together they account for about 15% of the total cost savings. In all cases, the costs of widening of the scope are greater than the benefits, although when combined with increased MEPS for products currently covered, each scenario remains cost-effective overall.

*Table 11 Summary of Projected Costs and Benefits, New Zealand (LRMC of generation and producer DT prices)*

| | Energy saved $M | CO2-e saved $M | Demand saved $M | Total benefit $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio |
|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $58.4 | $13.3 | $15.7 | $87.3 | $61.6 | $0.2 | $61.8 | $25.5 | 1.41 |
| MEPS2 added to scope | $5.7 | $1.3 | $1.5 | $8.5 | $14.8 | $0.2 | $15.0 | -$6.5 | 0.57 |
| MEPS2 total | $64.1 | $14.6 | $17.2 | $95.9 | $76.4 | $0.4 | $76.8 | $19.1 | 1.25 |
| MEPS3 current scope | $187.7 | $42.8 | $50.4 | $280.9 | $118.9 | $0.3 | $119.2 | $161.7 | 2.36 |
| MEPS3 added to scope | $19.0 | $4.3 | $5.1 | $28.5 | $35.6 | $0.2 | $35.7 | -$7.2 | 0.80 |
| MEPS3 total | $206.7 | $47.1 | $55.5 | $309.4 | $154.5 | $0.4 | $154.9 | $154.5 | 2.00 |
| MEPS4 current scope | $280.3 | $63.9 | $75.3 | $419.4 | $137.5 | $0.3 | $137.8 | $281.6 | 3.04 |
| MEPS4 added to scope | $27.3 | $6.2 | $7.3 | $40.8 | $52.9 | $0.2 | $53.1 | -$12.3 | 0.77 |
| MEPS4 total | $307.6 | $70.1 | $82.6 | $460.3 | $190.4 | $0.4 | $190.9 | $269.4 | 2.41 |

Source: Table 31. All $M values are present values calculated using a discount rate of 5%, and compared with BAU (MEPS1). Central $CO_2$-e prices.

## Uncertainty and Sensitivity

### Discount rates

The cost-effectiveness of the MEPS levels can be tested across a range of different discount rates and assumptions. Figure 11 and Figure 12 illustrate the impact of discounting the stream of future costs and benefits at 7% (the central discount rate used for cost-benefit analysis of GEMS measures in Australia) and at lower and higher discount rates. The lower the rate, the higher the present value (PV) of both future benefits and future costs.

The full height of each bar indicates the gross present value of the benefit of that MEPS option. The lower blue section of the bar indicates the present value of the costs, so the upper yellow section of the bar represents the net benefit (gross benefit less costs). The B/C ratio of each option is shown as a dot over the bar, scaled to the right side axis of the graph. The cost-effectiveness of each MEPS option is reasonably consistent across discount rates, because both costs and benefits accrue at roughly equal rates over time. The present dollar value is significantly higher when calculated using consumer prices (Figure 11) compared with producer prices (Figure 12). However, all options have a B/C ratio well above 1.0 under all assumptions and discount rates.

Figure 13 illustrates the impact of discounting the stream of futures costs and benefits for New Zealand, at a discount rate of 5% (as used for cost-benefit analysis of energy efficiency measures in New Zealand) and at lower and higher rates. As in Australia, the cost-effectiveness of each option is relatively constant across discount rates, because both costs and benefits accrue at roughly equal rates over time.

*Figure 11 Sensitivity of cost and benefits to discount rates, Australia (Consumer energy and DT prices, Lower $CO_2$-e value)*

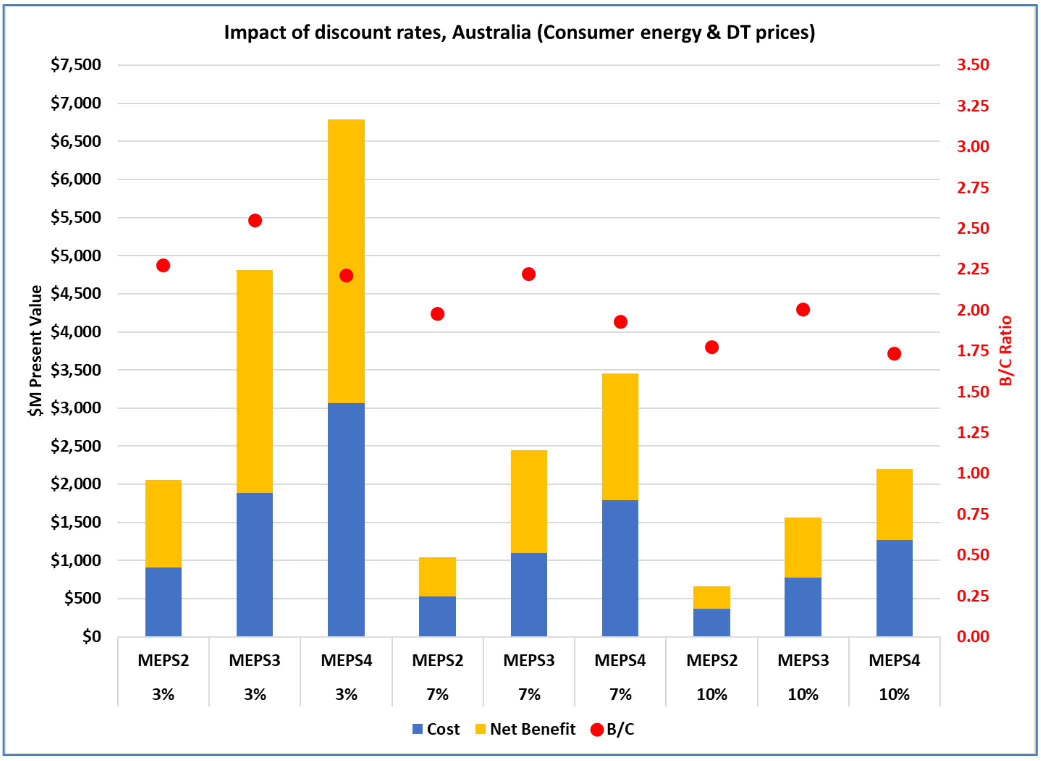


*Figure 12 Sensitivity of costs and benefits to key price assumptions, Australia (Marginal generation costs and producer DT prices, Lower $CO_2$-e value)*

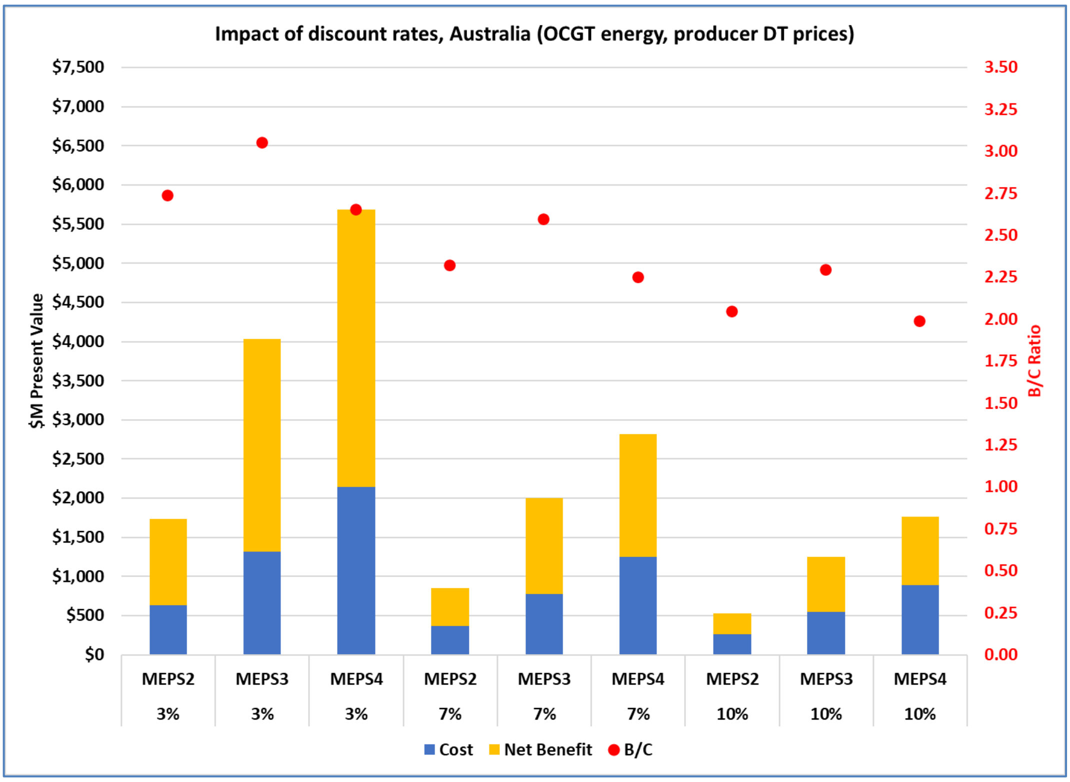
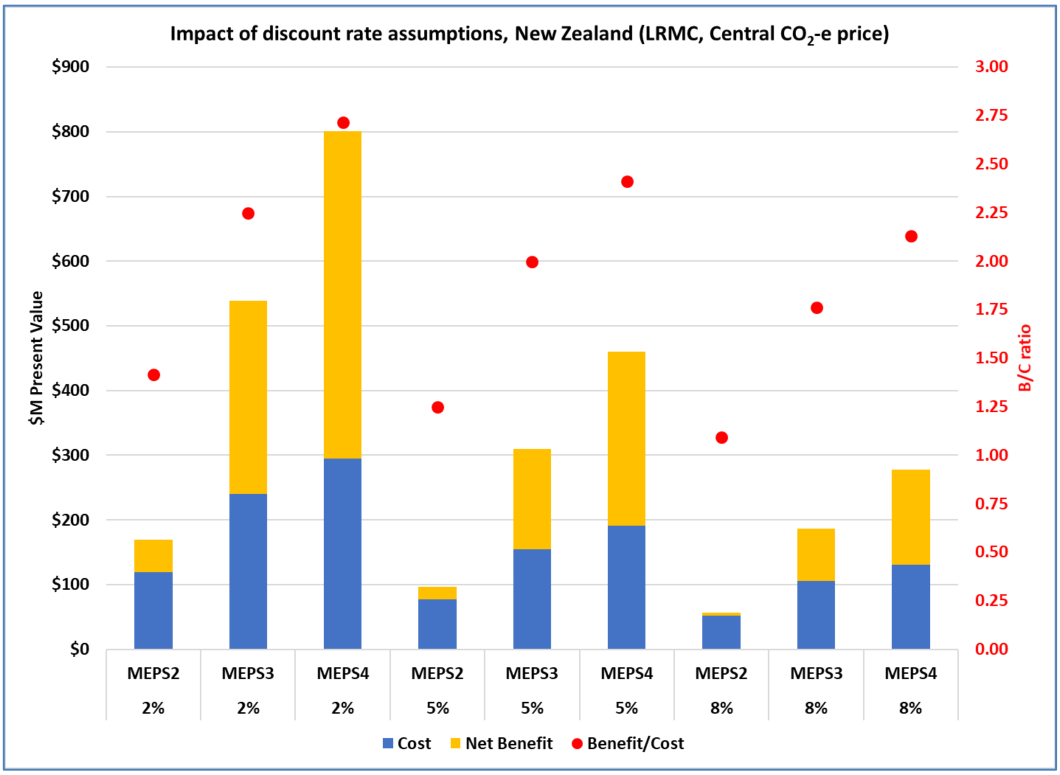



*Figure 13 Sensitivity of cost and benefits to discount rates, New Zealand*



**Emission Values**

The preceding analyses show benefits calculated using the lower value of $CO_2$-e emissions avoided for Australia and the central value for New Zealand. Table 12 compares the impacts of the Lower and Higher value projections for emissions avoided for Australia (based on consumer prices). It confirms that the sensitivity to $CO_2$-e prices is fairly small, because the savings are predominantly in energy costs. The corresponding calculations based on producer prices (Table 13) show much higher present value for $CO_2$-e avoided, because the $CO_2$-intensity of generation is the marginal fossil fuel (OCGT) rather than the average intensity, which is increasingly dominated by renewables. Hence the producer price costs and benefits show much greater sensitivity to the choice of Lower or Higher $CO_2$-e price projections. Even so, all scenarios are cost-effective even if zero value is assigned to $CO_2$-e savings.

*Table 12 Sensitivity to $CO_2$-e price assumptions, Australia (Consumer prices)*

| MEPS Level | Energy +dem-and $M | NPV $CO_2$-e savings Lower price $M | NPV $CO_2$-e savings Higher price $M | Net benefit at $CO_2$-e prices Zero price $M | Net benefit at $CO_2$-e prices Lower price $M | Net benefit at $CO_2$-e prices Higher price $M | B/C ratios at $CO_2$-e prices zero price $M | B/C ratios at $CO_2$-e prices Lower price $M | B/C ratios at $CO_2$-e prices Higher price $M |
|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $872 | $30 | $62 | $477 | $507 | $538 | 2.21 | 2.28 | 2.36 |
| MEPS2 added to scope | $128 | $6 | $14 | -$1 | $5 | $13 | 0.99 | 1.04 | 1.10 |
| MEPS2 total | $1,000 | $36 | $76 | $476 | $512 | $552 | 1.91 | 1.98 | 2.05 |
| MEPS3 current scope | $1,821 | $64 | $130 | $1,031 | $1,095 | $1,161 | 2.30 | 2.39 | 2.47 |
| MEPS3 added to scope | $535 | $26 | $57 | $225 | $251 | $282 | 1.72 | 1.81 | 1.91 |
| MEPS3 total | $2,356 | $90 | $187 | $1,255 | $1,346 | $1,443 | 2.14 | 2.22 | 2.31 |
| MEPS4 current scope | $2,689 | $95 | $191 | $1,457 | $1,552 | $1,648 | 2.18 | 2.26 | 2.34 |
| MEPS4 added to scope | $639 | $31 | $69 | $80 | $108 | $149 | 1.14 | 1.19 | 1.27 |
| MEPS4 total | $3,328 | $126 | $259 | $1,537 | $1,660 | $1,797 | 1.86 | 1.93 | 2.00 |

All $M values are present values calculated using a discount rate of 7%, and compared with BAU (MEPS1).

*Table 13 Sensitivity to $CO_2$-e price assumptions, Australia (Producer prices)*

| MEPS Level | Energy +dem-and $M | NPV $CO_2$-e savings Lower price $M | NPV $CO_2$-e savings Higher price $M | Net benefit at $CO_2$-e prices Zero price $M | Net benefit at $CO_2$-e prices Lower price $M | Net benefit at $CO_2$-e prices Higher price $M | B/C ratios at $CO_2$-e prices zero price $M | B/C ratios at $CO_2$-e prices Lower price $M | B/C ratios at $CO_2$-e prices Higher price $M |
|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $526 | $218 | $513 | $249 | $467 | $762 | 1.90 | 2.69 | 3.75 |
| MEPS2 added to scope | $78 | $31 | $73 | -$13 | $18 | $60 | 0.86 | 1.20 | 1.66 |
| MEPS2 total | $603 | $249 | $586 | $236 | $485 | $822 | 1.64 | 2.32 | 3.24 |
| MEPS3 current scope | $1,095 | $454 | $1,064 | $541 | $996 | $1,605 | 1.98 | 2.80 | 3.90 |
| MEPS3 added to scope | $321 | $130 | $295 | $104 | $233 | $399 | 1.48 | 2.07 | 2.83 |
| MEPS3 total | $1,416 | $584 | $1,359 | $645 | $1,229 | $2,004 | 1.84 | 2.59 | 3.60 |
| MEPS4 current scope | $1,615 | $670 | $1,567 | $753 | $1,423 | $2,320 | 1.87 | 2.65 | 3.69 |
| MEPS4 added to scope | $381 | $154 | $351 | -$10 | $144 | $341 | 0.97 | 1.37 | 1.87 |
| MEPS4 total | $1,996 | $824 | $1,918 | $743 | $1,567 | $2,660 | 1.59 | 2.25 | 3.12 |

All $M values are present values calculated using a discount rate of 7%, and compared with BAU (MEPS1).

Table 14 shows that the outcomes for New Zealand are relatively insensitive to whether high, central or low $CO_2$-e price scenarios are used, because the $CO_2$-intensity of generation is low. Again, all scenarios are cost-effective even if zero value is assigned to $CO_2$-e savings.

*Table 14 Sensitivity to $CO_2$-e price assumptions, New Zealand*

| MEPS Level | Energy +dem- $M | NPV CO2-e savings Lower | MEPS Level | Energy +dem- $M | NPV CO2-e savings Lower | MEPS Level | Energy +dem- $M | NPV CO2-e savings Lower | MEPS Level | Energy +dem- $M | NPV CO2-e savings Lower | MEPS Level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 added to scope | $7 | $1 | $1 | $2 | -$8 | -$7 | -$6 | -$6 | 0.48 | 0.54 | 0.57 | 0.60 |
| MEPS2 total | $81 | $10 | $15 | $19 | $4 | $14 | $19 | $24 | 1.06 | 1.18 | 1.25 | 1.31 |
| MEPS3 current scope | $238 | $28 | $43 | $57 | $119 | $147 | $162 | $176 | 2.00 | 2.24 | 2.36 | 2.48 |
| MEPS3 added to scope | $24 | $3 | $4 | $6 | -$12 | -$9 | -$7 | -$6 | 0.68 | 0.76 | 0.80 | 0.84 |
| MEPS3 total | $262 | $31 | $47 | $63 | $107 | $139 | $154 | $170 | 1.69 | 1.90 | 2.00 | 2.10 |
| MEPS4 current scope | $356 | $43 | $64 | $85 | $218 | $260 | $282 | $303 | 2.58 | 2.89 | 3.04 | 3.20 |
| MEPS4 added to scope | $35 | $4 | $6 | $8 | -$18 | -$14 | -$12 | -$10 | 0.65 | 0.73 | 0.77 | 0.81 |
| MEPS4 total | $390 | $47 | $70 | $94 | $199 | $246 | $269 | $293 | 2.04 | 2.29 | 2.41 | 2.53 |

All $M values are present values calculated using a discount rate of 5%, and compared with BAU (MEPS1).

