EQUIPMENT ENERGY EFFICIENCY PROGRAM

CONSULTATION REGULATORY IMPACT STATEMENT

Review of Minimum Energy Performance Standards for Distribution Transformers

Prepared for the Equipment Energy Efficiency Program

May 2011

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

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www.energyrating.gov.au

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Executive Summary

Background

Transformers are devices that change the voltage between the different stages of electricity generation, transmission, distribution and consumption. Distribution transformers are those that step voltage down for ultimate consumption in the electrical equipment of end users. Most distribution transformers are embedded in the distribution network, but many are also used by large consumers in commerce, industry, mining and renewable energy generation such as wind power.

There are many hundreds of thousands of distribution transformers in Australia and New Zealand; they are a significant source of energy loss and corresponding greenhouse gas emissions. In Australia and New Zealand, losses in distribution transformers comprise some 1.36% of total generation. In 2007, distribution transformers contributed about 2,980 GWh of electrical loss in Australia and 575 GWh in New Zealand.

An Australian Standard (AS2374.1.2) specifying Minimum Energy Performance Standard (MEPS) requirements for distribution transformers was issued in October 2004 and has been mandated as part of the Equipment Energy Efficiency (E3) program. All new distribution transformers that fall within the scope of the standard and sold in Australia or New Zealand are required to comply with these minimum efficiency (MEPS1) levels. The Standard also specifies voluntary high efficiency levels.

The MEPS 2004 standard foreshadowed a review after four years to determine whether further improvement was achievable. An initial technical report was released in December 2007 reviewing domestic and international developments. This report proposed a higher efficiency standard, referred to as MEPS2 in this report. It was prepared by the Equipment Energy Efficiency Committee (E3 Committee) under the Ministerial Council on Energy (MCE) on behalf of the Australian, state and territory governments and the New Zealand Government. Electrical supply and local transformer manufacturing industries and importers were consulted on the proposal between 2007 and 2009. This Regulatory Impact Statement (RIS) addresses the resulting proposal.

Objective

The objective of this proposal is to contribute to meeting emission reduction targets by reducing electricity losses in newly installed distribution transformers in Australia and New Zealand.

This Regulatory Impact Statement (RIS) examines the proposal to raise the efficiency of new distribution transformers installed in Australia and New Zealand for use in public electricity supply systems as well as in the industrial, mining and commercial sectors. The aim is to reduce transformer energy losses to below the business as usual (BAU) case while ensuring that savings exceed costs and quality and reliability of supply are not compromised.

The Problem

Introduced in 2004, MEPS1 for distribution transformers was estimated to generate greenhouse gas emission savings over a 30 year projection period of 65 Mt CO_2-e in total. In light of the currently available technology the original targets were not challenging and there is now room for further cost-effective improvement. Market failures hinder the use of more efficient technology available and these failures, left unaddressed, will incur greater costs as consumption and losses grow.

Market Failures and Future Developments

SPLIT INCENTIVES IN THE DISTRIBUTION SECTOR

Electricity markets in both Australia and New Zealand have separated out the businesses of investing in and maintaining distribution wires (distribution) from the wholesale purchase and sale of electricity to consumers (retailing). Retailers pay a fee for the use of the wires to deliver energy to their customers and retailers also pay for all the losses incurred. Distributors bear no costs for losses and are therefore not motivated to choose transformers that optimise losses; their prime focus is cost and reliability. The New Zealand EECA in direct correspondence has advised similar disincentives.

Power distribution networks in Australia are regulated by the Australian Energy Regulator (AER). The AER has recently considered regulating for incentives to optimise losses at the investment stage. After consultation the AER decided against such an approach for want of evidence of a significant departure from optimality at present. This assessment is probably correct for the time being. Until about ten years ago, transformer selection was optimised for losses in public sector utilities. There is some anecdotal evidence that commercial pressures in the corporatised and privatised distribution businesses are starting to drive efficiency levels down through increased use of low efficiency imported equipment. The current impact of this trend is small but the cumulative effect will be apparent in future.

OTHER MARKET FAILURES

In commercial buildings, the separation between the investor/builder who makes the transformer purchasing decision and the ultimate user can be a barrier to achieving an optimal level of efficiency. In industry and mining risk is a factor that biases decisions in favour of low capital cost and low efficiency. Also relevant are existing contracts for supplying equipment, products already held in storage as spares and consulting engineers who use previous design specifications. Decisions based on these criteria can be rational from the perspective of the individual decision-maker but may incur higher societal costs as circumstances change.

FUTURE DEVELOPMENTS

Although appropriate policy measures in some cases have been controversial, there is agreement in Australia and New Zealand that greenhouse gas emissions need to be reduced. Current government policy in both Australia and New Zealand is that a carbon price should be the centrepiece of such a policy. However, given the significant market failures previously described and the long lives of most transformer equipment, there is merit in supplementing a carbon price with direct measures to correct market failures and also to ameliorate the price impact of achieving a specific reduction target. MEPS2 is such a measure.

While greenhouse gas reduction policy is the most significant new development since the original standard was introduced, other factors likely to support an improvement in the efficiency standard include rapidly increasing energy and network costs due to other, non-greenhouse factors and the accelerating growth of losses associated with the use of electronic equipment.

Options Considered

The BAU case is a continuation of the current MEPS which includes a voluntary component (to a higher standard). This would operate in an environment of some uncertainty for emissions trading and pricing, network costs and the development of non-linear loads and associated loss increases.

The preferred and only alternative proposal examined is for the mandatory efficiency levels in Australian Standard AS2374 to be increased to values previously referred to as high efficiency levels, adjusted to take account of industry concerns. Further, the scope would be expanded to include transformers up to 3150kVA and system maximum voltage levels up to 36kV. Transformers used in private commerce, industry and mining as well as some relatively small generation equipment such as in wind farms are included. This RIS will refer to all these generically as distribution transformers. The draft standard also includes the requirement for distribution transformers to be marked as MEPS compliant, using a marking system defined in the proposed standard.

The proposed new standard, MEPS2, would take effect no earlier than 1 October 2011. It would cover distribution transformers sold in the Australia and New Zealand, regardless of whether they are manufactured domestically or overseas.

The expected result would be a steady improvement in the average efficiency of the population of distribution transformers over time as new equipment is installed in green-field sites and as new, higher efficiency transformers replace older units at the end of their useful lives. The proposal reflects international developments while taking account of domestic industry issues.

Energy and Emission Reduction from the Preferred Proposal

For the period 2010–2039 and assuming that electricity consumption increases at about 2.5% each year, cumulative energy savings from this proposal are estimated at 10,200 GWh for Australia and 2,000 GWh for New Zealand. To put these quantities into perspective, the average losses for a new transformer would be about 11% less than the losses under the old standard. For Australia, this loss reduction represents the output from a 40 MW generator over the whole 30 year period. The savings do ramp up over time, so they begin very low but in 2039 are equivalent to about 80 MW.

The electrical energy saved is equivalent to approximately 9.4 million tonnes CO_2-e in Australia and 1.8 million tonnes CO_2-e in New Zealand.

Compared with initiatives to improve the energy efficiency of consumer equipment, these projected energy and emission reductions are modest. For example, the December 2009 RIS for phasing out greenhouse-intensive water heaters in Australian homes estimates the loss reductions to be 50-100 million tonnes CO_2-e, depending on the strategy adopted. The reason is that distribution transformers are already highly efficient and the increment of efficiency improvement that is readily achievable is small. In contrast, consumer equipment, including domestic water heaters, can offer much greater scope for efficiency improvement.

Cost-Benefit Analysis

The costs associated with the proposal are primarily the increased capital cost of the higher efficiency transformers. A smaller cost is the incremental cost to both governments and industry of administering and complying with MEPS2, over and above costs for MEPS1.

Very little hard information is available on the incremental costs of increasing transformer efficiency under the proposed changes. Estimates for the increases in transformer costs were made from commercial-in-confidence information provided in discussions with industry.

The benefits flowing from MEPS2 would be the long run value of the reduction in losses in distribution transformers. The associated reduction in CO_2 emissions is a component of that value that can be separately evaluated. A profile of values of CO_2 reduction from Treasury modelling was used to make this estimate.

A cost of $114/MWh was used to evaluate the benefit of reducing losses, excluding the benefit of CO_2 reduction. This cost is based on recent Independent Pricing and Regulatory Tribunal of NSW (IPART) determinations of the long run marginal cost of supply (LRMC) in NSW to the point where distribution transformers operate. The same figure was applied across Australia. This figure is also representative of the LRMC of supply to private transformers used in industry, commerce, mining and renewable generation businesses. Note that it is not appropriate to use retail tariffs to evaluate energy savings from equipment embedded in the distribution network.

An equivalent figure was also used for the New Zealand cost-benefit analysis (converted at an exchange rate of A$1 = NZ$1.18). An examination of recent retail prices suggested little real difference in retail pricing between the countries.

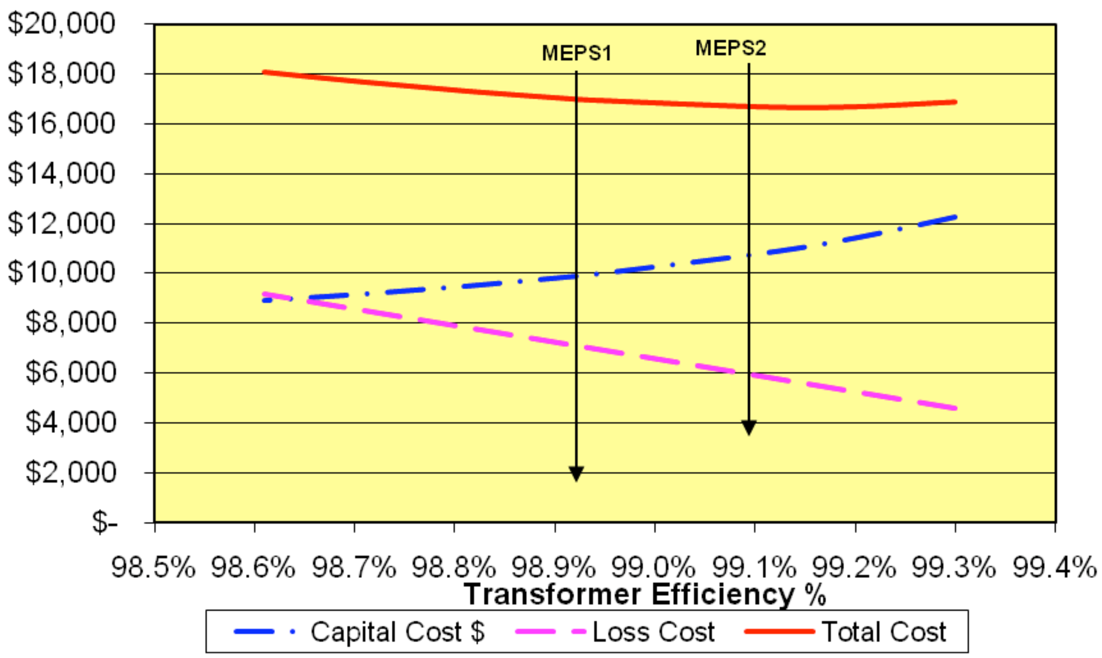
An analysis of the incremental costs and benefits of MEPS2 for a single transformer type and size, but ignoring greenhouse gas reduction benefits, shows that the cost curve (capital plus capitalised cost of losses) tends to favour a move from MEPS1 to the MEPS2 standard, provided business and governments overheads associated with the scheme are not too large. The total cost curve and its components are displayed below. The total cost is the top solid curve.

A system-wide analysis is required to take account of the overheads of the program and the timing of the transformer replacement process. The energy and CO_2 reduction totals, net present values (NPVs) and benefit/cost ratios for the transformer installations required across Australia and New Zealand between 2010 and 2039 are summarised in the following table. NPVs were calculated at a discount rate of 8%. The complete table is in the text.

Benefit/Cost Summary of Moving MEPS1 to MEPS2: 2010-39: Australia

	Units	Value
MEPS1 to MEPS2 Benefits		
MEPS1 Energy Losses	GWh	90,108
MEPS2 Energy Losses	GWh	79,911
Reduction in Energy Losses	GWh	10,197
Value of Loss Reduction	$M	277
Reduction in CO_2 Emissions	Mt CO_2-e	9.43
Value of CO_2 Reduction	$M	118
Total Annual Benefits without CO_2	$M	277
Total Annual Benefits with CO_2	$M	396
MEPS1 to MEPS2 Costs		
Incremental Cap Cost Annualised	$M	229
Annual Government Costs	$M	1.7
Annual Business Costs	$M	0.3
Total Annual Costs	$M	231
Benefit/Cost Ratios		
Benefit/cost without CO_2		1.20
Benefit/cost with CO_2		1.71

Indicative Incremental Cost Curves for Transformer Efficiency Improvement

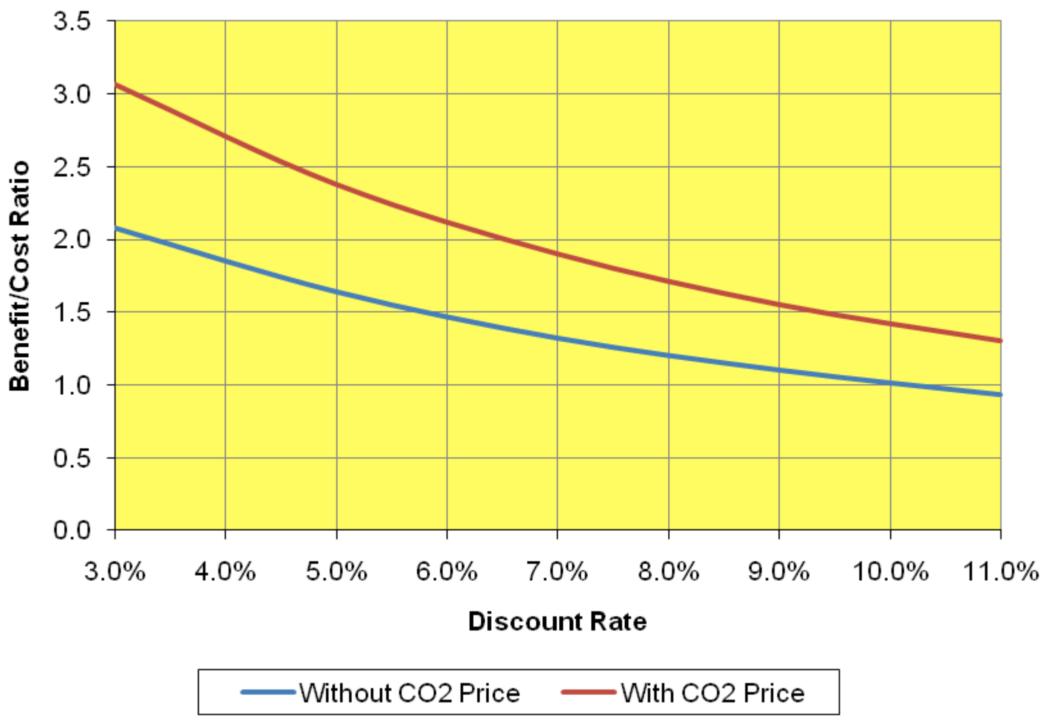


New Zealand costs and benefits were pro-rated from the Australian values according to the estimates made of the relative losses in the systems. Implementing the proposed MEPS in New Zealand is estimated to save about 2,000 GWh over a period 2010-2039. This is over and above the amount delivered by the current MEPS and is roughly equivalent to about 1.83 million tonnes of CO_2. Please refer to the EECA discussion document 'Proposed Revised Minimum Energy Performance Standards for Distribution Transformers" December 2010 for NZ cost-benefit analysis.

Following are some key observations from this analysis:

- The bulk of the increased costs from the proposal lie in the increased cost of transformers, which dominates other business and government costs. This additional cost is largely due to the increased cost of materials. It follows that a single transformer analysis effectively determines the benefit/cost outcome of the proposal.
- In the absence of a carbon price, there is a case for improving distribution transformer efficiency (a benefit/cost ratio of 1.2). However, given the uncertainties in cost estimates that case is not compelling, despite some anecdotal evidence that efficiency standards under MEPS1 may be lagging past practice. With a carbon price taken into account the benefit/cost ratio of 1.7 indicates a much more robust case for the proposal.
- Because benefits are dominated by value of emission reduction and costs are likely to be dominated by the cost of additional materials used in transformer manufacture (typically aluminium and copper), the ratio of emission price to materials price is an important determinant of the robustness of this analysis. While both are uncertain going forward, carbon price increases look to be longer term, supporting the case for the proposal.
- The analysis has not explicitly taken into account the additional losses that will occur as electronic equipment penetrates yet more into end use equipment. While difficult to estimate, this effect could improve the benefit/cost ratio over time by the order of 10%.
- As indicated in the following chart, the above conclusions are robust against changes in discount rate except for the higher discount rates without a carbon price factored in. The chart shows benefit/cost ratios for the key discount rates of 8% and 8.82%.
- The benefits of improved transformer efficiency under MEPS2 are unlikely to be realised in the electricity distribution sector even with a carbon price due to a lack of incentives for energy efficiency in the current electricity industry business arrangements and associated regulations. Most transformers now in service were installed by public utilities using engineering optimisation practices. Current disincentives are a relatively recent negative by-product of the electricity reforms that have been in place for about 10 years.