## Comparison with previous analyses

Table 15 and Table 16 compare the findings of this analysis with the 2011 RIS and the 2014 Deloitte study (which used gas fuel costs as the basis of valuing energy savings, i.e. analogous to the producer price calculations in the present CRIS). They are reasonably consistent with both, but resemble the earlier study more with respect to projected energy savings impact and benefit/cost ratios. The dollar values of both costs and benefits is substantially higher, partly due to higher real current and projected prices at the start of the modelling periods.

*Table 15 Cost impacts compared with previous studies, Australia (current scope only)*

| | MEPS at HE level **RIS 2011** | MEPS at HE level **Deloitte 2014** | MEPS above HE level **Deloitte 2014** | MEPS2 at HE level | MEPS3 | MEPS4 |
|---|---|---|---|---|---|---|
| <1,500 kVA | less than 10% | 6.0% | 10.5% | 6% | 7% | 10% |
| 1500-2000kVA | less than 10%" | | | 8% | 10% | 15% |
| >2,000 kVA | less than 10%" | 6.0% | 35.0% | 10% | 17% | 30% |
| NPV of cost increases | $M 231 | $M 74 | $M 351 | $M 367 | $M 770 | $M 1,253 |

(a) 8% discount rate; NPVs over 30 years in real 2011 dollars. (b) 7% discount rate; NPVs over 30 years in real 2014 dollars. (c) 7% discount rate; NPVs over 28 years in real 2024 dollars; producer prices; excludes testing and administrative costs.

*Table 16 Costs and benefits compared with previous studies, Australia (current scope only)*

| | MEPS at HE level **RIS 2011** | MEPS at HE level **Deloitte 2014** | MEPS above HE level **Deloitte 2014** | MEPS2 at HE level | MEPS3 | MEPS4 |
|---|---|---|---|---|---|---|
| Electricity losses avoided | 10,197 GWh (30 yrs) | 37.5 GWh/yr | 71.3 GWh/yr | 13,208 GWh (28 yrs) | 30,592 GWh (28 yrs) | 43,189 GWh (28 yrs) |
| NPV of energy cost reductions | NA | $M 498 | $M 946 | $M 513 | $M 1,199 | $M 1,694 |
| NPV of network cost savings | NA | $M 102 | $M 195 | $M 64 | $M 152 | $M 212 |
| Total NPV of energy saving | $M 277 | $M 600 | $M 1,141 | $M 577 | $M 1,351 | $M 1,716 |
| CO2 emissions avoided | 1.83 Mt | NA | NA | 1.1 Mt to 8.6 Mt | 2.1 Mt to 16.7 Mt | 3.0 Mt to 24.1 Mt |
| Value of emissions avoided | $30 rising to $84/tonne | NA | NA | Lower price: $83 rising to $125/tonne (ACIL) | | |
| | | | | Higher price: $70 rising to $420/tonne (AEMC) | | |
| Total NPV of emission savings | $M 118 | NA | NA | Lower price: $M 249 | Lower price: $M 584 | Lower price: $M 824 |
| NPV Total benefits | $M 395 | $M 600 | $M 1,141 | $M 825 | $M 1,935 | $M 2,730 |
| NPV total costs | $M 231 | $M 83 | $M 360 | $M 367 | $M 771 | $M 1,254 |
| NPV net benefit | $M 164 | $M 517 | $M 781 | $M 458 | $M 1,164 | $M 1,476 |
| B/C ratio | 1.7 | 7.2 | 3.2 | 2.3 | 2.5 | 2.2 |

(a) 8% discount rate; NPV over 30 years in real 2011 dollars. (b) 7% discount rate; NPV over 30 years in real 2014 dollars. (c) Consumer prices 7% discount rate; NPV over 28 years in real 2024 dollars; producer prices, includes testing and administrative costs. Totals subject to rounding.

## Stakeholder Impacts

### Suppliers

There is no doubt that any increase in MEPS levels and changes in scope would have a major impact on the suppliers of DTs. Products would need to be redesigned and in some cases manufacturing processes would need to be re-engineered. This has been captured in modelling as price increases, but for some product categories, such as pole-mount DTs, transportability and weight could become limiting factors.

The MEPS2 levels were previously proposed in the 2011 Consultation RIS, which reported:

> The proposed new MEPS2 levels have in principle support from the Australian and New Zealand distribution transformer manufacturers. Initial concerns raised by industry have largely been addressed through earlier modifications to the proposal (E3 2011,7/66).

In 2014 Deloitte reported:

> From our consultations with industry there were some indications that it would be very costly, or even not possible, to manufacture high rated transformers (particularly those at or above 2 MVA) to the HEPS2 level [equivalent to MEPS4 in this document]. However, this could not be confirmed through our consultations. In light of this we have used a higher cost multiplier (as estimated by industry) for moving from MEPS1 to HEPS2 for high rated transformers, however, we recommend that the feasibility of manufacturing high rated transformers should be further explored prior to implementing policy measures based on these results (Deloitte 2014,7/75).

Therefore previous indications are that manufacturers find the MEPS2 level relatively unchallenging but the MEPS4 level too challenging, at least for liquid-filled units. That is one of the reasons for modelling an intermediate MEPS3 level for liquid-filled DTs (see Figure 8).

The number of current DT models on the register at 2024 which would fail to pass each MEPS level is indicated in Table 17. However, many models are variants of the same basic model and the number of distinct models that would need redesign is significantly lower. The great majority of liquid-filled DTs are locally made and are essentially designed to the AS standards. The fact that only a few products meet a future MEPS level now is not a critical barrier, provided there is enough lead time for redesign and retooling. The two-year period used in the modelling between setting of MEPS levels and enforcement of compliance is probably the minimum feasible lead time for MEPS3, and a longer period may be required if MEPS4 is adopted.

*Table 17 Number of current models not passing MEPS levels*

| | Liquid-filled Number | Liquid-filled % of total | Dry type Number | Dry type % of total |
|---|---|---|---|---|
| MEPS2 | 119 | 44% | 3 | 18% |
| MEPS3 | 235 | 90% | NA | NA |
| MEPS4 | 256 | 98% | 13 | 82% |
| All Models | 261 | | 16 | |

Derived from Table 3

For imported liquid-filled DTs, the main countries of origin are Thailand, Vietnam and China (Table 18). If the same suppliers also build products to the EU Tier 2 level those models would also satisfy MEPS3. There is much less information on the number and performance of products that would be covered if the scope were widened, so the impact on suppliers is more speculative. For dry type DTs, the adoption of EU Tier 2 (MEPS4) should be feasible, as Tier 2 took effect in July 2021, and complying models are available on the global market.

*Table 18 Number of distinct DT models by country of manufacture*

| Country of origin | 1P/SWER | 3P | Dry | Total |
|---|---|---|---|---|
| New Zealand | 15 | 40 | | 55 |
| Australia | 6 | 44 | | 50 |
| Thailand | | 33 | | 33 |
| China | | 12 | 4 | 16 |
| Vietnam | 2 | 10 | 1 | 13 |
| Indonesia | | 1 | | 1 |
| South Korea | | 1 | 2 | 3 |
| Italy | | 4 | | 4 |
| Germany | | | 2 | 2 |
| Malaysia | | 1 | 1 | 2 |
| China,Turkiye | | | 1 | 1 |
| Turkiye | | | 1 | 1 |
| | 23 | 146 | 12 | 181 |

Source: Author analysis of register on www.energyrating.gov.au. April 2024.

## Purchasers and consumers

It is expected that the increases in DT prices will be fully passed on to purchasers. In the case of DNSPs and EDBs the purchase price of DTs will be covered by the regulated revenue requirements, so as capital costs increase so will the revenue recoverable from network users: electricity retailers and directly connecting medium voltage customers.

The expected cost of new DTs is one input into distribution businesses' budget proposals to the regulators (the AER in Australia, and the Commerce Commission in New Zealand). Under the National Electricity Rules, the AER is required to assess the prudence and efficiency of such expenditure proposals. At present, if a DNSP submits a 5-year proposal which includes the purchase of more efficient DTs– but more expensive – than the current MEPS level, they would presumably have to justify it to the regulator. This may not be cost-effective in terms of the operational cost savings to the DNSP alone, even though it would be cost-effective if all value streams were included, as demonstrated in the present analysis.

Raising the MEPS level would, in effect, absolve both the utilities and the regulators from assessing the case for purchasing DTs meeting the new MEPS level. As utilities would not have the choice of purchasing cheaper non-compliant DTs, the regulator would not need to apply a "prudent investment" test.

On the other hand, as DT losses will be lower than otherwise, the electricity retailers using the network and their customers in turn should save more over time than the initial capital cost increase. The electricity retailers would presumably pass on the savings in network charges due to lower losses and slower demand growth to their own customers, who should face lower electricity bills.

The initial cost impact should be modest. If transformer costs represent 29% of DNSP operating costs (AER 2021) then even a 10% increase would represent 3% of network charges, or about 1% of total bills: minor in comparison with regular fluctuations in wholesale prices. In any case this should be more than offset by savings in the cost of losses incorporated in retailer charges. Whether the costs of $CO_2$-e emission are internalised into electricity prices or not will depend on the policy settings at the time. If not, consumers will not benefit directly from the associated savings, but all MEPS scenarios remain highly cost-effective even at a zero $CO_2$-e price (Table 12, Table 12Table 13, Table 14).

Only a small part of an electricity distributor's transformer stock is purchased in any one year, so the impact of any price increases following the implementation of more stringent MEPS at the end of 2026 would be phased in over a number of years.  In New Zealand the current price quality pathway for EDBs runs from 1 April 2020 to March 2025. Any revision of DT MEPS levels would impact the next cycle.  In Australia, the DNSPs in each State are subject to 5-year price determinations commencing at staggered times, with the current determinations due to expire between December 2023 and December 2026.

Private DT buyers such as electrical contractors acting for DNSPs, commercial builders, manufacturing or mining companies will face higher capital costs as non-complying DTs are excluded from the market, but the ultimate occupants and energy consumers of those projects will face lower electricity bills. There may be a temptation for large contractors and private buyers to directly import non-compliant DTs, so compliance regulators may need to focus on this segment.

## Regulators and Administrators

Distribution transformers have been covered by energy efficiency regulations in Australia and New Zealand since 2004, so they are well integrated into the GEMS and EECA administrative frameworks. The GEMS Determination and EUP Regulations allows model families to be covered by a single registration, provided all members of the family share a common kVA rating and a common tested efficiency rating. This may need to be reviewed if MEPS levels increase, testing error margins tighten and minor differences in the performance of 11kV, 22kV and 33kV variants become a factor.

Recent experience with check testing has shown that it can be hard to identify a DT model in the field and link it to its registration. There are other significant issues with randomly selecting units for testing (as is regularly done for refrigerators, for example). Even if new units are available for testing, the cost and logistics of moving and testing them are challenging. If an initial ("Stage 1") test indicates non-compliance and the regulator may need to purchase a large unit for Stage 2 testing, the cost could run to tens of thousands of dollars.

Nevertheless, a successful check testing program has been completed by EECA in New Zealand. In 2022 EECA borrowed 20 liquid-filled DT units from two local EDBs, in the capacity range 15 to 1500 kVA.[23] While there were some logistics involved in transporting the units for testing this was not excessively onerous or costly. In all 20 cases, the tested efficiency was equal to or greater than the efficiency value registered with the regulator, although three passes were "marginal" in that the difference between the losses required to pass MEPS and the measured losses were 10 watts or less. The margin by which the tested value exceeded the claimed value averaged 0.08%, indicating that suppliers are on the whole conservative with their performance claims.[24] Where the registered efficiency qualified the model for HE status this was verified by

[23] EECA product-testing-results

[24] EECA, personal communication.

testing, and in fact some units reached HE status even though the registered model efficiency did not. All in all, the test results give regulators reason to be confident in the level of compliance, at least for the brands tested. (A similar safety margin to allow for production variability would be expected after MEPS levels were raised, so the impact on cost-benefit modelling is neutral).

Apart from moving DTs to test sites, there is the possibility of undertaking investigative testing with mobile test equipment. This is something that could be explored further.

## Testing and Metrics

Suppliers register the efficiency of models on the basis of type tests undertaken on prototypes. There is no obligation for the tests to be undertaken by an independent or accredited laboratory. All manufacturers have their own testing facilities, and most buyers require the data for each unit they purchase, for assurance that performance is within the specified parameters. One way in which the regulator could conduct an initial compliance screening is to obtain the actual test reports from the supplier for one or more units of that model, with the test reports selected at random.

The regulator's ability to verify performance relies on the availability of at least one independent test laboratory certified to undertake the relevant energy loss tests, e.g. AS 60076.1 for liquid-filled transformers. PowerLab in New Zealand has the necessary accreditation[25] but there is limited independent transformer testing capability in Australia at present. Caltest at Port Elliot in South Australia is registered for transformer MEPS testing up to 1,000 kVA.[26] The last major facility on the east coast, Ausgrid's facility at Lane Cove in Sydney, closed in 2021 but its System Test laboratory at Homebush may have capability.[27] Units imported to New Zealand from Australia and other countries could be readily tested in their country of manufacture, provided the Regulator accepts the integrity of the test laboratory there. The purchase and transportation of DTs for test would add significantly to the compliance checking cost, so would need to be a last resort.

DT prototype designs have to be tested and certified for safety as well as energy performance. A radical redesign would void the existing safety certifications and the unit would need re-testing, which could mean shipping Australian-made units to New Zealand or other overseas facilities at a cost of tens of thousands of dollars in addition to the testing fee and adding long lead times. An increase in energy efficiency that does not involve radical redesign might be accommodated by testing the core and winding losses at the factory. If self-certification were accepted for registration, it may be possible to modify designs to meet higher MEPS levels without voiding the original type test certification.

All energy testing of transformers involves measurement of energy losses under a range of operating conditions: typically, no load (NL) to measure core losses, and full load (FL) and/or an intermediate loading point to establish the winding losses. Different MEPS regimes then use this basic information in different ways to set energy performance standards.

As Table 2 indicates, Australia and New Zealand are in the group of countries that use the 50% load efficiency metric for MEPS, while others specify maximum FL and NL losses. The EU uses the maximum loss approach for transformers up to 3,150 kVA but an adaptation of the minimum efficiency approach for larger

[25] Powerlab
[26] Caltestlab
[27] Proposed-closure-of-lane-cove-testing-station

transformers. Those must achieve the Peak Efficiency Index (PEI) specified for their capacity, but it is up to the manufacturer to determine the loading at which this occurs, so buyers can select models which reach peak efficiency at the loading the user plans for. The efficiency calculations must also take into account energy used by cooling pumps or fans.

Efficiency at 50% load can be calculated by measuring the energy losses at FL and NL and scaling the FL losses back to 50% load, using the assumption that the load loss varies as the square of the load factor. However, this ignores the likelihood that the eddy and stray currents induced in the transformer tank may not scale by the square of the load factor, or that the original test may have been done at a temperature other than the reference temperature of 75 $^{o}$C as specified in AS 2374.

Another way to represent transformer efficiency is by measuring losses not at full load (or not only at full load) but one or more other loading point as well. Accurate NL and FL loss data for each unit (not just each model type) is often known to the manufacturer from their own tests. If this information were disclosed – e.g. by permanent marking on the rating plate, as required by the EU regulations – the user could monitor the actual loading and calculate the total energy loss for the transformer over time. Most electricity distributors are now able to remotely monitor DTs, so this information would be valuable for longer term energy efficiency strategies.

Australia and New Zealand are relatively small DT markets by global standards and the range of models available is narrow and will always be restricted by market dynamics (see Figure 6). The same DT models will necessarily be used in different loadings and applications. Buyers may not be fully aware of the likely “intended operational usage” in advance and loading patterns may change significantly over the service life, especially as new loads such as EV charging become more significant. Adoption of a PEI metric would complicate the DT design and the MEPS regulation process without any practical effect on market outcomes. A general metric such as efficiency at 50% loading is appropriate, although there may be case for moving the MEPS criterion to 40% loading, as in Japan.

The chosen compliance metrics will have an influence on design. Changing the MEPS criterion to minimum efficiency at 40% loading places greater emphasis on lowering the no-load (core) losses. This may be a more cost-effective pathway to improving efficiency than reducing winding losses. Lower loss variants of the most common core material, grain oriented silicon steel (GOSS) are now available. Although supply is not satisfying global demand at present, availability is improving. Amorphous metal core material is even lower loss but more expensive and requires higher manual labour input. Amorphous metal cores are mostly used in India and China.

Another option for core loss reduction is through the machine production of wound core types, using one continuous length of very thin GOSS to wind cores without the air gaps that cause disruption of the magnetic field. DTs of up to 500 kVA, including three-phase versions, are now available with wound cores, and core winding machinery is being designed to handle DTs up to 1000 kVA. AEM Unicore in Adelaide is a major supplier of wound-core machines, exporting to 52 countries.

It is likely that the barriers to greater efficiency are not the test method or the MEPS metrics but production methods and costs, and the general lack of buyer interest in and demand for products of higher efficiency – the market failures which MEPS aims to address. Furthermore, suppliers, buyers and regulators are all familiar with the present test and metrics, and there would be costs in changing, at least for liquid-filled products.

The cost of changing the tests and metrics for dry type transformers would be lower. All dry type models are imported, so there is no significant testing infrastructure or capability to be lost. If the EU Tier 2 MEPS levels, which specify maximum load and no-load losses, were adopted for dry type transformers (equivalent to MEPS4 in the present RIS) it would be consistent to require compliance to be demonstrated using the EN 50708 standard.

## Impacts on Competition and Innovation

The DT market is competitive and price sensitive. There are four established manufacturers in Australia and New Zealand, and several importers. The barriers to entry for new importers relate mainly to transport costs – transformers are heavy and bulky products. On the other hand, local manufacturers have to import most of their component materials and face higher labour costs.

The price-sensitivity of the market means that most buyers under-value energy efficiency. This makes it risky for any supplier to build in costs by running too far ahead of the MEPS level. Raising the MEPS would remove that risk and place all suppliers in the same competitive position.

Manufacturers of liquid-filled DTs have shown their ability to produce products more efficient than the existing MEPS level. Raising the level would advantage those suppliers who are best placed to innovate in terms of designs, materials and manufacturing techniques. On the other hand, if higher MEPS levels are too challenging, some suppliers may withdraw from the market, and so reduce competition.

For dry type transformers, most models already meet MEPS4, so adopting that as the MEPS level should not reduce competition.

As with all other products regulated under GEMS and the EUP, the same testing and MEPS requirements apply to both imports and locally manufactured products and there is no single international standard in widespread use, so there is no conflict with World Trade Organisation rules.

The Trans-Tasman Mutual Recognition Agreement 1997 (TTMRA) states that products that can legally be sold in one country (Australia or New Zealand) can be legally sold in the other country irrespective of differing technical standards. The products must be manufactured in or imported through the complying country. This means that New Zealand and Australia share a common DT market and model range and any inconsistency in regulatory requirements would have unintended implications for market competition, potentially undermining the benefits to the country with the higher MEPS levels. This is because the manufacturers in the country with the lower MEPS level would have a cost advantage and could legally sell their products in the country with higher MEPS.

This is a key consideration in determining the optimum policy option. If both New Zealand and Australia changed the MEPS requirements at the same time and to the same level and scope, the unintended TTMRA consequences would not arise.

## Refurbishment

There is some competition between new transformers and reconditioned or refurbished units. Several companies, including the major manufacturers, undertake transformer refurbishment. Refurbishment typically comprises inspection of windings, changing oil, insertion of new gaskets and repainting. Unlike electric motor refurbishment, the windings themselves are not renewed, so there is little scope for increasing the energy efficiency of transformers during the refurbishment process.

No data is available on the numbers of units refurbished each year. About 20 years ago it was a significant market, as utilities tried to extend the service lives of transformers and other capital assets. When DTs reached their capacity, the DNSPs replaced them with larger units, refurbished the original and used it elsewhere in the network or kept it in storage until wanted (GWA 2002). This practice now appears to be declining in Australia, where some DNSPs have closed their refurbishment workshops.

Most transformer manufacturers offer a refurbishment service for their own products but find that it is not economic for smaller DTs located beyond a certain distance, given transport costs to and from the factory. Also, it is uneconomic to refurbish older DTs built to imperial dimensions, as replacement parts have to be machined to fit. Refurbished products are considered 'second-hand' and so not subject to MEPS.

If there is an increase in the average price of new transformers due to MEPS, no change in the cost of refurbished units and no obligation on refurbished units to meet MEPS, there may be some increase in the tendency of buyers to opt for refurbishment in preference to new transformers. If refurbishers as a group chose to maintain rather than widen the cost advantage over new transformers (i.e. by increasing their prices in line with any MEPS-induced rise in new unit prices), then there would be no increase in preference for refurbished units.

The capacity to refurbish transformers would reduce the adjustment costs imposed by MEPS, since a higher proportion of dimensionally or weight-constrained applications could be handled by refurbishing the existing unit, or another unit of similar vintage, rather than rebuilding enclosures or reinforcing poles.

All in all, the tendency to refurbish transformers in preference to purchasing new ones may increase slightly, and this may offset to some degree the projected energy benefits of MEPS.  However it would also reduce the costs, since there would be a smaller rise in average transformer prices.  These effects are likely to be moderate, and not significantly impact the projected benefit/cost ratios of the MEPS options.

# 4. Implementation and Timing

## Conclusions

The electricity distribution transformer markets in Australia and New Zealand are highly price-sensitive, and very few buyers or market segments prefer DTs more efficient than the MEPS level. The great majority of sales are to distribution network service providers (DNSPs and EDBs) which are able to pass on the costs of energy losses to electricity retailers, which pass them on in turn to customers. This chain of split incentives works against the adoption of higher efficiency transformers even when they have lower discounted costs over their service lives, which often exceed 45 years.

The MEPS levels in AS 2374.1.2:2003, embodied in a 2012 GEMS Determination in Australia and in the Energy Efficiency Regulations in New Zealand, continue to be the main drivers of energy efficiency. There are models on the market which meet the high efficiency (HE) levels in AS 2374.1.2, but demand for them is restricted to a handful of DNSPs, EDBs, packaged substations and other niche applications.

The current MEPS and HE levels have not been revised since they were first adopted in 2004.[28] Since that time transformer MEPS levels in other countries have steadily increased, most recently with the adoption of the Tier 2 levels in the EU in July 2021 and new DOE standards in the USA in 2024. The present review of DT MEPS in Australia and New Zealand was originally prompted by the risk that the GEMS Determination was due to lapse in April 2023 (E3 2021). It has been confirmed that this is no longer the case but given that the original MEPS have remained unchanged for much longer than for other products covered by GEMS, this review is timely.[29]

While the methods and materials for building more efficient transformers are widely available, the societal value of doing so is a matter of costs compared with benefits. This RIS has modelled three MEPS levels that are more efficient than the current level (called MEPS1):

- MEPS2 is the existing HE level;
- MEPS3 is mid-way between MEPS2 and MEPS4; and
- MEPS4 is equivalent to the EU Tier 2 level, which is the most stringent among economies using 50Hz electricity supply (the USA and Canada use 60Hz).

Adopting more stringent MEPS levels is expected to drive up the cost of manufacturing DTs and hence the price to buyers. However, this will be more than compensated by the value of reductions in energy loss, electricity generated, transformer capacity freed or deferred and $CO_2$-e emissions avoided. These conclusions hold true for both Australia and New Zealand and are robust across a range of price and discount rate assumptions (noting that costs and benefits are calculated in real 2024 dollars, ignoring inflation).

There is no single international test standard or MEPS level for DTs, and countries with transformer MEPS regimes set their own levels (apart from the EU, whose member countries use a common standard). For

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[28] They are in fact slightly *less* stringent than those proposed in the first analysis of the potential for transformer MEPS in Australia (Ellis 2000).

[29]. [Energyrating]

Australia, MEPS3 offers the optimum balance of costs and benefits for liquid-filled DTs, which account for about 85% of the DT market. For New Zealand, with a different DT fleet and energy prices, the optimum point appears to be MEPS4. As the countries share a common DT market and model range they will need to retain common MEPS levels so the combined optimum MEPS level is MEPS3.

About 80-90% of liquid-filled DTs sold in Australia and New Zealand are made by four major local manufacturers: Schneider, Tyree and Wilson in Australia and ETEL in New Zealand (with significant trans-Tasman trade). These firms are experienced in manufacturing for specific local requirements and clients and should be able to adjust to higher MEPS given sufficient lead time. The same MEPS levels would of course apply to imports, which come mainly from Vietnam, China and Thailand.

While DNSPs use liquid-filled DTs almost exclusively, there is also a market for dry type DTs in commercial and high-rise building, manufacturing and mining where fire-safety and weight are issues. (Gas-filled products serve a similar niche, but gases with low flammability, low ozone depletion and low global warming potential are rare). All of the dry type DTs registered with GEMS are imported and many are already well above MEPS3 level. Therefore the logical progression for dry type DTs is either to MEPS4, equivalent to EU Tier 2 but still using AS/IEC tests, or perhaps complete adoption of EU Tier 2 together with the EN50708 test referenced in the European Commission Directive.

The current scope of the GEMS Determination is restricted to DTs "with power ratings from 10 kVA to 2,500 kVA and a system highest voltage up to 24 kV." This was designed to cover the most common voltage levels used by DNSPs (11kV and 22 kV) but there are also thousands of transformers with a high-side voltage level of 33 kV in public supply use in Australia today (not in New Zealand), with several hundred new ones added annually. Some of these are owned by Transmission Network Service Providers (TNSPs) rather than DNSPs but they are integral to the distribution function and are treated as such in electricity industry statistics. The TNSPs operate in the same regulatory environment as the DNSPs, to whom they can pass on the costs of losses, so are part of the same chain of market failures. It would be cost-effective to widen the scope of MEPS to transformers with a system voltage up to 36 kV.

The kVA limit should also be raised, from 2,500 to 5,000 kVA, the new upper limit adopted for MEPS in the USA. (The EU regulations use 3,150 kVA to mark the transition point from "medium power" to "large power" transformers). While few DNSP or EDB DTs exceed 2,500 kVA, the larger size bracket tends to be used in the commercial, mining and manufacturing sectors, which are subject to the same market failures as the public supply sector. Terrestrial wind turbines have step-up transformers greater than 2,500 kVA but generally no larger than 5,000 kVA, so would be covered by the expanded scope. Off-shore wind turbine transformers are 10,000 kVA or larger, and so are outside the scope of this RIS.

Defining power transformers solely in terms of electrical characteristics (number of phases), cooling (liquid-filled, gas-filled or dry) high-side voltage (e.g. 36 kV) and capacity (kVA) rather than intended use ("distribution") clarifies the scope of the regulation. However, some transformer types need to be further categorised in order to clarify their inclusion or exclusion. One aspect of the US regime which is worth considering is to set a maximum low side rating for MEPS coverage, so that unusual designs such as 33 to 11 kV models are excluded. The US MEPS regime excludes DTs with a low side rating exceeding 600V. A suitable maximum low side rating for Australia and New Zealand would be 1,200V. All but one of the currently registered DT models meets this criterion.

Step-up transformers for wind farms and utility-scale solar PVs and batteries were rare when the current regulations came into force in 2004. Now several hundred are installed annually in Australia and New Zealand. It has been argued that owners of these projects are among the few market segments that should be sensitive to transformer efficiency, since they bear the direct cost of losses in terms of sales revenue forgone. However, this market also is liable to fragmentation and incentives split between contractors, developers, operators and owners. Therefore the scope of MEPS should be widened to cover all AC transformers with a system highest rating up to 36 kV and a low side rating up to 1,200V, irrespective of whether to be used in a step-up applications, as in wind turbines, or step-down application as in normal supply grid operation. The test procedures are in effect reversible, in that the losses can be measured with energisation from either high or low voltage winding, but the Determination will need to be specific on this point.

Further, the transformers in wind turbine units and in PV farms are subjected to power electronic converter and inverter operation which generates substantial harmonic distortion in the voltage and current, and these harmonics are a major source of increased loss in transformer operation. It is thus imperative that the transformers in wind turbines and in PV farms be as efficient as is possible in their basic design.

All energy testing of transformers involves measurement of energy losses under a range of operating conditions: typically no load (NL) to measure core losses, and full load (FL) and/or an intermediate loading point to establish the winding losses. Different MEPS regimes then use this basic information in different ways to set energy performance standards. AS 2374.1.2, which is referenced in the GEMS Determination and the EUP Regulations, specifies the MEPS requirement as the power efficiency at 50% load and unity power factor. A 40% load test (as used in Japan) may be more representative of actual use. Feedback on the feasibility and the pros and cons of moving to a 40% load test would be appreciated as part of this consultation

## Draft Recommendations

The following draft recommendations are presented for consideration by stakeholders. Specific questions relating to these recommendations are in Section 5.

1. The existing GEMS Determination and EUP Regulations covering distribution transformers should be amended as soon as practicable, so that the societal benefits of higher MEPS levels can begin to accrue without delay.

2. The amended Determination and Regulation should cover electricity distribution transformers (DTs) with power ratings from 10 to 5,000 kVA (for single-phase and SWER), 25 to 5,000 kVA (for three-phase), a system highest voltage ($U_m$) up to 36 kV and a low side voltage up to 1.2 kV. (The current Determination covers DTs with a maximum power rating of 2,500 kVA system highest voltage up to 24 kV; it does not mention low-side voltage).

3. The new Determination and Regulations should categorise DTs into the product classes in Table 19. (Product classes 1B, 2B, 4B, 6B and 7 expand the scope of the current Determination).

4. The amended Determination and Regulations should specify the MEPS and HE levels indicated in Table 20 for each class of transformer, noting that:

- for liquid-immersed transformers, the new MEPS levels are more stringent than the HE levels in AS 2374.1.2-2003, and the new HE levels are approximately equal to the EU Tier 2 levels;
- for dry type transformers, the new MEPS levels are approximately equal to the EU Tier 2 levels and the new HE levels are as recommended in the 2011 consultation RIS.

*Table 19 Recommended product classification for distribution transformers*

| Product class | Products covered by class |
|---|---|
| 1A | Single-phase or SWER oil immersed type transformer where $U_m$ = 24 kV |
| 1B | Single-phase or SWER oil immersed type transformer where $U_m$ = 36kV |
| 2A | Three-phase, oil immersed type transformer where $U_m$ = 24 kV |
| 2B | Three-phase, oil immersed type transformer where $U_m$ = 36kV |
| 3 | Single-phase or single wire earth return, dry type transformer where $U_m$ = 12 kV. |
| 4A | Single-phase or single wire earth return, dry type transformer where $U_m$ = 24 kV. |
| 4B | Single-phase or single wire earth return, dry type transformer where $U_m$ = 36 kV. |
| 5 | Three-phase, dry type transformer where $U_m$ = 12 kV. |
| 6A | Three-phase, dry type transformer where $U_m$ = 24 kV. |
| 6B | Three-phase, dry type transformer where $U_m$ = 36 kV. |
| 7 | Step-up transformers with system highest voltage up to 36 kV |

5. The amended Determination/Regulation should reference:

- AS/NZS 60076.1:2014 *Power transformers General* and AS 60076.11:2018 *Power transformers Dry type transformers* as the method of test; and
- AS 2374.1.2:2003 *Power Transformers Part 1.2. Minimum Energy Performance Standards (MEPS) requirements for distribution transformers* as the method of determining the efficiency of transformers (except for Sections 2 and 3, which would be superseded by the inclusion of Table 20 in the Determination and the New Zealand regulations).

6. For dry type transformers, consideration should be given to accepting for registration models certified as complying with the requirements of Tier 2 in the European Commission Regulation (EU) 2019/1783 of 1 October 2019, as compliant with the amended Determination and Regulations.

7. The amended Determination and Regulations should explicitly cover transformers that are intended for use as step-up transformers for wind turbine and utility-scale photovoltaic or battery storage applications, provided that they otherwise fall within scope.

*Table 20 Recommended MEPS and HE levels*

| | kVA | Class 1A, 2A, 7 $U_m$ =24kV MEPS | Class 1A, 2A, 7 $U_m$ =24kV HE | Class 1B, 2B, 7 $U_m$ = 36 kV MEPS | Class 1B, 2B, 7 $U_m$ = 36 kV HE | Class 3, 5 Dry $U_m$ = 12 kV (a)MEPS | Class 3, 5 Dry $U_m$ = 12 kV (a)HE | Class 4A, 6A Dry $U_m$ = 24 kV (a)MEPS | Class 4A, 6A Dry $U_m$ = 24 kV (a)HE | Class 4B, 6B Dry $U_m$ = 36 kV (a)MEPS | Class 4B, 6B Dry $U_m$ = 36 kV (a)HE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1P, SWER | 10 | 98.58 | 98.74 | 98.30 | 98.42 | 97.53 | 98.20 | 97.32 | 97.90 | 96.87 | 97.50 |
| | 16 | 98.74 | 98.83 | 98.52 | 98.64 | 97.83 | 98.32 | 97.55 | 98.06 | 97.11 | 97.75 |
| | 25 | 98.86 | 98.91 | 98.70 | 98.80 | 98.11 | 98.48 | 97.78 | 98.20 | 97.34 | 97.98 |
| | 50 | 99.05 | 99.10 | 98.90 | 99.00 | 98.50 | 98.78 | 98.10 | 98.50 | 97.74 | 98.33 |
| 3P | 25 | 98.65 | 98.80 | 98.28 | 98.50 | 97.42 | 97.88 | 97.42 | 97.88 | 96.92 | 97.55 |
| | 63 | 98.88 | 98.94 | 98.62 | 98.82 | 98.01 | 98.37 | 98.01 | 98.37 | 97.30 | 97.96 |
| | 100 | 99.05 | 99.10 | 98.76 | 99.00 | 98.28 | 98.61 | 98.28 | 98.61 | 97.58 | 98.25 |
| | 200 | 99.19 | 99.26 | 98.94 | 99.11 | 98.64 | 98.83 | 98.60 | 98.72 | 98.26 | 98.51 |
| | 315 | 99.27 | 99.34 | 99.04 | 99.19 | 98.82 | 98.95 | 98.74 | 98.87 | 98.44 | 98.63 |
| | 500 | 99.34 | 99.42 | 99.13 | 99.26 | 98.97 | 99.08 | 98.87 | 99.01 | 98.62 | 98.79 |
| | 750 | 99.39 | 99.45 | 99.21 | 99.32 | 99.08 | 99.18 | 98.98 | 99.13 | 98.77 | 98.91 |
| | 1000 | 99.42 | 99.46 | 99.27 | 99.37 | 99.14 | 99.26 | 99.04 | 99.19 | 98.87 | 98.99 |
| | 1500 | 99.44 | 99.49 | 99.35 | 99.44 | 99.21 | 99.33 | 99.12 | 99.26 | 98.99 | 99.08 |
| | 2000 | 99.45 | 99.50 | 99.39 | 99.49 | 99.24 | 99.37 | 99.17 | 99.30 | 99.00 | 99.14 |
| | 2500 | 99.45 | 99.51 | 99.40 | 99.50 | 99.27 | 99.39 | 99.20 | 99.33 | 99.00 | 99.19 |
| | 3150 | 99.45 | 99.51 | 99.40 | 99.50 | 99.30 | 99.39 | 99.23 | 99.33 | 99.00 | 99.19 |
| | 5000 | 99.45 | 99.51 | 99.40 | 99.50 | 99.30 | 99.39 | 99.23 | 99.33 | 99.00 | 99.19 |

Note: For intermediate power ratings the efficiency levels shall be calculated by linear interpolation. (a) Alternatively, adopt EU Tier 2 maximum load and no-load losses, as tested in accordance with EN 50708.

8. The amended Determination and Regulations should exclude the following (noting that by this amendment, gas-filled dry type transformers are included in scope):

(a) instrument transformers; or

(b) auto transformers, that is transformers in which at least two windings have a common part; or

(c) traction transformers mounted on rolling stock; or

(d) starting transformers; or

(e) testing transformers; or

(f) welding transformers; or

(g) three-phase transformers with three or more windings per phase; or

(h) arc-furnace transformers; or

(I) earthing transformers; or

(j) rectifier or converter transformers; or

(k) uninterruptible power supply (ups) transformers; or

(l) transformers with an impedance of more than 8 percent [i.e. removal of the 3% lower limit]; or

(m) voltage regulating transformers; or

(n) transformers designed for frequencies other than 50 or 60 hertz; or

(o) flameproof transformers.