Benefit/Cost Discount Rate Sensitivity: 2010-2039: Australia & New Zealand



Industry Support

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. A particular concern was that local manufacturers could be placed at a competitive disadvantage and the intent of MEPS2 undermined through the import of low efficiency units. This issue and compliance strategies will be the subject of consultations with industry. They are also being considered in the current development of national legislation.

The proposed standard is consistent with international best practice and should provide a strong incentive for both local and overseas manufacturers to improve designs to increase efficiency.

Recommendations

It is recommended that the Ministerial Council on Energy agree:

1. *To implement increased minimum energy performance standards for distribution transformers by regulation.*
2. *That distribution transformers must meet or surpass the energy performance requirements set down in the draft Australian and New Zealand Standard AS/NZS 60076.99:200X, Minimum Energy Performance Standard (MEPS) requirements for distribution transformers as shown at Appendix A3.*
3. *That the new efficiency levels apply to all transformers currently within the scope of AS2374.1.2, to those included through modification of the list of exclusions as detailed in this RIS and to those added in the scope of the new Standard This transformer MEPS is to cover oil-immersed and dry type distribution transformers with power ratings from 10 kVA to 3150 kVA intended to be used on 11 kV, 22 kV and 33 kV networks.*
4. *That the amendments take effect no earlier than 1 October 2011.*
5. *That all jurisdictions take the necessary administrative actions to ensure that the new regulation levels can take effect no earlier than 1 October 2011.*
6. *That overseas manufacturers be provided with the amended test method procedures and be required to use this test method or equivalent to register their transformers with the MEPS program.*
7. *That the proposed new MEPS standard and its loss reduction benefits be advocated strongly to the private sector.*

Submissions on this Consultation RIS

Submissions are invited on any of the material in this document. You may wish to be guided by the following questions:

1. *Do you support the proposal to increase the required energy efficiency levels for distribution transformers? Please give reasons.*
2. *Do you agree with the proposed new efficiency levels for different transformer types? If not, give reasons.*
3. *How significant a role do you think that market failures (e.g. regulatory arrangements for distribution businesses) play in the distribution transformer market?*
4. *Do you agree with the methodology for estimating incremental capital costs for improving distribution transformer efficiency? If not, please provide an alternative methodology.*
5. *Do you agree with the methodology for estimating the incremental value of loss reductions, including the reduction in emissions?*
6. *What implications (positive or negative) would the proposals have for your industry, in terms of activity, profitability and employment over the short and longer terms?*
7. *Do you agree with expanding the scope of MEPS for distribution transformers to include 33kV networks and 3150kVA transformers?*
8. *Do you consider that there are any major technical or functional issues associated with the proposed new standard? If so, how should these be addressed?*
9. *Do you agree with the specific recommendations in the RIS? If not, please provide comments on those you wish to take issue with indicating the recommendation number(s).*
10. *Do you have any views or suggestions on compliance strategies for MEPS for distribution transformers?*

Submissions to the Consultation RIS can be either emailed to:

energyrating@climatechange.gov.au

or mail:

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ABARE	Australian Bureau of Agricultural and Resource Economics
AC	Alternating current
ACCC	Australian Consumer and Competition Commission
AEEMA	Australian Electrical and Electronic Manufacturers Association
AER	Australian Energy Regulator
AiG	Australian Industry Group
ANZMEC	Australian and New Zealand Minerals and Energy Council (precursor to MCE)
BAU	Business as Usual
CBA	Cost-Benefit Analysis
CENELEC	European Committee for Electrotechnical Standardisation
CFL	Compact Fluorescent Lamp
CoAG	Council of Australian Governments
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CPI	Consumer price index
CPRS	Carbon Pollution Reduction Scheme
DNSP	Distribution Network Service Provider
DOE	Department of Energy (USA)
DLF	Distribution Loss Factor
EBSS	Efficiency Benefit Sharing Scheme
EECA	Energy Efficiency and Conservation Authority [NZ]
EEEP	Equipment Energy Efficiency Program
EEEC	Equipment Energy Efficiency Committee
E2WG	Energy Efficiency Working Group
E3	Equipment Energy Efficiency
ENA	Energy Networks Association
ESAA	Energy Supply Association of Australia
ETS	Emissions Trading Scheme
GATT	General Agreement on Tariffs and Trade
GGRS	Greenhouse Gas Reduction Scheme
GHG	Greenhouse Gas
GWh	Gigawatt hour (1,000,000 kWh)
HEPS	High Efficiency Performance Standard
HEPS1	HEPS according to AS2374.1.2 – 2003
HEPS2	Proposed new HEPS with higher efficiency levels than HEPS1
Hz	Hertz
IA	Industry Australia group
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IES	Intelligent Energy Systems
IPART	Independent Pricing and Regulatory Tribunal of NSW
kV	kilovolts
kVA	kilovolt-ampere
kWh	kilowatt hour (1 kWh = 3600 kilojoules)
LBNL	Lawrence Berkeley National Laboratory
LF	Load utilisation factor
LL	Load loss

LRMC	Long run marginal cost of supply
MCE	Ministerial Council on Energy
MED	Ministry of Economic Development (NZ)
MEPS	Minimum Efficiency Performance Standards
MEPS1	MEPS according to AS2374.1.2 – 2003
MEPS2	Proposed new MEPS with higher efficiency levels than MEPS1
MRET	Mandatory Renewable Energy Target
Mt	Megatonne
MWh	Megawatt hour (1,000 kWh)
NAEEEC	National Appliance and Equipment Energy Efficiency Committee
NAEEEP	National Appliance and Equipment Energy Efficiency Program
NATA	National Association of Testing Authorities
NEM	National Energy Market
NEMA	National Electrical Manufacturers Association (USA)
NER	National Electricity Rules
NFEE	National Framework for Energy Efficiency
NGA	National Greenhouse Accounts
NGGI	National Greenhouse Gas Inventory
NGS	National Greenhouse Strategy
NLL	No-Load Loss
NPV	Net present value
NSW	New South Wales
NZ	New Zealand
NZEECS	New Zealand Energy Efficiency and Conservation Strategy
NZES	New Zealand Energy Strategy
NZETS	New Zealand Emissions Trading Scheme
OFGEM	Office of Gas and Electricity Markets [UK]
ORNL	Oak Ridge National Laboratory
PROPHET	Promotion Partnership for High Efficiency Transformers
REC	Renewable Energy Certificate
RIS	Regulatory Impact Statement
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SEEDT	Strategies for Energy Efficient Distribution Transformers
SWER	Single Wire Earth Return
TMC	Transformer Manufacturing Company
TNSP	Transmission network service provider
TWh	Terra Watt Hour (1,000,000,000 kWh)
TUF	Transformer Utilization Factor
Um	Term used to denote the highest operating voltage for equipment
UNFCCC	United Nations Framework Convention on Climate Change
WACC	Weighted Average Cost of Capital

1. Introduction

1.1 Report Rationale

Transformers are devices that change voltage between the different stages of electricity generation, transmission, distribution and consumption. Distribution transformers are those that step voltage down for ultimate consumption in the electrical equipment of end users. Most distribution transformers are embedded in the distribution network, but many are also used by large consumers in commerce, industry, mining and renewable energy generation such as wind power.

There are many hundreds of thousands of distribution transformers in Australia and New Zealand and they are a significant source of energy loss and corresponding emissions. In Australia and New Zealand, losses in distribution transformers comprise some 1.36% of total generation. In 2007, distribution transformers contributed about 2,980 GWh of electrical loss in Australia and 575 GWh in New Zealand.

An Australian Standard (AS2374.1.2) specifying Minimum Energy Performance Standard (MEPS) requirements for distribution transformers was issued in October 2004 and has been mandated as part of the MEPS program. All new distribution transformers sold in Australia and New Zealand are required to comply with these minimum efficiency (MEPS1) levels. The Standard also specifies voluntary high efficiency levels.

The MEPS 2004 standard foreshadowed a review after four years to determine whether further improvement was achievable. An initial technical report was released in December 2007, proposing a higher efficiency standard, referred to as MEPS2 in this report. It was prepared by the Equipment Energy Efficiency Committee (E3 Committee) under the Ministerial Council on Energy (MCE) on behalf of the Australian, state and territory governments and the New Zealand Government. Electrical supply and local transformer manufacturing industries and importers were consulted on the proposal between 2007 and 2009. This Regulatory Impact Statement (RIS) addresses the resulting proposal.

In accordance with the CoAG Principles and Guidelines [1], a RIS is required whenever new or more stringent mandatory measures are proposed by government. Under guidelines agreed by all Australian jurisdictions and New Zealand, regulation is undertaken only where the benefits outweigh the costs to the community of doing so, and the cost of improving equipment efficiency is justified by the energy and greenhouse gas emissions savings made over the lifetime of the equipment item.

1.2 Report Structure

This report is structured as follows:

- The background material in Section 2 is based on a technical report on the regulation of distribution transformers prepared for the Equipment Energy Efficiency (E3) Committee [2].
- Section 3 outlines the nature and dimension of the issue being addressed by the RIS, the exact nature of the proposal to address the issue and the reason why some form of intervention is under consideration.
- Section 4 examines the different ways the market weaknesses identified could be addressed, concluding that increasing the stringency of Mandatory Energy Performance Standards (MEPS) for distribution transformers offers the greatest assurance of achieving the objectives, but subject to its passing a cost-benefit analysis (CBA) test.
- The CBA itself is contained in Section 5.
- In Section 6, a range of industry considerations are identified and discussed. These issues were raised by stakeholders during consultations and taken into account in preparing the proposal examined in this RIS. The stakeholder consultations and Standards Australia processes are outlined in Section 7.
- The conclusions and recommendations of the RIS are contained in Section 8 and report references in Section 9.

The Appendices contain background information and the analysis used in the body of the report. These include:

- An outline of transformer technology and energy efficiency in Appendix A.
- The nature and scope of transformer installations in Australia and New Zealand in Appendix B.
- Transformer life costing procedures included in the current Australian Standard in Appendix C.
- The energy efficiency policy background in Australia and New Zealand in Appendix D.

This report was prepared by Intelligent Energy Systems (IES) and Associate Professor Trevor Blackburn of the School of Electrical Engineering and Communications at the University of NSW. Professor Blackburn prepared most of the technical material and the initial cost-benefit analysis. This analysis was refined and the report edited by IES.

2 Background

2.1 Overview

This section provides a summary of the policies in Australia and New Zealand that support the proposal to improve new distribution transformer efficiencies contained in this RIS. The broad framework is the commitment to reduce greenhouse gas emissions under the Kyoto Protocol in order to mitigate the risk of climate change. While governments believe that some form of carbon pricing is the most efficient way to reduce greenhouse emissions longer term, they have also implemented direct action strategies to improve device efficiencies to supplement this approach.

The section describes the role of distribution transformers, the current policy affecting their efficiency and how this policy relates to international practice. It also includes an estimate of the current size and value of losses incurred by distribution transformers. Distribution transformers are already efficient devices but international practice indicates that some improvement is possible (in the order of a 10% reduction from current loss levels). Distribution transformers are smaller and less efficient than those serving the transmission system.

The size of distribution transformer losses in Australia is estimated at 2,980 GWh or 1.36% of total generation, valued about A$340 million each year. The 10% reduction technically possible could only be achieved over a long period as new transformers are installed and old ones replaced. Greenhouse gas (GHG) emissions due to distribution transformer losses have recently averaged 2.75 million tonnes CO_2 each year. The corresponding estimates for New Zealand are 575 GWh of distribution transformer losses valued at NZ$78million and GHG emissions of about 0.53 million tonnes of CO_2 each year.

2.2 Responses to Climate Change

2.2.1 AUSTRALIA

Australia's greenhouse abatement and climate change policies have evolved steadily since the release of the National Greenhouse Response Strategy in 1997. That paper received overall bipartisan support, including support for national energy efficiency measures. Appendix D records the more important stages in that development.

On 11 March 2008, Australia's ratification of the Kyoto Protocol was officially recognised by the United Nations Framework Convention on Climate Change (UNFCCC). Under Kyoto, Australia is obliged to limit its greenhouse gas emissions in 2008-2012 to 108 percent of 1990 emission levels.

The Australian Government believes that an Emissions Trading Scheme (ETS) is the cheapest and most effective way of meeting the bipartisan emissions reductions targets. As of early 2011 the government had announced its intention to proceed with a mechanism to price greenhouse gas emissions prior to the introduction of an ETS in a few years time.

An ETS is intended to cover the broad spectrum of human activity to achieve greenhouse gas reductions at the lowest possible cost but does not address all elements of market failure. It relies on imposing an incremental price on greenhouse gas emissions, and in turn on emitting goods and services, to achieve emission reductions. Responses to energy price changes may be delayed or market failure in particular sectors may weaken the impact of such price increases on decision-making and hence the degree of emission reduction. This in turn could lead to higher energy prices than would occur if some of these lags and market failures had been dealt with directly. Thus, one reason for implementing measures to supplement an ETS is to contain potential price rises from an ETS.

In July 2009, the Council of Australian Governments (CoAG) agreed a National Strategy for Energy Efficiency (NSEE) to accelerate energy efficiency efforts across all governments through a range of measures which include MEPS and Energy Rating Labelling for energy using products.

Emissions reduction through direct energy efficiency measures is complementary to an ETS. The Carbon Pollution Reduction Scheme (CPRS) White Paper [24] released in December 2008 (Vol 2) stated on page 110 that:

> *"Energy efficiency is the final piece of the emissions reduction strategy. Energy use is the key driver of emissions growth in Australia. The Renewable Energy Target and CPRS will reduce the emissions produced and released in generating energy, but there is also considerable scope to increase the efficiency of energy use. Using energy more efficiently can significantly reduce the cost of greenhouse gas abatement and ease the transition to a low-carbon economy"*

The proposed regulation is an element of the NSEE, and would be managed by the Equipment Energy Efficiency (E3) Program, which includes a wide range of measures to increase the energy efficiency of products used in the residential, commercial and manufacturing sectors in Australia and New Zealand.

2.2.2 NEW ZEALAND

New Zealand ratified the Kyoto Protocol in 2002, and is committed to reducing its greenhouse gas emissions back to 1990 levels, on average, over the period 2008 to 2012 (or to take responsibility for any emissions above this level if it cannot meet this target).

More recently New Zealand adopted a provisional and conditional emission reduction target of 10-20% below 1990 levels in 2020 and a longer term target of 50% below 1990 levels in 2050.

Measures that reduce energy-related greenhouse gas emissions make an important contribution to meeting this target. Implementing energy efficiency is widely regarded to be amongst the most cost beneficial ways to reduce greenhouse gas emissions

Revised New Zealand Emissions Trading Scheme (NZETS) legislation was passed in November 2009. It forms the centrepiece of New Zealand's response to climate change by introducing a market price on greenhouse gases. The equipment energy efficiency program is one of a raft of measures which complement emissions pricing.

Minimum energy performance standards (MEPS) and labelling act to reduce energy costs which will include a price on greenhouse gas emissions. Further details are provided in Appendix D.

2.3 Equipment Energy Efficiency (E3) Program

In Australia, regulatory intervention in the market for energy-using products began in 1986 with mandatory appliance energy labelling introduced by the NSW and Victorian Governments. Between 1986 and 1999, most state and territory governments introduced legislation to make energy labelling mandatory. They agreed to coordinate labelling and MEPS decision making through the MCE. New Zealand has participated in monitoring the Australian program for more than a decade and has been a partner in decision making for several years. Regulatory interventions have consistently demonstrated the benefits of increasing energy efficiency standards to address market failure relating to lifetime energy cost information for appliances and equipment.

The proposal for MEPS2 is being developed through the Equipment Energy Efficiency Program (E3). E3 aims to increase the energy efficiency of products used in the residential, commercial and manufacturing sectors in Australia and New Zealand. An initiative of the MCE, E3 is managed under both Australia's National Framework for Energy Efficiency (NFEE) and the New Zealand Energy Efficiency and Conservation Strategy (NZEECS). It is organised as follows:

- Implementation of the program in Australia is the direct responsibility of the Equipment Energy Efficiency Committee (the "E3 Committee") which comprises officials from Australian federal, state and territory government agencies and representatives from New Zealand. These officials are responsible for implementing product energy efficiency initiatives in their jurisdictions.
- The E3 Committee reports through the Energy Efficiency Working Group (E2WG) and is ultimately responsible to the MCE.
- The MCE has charged E2WG to manage the overall policy and budget of the national program.
- The Australian and New Zealand members of the E3 Committee work to develop mutually acceptable labelling requirements and MEPS. New requirements are incorporated in Australian and New Zealand Standards and developed within the consultative process of Standards Australia.
- The program relies on state and territory legislation for legal effect in Australia, enforcing relevant Australian Standards for the specific product type. National legislation performs this task in New Zealand.

The broad policy mandate of E3 has been regularly reviewed over the last decade and was most recently modified in 2004. Any equipment that uses energy is a candidate for regulation provided such intervention can be justified after study and preparation of a RIS.

To be included in the program, appliances and equipment must satisfy certain criteria relating to the feasibility and cost-effectiveness of intervention. These include potential for energy and greenhouse gas emissions savings, environmental impact of the fuel type [3], opportunity to influence purchase, existence of market barriers, access to testing facilities, and considerations of administrative complexity. Policy measures are subject to a cost-benefit analysis (CBA) and consideration of whether the measures are generally acceptable to the community. E3 processes provide stakeholders with opportunities to comment on specific measures as they are developed.

2.4 Distribution Transformers

Transformer design is discussed briefly in Appendix A. Appendix B provides an overview of the role of transformers in the utilities and general industry.

Electrical energy passes through several network stages as it flows from the generating source to the consumer. These include the transmission, sub-transmission and distribution stages, each of which operates at a different voltage level. Broadly, the higher voltage parts of the system are used to transmit energy over longer distances and the lower voltages (at the distribution end) are suitable for short distances to local consumers. The use of higher voltages for long distance transmission greatly reduces the losses incurred. Lower voltages are required for safe and practical delivery and use. Transformers are used to change the voltage level between stages. Some energy is lost as it passes through each transformer.

Generation station and transmission transformers (see Figure 2-1(a)) are few in number, as are sub-transmission and major (zone) substation transformers. These transformer types are highly energy efficient by virtue of their size, design and general operational features.

Small consumers, including small industry and residential sites, are supplied through the distribution system usually at 415 volts from the secondary (low voltage) windings of distribution transformers (see Figure 2-1(b)). Distribution transformers are very large in number (hundreds of thousands) and have lower energy efficiency than sub-transmission units. Distribution transformers thus represent a significant source of overall network energy losses.

In Australia and New Zealand the average level of energy loss between power station and the consumer is around 9% of total generated energy. While the majority of this loss is in power lines, distribution transformer losses comprise some 1.36% of total generated energy. In 2007, distribution transformers contributed about 2,980 GWh of electrical loss in Australia and 575 GWh in New Zealand.

In the distribution sector, standard practice has been to use economic optimisation to inform the purchase of distribution transformers (see Appendix C). As will be described later in this report, the incentive to optimise in this way has been removed as a by-product of industry reforms in both New Zealand and Australia. In any case, the standard approach makes no mention of externalities such as the possible cost of CO_2 emissions. A CBA of a proposal to increase efficiency standards should recognise these issues.

Figure 2-1 Network transformers

(a) Large generation/transmission transformer

(b) Small pole-mounted distribution transformer

2.5 Current MEPS for Distribution Transformers (MEPS1)

Details of the full development of MEPS for transformers are covered in the previous RIS for MEPS1 [18]. The E3 Committee established a MEPS steering group for transformers in 2000 and commissioned Mark Ellis & Associates to prepare the case for inclusion of distribution transformers. The original proposal for MEPS1 for transformers was then issued in March 2001 [21].

Subsequent to this, a sub-committee of the Standards Australia Committee EL008 on Power Transformers was established to prepare an Australian Standard to provide the regulatory details. These included the proposed efficiency levels and the test method to determine efficiency. The Standard, AS2374.1.2--2003 [Power Transformers: Part 1.2: Minimum Energy Performance Standard (MEPS) Requirements for Distribution Transformers] was published in final form in March 2003. It would not take effect in Australia until 1 October 2004.

AS2374.1.2 provides tables of minimum efficiency levels covering the various rating classifications of distribution transformers. Two levels are given for each rating – a standard level and a high efficiency level. New transformers are required to comply with the standard level. The high efficiency levels were voluntary and intended to indicate the changes that might occur at a later time. However, transformers with efficiencies that complied with these higher levels were permitted to use a "high efficiency" designation in any promotional or advertising materials.

The standard and its requirements were incorporated into Australian state and territory legislation. New Zealand also adopted the MEPS levels for transformers through the regulations enforced by the New Zealand Energy Efficiency and Conservation Authority (EECA) [5]. The standard states that the efficiency levels specified would remain in force for four years and would then be reviewed in accordance with international best practice. Required efficiency levels would be made more stringent if international trends indicated such improvement was achievable and assessed as desirable. The status quo or business as usual (BAU) situation would be the continuation of the current MEPS1 efficiency regulations for all transformers within the scope of AS2374.1.2. Current MEPS1 efficiency levels are shown in Table 1 and Table 2 below.

Table 1 Existing MEPS levels for oil-immersed transformers

Transformer type	kVA	Power efficiency (%) at 50% load
Single phase	10	98.3
(and SWER)	16	98.52
	25	98.7
	50	98.9
Three Phase	25	98.28
	63	98.62
	100	98.76
	200	98.94
	315	99.04
	500	99.13
	750	99.21
	1000	99.27
	1500	99.35
	2000	99.39
	2500	99.40

Table 2 Existing MEPS levels for dry type transformers - Um[1] of 12 kV & 24kV

Transformer type	kVA	Power efficiency (%) at 50% load Um = 12 kV	Power efficiency (%) at 50% load Um = 24 kV
Single phase	10	97.29	97.01
(and SWER)	16	97.60	97.27
	25	97.89	97.53
	50	97.31	97.91
Three Phase	25	97.17	97.17
	63	97.78	97.78
	100	98.07	98.07
	200	98.46	98.42
	315	98.67	98.59
	500	98.84	98.74
	750	98.96	98.85
	1000	99.03	98.92
	1500	99.12	99.01
	2000	99.16	99.06
	2500	99.19	99.09

In this report, there is frequent reference to transformers of different types. The main types are "dry type" and various versions of liquid filled or oil-immersed transformers. While the most common liquid used is oil, other liquids are sometimes used. In later sections there are various references made to "oil-filled", "oil immersed", "liquid filled" and "oil-immersed", depending among other things on the data source used. For the purposes of this report these terms are interchangeable.

Under the current MEPS1 standard, all new transformers must have power efficiencies that are no lower than the levels listed above. These levels were set at values generally used in North America at the time and were based on US National Electrical Manufacturers Association (NEMA) and Canadian Standards. They were also consistent with general international efficiency specifications for transformers in about 1999-2000 as outlined in [20]. The cumulative greenhouse savings over 30 years, from introduction of MEPS1, was estimated at 65 Mt CO_2-e.

1 Defined in AS 2374.1 as the highest root mean square (rms) voltage of the system to which the transformer is to be connected.

2.6 International Practice

Australian manufacturers and importers provide transformers to the utility industry that meet the current MEPS1 standard, but not to the standard set by world's best practice. Figure 2-2 compares current MEPS1 levels for oil-immersed transformers with standards in the EU, US and Japan. The US Department of Energy (DOE) proposed levels (for 60Hz) are expected to become mandatory. The US benchmark levels are effectively maximum achievable efficiency levels. The comparison shows that MEPS1 levels are the lowest of the international standards, except only at 2500 kVA where the EU existing standard is slightly lower than MEPS1.

The Japanese levels shown are voluntary and are based on use of amorphous metal cores instead of standard steel cores. The EU levels are not mandatory. Some EU countries use them while others do not. US benchmark and regulated levels are based on steel core use only.

Figure 2-3 below shows a similar comparison for dry type transformers with the two MEPS1 levels (for 12 and 24 kV systems) shown. In this case the MEPS1 levels are better only than the existing European levels but are lower than the other levels.

There is a significant difference between MEPS1 efficiency levels and international best practice as represented, for example, by US benchmark levels. This in turn suggests significant potential for distribution transformer loss reduction in Australia and New Zealand. While relatively low energy costs in Australia and New Zealand may not warrant any attempt to exceed major benchmark levels, there may be a case to keep up with those benchmarks as greenhouse emission reduction takes on higher priority. This RIS aims to address this proposition.

Figure 2-2 International comparison of MEPS1 efficiencies for oil-immersed 3-phase transformers

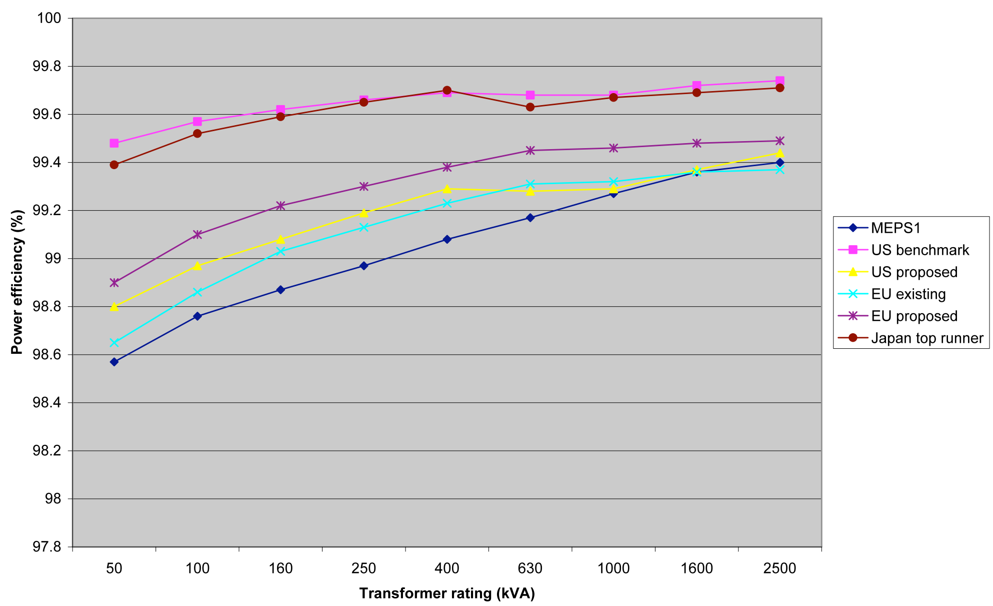
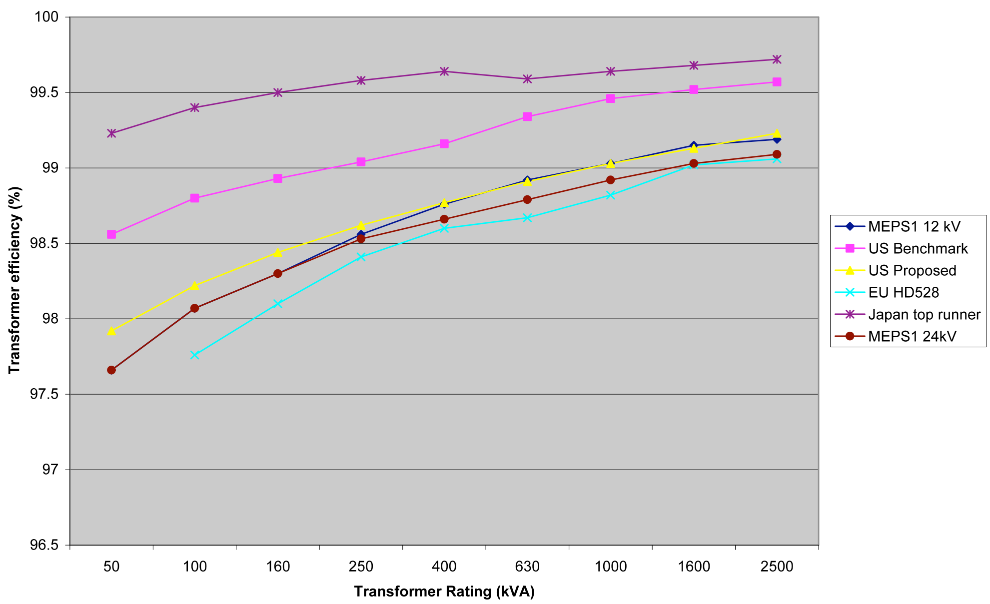


Figure 2-3 International comparison of MEPS1 efficiencies for dry type 3-phase transformers [12 and 24 kV]



2.7 Current Distribution Transformer Losses and Costs

2.7.1 NETWORK DISTRIBUTION TRANSFORMER LOSSES

In Australia the electrical networks that transfer the electrical energy from the generator stations to the consumer incurred losses of 9% of the total energy sent out from the power stations [6]. Over the last 10 years the average distribution loss (wires and transformers) has been about 5.6% when expressed as a percentage of power station energy sent out from power stations (called sent out energy). In New Zealand the national average distribution network loss was 5.3% in 2007 [15] and the long term average about 6.3%. Distribution transformers used in the electrical supply networks contribute, on average, about 30% to total distribution losses [16]. Additional detail on Australian and New Zealand distribution transformers is included in Appendix B.

A matrix of energy losses across Australia's transmission and distribution networks is shown in Table 3 below. This analysis is indicative only and features a hypothetical set of lines and substations that do not necessarily conform to the actual networks in various states. However, the level of losses shown is consistent with the overall average level of losses across Australia. The shaded cell in the Total column shows the transformer losses estimated for distribution transformers, which total 1.36% of sent out electrical energy.

In 2006/07, electricity generators in Australia supplied a total of 218,643 GWh of electrical energy to the transmission network and the transmission and distribution networks supplied 198,831 GWh to consumers [6]. The 5.6% loss in the distribution networks thus represents 12,240 GWh of energy loss and about 11.3 million tonnes of CO_2 equivalent greenhouse gas emission per year, based on data on the marginal emission rate for the Australian generation mix [17].

In New Zealand the total electrical energy consumed in 2007 was 38,546 GWh with losses in distribution of 5.3% [15]. This corresponds to losses of 2,160 GWh.

2.7.2 LONG RUN MARGINAL COST OF LOSSES

The annualised long run cost of these losses will vary depending on the location of the transformers in the network:

- For a transformer embedded in the distribution network, the cost of supply is the long run cost incurred upstream of the transformer i.e. generation costs and the part of the network upstream of the transformer.
- For private transformers in industry, commerce and mining, the complete cost of supply is captured in the supply tariff. This may vary depending on the location and voltage of off-take.
- For distribution-type transformers used in some forms of generation such as wind farms, the appropriate cost measure is the marginal cost of generation only. This is normally well approximated by a long run generation price as expressed in the wholesale spot and contract markets. However, this cost may be supplemented by additional incentives provided by various renewable energy initiatives such as the national Mandatory Renewable Energy Target (MRET) scheme.

Table 3 Average Energy Loss Matrix for Australia's Electricity Networks

Sector	Voltage Level	Transmission & Distribution Losses %[2]		
		Iron	Copper	Total
Transmission	330kV Lines		1.56	1.56
	330/132kV Subs	0.20	0.20	0.40
	132kV Lines		1.50	1.50
Total Transmission Losses		0.20	3.26	3.46
Distribution	132/66kV Subs	0.23	0.19	0.42
	66kV Lines		0.67	0.67
	66/11kV Subs	0.24	0.20	0.44
	11kV Lines		1.29	1.29
	11kV/415V Subs	0.59	0.77	1.36
	415V Lines		1.42	1.42
Total Distribution Losses		1.06	4.54	5.60

2 The loss percentages shown are a percentage of total power station energy sent out. Iron loss is the inductive heat loss in a transformer's iron core and is constant. Copper loss is the resistive heating loss in the transformer windings, which may be made of copper or aluminium, and is proportional to the square of the current flow, and hence transformer load.

Table 4 below shows a breakdown of the cost components of electricity supply in Australia, based on recent Long run marginal cost of supply (LRMC) determinations reported in Independent Pricing and Regulatory Tribunal (IPART) retail tariff determinations [27]. Even though this cost breakdown is for NSW, it should be a reasonable estimate for Australia as a whole given that generation costs across most states are linked by the National Electricity Market (NEM).

The cost of losses for distribution transformers embedded in distribution networks is reasonably represented by the first three components in the table, in the order of $114/MWh. For private transformers this cost will vary depending where off-take is taken. Some would be at around the retail level of $150/MWh or higher and some very large off-takes would be directly from the transmission system, around $82.5/MWh.

Table 4 Australian Electricity LRMC 2006/07 (Excluding GST)

Sector	$/MWh	Shares
Generation	$60.0	40%
Transmission	$22.5	15%
Distribution HV	$31.5	21%
Distribution LV	$16.5	11%
Retail	$19.5	13%
Total	$150.0	100%

IPART and other regulators expect electricity prices (and LRMC) in a few years to increase markedly (by the order of 50%) for two main reasons – the need to upgrade the network and to reflect the costs of emission reduction policy. This implies that the economic value of loss reduction is almost certainly likely to increase over time. On the other hand, the emission intensity of electricity is likely to reduce over time for the same reason although its price may increase. The cost-benefit analysis will initially set aside these likely trends, basing its case primarily on current emissions and costs. These assumptions will be shown to be conservative, leading to a conclusion that the analysis is likely to be robust against foreseeable changes.