9. Consideration should be given to requiring permanent marking on the transformer nameplates so that it is possible to identify every unit in the field against the register.

10. Consideration should be given to requiring the tested no-load loss and full load loss of every unit produced to be permanently marked on the rating plate, or if this is not practicable then the no-load loss and full load loss as determined in type testing of that model for the purpose of registration.

11. The amended Determination should allow for at least two years between the date of taking effect and the date at which products within its scope must meet the amended MEPS levels and other rules for registration.

12. New Zealand Energy Efficiency (Energy Using Products) Regulations 2002 should be amended so that the provisions regarding distribution transformers align with the amended GEMS Determination, including with regard to the timing of implementation.

## Implementation

## Determination under the GEMS Act

The current GEMS Determination should remain in place until a new Determination comes into force. If Ministers agree to changing the MEPS levels, the scope, referenced standards and other aspects of the amended Determination, then a draft Amended Determination would be published for comment.

The final amended Determination would take effect on or close to the date of signature by the Minister for Energy. It would need to confirm, among other things:

- the target date at which products within its scope must meet the amended MEPS levels and other rules in order to be registered in accordance with the GEMS Act;
- the fact that products registered up to the target date can be registered under the rules in the 2012 Determination (which may need to be reproduced for that purpose in the amended Determination);
- Whether or not products registered before the target date have the option of registration under the revised rules.

GEMS Determinations routinely include material that adds to or modifies the application of the standards they reference, or indeed technical content that does not exist in a standard. While it would be efficient in in the long run to revise AS2374.1.2 to align with the provisions of an amended Determination, it is not necessary to delay implementation on that account.

## New Zealand Regulations

New Zealand Energy Efficiency (Energy Using Products) Regulations 2002 will need to be amended so that the provisions regarding distribution transformers align with the amended GEMS Determination, including with regard to the timing of implementation. The regulations include no technical content for transformers, but only reference the relevant standards (AS 60076.1–2005, not the 2014 version, AS 60076.11–2006 and AS 2374.1.2–2003).

If the scope and MEPS levels change as recommended, then Regulations will need to depart from the nominated standards. This situation arose in 2012, when the then Ministry of Business Innovation and Employment recommended adoption of the revised MEPS and HE levels proposed in the 2011 RIS (E3 2011)[30].

Unless and until a revision of AS 2374.1.2 containing changes in scope, MEPS levels and HE levels is published, it may be necessary to amend the Energy Efficiency (Energy Using Products) Regulations 2002 themselves, as has been done with respect to transitional provisions for electric storage water heaters and ballasts for fluorescent lamps, and technical provisions for air conditioners up to 65kW and refrigerated cabinets, for which comprehensive schedules have been added.

The transition arrangements to any amended requirements may differ between Australia and New Zealand. In New Zealand products manufactured in or imported into the country before the enforcement date can legally be offered for sale, lease, hire, and hire-purchase after the enforcement date without meeting the new requirements, but must meet the requirements that were in force on the day they were manufactured or imported.

## Next Steps

The publication of this Regulation Impact Statement for Consultation (CRIS) marks the beginning of a process which will proceed in the following stages.

1. The CRIS will be circulated to stakeholders as widely as possible, and submissions invited for a period of 8 weeks from its initial publication.
2. E3 may hold an information session/s during that period to give an opportunity for stakeholders to ask questions and seek clarification on the CRIS. This would most likely be in the form of a video-conference.
3. E3 will review written submissions received up to the closing date. These will be made public unless the submitter indicates that a submission is confidential. Stakeholders may make both a public and a confidential submission if they wish.
4. E3 will review the CRIS in the light of submissions received, and if necessary review the analysis and recommendations accordingly.

[30] It was noted at the time that "both MEPS levels are set out in the draft transformers standard AS/NZS 60076.99. This standard is in the final stages of development. It is due to be released for public comment and is planned to be finalised early in 2013" (MBIE, 2013). That standard was never published.

5. E3 will prepare a Regulation Impact Statement for Decision (DRIS) for submission to Commonwealth, State, Territory and New Zealand Energy Ministers. (The Decision RIS is usually only made public after the Ministerial decision).
6. If Ministers (Cabinet in New Zealand) decide on a course of action that involves regulatory change, the Commonwealth Minister will oversee preparation of the appropriate Determination and the New Zealand Cabinet will approve any amendments to the Energy Efficiency (Energy Using Products) Regulations 2002.

*****

# 5. Questions for Stakeholders

### Impacts

1. How would your organisation or company be affected by the proposed changes in MEPS, HE levels, scope or other aspects of the regulations regarding energy efficiency of distribution transformers? Please give details.

### MEPS Levels

2. For liquid filled transformers, do you support the increase in MEPS levels recommended in Table 20 of this RIS for each of the categories of distribution transformers (DTs) covered by current MEPS regulations?? If not, please give reasons.

3. For dry type transformers, do you support:

- the increase in MEPS levels recommended in Table 20 of this RIS for each of the categories of distribution transformers (DTs) covered by the current MEPS regulations?; or
- adoption of the EU Tier 2 MEPS levels (as implemented in July 2021), as an alternative method of compliance?; or
- adoption of the EU Tier 2 MEPS levels and test standards as the sole method of compliance?

4. If you do not support the proposed increases, are there other MEPS levels that you would propose?

5. Do you agree with the assumptions used in the cost-benefit analysis? If not, can you please provide data that would support other assumptions? (Note that submissions will be kept commercial-in-confidence if so requested).

### Scope changes

6. Do you support expanding the coverage of MEPS to DTs with power ratings up to 5,000 kVA? If not, please give reasons.

7. Do you support expanding the coverage of MEPS to DTs with system highest voltage up to 36 kV. If not, please give reasons.

8. Do you support adding a scope limit of no greater than 1,200V on the low voltage side? If not, please give reasons.

9. Do you support expanding the coverage of MEPS to step-up transformers for wind turbine and utility-scale photovoltaic or battery storage applications? If not, please give reasons.

10. Do you support modifying the list of exclusions so that gas-filled DTs and DTs designed for 60Hz are not excluded, and there is no lower limit on impedance? If not, please give reasons.

## Method of test

11. For liquid-filled DTs, do you support the use of AS/NZS 60076.1:2014 *Power transformers General* as the method of test? If not, what alternative do you propose? If the scope of MEPS were expanded as proposed, would the standard need to be revised?

12. The New Zealand regulations reference AS 60076.1:2005. Are there any issues that would prevent the results of tests undertaken to that earlier edition being accepted to demonstrate compliance?

13. For dry type DTs, do you support the adoption of AS 60076.11:2018 *Power transformers Dry type transformers to replace AS 60076.11:2006* as the method of test? If not, what alternative do you propose? If the scope of MEPS were expanded as proposed, would the standard need to be revised?

14. Should products where evidence of MEPS compliance is based on tests conducted to IEC 60076-1, Ed. 3 (2011) or EN 50588-1 be accepted as equivalent to MEPS compliance based on AS/NZS 60076.1:2014?

15. Do you support the retention of AS 2374.1.2:2003 *Power Transformers Part 1.2. Minimum Energy Performance Standards (MEPS) requirements for distribution transformers* as the method of determining the efficiency of transformers.

16. If the AS 2374.1.2 approach is retained, do you support specifying the MEPS requirement at 50% load, 40% load or some other point?

17. If the scope of MEPS were expanded as proposed, would the test standard need to be revised?

18. For manufacturers, do you measure core losses and winding losses when the transformer is at 50%, 40% load or some other point?

## HE Levels

19. Should the Australian and New Zealand regulations for transformers continue to designate a High Efficiency level? Please give reasons.

20. Do you support the HE levels recommended in Table 20 for each of the categories of DTs covered by the current regulations, and those proposed to be covered? If not, please give reasons.

21. If you do not support the proposed increases, are there other HE levels that you would propose?

## Issue for Policymakers

22. Are there any aspects of the proposed options for regulating energy efficiency of DTs that may have wider implications for the electricity price/quality path? What are your recommendations to address those issues (if any)?

23. Are there any aspects of the proposed options for regulating energy efficiency of DTs that may have wider implications for national electricity infrastructure planning and investment? What are your recommendations to address those issues (if any)?

24. Are there any other potential policy and regulatory impacts that might not have been considered in this paper?

25.  Do you have any comments on the proposed timelines for revising DT energy efficiency regulations? Are there any other factors (e.g. relevant Government's strategy/policy/programmes etc.) that should be considered and aligned with?

### Issues for DNSPs and EDBs

26. How do EDBs/DNSPs currently plan for and implement the maintenance and asset replacement for DTs in their current networks?

27. How material are the potential cost increases to DTs under the proposed revised MEPS relative to overall planned capital expenditure (CAPEX).

28. What transition period do you think would be required before the introduction of the preferred MEPS option? What are the key constraints around timing?

### Registration and Administration

29. At present, a complying "family" of models can include models of different kV levels, provided they share kVA and energy efficiency levels. For registration purposes, should a family only contain products of the same voltage (e.g. variants with system voltage of 11kV, 22kV and 33 kV would need to be registered separately)?

30. Do you support the proposal that registration rules should be clarified so that it is possible to identify every unit in the field against the register? If not, please give reasons. What is the best way to link units to the register?

31. Do you support the proposal that no-load loss and full load loss for each individual unit should be permanently marked on its rating plate, or if this is not available then the no-load loss and full load loss as determined in type testing of that model for the purpose of registration? If not, please give reasons.

### Lead times and transition

32. If the proposed changes were adopted by governments, what should be the lead time between finalisation of the requirements and their implementation (the recommendation in this CRIS is 2 years)? Please give reasons.

33 . Do you have any other points you wish to raise?

*****

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# Appendix A – Consultations to Date

Information was obtained from the following organisations (via interviews, return of questionnaire or both). The authors are grateful for their co-operation.

Australian Industry Group Electrical Equipment Suppliers Forum

CIGRÉ Australia Transformer Workshop

Electricity Network Association, New Zealand

Energy Networks Australia

ETEL Ltd, New Zealand

Powercor, Victoria

Schneider Electric, Victoria

South Australian Power Networks

Tyree Transformers, NSW

Unison Power, New Zealand

Victorian Distributors Group

Ten other organisations were also contacted.

# Appendix B – Current MEPS levels

The GEMS Determination covers distribution transformers in the product classes set out in Table 21, with power ratings from 10 kVA to 2500 kVA and a system highest voltage up to 24 kV. New Zealand covers the same scope using the EUP Regulations.

*Table 21 Specified product classes covered by GEMS Determination*

| Product class | Products covered by class |
|---|---|
| 1 | Single-phase or single wire earth return oil immersed type transformer. |
| 2 | Three-phase, oil immersed type transformer. |
| 3 | Single-phase or single wire earth return, dry type transformer where the $U_m$ is 12 kV. |
| 4 | Single-phase or single wire earth return, dry type transformer where the $U_m$ is 24 kV. |
| 5 | Three-phase, dry type transformer where the $U_m$ is 12 kV. |
| 6 | Three-phase, dry type transformer where the $U_m$ is 24 kV. |

The existing MEPS (“MEPS1”) and HE levels for Class 1 and 2 are illustrated in Figure 14, for Class 3 and 5 in Figure 16 and Class 4 and 6 in Figure 18. The MEPS2 levels and the maximum efficiency levels (“MEPS4”) proposed in the 2011 RIS are also indicated. Where the MEPS2 levels coincides with the existing HE level the lines are superimposed, so are shown as dashed lines for clarity.

The 2011 RIS also proposed extensions of the scope, to cover transformers up to 34 kV (from the present 24 kV) and up to 3,150 kVA (from the present 2,500 kVA). The proposed MEPS and HE levels for these additional criteria are also shown.

As minimum efficiencies for DTs are all relatively high it is difficult to visualise the magnitude of the differences between them. Therefore Figure 15, Figure 17 and Figure 19 illustrate the “maximum losses” – the difference between the MEPS and HE levels and 100% efficiency (e.g. 100% minus MEPS%). For example, Figure 14 shows that the MEPS1 level for a 200 kVA three-phase old-filled transformer is an efficiency of 98.94% and the current HE level is 99.11%. The proposed new MEPS level (MEPS3) is 99.19% and the proposed HE (MEPS4) level is 99.26% (see Table 20). This may not seem like a major improvement, but Figure 15 shows that the energy loss level would need to fall from a maximum of 1.06% under MEPS1 to 0.74% under MEPS4. This represents a 30% reduction in actual energy losses, which is technically challenging.

Table 22 gives the European Union Tier 2 MEPS rules for liquid-filled and dry type transformers. These are expressed in terms of per cent Peak Efficiency Index (which can be measured at any loading level nominated by the supplier) and, for most dry-types, in maximum no-load and load losses (in W). They cannot therefore be compared directly with the MEPS and HE levels in AS 2374.1.2, which are expressed as efficiency at 50% loading.