In the case of wind farms and under the cost-splitting logic just described and shown in Table 4, the cost of losses in transformers at the generation level would not exceed $60/MWh. Wind-driven power output may be correlated with electricity wholesale prices, either positively or negatively. An average value of generation produced by the Hallett wind farm in South Australia was calculated from NEM published data to be just under $40MWh in 2007-08. However, such calculations also need to recognise the presence of the MRET scheme and its proposed expanded version with the renewable target increased to 20% of electrical energy generated.

Under MRET, retailers are required to obtain a fixed proportion of their electrical energy from renewable sources. The cost of Renewable Energy Certificates (RECs) must reach a price sufficient to provide that level of renewable generation. The most cost-effective renewable source at the moment (other than hydro, which is limited and mostly already committed) is wind power. Wind power is much more expensive than generation from traditional fossil-based sources. To justify wind farm construction, the value of RECs must rise until the value of RECs and the wholesale electricity price together are sufficient to fund wind projects. Therefore, one MW less of wind farm transformer loss is offset by the cost of one MW of wind farm. The cost of wind farm energy at reasonable sites in Australia is in the range of $110-$130/MWh about double the long run wholesale price of electricity at source. This represents fair value of the energy saved by improvements in wind farm transformer efficiency. The range aligns closely with the $114/MWh determined for transformers embedded in the distribution network, at least for the present.

A similar logic would apply when evaluating distribution losses in New Zealand. According to the New Zealand Ministry of Economic Development [28], the average New Zealand retail price including GST of 12.5% on 2006-2007 (the same period as the IPART analysis above) was NZ$ 0.214/kWh. Adjusting for GST and converting to A$ at a rate of 1.18 gives an equivalent Australian price of A$160/MWh, only slightly more than the IPART assessed NSW price for that year. Given that NSW prices and Australian prices generally have increased at more than CPI in the intervening years, there is little basis for assessing any significant difference in energy prices between the two countries.

2.7.3 TOTAL COST OF DISTRIBUTION TRANSFORMER LOSSES

The annual loss attributable to the distribution transformers in Australia is assessed to be 1.36% of generation compared with about 5.6% for the distribution networks as a whole as noted earlier. Pro-rating the losses and emissions associated with distribution, this translates to 2,980 GWh of transformer losses in 2006/07, with associated emissions of 2.75 million tonnes of CO_2. Valued at $114/MWh, the annual cost of these losses in 2006-07 was approximately $340 million. There is scope to reduce this cost as well as CO_2 emissions by reducing distribution transformer losses. These figures include industrial, commercial and mining industry transformers and upstream transformers in the smaller size range.

Pro-rating for distribution transformer losses of 1.36% in New Zealand, the total distribution transformer losses in New Zealand in 2007 would be about 575 GWh with associated emissions of 0.53 million tonnes of CO_2. The value of these losses at the same cost as used in Australia would be about $NZ78 million per year at present.

3.1 Overview

The MEPS 2004 (MEPS1) standard for distribution transformers foreshadowed a review after four years to determine whether further improvement was achievable. As noted in Section 2, a review of international practice certainly suggests that efficiency improvements are technically possible and are being implemented in many countries.

In this section, the outcome (so far) of MEPS1 is reviewed and set against the economic and policy developments that have emerged or evolved since 2004. We find that the impact of the MEPS1 standard has been modest on both the cost and benefits side. In fact, with the electricity distribution networks now corporatised or substantially privatised, current electricity industry arrangements offer no incentive to maintain transformer efficiency above the currently low mandated levels.

In industry, commerce and mining the market failures that prompted the original MEPS1 standard persist, but in an environment of increasing network costs, increasing pressure to reduce greenhouse gas emissions, and increased losses arising from the electrical characteristics of electronic equipment. Together these factors point to the possible merits of increasing the current MEPS1 transformer efficiency standards.

3.2 Assessment of Current MEPS for Transformers (MEPS1)

3.2.1 MEPS1 REGULATION

The Preface to AS2374.1.2 that currently sets efficiency standards for distribution transformers states that:

> *"The minimum power efficiency levels specified in this Standard are in accordance with world best practice at the time of publication. The intention is that these levels will remain in place for a minimum of four years and will be reviewed in accordance with international trends. High efficiency levels are also included as a guide to future MEPS levels."*

The general MEPS1 levels were chosen to be in accord with world best practice at the time, as summarised in the document National Appliance and Equipment Energy Efficiency Program: Future Directions 2002-04:

> *"In 1999 ANZMEC agreed that Australia would match the best MEPS levels of our trading partners after taking account of test method differences and other differences (e.g. climate, marketing and consumer preference variations). This new policy represented a radical change of direction from the previous Australian practice of debating the technical possibilities of MEPS levels with all stakeholders. The new policy covered any product regulated by mandatory labelling or MEPS programs in other developed countries."*

3.2.2 Impact of MEPS1 on Stakeholders

Hard data on transformer efficiency levels in Australia before and after MEPS1 are not readily available; only a few NZ figures were available for this study. Therefore, an assessment of the outcome of the current MEPS program for transformers is based on anecdotal evidence from discussions with manufacturers and major users.

Because the efficiency levels mandated in MEPS1 were relatively modest, most Australian manufactured transformers were already compliant with the new efficiency standard. There were no significant additional manufacturing or material costs imposed by the new standard. The only additional costs were for compliance testing. Some higher accuracy measuring equipment was required and manufacturers implemented routine tests for every transformer as it left the production line; in some cases these tests were already being done. The costs of registration under the scheme were also relatively minor.

While MEPS1 did little to increase distribution transformer efficiency, a case was reported during industry discussions where efficiency was reduced from prevailing levels (while still maintaining compliance to the new standard) so as to offer cheaper contract prices. However, some transformer models continued to meet the higher, voluntary HEPS standard.

For the commercial, industrial and mining sectors, the impact of MEPS1 was even less because most transformers were imported directly. They were not subject to MEPS unless imported by an agent and purchased in Australia.

The experience in New Zealand is similar. Data from 2007 provided by two manufacturers indicate compliance with the basic MEPS standard by both manufacturers and compliance with the higher HEPS voluntary standards by one of them, over all models ranging from 15 to 1000kVA for three phase units, and over 3,000 such units in total. A similar pattern of compliance was evident for the smaller, single phase units from these manufacturers.

In summary, the impact of MEPS1 on both improving efficiency and on industry costs has been relatively small. It did not impose significant increased costs on manufacturers; nor did it provide the anticipated benefit in loss reduction.

3.3 Relevant Developments since MEPS1

This section reviews three factors that will tend to justify efficiency levels in future higher than they have been in the past. Section 3.4 considers whether current industry arrangements are adequate to promote these levels. In summary, the three factors are:

- carbon dioxide emission reduction policy is leading to an increase in the economic cost for generated electricity;
- the components of load that generate sharp-edged waveforms (i.e. which have high harmonic content) and which, as a result, tend to increase losses are growing rapidly as the use of electronic equipment increases; and
- electricity costs are also increasing for other reasons, such as the need to fund network rehabilitation and augmentation.

Each of these is discussed in more detail in the following sub-sections.

3.3.1 CARBON EMISSION REDUCTION POLICY

Section 2.2 outlines government policy on climate change in Australia and New Zealand.

There is a broad consensus in Australian and New Zealand politics that cost-effective measures to reduce carbon emissions should be pursued. The debate is about the degree of reduction to be sought and the policy approach.

New Zealand already has an emissions trading scheme (ETS). In Australia, a price on emissions is expected to be implemented sooner rather than later. The question to be answered is whether a price on emissions is sufficient to achieve policy goals. Such goals include not only a reduction in emissions, but also that targeted reductions be achieved without undue economic disruption and wealth transfer between businesses and individuals.

3.3.2 INCREASING HARMONIC LOSSES

Appendix A includes a sub-section on the source of losses within transformers.

In a normal alternating current power system, the voltage varies at a specific frequency. In general, when a linear electrical load is connected to the system, it draws a current at the same frequency as the voltage. Harmonics are caused by non-linear loads, which include power supplies for computer equipment, variable speed drives, and discharge lighting.

Until the last few decades, most electricity loads were either rotating machinery that generate smooth 50 Hertz voltage and current waveforms, or simple resistive loads such as incandescent lamps. Loads controlled by the new technology of power electronics are a growing additional source of losses.

Loads controlled by power electronics are called non-linear because they depart from the smooth waveforms of simple equipment; they are cut up by electronic switching. The resulting waveforms can be broken into components; sharp-edged waveforms generate a range of high frequency components called harmonics. The sharper the edges, the larger the harmonic, higher frequency components are. As losses in transformers increase to some extent with frequency, non-linear power electronic loads incur more losses in transformers than do equivalent loads with a smoother waveform - potentially in the range of 25-30% more. Non-linear power electronic loads are already present in the system but will grow more than proportionately as this technology proliferates.

Special transformers, known as K-Factor transformers, can be designed and built that effectively deal with the potential losses due to harmonics. However, they cost up to twice as much as standard transformers. While such units may find specific application in industry, they are far too costly to be used in the general distribution network. It follows that the practical way to manage losses from harmonic loads in the distribution network is to use a standard transformer with relatively high efficiency. As harmonic losses are increasing, the optimal efficiency of transformers will tend to increase, all else being equal.

The projections in this RIS are based on historical loss estimates and transformer efficiencies are assessed with a pure 50Hz waveform. They are likely to underestimate future losses and the scope for loss reduction through transformer efficiency improvement. Rather than try to adjust projections for the effect, which would require many assumptions, we instead perform a sensitivity analysis on the cost-benefit outcome to account for these additional losses.

3.3.3 INCREASING ELECTRICITY COSTS AND PRICES

There are signs emerging that retail prices, in Australia at least, will increase in future at greater than historical rates, not only because of the cost of emission mitigation. In NSW, for example, a March 2010 determination by the pricing regulator IPART [29] estimates that prices will increase by 20% to 42% even if the CPRS is not introduced and 46% to 64% if it is. Thus a substantial part of this price increase is due to the anticipated cost of keeping the distribution network to an appropriate standard of reliability.

Given the uncertainties surrounding a possible emissions price and future electricity prices generally, in this report the cost-benefit analysis will be based on recent historical prices and the possibility or likelihood of higher prices treated with a sensitivity analysis. However, the impact of imposing a carbon price will be examined explicitly.

3.4 Assessment of Market Deficiencies and Failures

Transformers affected by the higher MEPS proposed by this RIS fall into three main categories:

- transformers embedded in the distribution networks of electricity distribution utilities;
- transformers installed "behind the meter" by commerce, industry and mining (sometimes collectively called "industry" or "private industry" in this report); and
- transformers used in certain supply-side applications.

Each faces different market and regulatory environments.

3.4.1 ELECTRICITY DISTRIBUTION UTILITIES (DNSPS)

DNSPs in Australia and New Zealand must deal in future with a range of interacting issues affecting transformer choice that are growing in importance over time:

- historical transformer stock and stock installed since MEPS1 that generally fall short of efficiency standards achievable at reasonable cost today;
- an increasing focus on reducing losses to reduce greenhouse gas emissions, but continuing uncertainty about the regulatory approach;
- rapid growth in harmonic loads and associated losses;
- accelerated equipment replacement and growth; and
- lack of commercial incentive to optimise losses.

There are currently two clear forms of market failure evident when DNSPs are making transformer choices.

One is the current lack of a price on greenhouse gas emissions, despite the consensus that such emissions do bear some cost. The second and overriding factor in Australia is the recent AER determination that continues the regime whereby parties responsible for choosing and maintaining distribution transformers (DNSPs) bear none of the cost of the resulting losses incurred in the equipment. The background to this state of affairs is described in Appendix D.3. These failures are exacerbated by the rapid growth in harmonic losses (growing faster than loads) and the cost of the requirement in some regions to accelerate the replacement of old equipment and to meet new demand.

3.4.2 COMMERCE, INDUSTRY AND MINING

Information about transformer use and supply is not readily available for these sectors. Discussions with local transformers manufacturers who supply these sectors with MEPS type transformers indicate that they supply only a minute fraction of the demand, only around a thousand of the tens of thousands installed each year. These sectors rely heavily on transformer imports. Many distribution transformers used in these sectors are specialised and do not fall within the scope of MEPS. Other imported types fall within the MEPS category but are not necessarily MEPS compliant because they are purchased overseas.

The only major Australian transformer manufacturers who supply these sectors are the Transformer Manufacturing Company (TMC) in Melbourne and AmpControl in Newcastle. TMC only produces about 200 transformers per year, most of which are of special 'one-off' designs. Its main customers are the rail and tram systems. TMC has no single transformer model type production line. AmpControl in Newcastle specialises in mining transformers which are generally also special types, usually for use in hazardous atmospheres; they are thus not within MEPS specifications. AmpControl does make standard oil transformers for utilities; they supply mainly zone substation types with high power ratings (up to 80 MVA) and voltages (up to 66 and 132 kV) and are thus outside the scope of MEPS. ABB at Darra in Brisbane and in Perth does supply mining transformers but many of these are imported from ABB factories overseas.

Manufacturing and mining industries plan on a lower life expectation for transformers; about 15 -20 years is normal in manufacturing industry and as low as 5-10 years in the mining sector. In the other sectors such as commercial buildings with private transformers and also in transport infrastructure, the expected life is more typically about 20 years. Utilisation factors of these transformers are typically higher than those in the distribution network.

In all of these sectors, particularly in the mining and manufacturing but also in commercial buildings, it is often argued that the only economic consideration in transformer costing has been the initial purchase cost. No consideration is normally given to the overall lifetime cost, which includes cost of losses. The argument is that all ongoing costs are omitted, not just the incremental costs of greenhouse emissions and other externalities.

One strand of evidence for this assertion is the consistent finding that, over all these sectors, it is generally easy to find many examples where different equipment and design choices in favour of energy efficiency could have yielded very short payback times at the margin, even neglecting greenhouse issues. However, Golove and Eto [30] and other authors take a more subtle approach by noting that:

- energy efficiency is affected typically by a wide range of closely related markets, even in a single project such as a commercial building;
- neglect of second order costs is not necessarily irrational or a sign of market failure; and
- market Market failure does not in itself justify intervention and, if it does, many different types of intervention are possible and require evaluation.

For example, the short lifetime assumptions used in mining (which necessarily places an emphasis on capital cost rather than operating costs) may relate not only to the rugged working environment typical in the sector, but also to the high level of commercial and sometimes technical risks. Capital rationing is also a major factor, not only in mining but also in most industries. Decision-making that emphasises capital minimisation is perfectly rational in these cases, but does it represent market failure and, further, market failure that is correctable and of sufficient significance to justify intervention?

The commercial building sector is another case examined closely by Golove and Eto. They point out that designing and constructing an energy-efficient building typically requires high level coordination between architects, engineers, builders and investors. When time is of the essence, implementing efficient design can significantly increase lead-times and cost overheads, and therefore risk. As with a mine development, this is a real risk to the investor arising from the way buildings are put together. It is also different to the situation where the cost of future losses is ignored simply because the building investor can pass those costs on, however high, to uninformed purchasers or tenants. This type of perceived market failure is in any case addressed by the government's Commercial Building Energy Efficiency Disclosure Scheme [31]. With such a scheme in place, is it desirable also to intervene to improve transformer efficiencies in commercial buildings?

In the above examples, it might be argued that policy to lift transformer efficiency across the board would affect all transformer users equally (at least within Australia and New Zealand) and perhaps simplify a lot of decision-making. There are however more compelling arguments to move to higher efficiency in these sectors. As with transformers used in the distribution network, future installations will be influenced by:

- the general push to improve energy efficiency on greenhouse emissions grounds, irrespective of the mechanisms ultimately implemented;
- the expected rapid increases in electricity prices driven by the need to maintain network reliability; and
- the general increase in non-linear loads and associated harmonic losses.

The first factor can be considered a case of market failure due to the current lack of an emissions price, while the latter two are simply factors that will influence decision-making, however made, in favour of higher efficiency as time goes by. Unlike DNSPs, direct users of transformers in these sectors do see a financial impact from losses, but the weight given to these costs when selecting transformers will vary widely for a range of reasons, some of which may have elements of market failure. However, the three factors listed above are likely to be the main ones justifying any improved transformer efficiency.

3.4.3 SUPPLY-SIDE APPLICATIONS

The most common supply-side application of distribution-type transformers proposed to be covered by MEPS are transformers used in wind farms, a sector that has grown rapidly in recent years and which is expected to grow further in the future. In this case, transformers are used to step up the voltage of the generated power to allow it to be fed into the local distribution network or, possibly, the transmission network.

Wind farms are relatively simple businesses at one level, in that the owner/operator is likely to be a single enterprise. The value of power delivered to the grid is made up of a pure electricity price, supplemented in Australia with income from selling renewable Energy Certificates (RECs), with similar incentives applying in New Zealand. Modelling shows that a carbon price, if and when implemented, will tend to reduce the value of RECs, so it is not clear that a carbon price will provide any additional efficiency incentive to wind farms not already present through the renewable energy schemes. The case for regulating transformers in this application largely rests on the desirability of maintaining consistency of regulation across similar products.