*Figure 14 Oil filled transformers MEPS and HE*

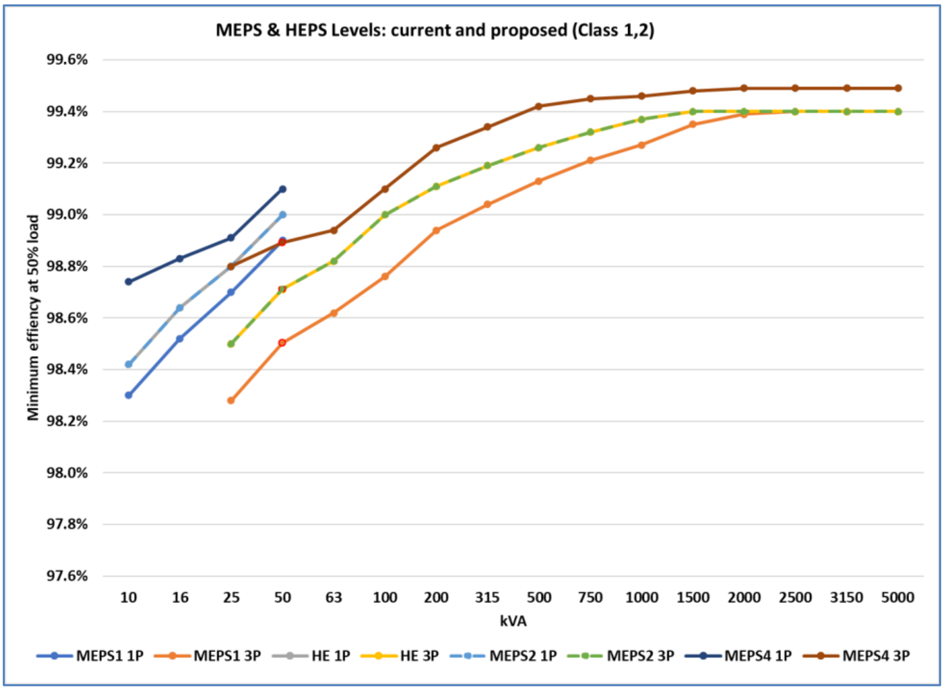



*Figure 15 Oil filled transformers maximum losses*

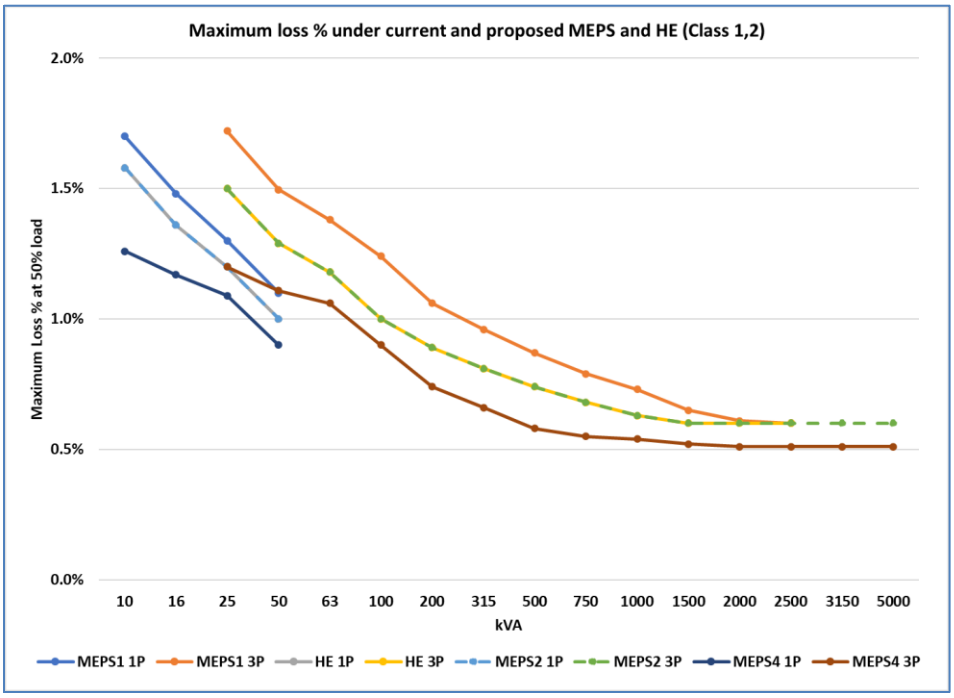


*Figure 16 Dry type transformers up to 12 kV, MEPS and HE*

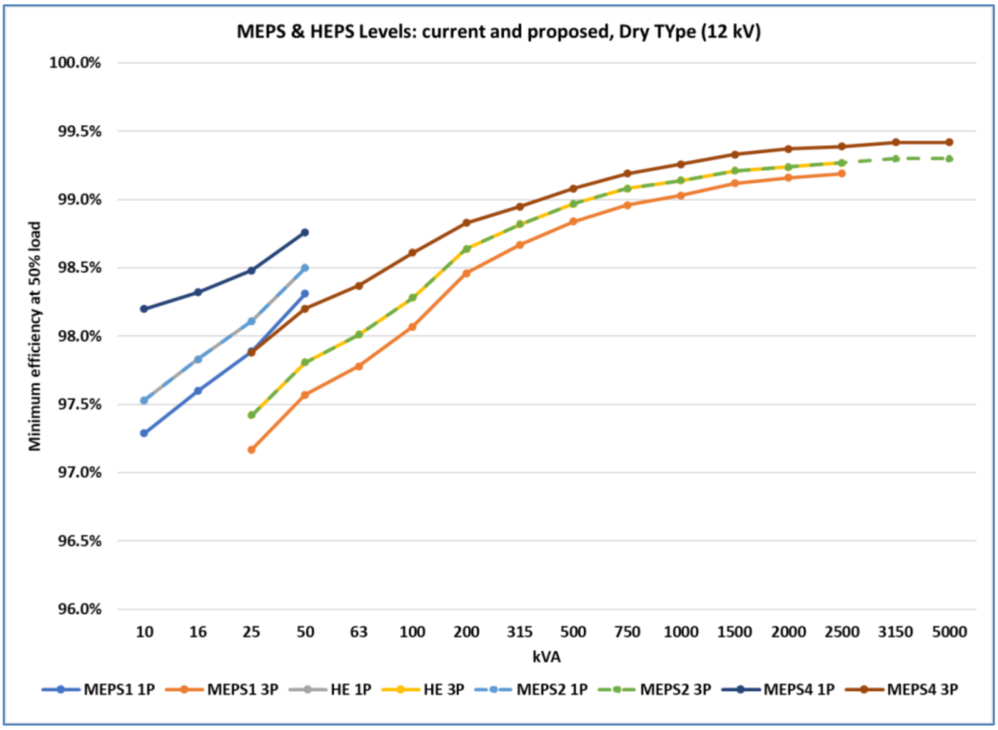



*Figure 17 Dry type transformers up to 12 kV, MEPS and HE*

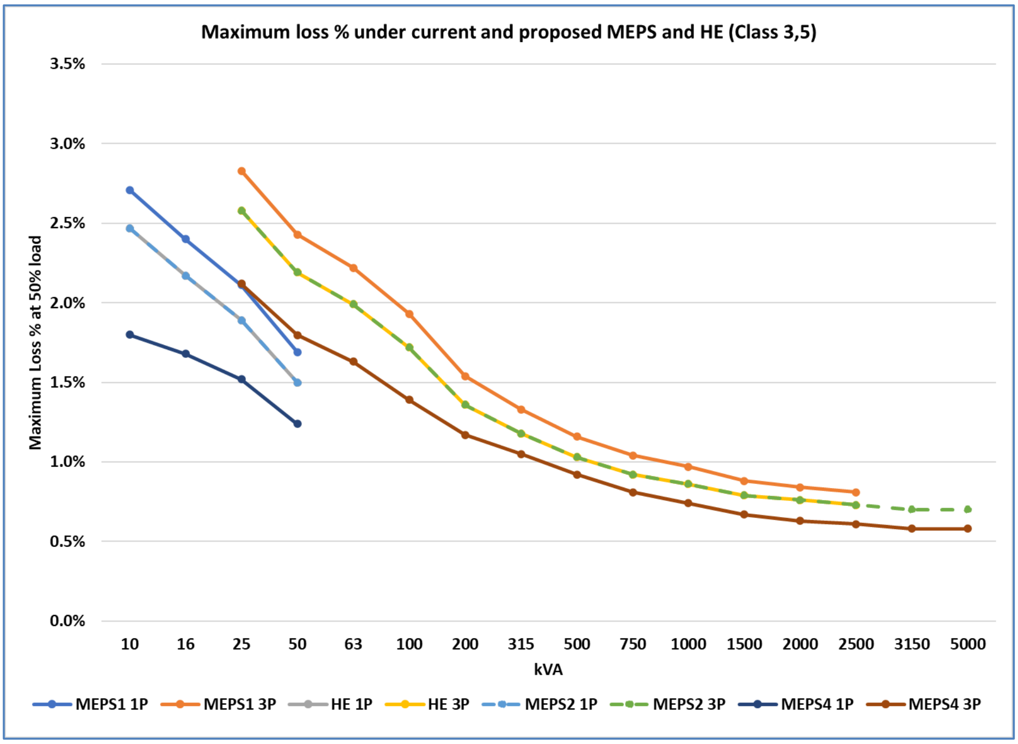


*Figure 18 Dry type transformers up to 34 kV, MEPS and HE*

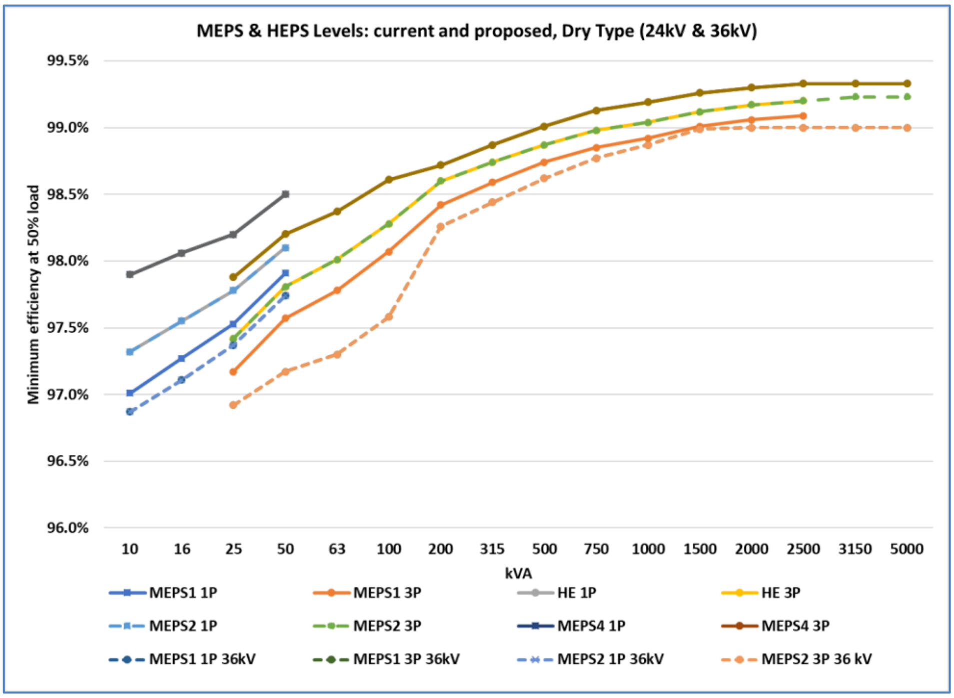



*Figure 19 Dry type transformers up to 34 kV, MEPS and HE*

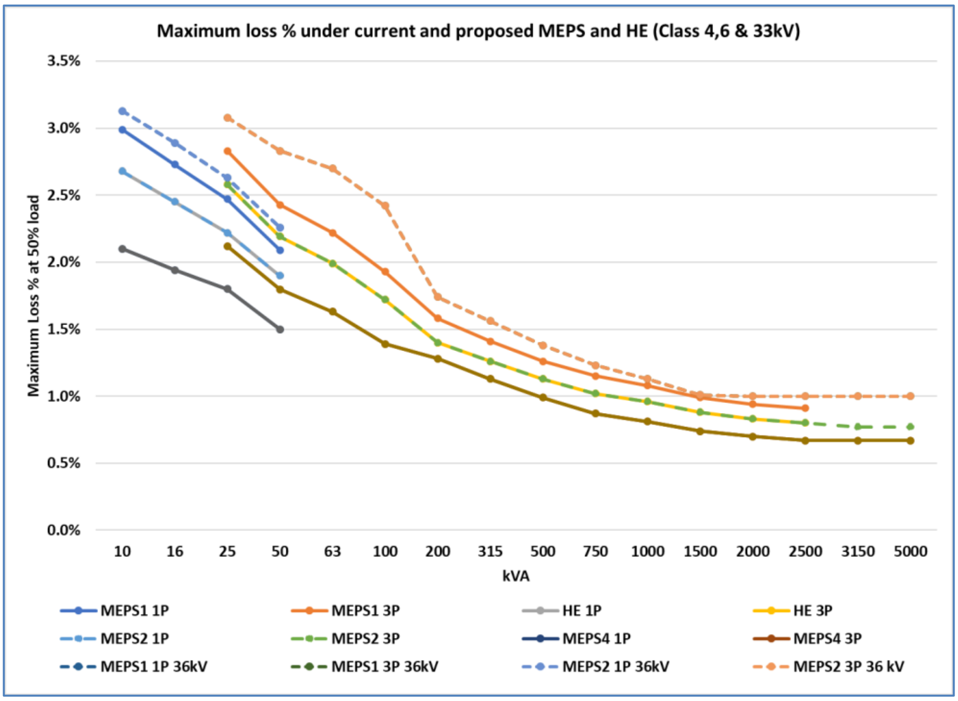


*Table 22 European Union Tier 2 Transformer Energy Efficiency Requirements applying from July 2021*

<table>
<tr><th>Rated power (kVA)</th><th>Liquid-immersed large power transformers Minimum Peak Efficiency Index %</th><th>Three-phase dry type power transformers with one winding $U_m$ <=24kV and the other one with $U_m$ <= 2.4 kV Maximum load loss $P_k$ (W) [a]</th><th>Three-phase dry type power transformers with one winding $U_m$ <=24kV and the other one with $U_m$ <= 2.4 kV Maximum no-load loss $P_0$ (W)</th></tr>
<tr><td><= 25</td><td>98.251</td><td rowspan="2">1,500</td><td rowspan="2">180</td></tr>
<tr><td>50</td><td>98.891</td></tr>
<tr><td>100</td><td>99.093</td><td>1,800</td><td>252</td></tr>
<tr><td>160</td><td>99.191</td><td>2,600</td><td>360</td></tr>
<tr><td>250</td><td>99.283</td><td>3,400</td><td>468</td></tr>
<tr><td>315</td><td>99.320</td><td>3,877 [b]</td><td>558 [b]</td></tr>
<tr><td>400</td><td>99.369</td><td>4,500</td><td>675</td></tr>
<tr><td>500</td><td>99.398</td><td>5,630 [b]</td><td>812 [b]</td></tr>
<tr><td>630</td><td>99.437</td><td>7,100</td><td>990</td></tr>
<tr><td>800</td><td>99.473</td><td>8,000</td><td>1,170</td></tr>
<tr><td>1000</td><td>99.484</td><td>9,000</td><td>1,395</td></tr>
<tr><td>1250</td><td>99.487</td><td>11,000</td><td>1,620</td></tr>
<tr><td>1600</td><td>99.494</td><td>13,000</td><td>1,980</td></tr>
<tr><td>2000</td><td>99.502</td><td>16,000</td><td>2,340</td></tr>
<tr><td>2500</td><td>99.514</td><td>19,000</td><td>2,790</td></tr>
<tr><td>3150</td><td>99.518</td><td>22,000</td><td>3,420</td></tr>
<tr><td>4000</td><td>99.532</td><td colspan="2">99.382 [c]</td></tr>
<tr><td>5000</td><td>99.548</td><td colspan="2">99.387 [c]</td></tr>
</table>

Source: EU (2019) a. $P_k$ is the measured load loss rate at rated current and rated frequency on the rated tap corrected to the reference temperature. b. Linearly interpolated values. c. Dry type transformers rated over 3150 kVA must meet these minimum Peak Efficiency Index levels, rather than maximum LL and NL losses.

# Appendix C – Cost/Benefit Modelling

## Modelling Approach

It is estimated that public networks account for about 80% of DTs, so it is necessary to assess how aggregate in-use efficiency and energy loss corresponds to rated values. For example, increasing the MEPS level for a given configuration of DT from say 99.10% to 99.25% would reduce the rated energy loss from 0.90% to 0.75%: a reduction in energy loss of (0.90-0.75)/0.9 = 16.6%. However, this presupposes that the in-use loading is always 50% of rated load, which will not be the case.

The Australian Energy Council (AEC) and its predecessors have published annual data on distribution network performance by state from 1988 to 2016.[31] These include:

a) Number of DNSP transformers in use, by category (33 kV, 22 kV, <= 11 kV and SWER);

b) Total rating (MVA) for each category (see Figure 7);

c) Energy entering distribution networks (GWh);

d) Energy sales from distribution networks (GWh);

e) Per cent of energy lost from distribution networks (see Figure 20);

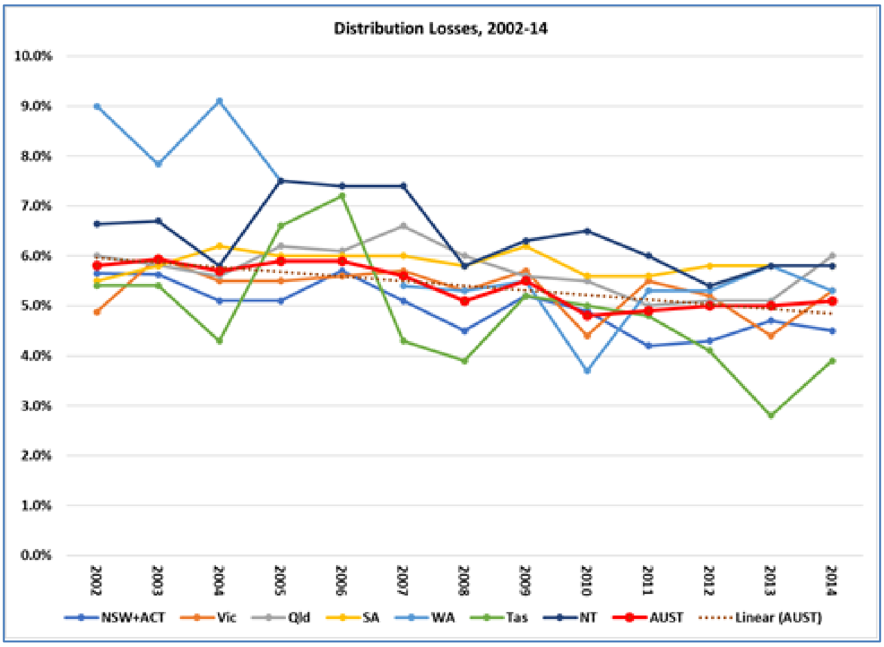
f) Distribution utilisation factors (annual energy throughput divided by the maximum throughput possible if the network were operating at full capacity for the entire year – see Figure 21).

It is projected that electricity consumption will increase due to both population growth and greater per-customer electricity use from electric vehicles and the electrification of end uses currently supplied by natural gas and other fuels, but the rate of change will depend on government policy (AEMO 2023). Some of the additional energy needed will be generated at or near the point of use (e.g. rooftop PV) but most will still need to be transmitted and distributed at high and medium voltage, even if sourced from large scale renewables.

The impact on distribution network DTs will be complex. At peak solar times the load on DTs will be lowered from current levels by local PV production, while at other times the draw on remote supply and storage will be higher. Therefore it is assumed that in aggregate the average loadings will remain as they are today. The total number of DTs in use will continue to increase with new greenfield developments (residential, commercial, manufacturing and mining) and the number sold each year will need to cover both this expansion and the number of DTs that need replacement at end of their service life. In Australia, the total number of DNSP DTs in use increased at 1.4% per annum between 2000 and 2014, while the total MVA increased at 3.8% per annum, indicating that average transformer capacity was growing at about 2.4% per annum.  The rate of increase in DT number in New Zealand was a modest 0.75% per annum (Figure 23) and consolidated data on average kVA is not available.

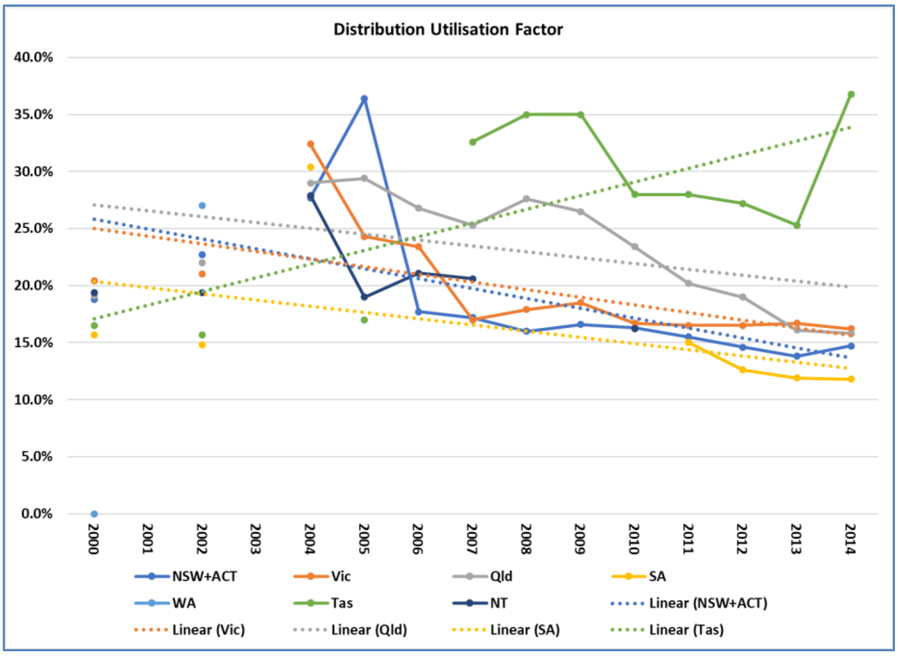
[31] The data were published in *Electricity Australia* and then *Electricity Gas Australia* (EGA) by the former Energy Supply Association of Australia (ESAA) and continued by its successor organisation, the Australian Energy Council (AEC) until 20215/16, when the series was discontinued. A further 6 years' data has been accessed since GWA (2022b) was prepared.

*Figure 20 Energy loss from distribution networks, Australia 2002-2014*



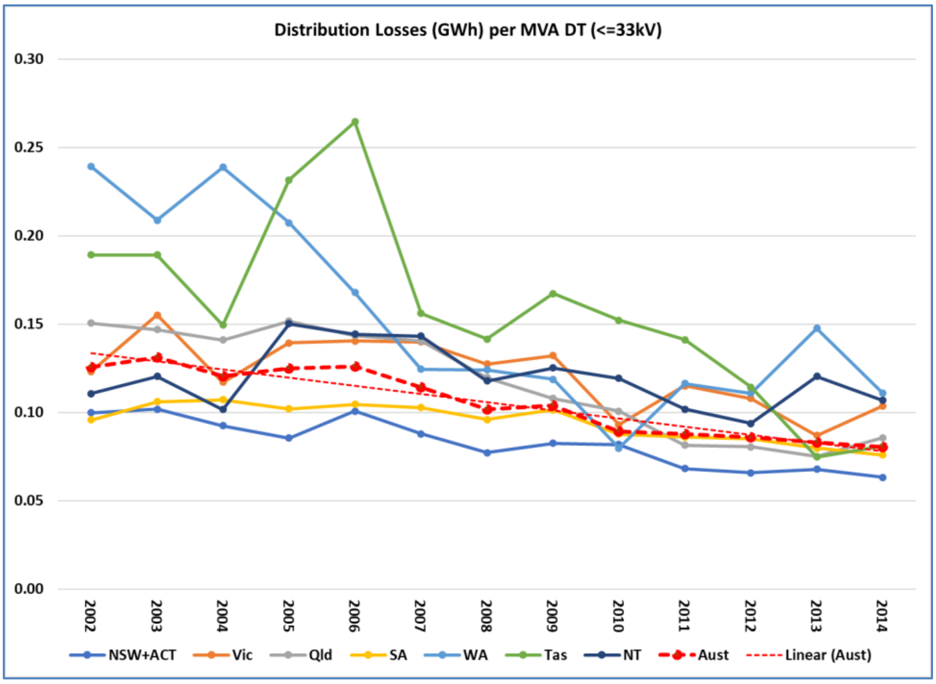

Source: Author analysis of AEC data

*Figure 21 Distribution utilisation factors by State, 2000-2014*



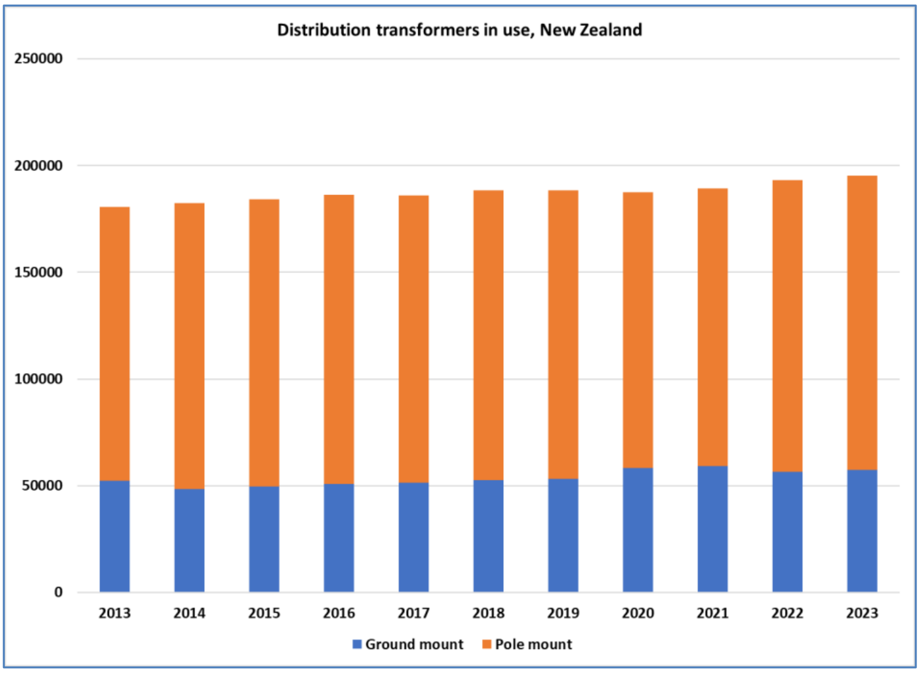

Source: Author analysis of AEC data

*Figure 22 Distribution losses per MVA of transformer capacity*




Source: Author analysis of AEC data

*Figure 23 Number of Distribution transformers in use, New Zealand 2013-2023*




Source: https://public.tableau.com/app/profile/commerce.commission/viz/Performanceaccessibilitytool-NewZealandelectricitydistributors-Dataandmetrics/Homepage

The state network utilisation factors reported by the AEC range from about 16% to 30%, indicating that the majority of DTs are lightly loaded for much of the time, and so operating below their rated efficiency. One DNSP reports an average loading of 29%.[32] EECA estimates that with existing DTs, efficiency peaks at 30% of rated load. It is possible that average loadings will increase with the growth of potentially time-concentrated loads, such as electric vehicle recharging. Alternatively, the increased distributed energy resources and demand response capable technologies may increase in the average loading of DTs more than the peak loading. This means the transformer capacity may not need to increase, but losses will still increase due to greater average loading.

There are different approaches to modelling these uncertainties:

- Estimate an average annual loading and average load curve for all DTs, based on assumptions about daily variations in load (e.g. a "bottom up" approach); or
- Estimate the total energy lost by DTs in use, and the reductions in loss that would be achieved by transition of the stock to higher rated efficiencies (e.g. a "top-down" approach).

The previous MEPS analyses (E3 2011, Deloitte 2014) used a form of bottom-up analysis. The present analysis made use of the AEC data set to develop a form of top-down analysis.

The total annual distribution system losses per MVA of transformer capacity, derived from the AEC data, is indicated in Figure 22. However, distribution losses comprise three main categories: line losses, transformer losses and unaccounted losses (mainly energy theft). The NSW DNSPs have published detailed loss breakdowns which indicate that transformer losses comprise 44-48% of distribution loss (Ausgrid 2022, Essential Energy 2021). Consequently, it has been assumed that for the more densely settled States 45% of distribution losses are incurred in transformers, and 40% for Qld, WA and NT, where line lengths per customer are greater. This assumption allows calculation of an annual in-use *transformer* energy loss per transformer MVA (i.e. either 40% or 45% of the value in Figure 22, depending on jurisdiction).

Rated efficiency and rated loss derived from market modelling need to be translated into actual efficiency and loss values. This is done for each jurisdiction by scaling the rated losses to the average GWh loss per MVA values reported by DNSPs, illustrated in Figure 22 (the averaged values for 2010-2014 are used). The resultant scaling factors are given in the last line of Table 23. For example, the actual energy loss of new DTs installed in NSW is estimated to be 32% of what it would be if they were all operating at 50% of rated load all the time. For WA it is 56%.

*Table 23 Derived scaling factors by jurisdiction*

| | NSW | Vic | Qld | SA | WA | Tas | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| GWh total distribution loss per DT MVA | 0.07 | 0.10 | 0.08 | 0.08 | 0.11 | 0.11 | 0.11 | 0.07 |
| Share distribution loss attributed to DT | 45% | 45% | 40% | 45% | 40% | 45% | 40% | 45% |
| Ratio of actual DT loss to rated loss | 0.32 | 0.41 | 0.35 | 0.43 | 0.56 | 0.41 | 0.46 | 0.28 |

Source: Author analysis of AEC data

[32] Personal correspondence (confidential).

Each jurisdiction is also allocated a different share of the new DTs entering the market each year, based on historical DNSP data in the case of oil filled types, and for dry-types an estimate of the share of national commercial building, data centre, mining and manufacturing applications (Table 24).

*Table 24 Annual share of the Australian market by jurisdiction, for main DT types*

| Type | NSW | Vic | Qld | SA | WA | Tas | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| SWER liquid-filled | 8.0% | 27.5% | 16.5% | 17.0% | 30.3% | 0.5% | 0.1% | 0.1% |
| <=11 kV liquid liquid-filled | 46.5% | 2.5% | 30.0% | 15.0% | 1.5% | 2.5% | 0.5% | 1.5% |
| 22 kV liquid-filled | 15.8% | 55.0% | 7.0% | 0.1% | 11.5% | 9.5% | 1.0% | 0.1% |
| 33 kV liquid-filled | 24.5% | 0.3% | 20.0% | 22.0% | 32.5% | 0.5% | 0.1% | 0.1% |
| Dry type | 27.0% | 22.5% | 20.0% | 5.0% | 15.0% | 5.0% | 5.0% | 0.5% |

Source: Liquid-filled: Author analysis of AEC data; Dry type estimated. Rows add to 100%.

## Model Structure

The model is structured so that numbers, efficiencies, costs and benefits for each of the DT categories in Table 25 can be separately calculated (although for simplicity results are presented as aggregations of categories). The breakdown into capacity groups (<1500 kVA, 1500-2000 kVA and > 2000 kVA) permits different cost impacts to be assessed, reflecting advice from industry that larger transformers would incur greater proportional price impacts (apart from material costs) because automation of production is more difficult and they are manufactured in more labour-intensive ways. The categories under consideration for scope expansion are also separately modelled.

Based on an analysis of the AEC data set, it is estimated that about 15,000 existing DTs (out of a national stock of about 767,000 in the categories in scope of GEMS) are replaced with new DTs each year, and another 11,000 added to accommodate growth and private DT purchases. This gives a national market of about 26,000 units in 20243, with a value of A$M 756. The Australian market is projected to grow at 2.0% to 2.5% per annum, depending on size category. Liquid-filled DTs account for about 82% of sales, and dry type for about 18%. It is estimated that expanding the scope would cover an extra 1,950 DT sales each year.[33]

For New Zealand, it is estimated that annual sales are in the range 5,000 – 7,000 units. For modelling purposes, it is estimated that the national market is 6,000 units in 2024, with a value of NZ$M 125. The market is projected to grow at 0.5% per annum. expanding the scope would cover an extra 400 DT sales each year (Table 25).

The model divides annual sales into three energy efficiency grades:

1. Models which meet or exceed MEPS1 but do not meet HE (MEPS2);
2. Models which meet or exceed MEPS2 but do not meet the MEPS4 level (EU Tier 2); and
3. Models which meet or exceed the MEPS4 level.

[33] This includes step-up transformers for utility-scale renewable generation and batteries. An average of about 270 wind turbines alone were installed annually in Australia between 2017 and 2021 (CEC 2021).

The E3 register indicates that most liquid-filled DT models exceed MEPS by a significant margin (i.e. are in EE grade 1), about 30% exceed HE (by a smaller margin) and none exceed the Max level. For dry type models, 14% are in EE grade 1, 55% in EE grade 2 and 32% in EE grade 3. The model-average MEPS level for each DT type and the average margin by which the actual reported values exceed the relevant efficiency for that grade are indicated in Table 26.

*Table 25 DT categories for modelling and estimated sales, 2022*

| GEMS Class | Voltage kV | Capacity kVA range | Description | Aust sales 2024 (est.) |
|---|---|---|---|---|
| 1 | 11 | A (<1500 kVA) | 1P oil filled | 4000 |
| 1 | 22 | A (<1500 kVA) | 1P oil filled | 2000 |
| 1 | 22 | SWER | SWER, oil filled <=22kV | 1500 |
| 2 | 11 | A (<1500 kVA) | 3P oil filled <11 kV | 6500 |
| 2 | 22 | A (<1500 kVA) | 3P oil filled 11-22 kV | 5000 |
| 2 | 11 | B (1500-2000) | 3P oil filled 11-22 kV | 750 |
| 2 | 22 | B (1500-2000) | 3P oil filled 11-22 kV | 500 |
| 2 | 11 | C (>2000-2500) | 3P oil filled 11-22 kV | 500 |
| 2 | 22 | C (>2000-2500) | 3P oil filled 11-22 kV | 500 |
| 5 | 11 | A (<1500 kVA) | 3P dry Um = 12 kV | 3000 |
| 5 | 11 | B (1500-2000) | 3P dry Um = 12 kV | 750 |
| 5 | 11 | C (>2000-2500) | 3P dry Um = 12 kV | 250 |
| 6 | 22 | A (<1500 kVA) | 3P dry Um = 24 kV | 500 |
| Added | 11 | D (>2500-5000 kVA) | 3P oil filled 11-22 kV | 300 |
| Added | 22 | D (>2500-5000 kVA) | 3P oil filled 11-22 kV | 300 |
| Added | 33 | A-C (<=2500 kVA) | 1P/SWER Oil filled 24-33 kV | 100 |
| Added | 33 | D (>2500-5000 kVA) | 1P/SWER Oil filled 24-33 kV | 200 |
| Added | 33 | A-C (<=2500 kVA) | 3P Oil filled 24-33 kV | 200 |
| Added | 33 | D (>2500-5000 kVA) | 3P Oil filled 24-33 kV | 350 |
| Added | 33 | A-C (<=2500 kVA) | 3P Dry 24-33 kV | 250 |
| Added | 33 | D (>2500-5000 kVA) | 3P Dry 24-33 kV | 250 |
| | | All in current scope | | 25,750 |
| | | All 33 kV types added to scope | | 1,350 |
| | | All <=22 kV additions to scope | | 600 |
| | | **Total** | | **27,700** |

Source: Author estimates based on AEC and confidential data. A detailed break down of data is not provided for New Zealand to maintain confidentiality requirements. E3 welcomes data from industry that can be considered as part of this consultation.

*Table 26 Registered distribution transformers by type and energy efficiency, 2024*

| | All models Number | All models Average MEPS (a) | EE Grade A (MEPS1) Number of models this group | EE Grade A (MEPS1) Average margin (a) | EE Grade B (MEPS2) Number of models this group | EE Grade B (MEPS2) Average margin (a) | EE grade C (MEPS4) Number of models this group | EE grade C (MEPS4) Margin (a) |
|---|---|---|---|---|---|---|---|---|
| All oil immersed | 261 | 0.9914 | 119 | 0.0007 | 142 | 0.0003 | 5 | 0.0006 |
| All Dry type | 16 | 0.9908 | 3 | 0.0006 | 0 | NA | 13 | 0.0007 |
| All | 277 | 0.9913 | 122 | 0.0007 | 142 | 0.0003 | 18 | 0.0007 |

Source: Author analysis of DTs registered on www.energyrating.gov.au April 2024 (a) Note values are decimalised, not percentages

It is projected that the average applicable MEPS level for each class of DTs will rise over time as a function of a projected rise in sales-weighted average kVA capacity. However, the actual efficiency continues to exceed the applicable MEPS level in most cases. Figure 24 illustrates the average margin by which liquid-filled DTs sold exceed MEPS1, and the projected margin by which they would exceed HE and EU Tier 2 if those were set as the statutory levels. It is assumed the margin in EE Grade 2 would temporarily narrow if HE became mandatory, because models which do not currently meet the HE level would have to achieve compliance, and would probably do so by as small a margin as possible. This would bring the average exceedance margin down.

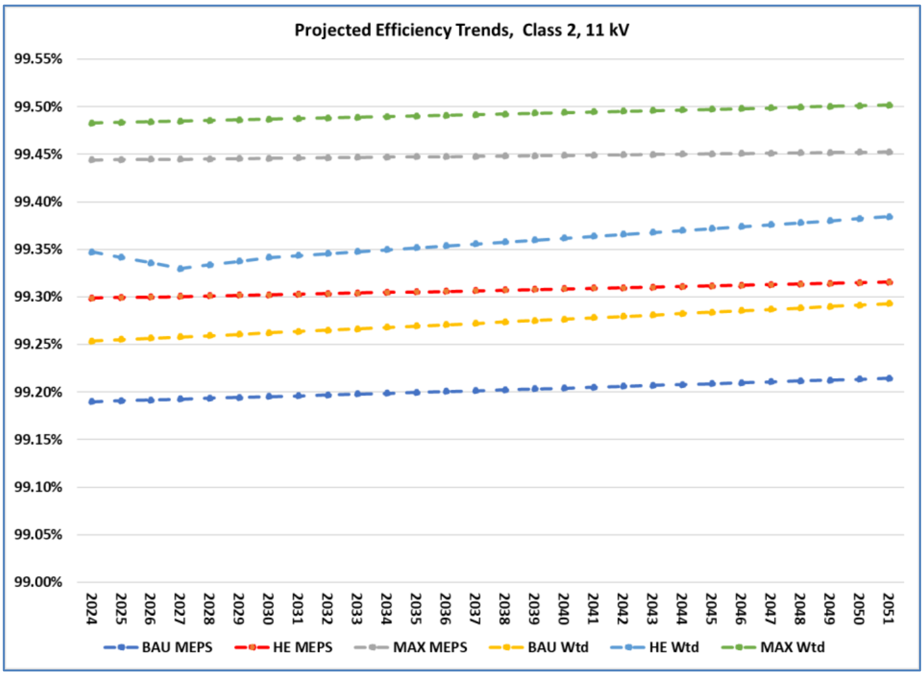
This is not the case for the most efficient category. There are very few EE Grade 3 models at present, and setting such a stringent benchmark would most likely mean that nearly the entire model range would need to be changed, and suppliers would have difficulty in meeting the MEPS level, let alone significantly exceeding it.

Figure 25 illustrates the projected market share of the three EE grades under BAU (when all three grades can be on the market), MEPS2 (when only HE and better can lawfully be sold) and Scenario 3 (when only the highest grade can be lawfully sold, whether MEPS3 or MEPS4). From this it is possible to project sales-weighted trends in rated efficiency) (Figure 26) and rated energy loss (Figure 27).

The model calculates the energy loss from the cohort of DTs entering the stock in every year from 2023 to 2050 (i.e. 28 years). Once a cohort of DTs enters the stock it is assumed that their energy losses remain constant throughout their service lives. This would not be the case if there were major changes in supply patterns and loadings but Figure 22 indicates that losses per MVA stabilised after about 2010. Expected growth in network throughput is accommodated by projecting an annual increase in both DNSP numbers and in average kVA. The model calibrates losses with the total MVA of each new DT cohort as well as its average efficiency, so as DT MVA in use increases so do losses, all else being equal. The energy saved by each MEPS scenario is then calculated by subtracting the aggregate DT losses from the DT losses in the BAU case, scaled up by a factor that captures the additional energy saved upstream in the generation and transmission process. Deloitte (2014,19) estimates this factor increases DT energy savings by 48%.