4 Options Considered

4.1 Overview

In this section the options to be analysed are set out and their impacts on losses and emissions examined.

The Business as Usual (BAU) case is a continuation of the existing MEPS regime. As the motivation for this RIS is the requirement to review the current MEPS to see whether further improvement is achievable, the only other option considered is an upgrade of the standard as proposed through the E3 Committee processes.

An upgraded MEPS standard would apply to all new and replacement distribution transformers sold in Australia and New Zealand. To estimate the impact on losses and emissions in the short and longer terms we need to:

- estimate the rate at which new distribution transformers are likely to be installed and older ones replaced;
- estimate the reduction in losses over the range of distribution transformer types, noting that the efficiency improvements in the new standard are vary over different types;
- combine these two estimates to get the reduction in losses year-on-year and the total reduction over an extended period of 30 years, which is a typical minimum lifetime of such equipment; and
- assess the corresponding reduction in greenhouse emissions using appropriate conversion factors.

From this analysis we can determine appropriate electrical loss and greenhouse gas reduction targets to be achieved by implementing the new standard.

4.2 The Business as Usual (BAU) Case: Continuation of MEPS1

The BAU case for distribution transformer efficiency has several elements as discussed in Section 3 and summarised below.

The current MEPS for distribution transformers established a regulatory regime to maintain transformer energy efficiency levels. The MEPS1 standard was set at a level that has had little impact either in imposing additional manufacturing and other costs or in reducing losses.

There is an element of voluntary compliance in the current High Energy Performance Standard (HEPS). Some manufacturers meet the HEPS standard for at least some of their products, suggesting that the market rather than MEPS is still driving efficiencies in parts of the transformer market. In some sub-sectors there is a trend to K-Factor transformers designed to handle efficiently loads that are rich in harmonics.

The BAU case operates in a changing and uncertain environment as discussed in Section 3:

- an increasing focus on reducing losses to reduce greenhouse gas emissions, but continuing uncertainty about the regulatory approach;
- rapid growth in non-linear loads and associated harmonic losses; and
- increasing electricity costs from accelerated equipment replacement and growth.

All these factors point towards increasing losses as well as higher electricity costs, and therefore increases in the cost of losses above historical trends.

4.3 A Higher MEPS for Transformers (MEPS2)

4.3.1 OVERVIEW OF THE PROPOSED STANDARD

The proposal to be examined is for the mandatory efficiency levels defined in the Australian Standard to be increased to values previously referred to as high efficiency levels, with some adjustment to take account of industry concerns. At the same time, the voltage range covered by MEPS would be increased to include 33kV transformers (with maximum system voltage of 36 KV), to maintain consistency with international definitions. The highest rating level included would increase from 2500 kVA to 3150 kVA. The draft standard would also require that distribution transformers be marked as MEPS compliant, using a marking system defined to aid compliance checking in the proposed new standard.

The new regulation would cover all new distribution transformers specified in the proposed standard and sold in the Australian and New Zealand markets, whether manufactured locally or overseas. These changes would take effect no earlier than 1 October 2011.

4.3.2 PROPOSED NEW MEPS EFFICIENCY LEVELS

The proposed new regulatory levels are as tabulated in Table 5 (for oil-immersed transformers) and Table 6 (for dry types). They are compared with the existing MEPS1 standard in these tables. The 33kV (Um = 36kV) standard is new.

Under the proposed MEPS2 levels, the voltage range is increased to include 33kV transformers (with maximum system voltage Um of 36 kV) to maintain consistency with international definitions. The highest rating level is also increased from 2500 kVA to 3150 kVA to cover developments in distribution transformer sizes now being installed.

There have been some slight variations from the high efficiency levels detailed in AS2374.1.2 in that the high power rating efficiencies (1500, 2000 and 2500 kVA) for oil-immersed transformers have been flattened out to 99.40%. Discussions with manufacturers indicated that the original levels would increase manufacturing costs severely. The 99.40% efficiencies at these levels are still consistent with international practice.

The proposal includes some modifications to the listed exclusions in AS2374.1.2. Some small changes to test procedures are proposed. The draft standard includes a requirement for distribution transformers to be marked as MEPS compliant, using a marking system defined in the proposed new standard. Other changes proposed would have no significant cost impact.

Table 5 Existing and proposed MEPS levels for oil-immersed transformers

Transformer type	Rating (kVA)	Current efficiency levels (MEPS1) at 50% load (%)	Proposed new efficiency levels (MEPS2) (%)
Single phase (and SWER)	10	98.30	98.42
	16	98.52	98.64
	25	98.70	98.80
	50	98.90	99.00
Three Phase	25	98.28	98.50
	63	98.62	98.82
	100	98.76	99.00
	200	98.94	99.11
	315	99.04	99.19
	500	99.13	99.26
	750	99.21	99.32
	1000	99.27	99.37
	1500	99.35	99.40
	2000	99.39	99.40
	2500	99.40	99.40
	3150	NA	99.40

Table 6 Existing and proposed MEPS levels for dry type transformers

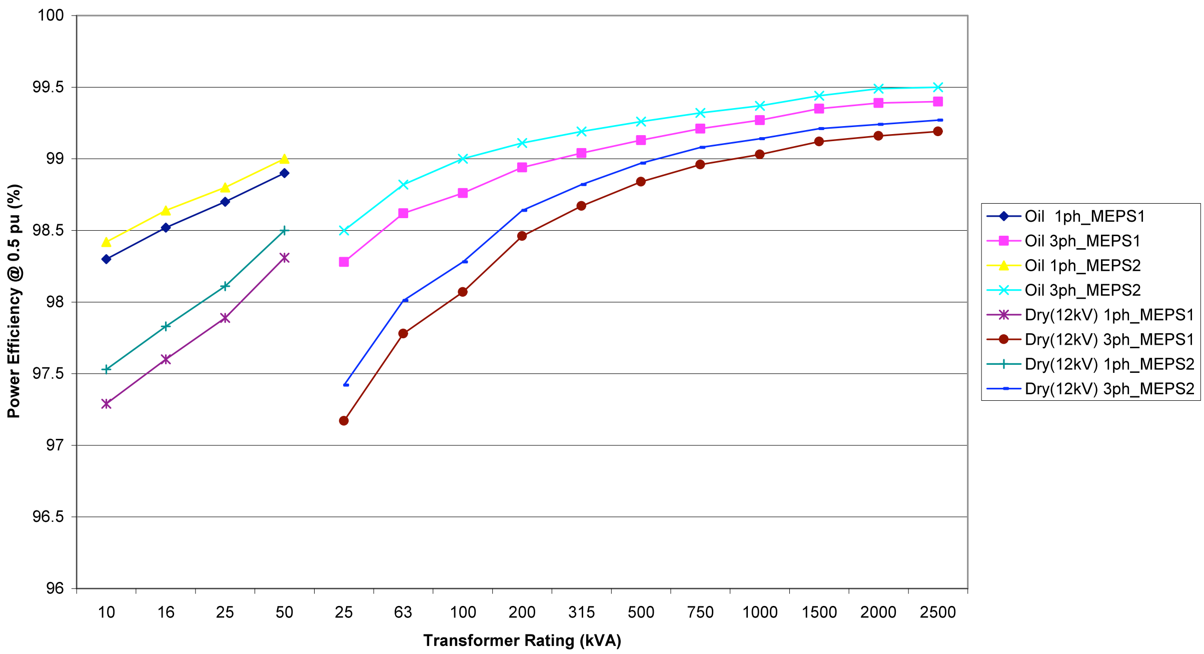
Transformer type	Rating (kVA)	Efficiency (%) at 50% load Um = 12 kV		Efficiency (%) at 50% load Um = 24 kV		Efficiency (%) at 50% load Um =36 kV	
		Existing MEPS1	Proposed MEPS2	Existing MEPS1	Proposed MEPS2	Existing MEPS1	Proposed MEPS2
Single phase (and SWER)	10	97.29	97.53	97.01	97.32	NA	96.87
	16	97.60	97.83	97.27	97.55		97.11
	25	97.89	98.11	97.53	97.78		97.37
	50	97.31	98.50	97.91	98.10		97.74
Three Phase	25	97.17	97.42	97.17	97.42	NA	96.92
	63	97.78	98.01	97.78	98.01		97.30
	100	98.07	98.28	98.07	98.28		97.58
	200	98.46	98.64	98.42	98.60		98.26
	315	98.67	98.82	98.59	98.74		98.44
	500	98.84	98.97	98.74	98.87		98.62
	750	98.96	99.08	98.85	98.98		98.77
	1000	99.03	99.14	98.92	99.04		98.87
	1500	99.12	99.21	99.01	99.12		98.99
	2000	99.16	99.24	99.06	99.17		99.00
	2500	99.19	99.27	99.09	99.20		99.00
	3150	NA	99.27	NA	99.20		99.00

Source: from AS2374.1.2, in part

The MEPS1 and proposed MEPS2 efficiencies are compared in Figure 4-1 for ratings up to 2500 kVA. Distribution transformer efficiencies are typically well over 97.5% already and the absolute efficiency improvement proposed might appear small. The best way to visualise the significance of the proposed improvement is to note that the 100% efficiency line along the top of the plot represents no losses.

The proposed improvement varies with the rating and transformer type, but is in the order of a 10% loss reduction or slightly more across the board. Seen in this way, the loss reduction from each new transformer under the proposed standard will be significant. However, it will take a long time to replace all or most existing transformers via normal growth and replacement, so the improvement will be gradual.

Figure 4-1 Existing (MEPS1) and proposed (MEPS2) efficiencies for all transformer types and ratings



4.3.3 PROPOSED NEW HIGH EFFICIENCY LEVELS

The new proposed draft MEPS standard provides a table of voluntary high efficiency performance levels (HEPS) for transformers which are more stringent than the current HEPS high efficiency levels. They are similar to the USA DOE's MaxTech levels and the Japanese TopRunner levels but have been determined from an assessment of all international high efficiency tables, none of which are mandatory. Proposed new voluntary high efficiency levels are shown in Table 7 for oil-immersed units and Table 8 for dry type units.

Proposed new high efficiency levels are not intended to be de facto mandatory efficiency levels for any future MEPS. They are a guide to efficiency levels technically achievable with current best practice manufacturing methods and with commonly used and available materials. Specifically, the new high efficiency levels do not cover the use of amorphous metal core transformer construction.

Table 7 Proposed new High Efficiency HEPS2 levels for oil-immersed transformers, with proposed mandatory MEPS2 for comparison

Transformer type	Rating (kVA)	Mandatory levels (%) At 50% load	High efficiency levels (%) At 50% load
Single phase (and SWER)	10	98.42	98.74
	16	98.64	98.83
	25	98.80	98.91
	50	99.00	99.10
Three Phase	25	98.50	98.80
	63	98.82	98.94
	100	99.00	99.10
	200	99.11	99.26
	315	99.19	99.34
	500	99.26	99.42
	750	99.32	99.45
	1000	99.37	99.46
	1500	99.40	99.48
	2000	99.40	99.49
	2500	99.40	99.49
	3150	99.40	99.49

Table 8 Proposed High Efficiency HEPS2 levels for dry type transformers, with proposed mandatory MEPS2 for comparison

Transformer type	Rating (kVA)	Efficiency (%) at 50% Load Um = 12 kV		Efficiency (%) at 50% Load Um = 24 kV		Efficiency (%) at 50% Load Um =36 kV	
		Mandatory	High efficiency	Mandatory	High efficiency	Mandatory	High efficiency
Single phase (and SWER)	10	97.53	98.20	97.32	97.90	96.87	97.50
	16	97.83	98.32	97.55	98.06	97.11	97.75
	25	98.11	98.48	97.78	98.20	97.37	97.98
	50	98.50	98.78	98.10	98.50	97.74	98.33
Three Phase	25	97.42	97.88	97.42	97.88	96.92	97.55
	63	98.01	98.37	98.01	98.37	97.30	97.96
	100	98.28	98.61	98.28	98.61	97.58	98.25
	200	98.64	98.83	98.60	98.72	98.26	98.51
	315	98.82	98.95	98.74	98.87	98.44	98.63
	500	98.97	99.08	98.87	99.01	98.62	98.79
	750	99.08	99.19	98.98	99.13	98.77	98.91
	1000	99.14	99.26	99.04	99.19	98.87	98.99
	1500	99.21	99.33	99.12	99.26	98.99	99.08
	2000	99.24	99.37	99.17	99.30	99.00	99.14
	2500	99.27	99.39	99.20	99.33	99.00	99.19
	3150	99.30	99.39	99.23	99.33	99.00	99.19

4.4 Projected Energy Loss Reduction

4.4.1 IMPACT OF PROPOSED MEPS STANDARD

The BAU case assumes that future distribution transformer installations to cover load growth and aged transformer retirements will be in accordance with the current Australian Standard AS2374.1.2 mandatory efficiency levels. Figure 4 2 below shows the projected energy losses that will accumulate from new transformer installations in Australia and New Zealand over the period 2010 – 2025 in the BAU case.

The percentage loss reduction varies across the range of transformers specified in the Australian Standard. To estimate the effect of MEPS2 on losses and emissions, some analysis is required of power system growth rates, the numbers, types and ratings of transformers to be installed in the future and their average loading.

Most of the required information is either readily available or can be estimated with reasonable accuracy. However, there are no data available on the number of transformers in each rating category. Some broad estimates can be made that are sufficient for the requirements of this RIS. The detailed analysis is presented in Appendices B.4 and B.5.

Total annual losses for the years modelled (with the impact of new transformers accounted for in the years after their installation) are shown in Figure 4 3 for both MEPS1 and MEPS2 efficiencies, for all new transformers installed in Australia. The modelling on which Figure 4 3 is based indicates that the cumulative energy loss reduction in Australia over 30 years under MEPS2 instead of MEPS1 would be 10,200 GWh of energy and about 2,000 GWh in New Zealand.

Using a CO_2 intensity of 0.925 tonnes CO_2-e produced for each MWh generated, the corresponding CO_2 loss reduction would be 9.43 million tonnes of CO_2-e and 1.83 million tonnes of CO_2-e in New Zealand. While New Zealand is a predominantly hydro system, this analysis assumes that marginal generation will be from gas. These figures are an overestimate to the extent that CO_2 intensity declines over time either spontaneously or as a result of explicit policy.

Figure 4-2 Total accumulating losses of new transformers with no improvement of transformer energy efficiency for Australia and New Zealand

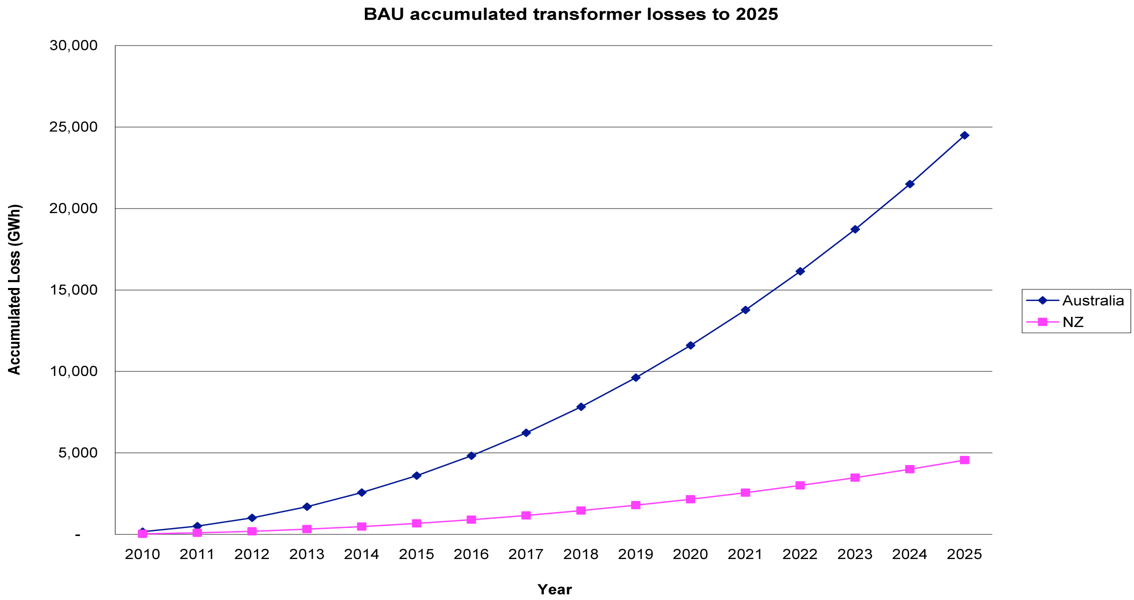
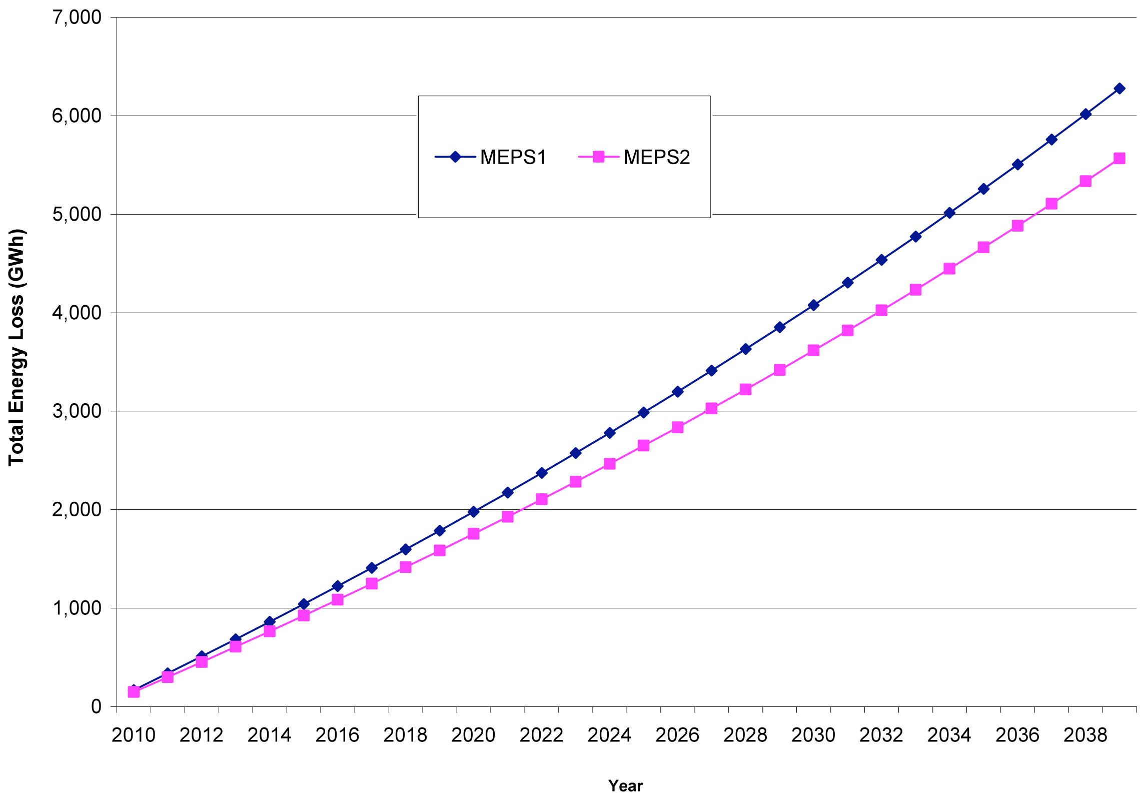