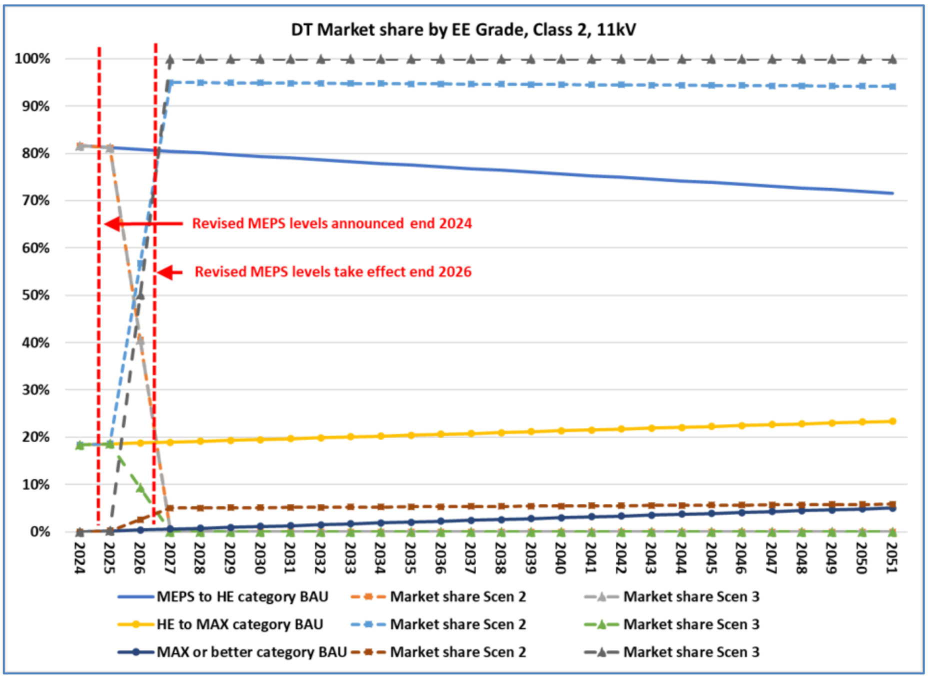
It is not necessary to model the losses from the entire DT stock, since there will be no change in the efficiency of DTs installed before the revised MEPS take effect. For modelling purposes, it is assumed that revised MEPS levels are announced at the end of 2024, and take legal effect at the end of 2026, i.e. a two-year lead time. The efficiency of DTs sold begins to increase in the year before implementation, since suppliers will need to progressively test, redesign and ensure that all models comply prior to that date.

*Figure 24 Projected rated energy efficiency, 11 kV liquid-filled transformers*



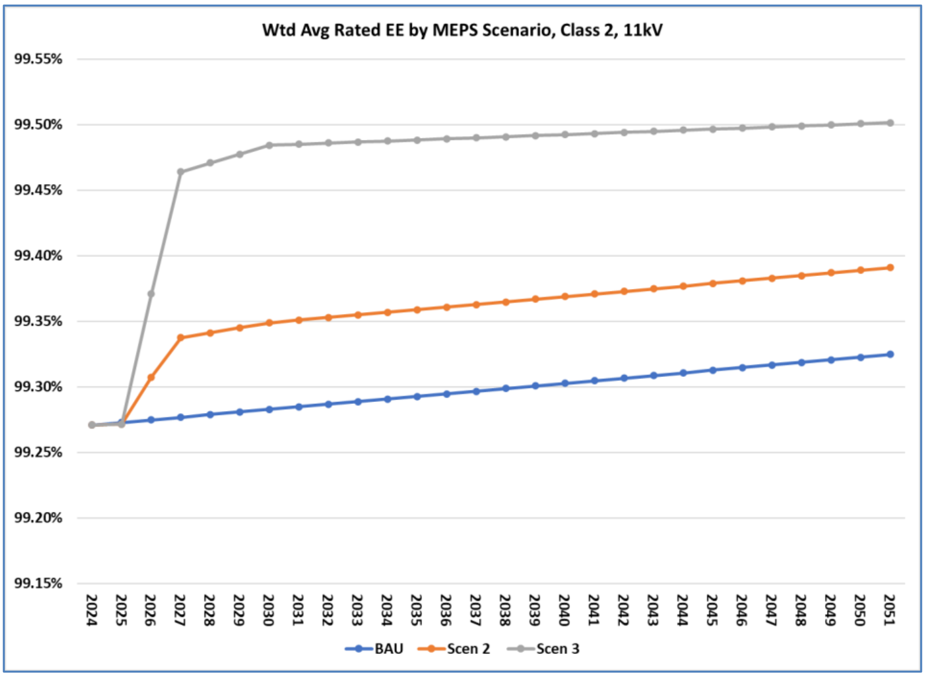

Note that scenario labels refer to model setting at the time, rather than to specific MEPS levels

*Figure 25 Projected market share by EE Grade, 11 kV liquid-filled transformers*



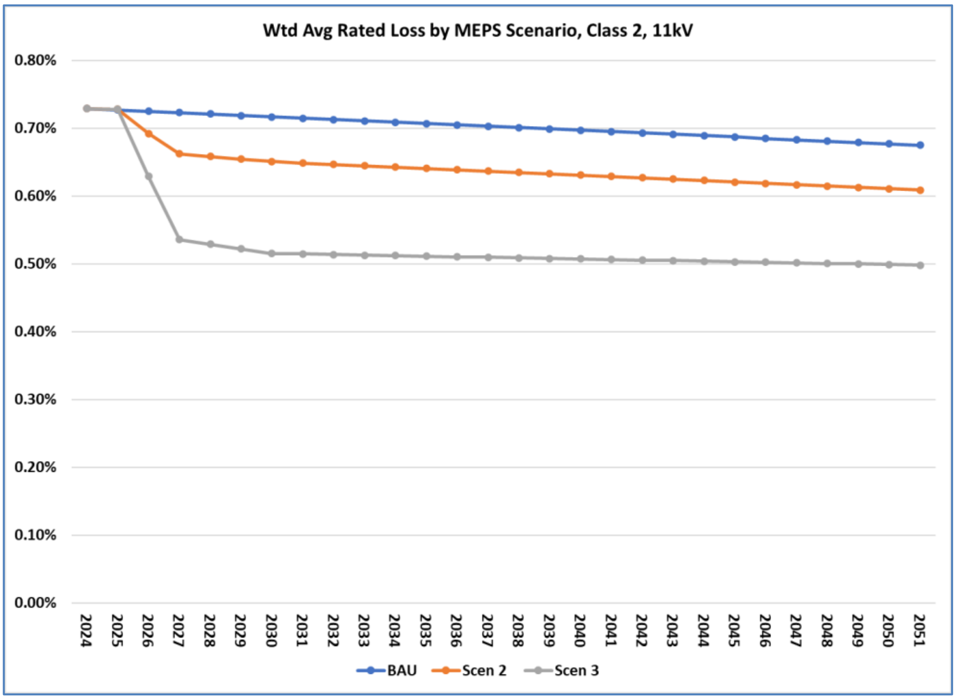

Note that scenario labels refer to model setting at the time, rather than to specific MEPS levels

*Figure 26 Weighted average rated efficiency by MEPS scenario, 11 kV liquid-filled transformers*




Note that scenario labels refer to model setting at the time, rather than to specific MEPS levels

*Figure 27 Weighted average rated loss by MEPS scenario, 11 kV liquid-filled transformers*



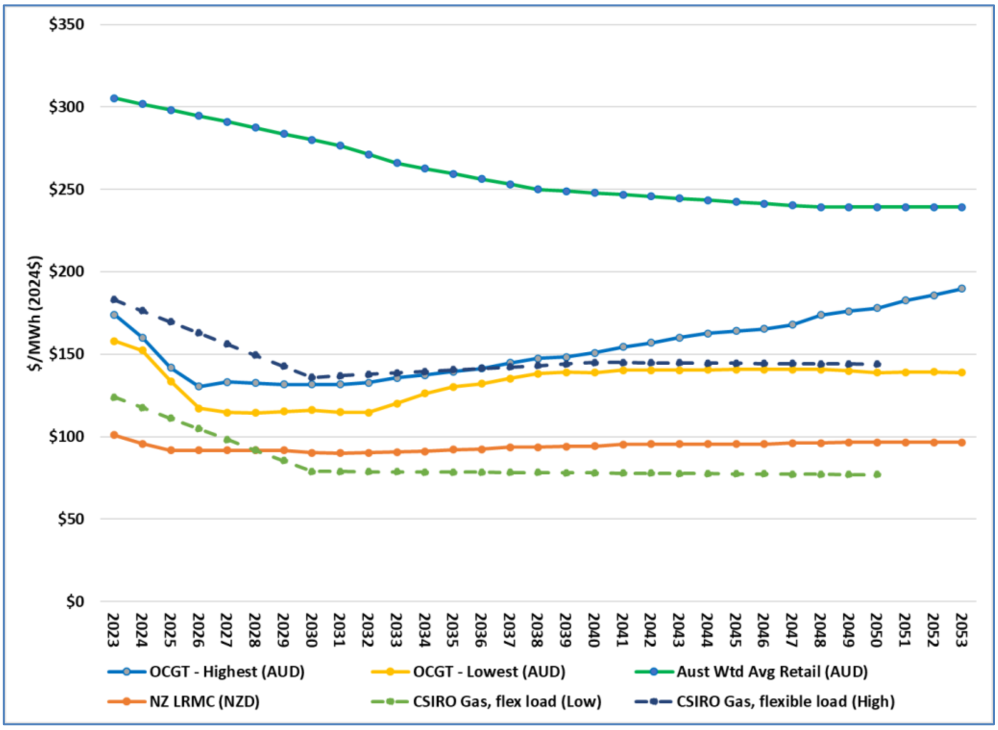

Note that scenario labels refer to model setting at the time, rather than to specific MEPS levels

## Input Parameters

The model calculates quantity of energy saved (GWh per year) from the application of any given MEPS level above the current BAU (MEPS1). For New Zealand, the value of electricity saved is calculated at the projected Long Run Marginal Cost (LRMC) of production, as advised by EECA. For Australia, the value of electricity saved can be calculated using either the cost of electricity to end users (the consumer price) or the price of marginal open cycle gas generation (OCGT) (Figure 28). The gas supply [price used to calculate the cost of OCGT generation in each State and Territory is indicated in Figure 29.

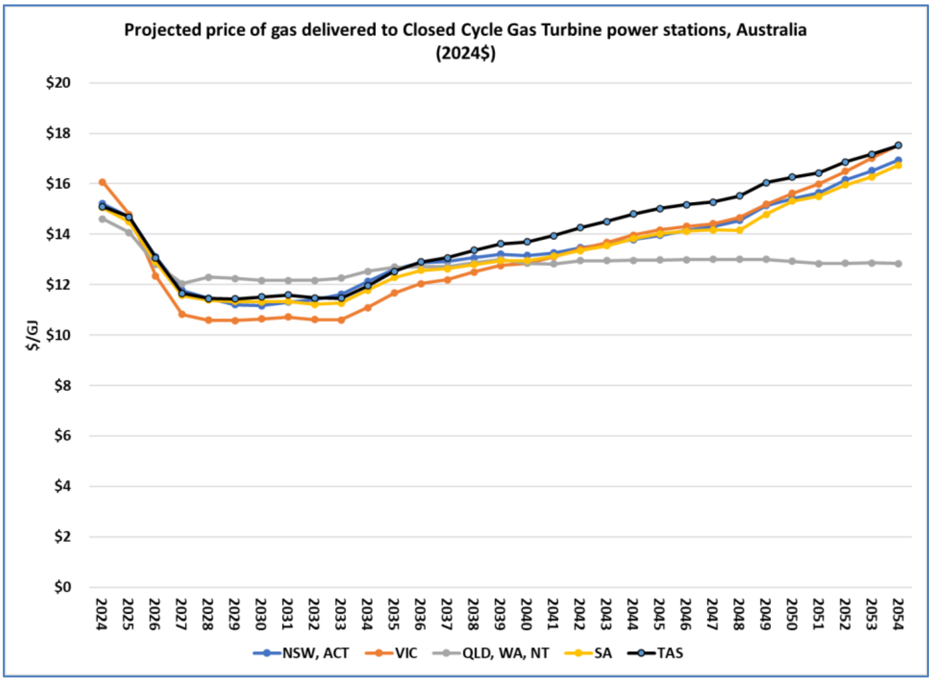
The emissions avoided can be calculated using either the average greenhouse-intensity of electricity supplied or intensity or the greenhouse-intensity of marginal OCGT generation. The values for these options are given in Figure 30. Once emissions savings are calculated it is possible to assign a value, as indicated in Figure 31.

*Figure 28 Projected electricity prices, Australia and New Zealand*



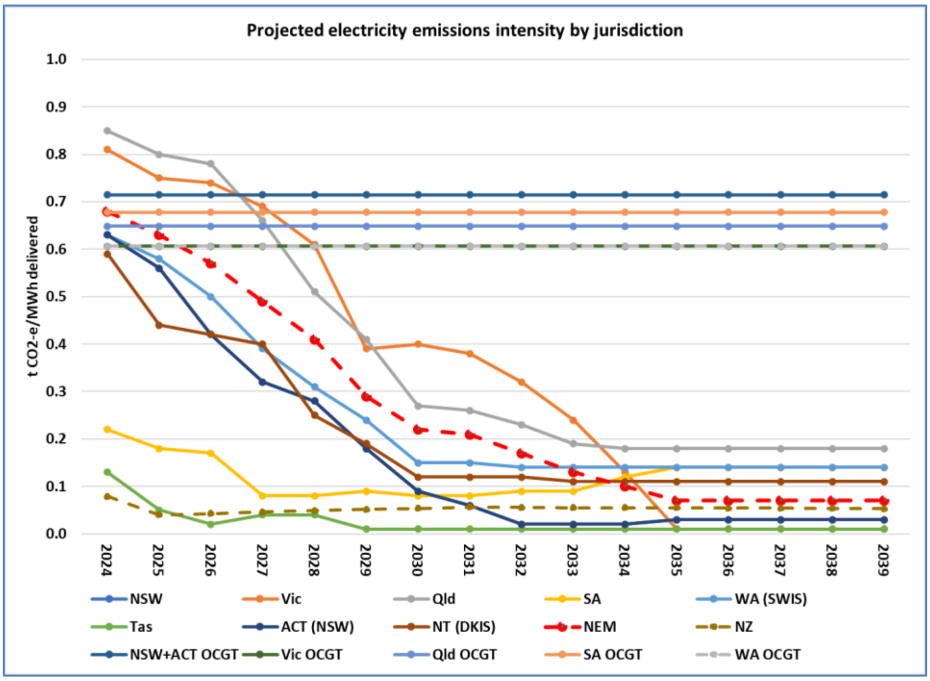

OCGT prices are calculated using gas prices in Figure 29.

*Figure 29 Indicative gas price projections, Australia*



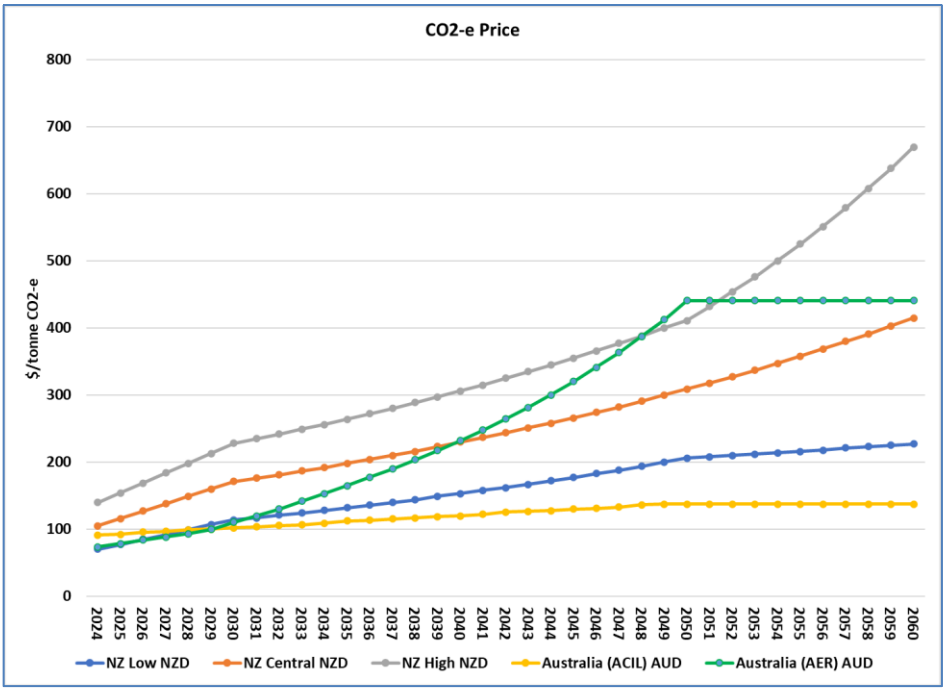

Source: Lewis Gray (2023)

*Figure 30 Projected greenhouse gas intensity of electricity delivered*




Source: DCCEEW (2023); NZ projection from EECA (personal communication, 2024)

*Figure 31 Projected value of CO2-e emissions avoided*




Source: NZ projections in constant NZ$ from EECA (personal communication, 2024). Aust Lower projections in constant A$ from ACIL Allen (2022); Aust Higher values taken from AEMC (2024).

## Outputs

The projected costs and benefits of the three MEPS options are summarised in Table 27 to Table 30 for Australia and Table 31 for New Zealand. Table 32 summarises the costs and benefit ratios in Table 27 to Table 30 for each State and Territory. For the preferred option (MEPS3) Victoria and Tasmania have the highest average B/C ratios (over 3.5) while the ACT has the lowest (1.8). The B/C ratios for the other jurisdictions are in the range 2.3 to 2.7.