Figure 4-3 Annual losses of all newly installed transformers in Australia: MEPS1 & MEPS2



5 Costs and Benefits

5.1 Overview

This section identifies costs and benefits of the MEPS2 proposal relative to BAU and presents a cost-benefit analysis together with the assumptions. Most of the assumptions that apply to Australia similarly apply to New Zealand. The analysis should be regarded as indicative as there is a general paucity of information available on the cost and mix of transformer types and sizes that are likely to be installed over the next thirty years.

In this section, $ values are A$ (Australian dollars) unless otherwise specified to be NZ$. Unless specific New Zealand data are available, Australian values are converted to New Zealand values at a rate of A$1 = NZ$1.18 which applied at the time of report drafting.

5.2 Costs to the Taxpayer

The proposed MEPS program will impose costs on governments for:

- administration of the program, salaries and overheads including attendance at E3 and standards meetings;
- maintaining a registration and approval capability;
- random check testing to protect the integrity of the program;
- producing leaflets and other consumer information; and
- consultancies for standards development, market research/analysis and RIS preparation.

Using methods consistent with long-term E3 practice for other regulated products, government costs are estimated at:

- $50,000 per year for salary and overheads for administering the program;
- $75,000 per year for check testing, research and other costs - half of it borne by the Commonwealth and half by other jurisdictions, in accordance with E3 cost-sharing arrangements; and
- $25,000 per year for education and promotional activities.

Hence the total Australian Government program costs are estimated at $150,000 per annum. New Zealand costs are estimated to be 25% of the total Australian government costs or NZ$45,000. These costs have been included in the national cost-benefit analyses in later sections for both Australia and New Zealand.

This estimate should be at the upper end of likely costs as there is already a program in place in respect to MEPS1 - MEPS2 is simply lifting the efficiency bar. MEPS2 may be no more costly to administer than MEPS1 so that the incremental cost could be as low as zero. On the other hand, some improvement in testing procedures and oversight is warranted, which has a cost. In any case these costs turn out to be insignificant relative to other costs associated with the MEPS2 proposal.

5.3 Business Compliance Costs

This section reviews the impacts of the MEPS2 proposal on suppliers.

Responsibility for MEPS compliance lies with the seller (i.e. generally the importer or local manufacturer) of the transformer. This analysis assumes that any increases in product design and construction costs will be passed to customers as higher purchase prices. The Business Cost Calculator [23] has been used to estimate the costs for MEPS compliance as follows:

- Education: maintaining awareness of legislation, regulations, and changes to regulation.
- Permission: applying for and maintaining registration to conduct an activity, usually prior to commencing that activity.
- Record Keeping: keeping statutory documents up-to-date.

The costing assumptions are detailed in Table 9 below. The costs of all materials, equipment and other items purchased to comply with the regulation were not included in the business compliance cost category. These costs are explicitly included in the cost-benefit analysis as increased purchase costs to the consumer.

Table 9 Business Compliance Cost Components

Category	Task	Cost Inputs	Source
Education	Training staff, up-to-date with regulations	80 hours/year per supplier	Estimated from other MEPS programs
Compliance	Complete MEPS registration	8 hours per transformer model	Estimated from other MEPS programs
Record Keeping	Maintain documents for 5 years	8 hours per 5 years per supplier	Estimated from other MEPS programs
Other inputs:		Staff costs $40/hr	Australian Jobs 2006

The total cost of business compliance for the MEPS depends on the number of businesses manufacturing and importing transformers and the number of models supplied. There are 45 different models under the MEPS scope although only about 30 of these are supplied in significant numbers. Of these only about 20 are locally manufactured in significant numbers. As the market details are not known cost estimates are made on the following assumptions:

- 8 major local manufacturers in Australia and New Zealand supplying 20 different models in large numbers; and
- 15 importers supplying 30 different models in lower numbers.

Business costs were estimated to be $12,000 per manufacturer/importer, giving a total cost to business of $276,000, based on 23 suppliers. Of these 17 are in Australia and six in NZ. Thus the national breakdowns are A$204,000 in Australia and NZ$85,000 in NZ, using 1A$ ≡1.18 NZ$. It is assumed that new models will be introduced regularly over time so that the above figures will need to be distributed over time. These costs are amortized over a period of ten years at an interest rate of 10% giving A$33,200 and NZ$13,800 per year respectively. After that period the annual cost is estimated to be A$6,000 and NZ$3,500.

These costs are relatively low, explained to some extent by the fact that most local manufacturers already have a compliance regime in place under the current MEPS. Manufacturers that may have avoided MEPS compliance in the past may need to do more than some others to set up their systems for compliance with the proposed new MEPS.

5.4 Increased Costs of Manufacturing Transformers

Improving transformer efficiency involves reducing losses by using improved materials in the core and/or windings or more of the same material in these components, for example by using conductors with a larger cross-sectional area. These days, conductors are generally made of aluminium, which has tended to replace copper. While copper has greater electrical conductivity than aluminium, the increasingly higher price of copper relative to aluminium has been unfavourable to copper. There may be consequential additional manufacturing costs and certainly some costs in revising designs although these would be one-off.

Some transformer costs were obtained from industry consultation, but it is difficult to obtain detailed costing because of commercial in confidence considerations. However it was possible to develop a capital cost for each size of transformer under consideration, based on information provided by one manufacturer on a confidential basis.

For the purpose of this RIS, the incremental cost of MEPS2 compliance across the range of transformers sizes was linked to the level of loss reduction for each size. The percentage reduction in losses is inversely proportional to the quantity and hence cost of material required, either through conductor diameter or core volume. Estimates were made of the increase in capital cost for each transformer size assuming that material cost was 70% of total cost, with labour and other costs comprising 30%. These estimates of increases in capital cost varied across the range of transformer sizes, but were in the range of 5%-10%, enabling an estimate to be made of the total incremental capital cost of the oil-immersed and dry type transformer cohorts expected to be installed between 2010 and 2039. This total cost came out at approximately $20 million/yr in 2010, increasing to $32 million/yr by 2039, and is slightly less than 10% of the total capital cost of transformers added over the period. The level of capital cost increase is considered to be conservative. One manufacturer indicated that the incremental cost increase for MEPS 2 would be nearer to 5%, rather than 10%. The NPV of these annual capital cost increments over the study period was calculated to be $218 million.

Because additional costs relate mainly to materials, increased manufacturing costs will be similar in Australia and New Zealand, as will any increase in imported transformer costs when converted at the prevailing exchange rate. However, the costs of transformer materials such as aluminium or copper are subject to fluctuation on world markets.

5.5 Cost-Benefit Analysis

The following analysis focuses on Australia as the New Zealand analysis will follow a very similar path. It begins with a single transformer analysis which gives a good indication of the likely outcome of a whole of Australia analysis. Neglected in the single transformer case are system-wide costs such as regulatory and compliance overheads which, as it turns out, are relatively small compared with the increase in unit manufacturing costs.

While the primary benefit of MEPS2 is a reduction in energy losses and CO_2 emissions, it is offset by the incremental transformer capital cost required to increase efficiency from the MEPS1 to MEPS2 level. The proposal is to substitute capital for energy.

5.5.1 SINGLE TRANSFORMER ANALYSIS

The annual costs and benefits of energy losses can be capitalised over a transformer's life to give a single figure of benefit that can be compared with the incremental capital cost. Provided the capitalised benefit is greater than the incremental capital cost, then the benefit/cost ratio is greater than one. The standard methodology for this is given in Appendix C.

In performing a cost-benefit analysis of a single transformer, the capitalisation process requires that the future benefits be discounted to the point in time that the transformer goes into service. An appropriate discount rate for this is the WACC for DNSPs as determined by the Australian Energy Regulator (AER). This was determined to be 8.82% in their most recent (May 2009) determination [26]. A transformer life of 30 years is also assumed, although in practice longer lifetimes can be achieved. However the discounting process also means that benefits beyond 30 years are not very significant. The annual cost of losses is calculated from the upstream LRMC of $114/MWh defined in sub-section 2.7.2. This is likely to be an underestimate as LRMC is expected to increase over time, partly as a result of increased wires costs (only part of which will affect distribution transformers) and partly as a result of policies promoting renewable energy and reductions in carbon emissions.

Figure 5-1 shows an optimisation for a 200 kVA oil-immersed three phase distribution transformer using the parameters defined above. The minimum total cost is achieved when the marginal cost of reducing losses equals the marginal capital cost required to achieve the loss reduction. This is where the total cost curve (the top unbroken line) achieves a minimum.

The single transformer analysis needs to be adjusted for the government and industry overheads associated with any change in efficiency standards.

5.5.2 COUNTRY WIDE ANALYSES

The country-wide costs associated with the proposal are not only the increased capital cost of the higher efficiency transformers but also include the cost to both government and industry of administering and complying with the MEPS2 scheme, over and above the current MEPS1 standard. The benefits are the reduction in the long run cost of losses in electricity supply to the distribution transformer level and the associated reduction in CO_2 emissions. A cost of loss figure of A$114/MWh (excluding emission costs) was used to evaluate the loss reduction benefit, as outlined earlier.

The costs and benefits of transformer installations required across Australia and New Zealand between 2010 and 2039 were projected and the NPVs and benefit/cost ratio determined. Table 10 summarises the loss and CO_2 reductions as well as benefit and cost projections (in $M for each currency) for 30 years from 2010. Table 11 at the end of this section gives a year-by year breakdown. NPVs were calculated at discount rate of 8.0%, consistent with other Government economic analyses. Annualised capital cost figures were used in all calculations to account for the residual value at the end of the study period.

Benefit/cost ratios were calculated with and without the benefit of CO_2 reductions. The mechanisms for future price-driven CO_2 reductions are as yet unclear. However, a carbon price or cap and trade will have the effect of increasing the cost and hence price of wholesale electricity. This price increase will represent the inclusion of the externality cost of CO_2 emissions on the environment.

In order to include the benefit of CO_2 reduction, the analysis included an explicit price on CO_2 emissions, starting at $30/tonne in 2011 and increasing linearly to $83.60 by 2039. This trajectory is based on Table 5.3 in the Federal Treasury Document "Low Pollution Future". For the sake of simplicity, the analysis used a constant emissions factor of 0.925 tonnes CO_2/MWh. (See National Greenhouse Accounts (NGA) Factors November 2008). Inclusion of this environmental benefit increases the benefit/cost ratio from 1.2 to 1.71.

Figure 5-1 Optimum efficiency for a transformer (based on 200kVA oil-immersed)

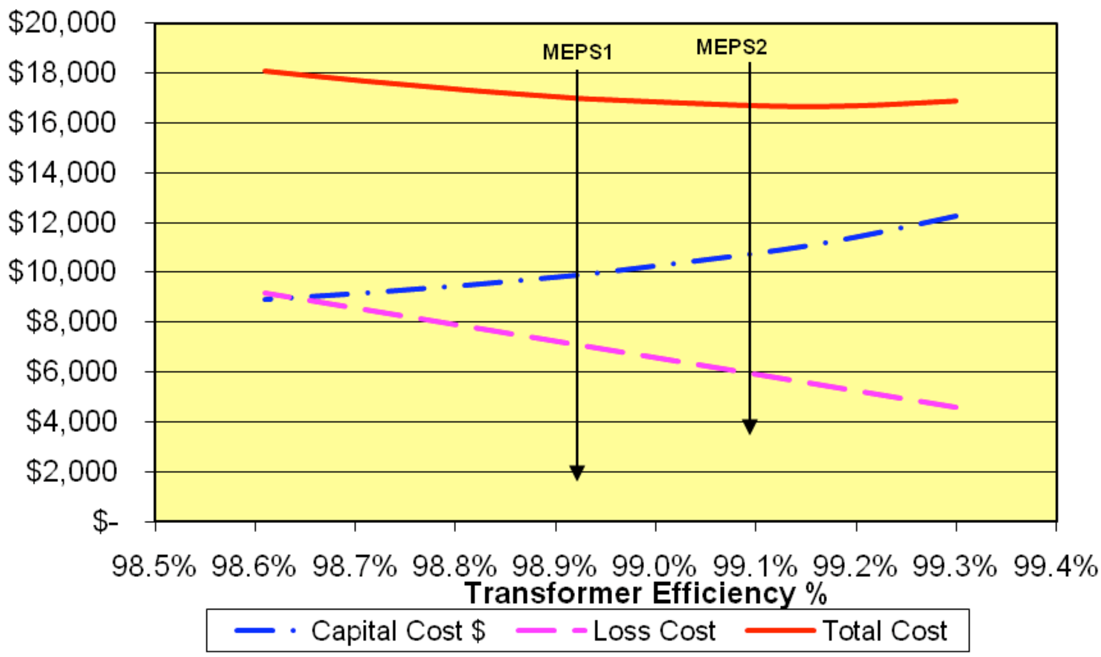


Table 10 Benefits & Costs of MEPS2 Proposal 2010–39: Australia

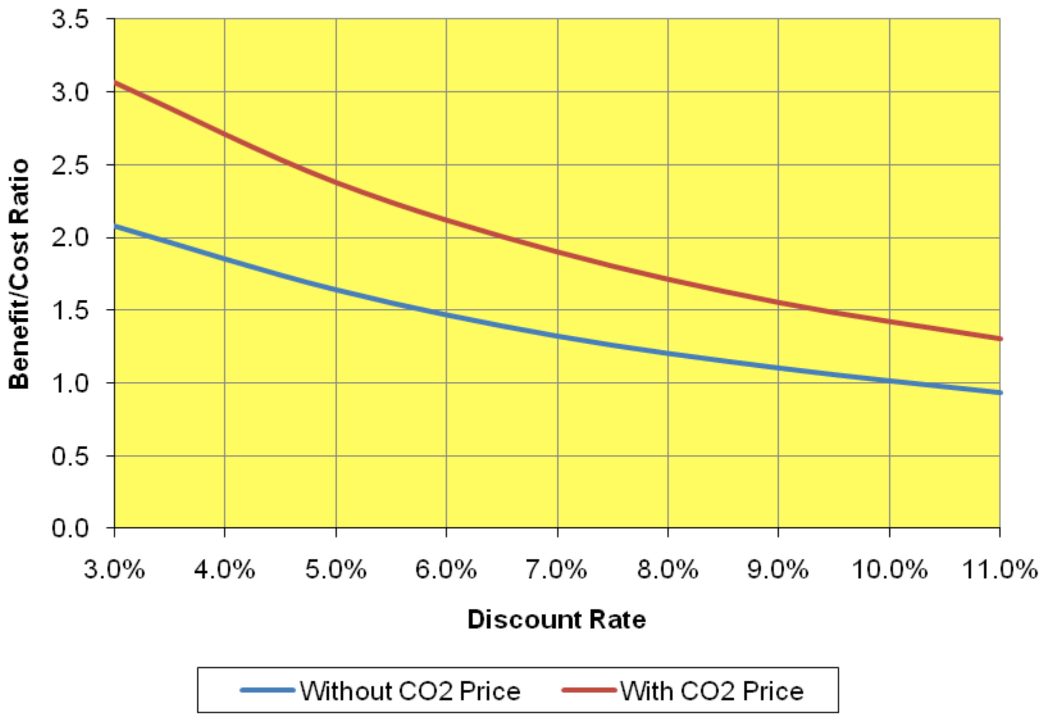
	Units	Value
MEPS1 to MEPS2 Benefits		
MEPS1 Energy Losses	GWh	90,108
MEPS2 Energy Losses	GWh	79,911
Reduction in Energy Losses	GWh	10,197
Value of Loss Reduction	$M	277
Reduction in CO_2 Emissions	Mt CO_2-e	9.43
Value of CO_2 Reduction	$M	118
Total Annual Benefits without CO_2	$M	277
Total Annual Benefits with CO_2	$M	396
MEPS1 to MEPS2 Costs		
Incremental Cap Cost Annualised	$M	229
Annual Government Costs	$M	1.7
Annual Business Costs	$M	0.3
Total Annual Costs	$M	231
Benefit/Cost Ratios		
Benefit/cost without CO_2		1.20
Benefit/cost with CO_2		1.71

New Zealand costs and benefits were pro-rated from the Australian values according to the estimates made of the relative losses in the systems. Implementing the proposed MEPS in New Zealand is estimated to save about 2,000 GWh over a period 2010-2039. This is over and above the amount delivered by the current MEPS and is roughly equivalent to about 1.83 million tonnes of CO_2. Please refer to the EECA discussion document 'Proposed Revised Minimum Energy Performance Standards for Distribution Transformers" December 2010 for NZ cost-benefit analysis.

The choice of the appropriate discount rate to the future costs and benefits is another area of uncertainty. The above analysis used the 8% used in other areas of Government advice, in particular analyses carried out into the costs of CO_2 emissions. The current WACC for distribution utilities, as recently determined by the Australian Energy Regulator, is slightly higher at 8.82%.

Figure 5-2 below shows the benefit/cost ratio for the MEPS1 to MEPS2 transition for discount rates between 3% and 11%. Two curves are shown, the lower one without any CO_2 reduction benefit, and the upper one with the CO_2 reduction benefit included. The increase of the benefit/cost ratio by the inclusion of the CO_2 reduction benefit is maintained across the full range of discount rates considered. Specifically, benefit/cost ratios for the specific discount rates of 8% and 8.82% can be read from the chart.

Figure 5-2 Evaluation Sensitivity to Discount Rate



Some consideration should be given to whether a more modest loss reduction, to say the order of 5% rather than 10%, might be sought. Loss reduction is more or less proportional to the incremental volume and cost of materials required. Benefit/cost ratios are likely to be very similar for different target efficiencies as long as engineering considerations do not force new designs and much more expensive manufacturing methods and materials. The current proposal aims to minimise future losses within that constraint.

Table 11 below shows the snapshots of the benefits and costs over the study period from 2011 to 2039. Annual incremental capital cost is determined from the NPV of annualised cost of capital cost increases for MEPS2 transformers over MEPS1 transformers. This avoids the need to consider salvage values at the end of the study period. The benefit/cost ratios in each year are indicative numbers and are simply the annualised costs of incremental annualised benefits over incremental annualised costs in each year. The true NPVs over the whole 30 year period are contained in the last column. Cumulative totals of loss reductions and greenhouse gas emission reductions are also shown in the last column.

Table 11: MEPS1 to MEPS2 Cost Benefit Analysis for Australia - 2010-2039

Parameter / Year	Units	2010	2011	2012	2013	2014	2019	2024	2029	2034	2039	Totals /NPV
Total No. of Transformers		863,744	885,338	907,471	930,158	953,412	1,078,698	1,220,448	1,380,825	1,562,277	1,767,573	
Total New Transformers		39,606	40,133	40,672	41,226	41,793	44,849	48,306	52,218	56,643	61,650	1,481,063
Assumed Carbon Price	$/t CO_2	$0.00	$30.00	$31.12	$32.28	$33.48	$40.20	$48.27	$57.97	$69.60	$83.58	
MEPS1 to MEPS2 Benefits												
MEPS1 Energy Losses	GWh	168	338	510	685	862	1,786	2,780	3,852	5,014	6,277	90,108
MEPS2 Energy Losses	GWh	149	300	453	608	765	1,584	2,465	3,416	4,447	5,566	79,911
Reduction in Energy Losses	GWh	19	38	58	78	98	202	315	436	567	710	10,197
Value of Loss Reduction	$M	2.2	4.4	6.6	8.8	11.1	23.0	35.9	49.7	64.7	81.0	277.2
Reduction in CO_2 Emissions	Mt of CO_2	0.02	0.04	0.05	0.07	0.09	0.19	0.29	0.40	0.52	0.66	9.43
Value of CO_2 Reduction	$M	0.000	1.061	1.662	2.314	3.021	7.515	14.045	23.373	36.532	54.916	118.426
Total Annual Benefits w/o CO_2	$M	2.165	4.359	6.583	8.837	11.121	23.039	35.857	49.694	64.684	80.978	277.235
Total Annual Benefits with CO_2	$M	2.165	5.420	8.245	11.151	14.143	30.554	49.902	73.067	101.216	135.895	395.661
MEPS1 to MEPS2 Costs												
Annualised Inc. Cap Cost	$M	1.783	3.591	5.424	7.282	9.167	19.006	29.606	41.067	53.502	67.039	228.962
Government Costs	$M	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	1.689
Business Costs	$M	0.033	0.033	0.033	0.033	0.033	0.033	0.006	0.006	0.006	0.006	0.251
Total Annual Costs	$M	1.967	3.774	5.607	7.465	9.350	19.189	29.762	41.223	53.658	67.195	230.901
Benefit/cost Ratios												
Benefit/cost Ratio w/o CO_2		1.10	1.15	1.17	1.18	1.19	1.20	1.20	1.21	1.21	1.21	1.20
Benefit/cost Ratio with CO_2		1.10	1.44	1.47	1.49	1.51	1.59	1.68	1.77	1.89	2.02	1.71

6 Industry Considerations

6.1 Overview

While net cost savings and associated greenhouse gas reduction benefits are projected by adopting MEPS2, further assessment is required on:

- impact on manufacturers and suppliers of transformers;
- the impact on users and owners of transformers;
- consistency with international practice;
- compliance testing issues; and
- trade issues.

6.2 Manufacturers and Suppliers of Transformers

About 80-85% of utility distribution transformers in Australia and New Zealand are manufactured in Australasia, most of which by these six companies:

- Wilson Transformers
- ABB T&D Australia
- Schneider-Electric
- Tyree Transformers
- ABB T&D New Zealand
- ETEL Transformers New Zealand.

All of the major transformer manufacturers are long-established with good in-house design and manufacturing capabilities. Some have subsidiary factories in SE Asia which also manufacture for the utility market in Australia.

Most but not all of the major manufacturers in Australia are now represented by the Australian Industry Group (AiG). The Australian Electrical and Electronic Manufacturers Association (AEEMA) joined AiG in January 2008. The AiG Electrical Capital Equipment Forum is the industry association representing transformer manufacturers and suppliers. AEEMA and now AiG have been involved in ongoing negotiations on the development of the draft standard.

Appendix B provides more detail on the characteristics of the distribution transformer manufacturing and supply industry in Australia and New Zealand.

6.3 Users and Owners of Transformers

Introducing MEPS2 efficiency levels will affect power utilities and the private sector differently.

6.3.1 UTILITIES SECTOR

Restraints currently imposed by the Australian Energy Regulator (AER) on utility infrastructure expenditure will have some impact if a tighter MEPS2 efficiency standard is introduced. With a restrained capital budgets and higher costs for new transformers, utilities may consider leaving older, less efficient transformers in service for longer. The cost-benefit analysis has attempted to make some allowance for this. On the other hand, when new transformers are installed and older ones eventually replaced, the new standard will ensure that overall efficiency is gradually improved. In any case, utilities that follow good industry practice should be able to convince the regulator of the need for an appropriate return on the incremental investment. The energy component of customer tariffs should be reduced over time, relative to what they otherwise would have been, due to the lower level of losses.

6.3.2 PRIVATE SECTOR - MANUFACTURING, MINING AND COMMERCIAL

Transformers used in the private sector are more likely to be imported. Re-design by some overseas manufacturers to meet the MEPS2 standard may be required and local manufacturers may gain a temporary greater market share as a result. The private sector may use re-furbished transformers more if supply difficulties arise, delaying some of the intended loss reduction.

On the other hand, more efficient transformers will tend also to reduce intrinsic transformer losses from non-linear industrial loads, a factor that will tend to encourage greater expenditure on lowering losses as such non-linear loads are growing in importance.

6.4 Consistency with International Best Practice

Figure 6-1 below shows the comparative ratings of the proposed MEPS2 levels with some international efficiency standards for oil-immersed transformers. MEPS standard clearly lags the others. Proposed MEPS2 levels are higher than levels proposed by the US above about 1000 kVA and are also higher than the current European Union CENELEC C levels (which are at the highest efficiency range of several alternatives specified by the EU). MEPS2 levels are slightly lower than proposed prEN50464-1 levels which have not been implemented by the EU.

Originally proposed MEPS2 efficiency levels for higher ratings were slightly higher than some (but not all) international efficiency levels. Some local transformer manufacturing industry representatives argued that significant changes in designs would be required and higher manufacturing costs would be incurred to achieve compliance in these cases. After further discussion with local manufacturers the efficiency targets at the higher ratings (1,500-2,500 kVA) were reduced slightly. MEPS2 targets for other rating levels did not raise the same concerns.

MEPS1 levels for dry type transformers also lag international standards. Figure 6-2 shows a comparison for dry type transformers (12 kV Um rating only). The proposed 24 kV and the 36 kV efficiency levels are slightly lower than for 12 kV. The figure shows that MEPS2 levels are higher than most others. They are exceeded only by the US benchmark and the Japanese TopRunner levels, which are based on amorphous core transformers.

The Japanese levels and the US benchmark levels are not mandatory; they are designated by those countries as an indication of theoretically achievable levels. Apart from the Japanese range, all of the efficiency levels shown, including MEPS2, are based on standard silicon steel cores. While amorphous core transformer technology can be more efficient than silicon steel cores, up to 2009 this technology had not yet been introduced into Australia.

In summary, transformer manufacturer to MEPS2 standards appears readily achievable using standard materials but improved designs, despite being at the leading edge of international standards. Amorphous cores are not required to achieve the specified efficiency levels. Only at the highest ratings of oil transformers are these targets likely to be challenging.

Figure 6-1 Comparison of MEPS1 and MEPS2 oil-immersed transformer efficiencies with international standards

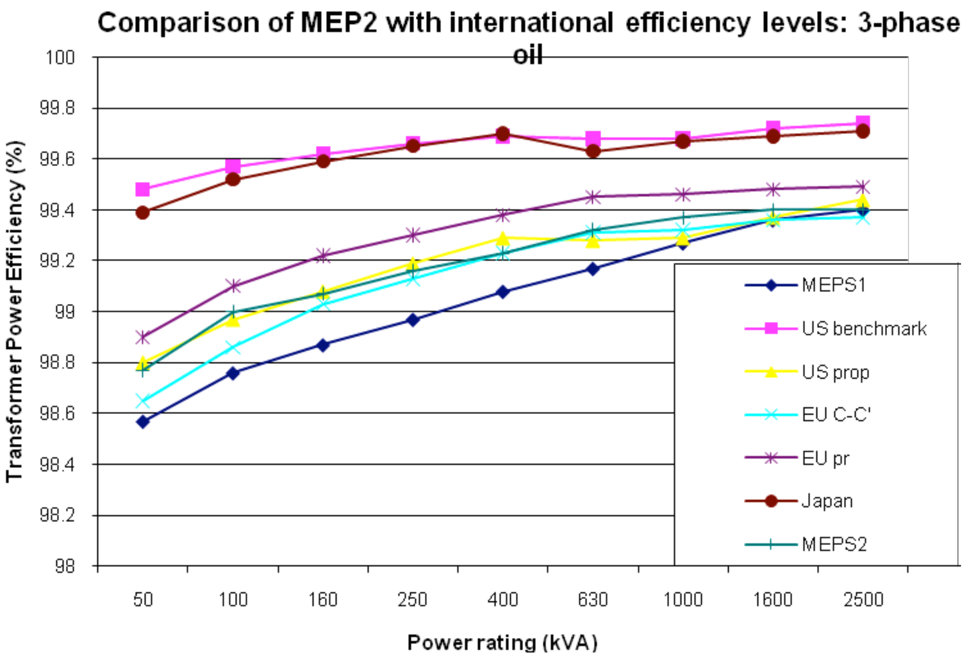
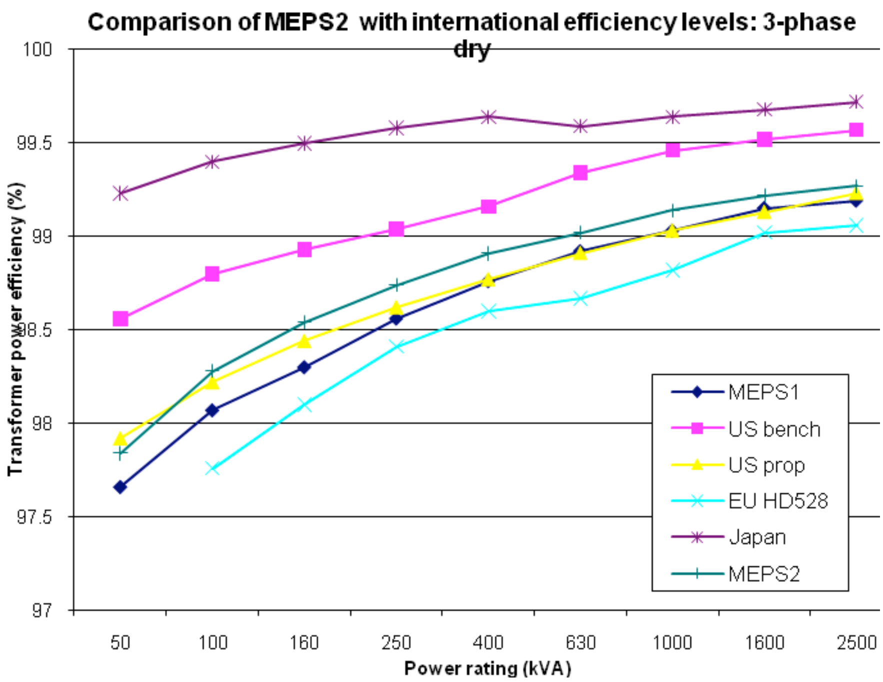


Figure 6-2 Comparison of MEPS1 and MEPS2 dry type transformer efficiencies with international standards [Um = 12 kV]



6.5 Compliance Testing of Transformers

The MEPS program requires registration of each unit type with the E3 Committee. This process requires each transformer type to be tested to determine its efficiency, either by the manufacturer or by some test organisation commissioned by the manufacturer. However, as transformer production is labour-intensive, it is now common practice for Australian manufacturers to test every transformer as it comes off the production line.

The test procedure creates additional costs and takes some time to perform. Equipment and standards must be maintained to comply with accuracy requirements. Temperature equilibrium is required to measure accurately resistance and electrical power. Ideally the transformer under test should be left for a day or so to achieve thermal equilibrium, increasing transformer production time.

6.5.1 TEST PROCEDURES

Test methods used to register and check test transformers are specified in Australian Standard AS2374.1 Power transformers – Part 1: General. The MEPS standard, Australian Standard AS2374.1.2 refers to the test method outlined in AS2374.1. This Standard has now been superseded by AS60076.1-2005: Power Transformers – Part 1: General but the test method has been left unchanged.

The test method specified in AS60076.1 aims to measure load and no-load losses to determine whether they satisfy the tolerance requirement for losses. The tolerance requirement is that each transformer must be within 10% of the specified total loss for the transformer type, or within 15% for either component of total loss. The calculated efficiency is required to be accurate to within about 0.01%. Achieving this level of accuracy requires good quality measurement equipment and care and accuracy in its calibration, a costly process.

6.5.2 TEST LABORATORIES

There are only a few laboratories in Australia and New Zealand able to perform MEPS tests. This will limit the check testing program unless throughput can be increased. Furthermore, testing laboratories should ideally be accredited through the National Association of Testing Authorities (NATA) to ensure that they use adequate test techniques and that can be an expensive and drawn out process.