*Table 27 Projected impacts of MEPS2, MEPS3 and MEPS4, Australia (Consumer energy and DT prices, Lower $CO_2$-e values)*

| | Energy value $M (a) | CO2-e value $M (a) | Demand value $M | Total value $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | GWh saving 2024-51 | kt $CO_2$-e saving 2024-51 | GWh/yr saving 2024-51 | GWh cf BAU | Derived P/E ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $795 | $30 | $77 | $902 | $395 | $0.3 | $395 | $507 | 2.28 | 11566 | 910 | 413 | -9.1% | 0.55 |
| MEPS2 added to scope | $114 | $6 | $14 | $135 | $129 | $0.3 | $129 | $5 | 1.04 | 1641 | 206 | 59 | -5.0% | 2.45 |
| MEPS2 total | $909 | $36 | $91 | $1,037 | $524 | $0.6 | $525 | $512 | 1.98 | 13208 | 1116 | 472 | -8.3% | |
| MEPS3 current scope | $1,662 | $64 | $159 | $1,885 | $790 | $0.5 | $790 | $1,095 | 2.39 | 23950 | 1915 | 855 | -18.9% | 0.65 |
| MEPS3 added to scope | $478 | $26 | $58 | $561 | $310 | $0.3 | $311 | $251 | 1.81 | 6642 | 206 | 237 | -20.4% | 0.97 |
| MEPS3 total | $2,139 | $90 | $217 | $2,447 | $1,100 | $0.8 | $1,101 | $1,346 | 2.22 | 30592 | 2121 | 1093 | -19.2% | |
| MEPS4 current scope | $2,455 | $95 | $234 | $2,783 | $1,231 | $0.5 | $1,231 | $1,552 | 2.26 | 35300 | 2812 | 1261 | -27.9% | 0.83 |
| MEPS4 added to scope | $567 | $31 | $69 | $667 | $559 | $0.3 | $559 | $108 | 1.19 | 7889 | 225 | 282 | -24.2% | 1.49 |
| MEPS4 total | $3,022 | $126 | $303 | $3,450 | $1,790 | $0.8 | $1,790 | $1,660 | 1.93 | 43189 | 3036 | 1542 | -27.1% | |

$M NPV at 7% discount rate, ACIL $CO_2$-e values (a) Average generation mix and $CO_2$-e intensity.

*Table 28 Projected impacts of MEPS2, MEPS3 and MEPS4, Australia (Consumer energy and DT prices, Higher $CO_2$-e values)*

| | Energy value $M (a) | CO2-e value $M (a) | Demand value $M | Total value $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | GWh saving 2024-51 | kt $CO_2$-e saving 2024-51 | GWh/yr saving 2024-51 | GWh cf BAU | Derived P/E ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $795 | $62 | $77 | $934 | $395 | $0.3 | $395 | $538 | 2.36 | 11566 | 910 | 413 | -9.1% | 0.55 |
| MEPS2 added to scope | $114 | $14 | $14 | $143 | $129 | $0.3 | $129 | $13 | 1.10 | 1641 | 206 | 59 | -5.0% | 2.45 |
| MEPS2 total | $909 | $76 | $91 | $1,076 | $524 | $0.6 | $525 | $552 | 2.05 | 13208 | 1116 | 472 | -8.3% | |
| MEPS3 current scope | $1,662 | $130 | $159 | $1,951 | $790 | $0.5 | $790 | $1,161 | 2.47 | 23950 | 1915 | 855 | -18.9% | 0.65 |
| MEPS3 added to scope | $478 | $57 | $58 | $593 | $310 | $0.3 | $311 | $282 | 1.91 | 6642 | 206 | 237 | -20.4% | 0.97 |
| MEPS3 total | $2,139 | $187 | $217 | $2,544 | $1,100 | $0.8 | $1,101 | $1,443 | 2.31 | 30592 | 2121 | 1093 | -19.2% | |
| MEPS4 current scope | $2,455 | $191 | $234 | $2,879 | $1,231 | $0.5 | $1,231 | $1,648 | 2.34 | 35300 | 2812 | 1261 | -27.9% | 0.83 |
| MEPS4 added to scope | $570 | $69 | $69 | $708 | $559 | $0.3 | $559 | $149 | 1.27 | 7889 | 225 | 282 | -24.2% | 1.49 |
| MEPS4 total | $3,025 | $259 | $303 | $3,587 | $1,790 | $0.8 | $1,790 | $1,797 | 2.00 | 43189 | 3036 | 1542 | -27.1% | |

$M NPV at 7% discount rate, AEMC $CO_2$-e values (a) Average generation mix and $CO_2$-e intensity.

*Table 29 Projected impacts of MEPS2, MEPS3 and MEPS4, Australia (Marginal generation and producer DT prices, lower $CO_2$-e values)*

| | Energy value $M (a) | CO2-e value $M (a) | Demand value $M | Total value $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | GWh saving 2024-51 | kt $CO_2$-e saving 2024-51 | GWh/yr saving 2024-51 | GWh cf BAU | Derived P/E ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $449 | $218 | $54 | $720 | $276 | $0.3 | $277 | $444 | 2.60 | 11566 | 7524 | 413 | -9.1% | 0.55 |
| MEPS2 added to scope | $64 | $31 | $10 | $105 | $90 | $0.3 | $91 | $14 | 1.16 | 1641 | 1069 | 59 | -5.0% | 2.45 |
| MEPS2 total | $513 | $249 | $64 | $825 | $367 | $0.6 | $367 | $458 | 2.25 | 13208 | 8593 | 472 | -8.3% | |
| MEPS3 current scope | $935 | $454 | $112 | $1,501 | $553 | $0.5 | $553 | $948 | 2.71 | 23950 | 15591 | 855 | -18.9% | 0.65 |
| MEPS3 added to scope | $263 | $130 | $40 | $433 | $217 | $0.3 | $218 | $216 | 1.99 | 6642 | 1069 | 237 | -20.4% | 0.97 |
| MEPS3 total | $1,199 | $584 | $152 | $1,935 | $770 | $0.8 | $771 | $1,164 | 2.51 | 30592 | 16660 | 1093 | -19.2% | |
| MEPS4 current scope | $1,381 | $670 | $164 | $2,215 | $862 | $0.5 | $862 | $1,353 | 2.57 | 35300 | 22964 | 1261 | -27.9% | 0.83 |
| MEPS4 added to scope | $313 | $154 | $48 | $515 | $391 | $0.3 | $391 | $123 | 1.32 | 7889 | 1164 | 282 | -24.2% | 1.49 |
| MEPS4 total | $1,694 | $824 | $212 | $2,730 | $1,253 | $0.8 | $1,254 | $1,476 | 2.18 | 43189 | 24128 | 1542 | -27.1% | |

$M NPV at 7% discount rate, ACIL $CO_2$-e values (a) Marginal generation from Open Cycle Gas Turbines.

*Table 30 Projected impacts of MEPS2, MEPS3 and MEPS4, Australia (Marginal generation and producer DT prices, higher $CO_2$-e values)*

| | Energy value $M (a) | CO2-e value $M (a) | Demand value $M | Total value $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | GWh saving 2024-51 | kt $CO_2$-e saving 2024-51 | GWh/yr saving 2024-51 | GWh cf BAU | Derived P/E ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $449 | $513 | $54 | $1,016 | $276 | $0.3 | $277 | $739 | 3.67 | 11566 | 7524 | 413 | -9.1% | 0.55 |
| MEPS2 added to scope | $64 | $73 | $10 | $147 | $90 | $0.3 | $91 | $56 | 1.62 | 1641 | 1069 | 59 | -5.0% | 2.45 |
| MEPS2 total | $513 | $586 | $64 | $1,162 | $367 | $0.6 | $367 | $795 | 3.16 | 13208 | 8593 | 472 | -8.3% | |
| MEPS3 current scope | $935 | $1,064 | $112 | $2,111 | $553 | $0.5 | $553 | $1,557 | 3.81 | 23950 | 15591 | 855 | -18.9% | 0.65 |
| MEPS3 added to scope | $263 | $295 | $40 | $599 | $217 | $0.3 | $218 | $382 | 2.75 | 6642 | 1069 | 237 | -20.4% | 0.97 |
| MEPS3 total | $1,199 | $1,359 | $152 | $2,710 | $770 | $0.8 | $771 | $1,939 | 3.52 | 30592 | 16660 | 1093 | -19.2% | |
| MEPS4 current scope | $1,381 | $1,567 | $164 | $3,112 | $862 | $0.5 | $862 | $2,249 | 3.61 | 35300 | 22964 | 1261 | -27.9% | 0.83 |
| MEPS4 added to scope | $313 | $351 | $48 | $712 | $391 | $0.3 | $391 | $320 | 1.82 | 7889 | 1164 | 282 | -24.2% | 1.49 |
| MEPS4 total | $1,694 | $1,918 | $212 | $3,823 | $1,253 | $0.8 | $1,254 | $2,570 | 3.05 | 43189 | 24128 | 1542 | -27.1% | |

$M NPV at 7% discount rate, AEMC $CO_2$-e values (a) Marginal generation from Open Cycle Gas Turbines.

*Table 31 Projected impacts of MEPS2, MEPS3 and MEPS4, New Zealand*

| | Energy value $M | CO2-e value $M | Demand value $M | Total value $M | Price Increase $M | Test & Admin $M | Total cost $M | Net Benefit $M | B/C ratio | GWh saving 2024-51 | kt $CO_2$-e saving 2024-51 | GWh/yr saving 2024-51 | GWh cf BAU | Derived P/E ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEPS2 current scope | $58.4 | $13.3 | $15.7 | $87.3 | $61.6 | $0.2 | $61.8 | $25.5 | 1.41 | 1640 | 139 | 59 | -4.7% | 0.50 |
| MEPS2 added to scope | $5.7 | $1.3 | $1.5 | $8.5 | $14.8 | $0.2 | $15.0 | -$6.5 | 0.57 | 157 | 13 | 6 | -5.3% | 2.20 |
| MEPS2 total | $64.1 | $14.6 | $17.2 | $95.9 | $76.4 | $0.4 | $76.8 | $19.1 | 1.25 | 1796 | 152 | 64 | -4.7% | |
| MEPS3 current scope | $187.7 | $42.8 | $50.4 | $280.9 | $118.9 | $0.3 | $119.2 | $161.7 | 2.36 | 5163 | 443 | 184 | -14.7% | 0.47 |
| MEPS3 added to scope | $19.0 | $4.3 | $5.1 | $28.5 | $35.6 | $0.2 | $35.7 | -$7.2 | 0.80 | 513 | 13 | 18 | -17.5% | 1.09 |
| MEPS3 total | $206.7 | $47.1 | $55.5 | $309.4 | $154.5 | $0.4 | $154.9 | $154.5 | 2.00 | 5676 | 456 | 203 | -14.9% | |
| MEPS4 current scope | $280.3 | $63.9 | $75.3 | $419.4 | $137.5 | $0.3 | $137.8 | $281.6 | 3.04 | 7697 | 661 | 275 | -22.0% | 0.36 |
| MEPS4 added to scope | $27.3 | $6.2 | $7.3 | $40.8 | $52.9 | $0.2 | $53.1 | -$12.3 | 0.77 | 735 | 16 | 26 | -25.0% | 1.22 |
| MEPS4 total | $307.6 | $70.1 | $82.6 | $460.3 | $190.4 | $0.4 | $190.9 | $269.4 | 2.41 | 8432 | 677 | 301 | -22.2% | |

$M NPV at 5% discount rate, EECA Central $CO_2$-e values

*Table 32 Benefit/Cost ratios, energy and $CO_2$-e savings by State and Territory*

| | | Retail, lower $CO_2$ price | | | Retail, higher $CO_2$ price | | | Producer, lower $CO_2$ price | | | Producer, higher $CO_2$ price | | | Average - all scenarios | | | Savings 2024-2051 Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Current | Expand | Total | Current | Expand | Total | Current | Expand | Total | Current | Expand | Total | Current | Expand | Total | GWh | GWh/yr | kt $CO_2$(a) | kt $CO_2$(b) |
| NSW | MEPS2 | 1.41 | 0.65 | 1.26 | 1.43 | 0.66 | 1.28 | 1.74 | 0.80 | 1.56 | 2.51 | 1.15 | 2.24 | 1.8 | 0.8 | 1.6 | 3657 | 118 | 113 | 2354 |
| | MEPS3 | 1.98 | 1.37 | 1.84 | 2.01 | 1.39 | 1.86 | 2.45 | 1.67 | 2.27 | 3.51 | 2.37 | 3.24 | 2.5 | 1.7 | 2.3 | 7913 | 235 | 226 | 4692 |
| | MEPS4 | 1.86 | 0.90 | 1.61 | 1.89 | 0.91 | 1.64 | 2.30 | 1.10 | 1.99 | 3.30 | 1.56 | 2.84 | 2.3 | 1.1 | 2.0 | 11206 | 343 | 332 | 6865 |
| VIC | MEPS2 | 2.15 | 0.99 | 2.15 | 2.17 | 1.00 | 2.17 | 2.48 | 1.14 | 2.48 | 3.46 | 1.58 | 3.45 | 2.6 | 1.2 | 2.6 | 3782 | 135 | 149 | 2289 |
| | MEPS3 | 2.91 | 2.09 | 2.91 | 2.94 | 2.11 | 2.93 | 3.34 | 2.37 | 3.34 | 4.65 | 3.25 | 4.64 | 3.5 | 2.5 | 3.5 | 7248 | 258 | 293 | 4380 |
| | MEPS4 | 2.81 | 1.38 | 2.80 | 2.84 | 1.39 | 2.83 | 3.23 | 1.56 | 3.22 | 4.48 | 2.15 | 4.47 | 3.3 | 1.6 | 3.3 | 10881 | 388 | 445 | 6580 |
| QLD | MEPS2 | 1.71 | 0.84 | 1.51 | 1.84 | 0.91 | 1.63 | 1.94 | 0.96 | 1.71 | 2.64 | 1.30 | 2.33 | 2.0 | 1.0 | 1.8 | 2476 | 77 | 407 | 1398 |
| | MEPS3 | 2.43 | 1.77 | 2.24 | 2.62 | 1.90 | 2.42 | 2.75 | 1.99 | 2.54 | 3.73 | 2.67 | 3.44 | 2.9 | 2.1 | 2.7 | 5532 | 155 | 821 | 2817 |
| | MEPS4 | 2.27 | 1.17 | 1.93 | 2.45 | 1.25 | 2.08 | 2.58 | 1.31 | 2.19 | 3.49 | 1.76 | 2.96 | 2.7 | 1.4 | 2.3 | 7737 | 226 | 1196 | 4102 |
| SA | MEPS2 | 1.72 | 0.78 | 1.29 | 1.84 | 0.84 | 1.38 | 2.00 | 0.91 | 1.50 | 2.87 | 1.30 | 2.15 | 2.1 | 1.0 | 1.6 | 1393 | 36 | 137 | 683 |
| | MEPS3 | 2.28 | 1.64 | 1.95 | 2.45 | 1.75 | 2.09 | 2.65 | 1.89 | 2.25 | 3.79 | 2.67 | 3.21 | 2.8 | 2.0 | 2.4 | 3330 | 68 | 257 | 1286 |
| | MEPS4 | 2.18 | 1.08 | 1.57 | 2.34 | 1.16 | 1.68 | 2.53 | 1.25 | 1.82 | 3.62 | 1.76 | 2.58 | 2.7 | 1.3 | 1.9 | 4521 | 101 | 382 | 1911 |
| WA | MEPS2 | 1.53 | 1.08 | 1.29 | 1.63 | 1.15 | 1.37 | 1.73 | 1.22 | 1.46 | 2.34 | 1.65 | 1.97 | 1.8 | 1.3 | 1.5 | 1554 | 31 | 122 | 519 |
| | MEPS3 | 2.28 | 2.28 | 2.28 | 2.42 | 2.41 | 2.42 | 2.57 | 2.55 | 2.56 | 3.46 | 3.40 | 3.43 | 2.7 | 2.7 | 2.7 | 4400 | 64 | 259 | 1095 |
| | MEPS4 | 2.12 | 1.50 | 1.73 | 2.26 | 1.59 | 1.84 | 2.39 | 1.68 | 1.94 | 3.22 | 2.24 | 2.61 | 2.5 | 1.8 | 2.0 | 5699 | 94 | 375 | 1588 |
| TAS | MEPS2 | 2.26 | 1.00 | 2.22 | 2.27 | 1.00 | 2.23 | 2.79 | 1.23 | 2.74 | 3.79 | 1.67 | 3.73 | 2.8 | 1.2 | 2.7 | 823 | 29 | 8 | 492 |
| | MEPS3 | 3.07 | 2.10 | 3.03 | 3.09 | 2.11 | 3.05 | 3.78 | 2.56 | 3.74 | 5.13 | 3.43 | 5.06 | 3.8 | 2.5 | 3.7 | 1606 | 56 | 16 | 949 |
| | MEPS4 | 2.95 | 1.38 | 2.88 | 2.96 | 1.39 | 2.90 | 3.63 | 1.69 | 3.55 | 4.92 | 2.26 | 4.80 | 3.6 | 1.7 | 3.5 | 2387 | 84 | 24 | 1418 |
| NT | MEPS2 | 1.10 | 1.05 | 1.10 | 1.17 | 1.12 | 1.16 | 1.23 | 1.18 | 1.23 | 1.78 | 1.70 | 1.78 | 1.3 | 1.3 | 1.3 | 122 | 4 | 13 | 77 |
| | MEPS3 | 1.97 | 2.22 | 1.97 | 2.08 | 2.35 | 2.09 | 2.20 | 2.47 | 2.20 | 3.16 | 3.50 | 3.17 | 2.4 | 2.6 | 2.4 | 308 | 11 | 34 | 194 |
| | MEPS4 | 1.73 | 1.47 | 1.72 | 1.83 | 1.55 | 1.82 | 1.93 | 1.63 | 1.92 | 2.78 | 2.31 | 2.76 | 2.1 | 1.7 | 2.1 | 421 | 15 | 46 | 266 |
| ACT | MEPS2 | 0.72 | 0.62 | 0.72 | 0.73 | 0.63 | 0.73 | 0.89 | 0.76 | 0.88 | 1.30 | 1.10 | 1.29 | 0.9 | 0.8 | 0.9 | 92 | 3 | 3 | 64 |
| | MEPS3 | 1.42 | 1.30 | 1.42 | 1.44 | 1.32 | 1.44 | 1.74 | 1.58 | 1.74 | 2.53 | 2.27 | 2.52 | 1.8 | 1.6 | 1.8 | 255 | 9 | 9 | 178 |
| | MEPS4 | 1.21 | 0.86 | 1.20 | 1.23 | 0.87 | 1.22 | 1.48 | 1.05 | 1.47 | 2.15 | 1.50 | 2.13 | 1.5 | 1.1 | 1.5 | 336 | 12 | 11 | 236 |

(a) Calculated with projected average tonnes $CO_2$/GWh sent out. (b) Calculated with projected marginal tonnes $CO_2$/GWh sent out (based on open cycle gas turbine).