The check testing problem is potentially more challenging when imported units are taken into account. In the period 2000-06, some 4,785,000 transformers were imported into Australia from 42 countries. The break down was about 307,000 oil-immersed units up to 10 MVA and about 4,478,000 dry type units. The total value of these imports was about $421 million. Of these, most of the oil-immersed units but only about 2,432,000 of the dry type units were within the MEPS rating range.

6.6 Trade Issues

Many of the imported transformers are dry types destined for the mining, industry and commerce.

The proposed MEPS2 efficiency levels will apply equally to imported and locally manufactured transformers. Manufacturers are required to seek registration for their units by supplying test data. The challenge is to ensure that tests are carried out to the same standard as locally manufactured transformers so that efficiency levels can be fairly compared.

The Australian Standard setting out the basic test method is based on the international standard IEC 60076 on power transformers so it does have some international coverage. However, not all countries adopt and use IEC standards. North America uses its own standards (ANSI, IEEE or in this case NEMA based) which is appropriate as they operate on a different frequency i.e. 60Hz.

Further, not all countries have organizations like NATA to accredit test laboratories and ensure that they use adequate test techniques. This may result in some challenges for manufacturers in countries that do not themselves have efficiency programs and associated test standards and facilities. However as transformers usually have to have a "type test" certificate before being sold, efficiency testing should not add a great deal to the cost.

Of the 42 countries that supplied transformers to Australia, only a few have transformer efficiency programs. Those that do are:

- Brazil
- Mexico
- India
- China and Hong Kong
- United States
- European Union
- Canada
- Taiwan
- Japan

Other countries not known to have transformer efficiency programs in place and supplying transformers to Australia within the MEPS range include the following:

- Colombia
- South Africa
- Malta
- Indonesia
- Turkey
- Singapore
- Korea
- Malaysia
- Croatia
- Switzerland
- Philippines
- Israel
- Vietnam
- Slovenia

In summary, the MEPS2 proposal, as with the MEPS1 regulation already in force, meets Australia's obligations under General Agreement on Tariffs and Trade (GATT) not to discriminate against imports. The proposed MEPS2 efficiency levels are consistent with best practice international efficiency standards and all new transformers installed in Australia would need to satisfy the specified efficiency standards. Test methods used are based on international standards with some variation to adequately account for measurement uncertainty.

There may be some impact of MEPS2 on countries with no MEPS-like programs. To continue to supply Australia and New Zealand they will need to improve designs and provide test facilities that will enhance their technology and competitiveness in transformer manufacture.

6.6.1 COMPETITION

Implementation of this proposal is unlikely to affect the competitiveness of one local manufacturer over another. Local industry representatives have reported that transformers that meet MEPS2 standards are available or can be manufactured locally. There is a potential challenge with supply of low loss core materials but this would affect all manufacturers equally.

Some transformer importers escaped the provisions of the previous MEPS but will be subject to the provisions of the new one, which will more fully cover imported transformers. Clearly, non-conforming transformers will be removed from the market and a high proportion of those affected will be imports. This may give local manufacturers a temporary advantage but such an advantage is unlikely to last for long; only as long as it takes imported suppliers to gear up to the new standard. The technology involved is not radical.

6.6.2 TRANS-TASMAN TRADE

NZ is a significant supplier of transformers to Australia. However, it is also a partner in the MEPS program for transformers. As the same efficiency standard would be applied on both sides of the Tasman, there should be no discernable effect on trans-Tasman trade.

7 Industry Consultations & Standards Australia Processes

7.1 Overview

Issues raised at the various industry consultations detailed below have influenced the structure of the proposal in this RIS.

The proposed new efficiency levels in the draft standard have been determined with industry input and concerns taken into account. MEPS2 levels have been based on current HEPS1 levels but reduced slightly for the larger transformers. HEPS2 levels are included as a voluntary guide for purchasers who wish to use more efficient products and are not intended as an indication of future minimum power efficiency levels.

The proposed MEPS and HEPS for oil-immersed transformers used in 33kV networks have been set at the same level as for 11 and 22kV networks. For dry type transformers the proposed MEPS values for 33kV networks were determined from industry data at levels fairly close to current practice. HEPS levels were set substantially higher to provide an aspirational target for the renewable energy sector.

The following sub-sections outline in more detail the consultation processes used and outlines the issues raised by industry and used to refine the proposal.

7.2 Consultation Approach

E3 announced a proposed move to MEPS2 for transformers at the Energy21C conference in November 2007, to come into effect no earlier than October 2010.

On 14 December 2007, E3 released a Technical Report "Distribution Transformers: Proposal to Increase MEPS Levels" as the first stage in the consultation process. Public comments for this report closed on 25 January 2008. Electronic copies of the Technical Report were sent to stakeholders and also made available on the www.energyrating.gov.au website. Whilst New Zealand stakeholders provided comments, none were received from Australian stakeholders.

7.3 Standards Australia Processes

All standards developed through Standards Australia processes are developed consultatively with industry stakeholders involved throughout.

The Standards Australia Committee, EL-008 Power Transformers, had preliminary discussions in December 2007 about this proposal. In July 2008, EL-008 discussed the scope of the draft MEPS2 Standard and technical feasibility in July 2008.

Subsequently, a Standards Working Group was set up to progress the development of the draft standard. This group met twice (October 2008, November 2008). Membership included:

- ABB
- DEWHA (on behalf of E3)
- E3 consultant
- Electricity Networks Association (ENA)
- ETEL (NZ)
- Schneider-Electric
- Tyree
- Wilson Transformer Company.

The Standards Working Group gave in-principle support for a move to MEPS2 levels no earlier than October 2010.

In March 2009, EL-008 Power Transformers met to consider the draft MEPS2 standard. The draft was accepted in principle and it was agreed to include:

- 33 kV transformers for the first time (as used in wind farms and other renewable energy generation) pending further consultation with the sector;
- efficiency values for transformers up to 3,150 kVA for 11kV, 22kV and 33 kV networks; and
- the marking of transformers as MEPS compliant.

7.4 Other Industry Consultations

Other industry consultation **in Australia** has included:

- discussions held with the Australian Electrical and Electronic Manufacturers Association's (AEEMA) Electrical Capital Equipment Forum;
- ongoing consultation with the Australian Industry Groups (AiG's) Electrical Capital Equipment Forum (March 2007, October 2007, December 2007, March 2008, August 2008) as well as ad hoc consultation from time to time (note AEEMA joined with AiG in Jan 2008);
- meeting with Energy Networks Association (ENA) in November 2008 and ad hoc consultation from time to time;
- discussion of proposal and draft cost-benefit analysis at an industry stakeholder consultation forum in February 2009 in Sydney;
- a wind farm sector stakeholder consultation forum in Adelaide in February 2009 and ad hoc consultation from time to time;
- informal consultation with the Clean Energy Council; and
- ongoing ad hoc consultation with stakeholders.

In **New Zealand**, EECA advised NZ suppliers of the MEPS2 proposal in November 2008 and presented to stakeholders in Auckland. EnergyNews distributed this advice in their email newsletter. EECA received submissions which were considered.

EECA advised stakeholders of the proposal to include wind turbine transformers in May 2009. This notification was available on the Wind Energy Association website, submissions were received and considered.

7.5 Issues of Concern about MEPS2 Raised by Industry

The Electrical Capital Equipment forum members (first under AEEMA and then under AiG) raised the following issues:

- it was difficult for manufacturers to comply with the transformer MEPS efficiencies that were initially proposed at the very high rating levels (2000 kVA and above);
- there were potential increases in costs and problems with availability of materials including low loss core material;
- there could be potential contract problems for long-term, multi-year supply contracts with utilities;
- increased compliance efforts by E3 were required to avoid suppliers complying with regulations being undercut by cheap non-compliant product with the regulations; and
- industry also had some concern that HEPS2 levels may be intended to become mandatory in the future.

The first point has been dealt with by easing the target efficiencies for the higher rating transformers as noted earlier and discussed in Section 3.

On the second point, there are few manufacturers (mainly Japanese) of high grade low loss core steel and none in Australia. Australian manufacturers were concerned that the steel supplies needed to manufacture so many transformers to the MEPS2 standard may be hard to secure in the face of high competing demand for this steel. On the other hand, Australia is a small proportion of the world market for transformer materials so that the improved standard is not likely to have an influence on world prices for these materials.

The third point is a contractual issue that buyers and sellers will need to deal with.

The issue of compliance testing and enforcement is important. The Department of Climate Change and Energy Efficiency is working on a major reform with proposed national legislation for MEPS and Energy Labelling. This problem has been identified as an issue that needs to be addressed in that context.

The last point was dealt with by adjusting the wording in the draft standard.

A draft cost-benefit analysis (CBA) and various options for estimating benefits for the CBA were discussed with industry representatives at the stakeholder forum in February 2009 in Sydney.

One view expressed was that the benefits claimed in the draft CBA may not be realised because transformers are already being purchased at higher than MEPS1 efficiencies. Hence the base line is unclear. However, it was acknowledged that while this would result in reduced benefits, costs would also be lower; the benefit/cost ratio would be little changed. It was suggested that the difference between MEPS1 and MEPS2 could be seen as an opportunity cost because, in the BAU case, manufacturers would be at liberty to revert down to MEPS1.

At industry consultations it has been agreed by manufacturers and suppliers that MEPS2 for distribution transformers does need to go ahead. At the same time the following additional issues have been raised:

- concern has been expressed by industry that MEPS should apply to all transformers installed in Australia rather than just transformers sold in Australia - it is alleged by local manufacturers that some companies purchase transformers overseas and bring them into Australia and install them without ever being required to register the transformers;
- industry has suggested licensing installers (in accordance with AS3000) and they could then be asked to check that a transformer is registered;
- importers could be required to meet Australian Standards when importing; and
- it was claimed that some manufacturers had been making transformers at higher than MEPS1 level of efficiency prior to the introduction of MEPS1 and actually decreased their standards as a result of the introduction of MEPS1.

As noted in the previous sub-section, the issue of ensuring that all distribution transformers installed in Australia are compliant to MEPS is being addressed in legislation currently under development.

The proposal to extend MEPS coverage (at MEPS 1 levels or higher) to 33kV transformers (which are widely used with wind power turbines) was promulgated to the wind farm sector and wind generator suppliers. At a consultation forum held in Adelaide, one supplier expressed the view that transformers in this sector should not be regulated because the sector already produces renewable energy and producers of wind power have incentives to maximise efficiency. However, E3 remains concerned that capital cost rather than total life-time cost may be overly influencing purchasing choices when more efficient technologies are available.

8 Conclusions and Recommendations

8.1 Conclusions

The proposed regulations to increase mandatory efficiency performance standards for distribution transformers affect:

- transformer manufacturers in Australia and New Zealand;
- importers of transformers for use in Australia and NZ; and
- owners of the transformers who are primarily:
  - owners of the public electrical distribution system; and
  - private owners of distribution transformers in the manufacturing, commercial, mining and processing sectors.

In the main, the incentives for these parties to adopt higher efficiency transformers are weak. Distribution businesses that make transformer purchase decisions do not benefit directly from improved efficiency and the electricity network regulator has declined to implement explicit incentives for them to do so. In the case of general industry the focus on minimising up-front costs as a risk management measure is understandable. In the case of wind farms, the case for high efficiency transformers is strengthened by the high cost that this energy source incurs in meeting mandated renewable energy targets. A mandatory efficiency requirement such a MEPS overcomes these weak incentives in a way that does not disadvantage one supplier over another.

Implementing MEPS2 will have the following effects:

- lifetime costs of distribution transformers will be reduced when capital and energy costs are taken into account;
- transformers used in private industry and in private wind farms, although faced with somewhat different incentives and cost conditions, are similarly likely to reduce their lifetime costs;
- taking business and regulatory overheads into account the benefits will outweigh costs, with a benefit/cost ratio of about 1.1 without taking emissions into account, and of the order of 2, if the cost of emissions is included;
- there should be no negative impact on product quality and function;
- there should be no significant negative impacts on manufacturers and suppliers as potential issues have been recognised and removed;
- the standard is consistent with the objectives of the National Appliance and Equipment Efficiency Program to match international best practice; and
- significant additional benefits will be gained from reducing greenhouse gas emissions, although this component of benefit is not strictly required to justify the proposal.

A carbon price will certainly tend to encourage greater efficiency but does not in itself address the weak market incentives for efficiency when transformer purchase decisions are made. The MEPS option will complement a carbon price in meeting the stated objective.

The MEPS2 proposal for transformers has been in the public domain since October 2007. Proposed efficiency levels are agreed by manufacturers and users in Australia and New Zealand. An Australian/New Zealand Standard is in the process of being developed on the basis of the efficiency levels in this RIS. Industry stakeholders have been advised that MEPS2 will be not be introduced before October 2011.

8.2 Recommendations

It is recommended that the Ministerial Council on Energy agree:

1. *To implement increased mandatory energy performance standards for distribution transformers by regulation.*
2. *That distribution transformers must meet or surpass the energy performance requirements set down in the draft Australian and New Zealand Standard AS/NZS 60076.99:200X, Minimum Energy Performance Standard (MEPS) requirements for distribution transformers as shown at Appendix A.3.*
3. *That the new efficiency levels apply to all transformers currently within the scope of AS2374.1.2, to those included through modification of the list of exclusions as detailed in this RIS and to those added in the scope of the new Standard. This transformer MEPS is to cover oil-immersed and dry type distribution transformers with power ratings from 10 kVA to 3150 kVA intended to be used on 11 kV, 22 kV and 33 kV networks.*
4. *That the amendments take effect no earlier than 1 October 2011.*
5. *That all jurisdictions take the necessary administrative actions to ensure that the new regulation levels can take effect no earlier than 1 October 2011.*
6. *That overseas manufacturers be provided with the amended test method procedures and be required to use this test method or equivalent to register their transformers with the MEPS program.*
7. *That the proposed new MEPS standard of its loss reduction benefits be advocated strongly to the private sector.*

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A.1 Transformer Application and Structure

The role of the transformer in electrical networks is to change the voltage level as power flows from one part of the network to another. Electrical energy transfer over long distances is more efficient if the current is low, because losses in transmission lines are proportional to the square of the current and appear as heat known as ohmic heating. Low current requires high voltage to transfer a given amount of electrical power, as power transfer is proportional to current and voltage level. The consumer will normally take power at low voltage (415/240 V).

Transformers use the magnetic induction principle. Alternating current in a coil of wire around a soft magnetic material core generates an alternating magnetic field (flux) in the core. The core is configured in a closed loop to constrain the magnetic field to core material by reducing the leakage flux outside the core material. The alternating magnetic field in the core then induces a voltage in another winding on the same core. This winding may be contiguous with or separated from the first winding, but still on the common core. Voltage in the second winding is determined by the relative number of turns in the two windings.

One reason for using alternating current rather than direct current in electrical power systems is that it supports the use of transformers operating on this principle to change voltage levels.

Both the magnetic core material and the windings generate heat when the transformer is in operation so the efficiency of energy transfer through the transformer is less than 100%. Higher temperatures produced by this heating also increase loss in the transformer windings. There are essentially only two ways to improve efficiency:

- use of lower loss core material; and
- use of windings with lower electrical resistance to reduce ohmic heating; this implies a larger cross sectional area for the windings or use of a material of lower resistance.

The pattern of transformer operation may limit the effectiveness of these approaches.

Electrical distribution networks use different types of transformers. The subjects of this RIS are transformers used to transfer power between two electrical networks operating at different voltages. Other types used in the network are so-called "instrument transformers"; ammeters and voltmeters used to measure current and voltage levels for billing and operational purposes, including the protection of electrical equipment. Operating on the same induction principle as the energy transfer transformers, current and voltage transformers are designed for high measurement accuracy and minimal impact on the circuit from their own operation. Their very small losses make no significant contribution to total network losses. Metering losses are normally considered to be part of the non-technical losses in the network; technical losses are those incurred by the wires and power transfer transformers.

A.2 Transformer Design

A.2.1 GENERAL DESIGN FEATURES

The simplest form of transformer is the standard single phase transformer shown in Figure 9-1. It comprises a soft magnetic metal core built up from thin laminations made of highly refined magnetic steel sheets. Wound around the magnetic metal core are two separate electrical windings, the primary and the secondary. The two windings carry alternating current and transform the voltage of the power supply according to the relative number of turns in each winding. The current in each winding will be different and thus the size of the winding conductors must be different to accommodate the different current levels. The windings are most commonly copper wire or strip but in many distribution transformers the secondary (low voltage) winding is made of aluminium sheet.

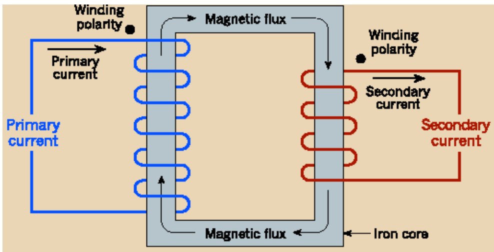
The magnetic steel core is used to contain and channel the alternating (AC) magnetic field flux around the core structure (the magnetic circuit). The magnetic flux in the core is generated by passing a small electrical current (the core magnetising current) through one of the windings (the primary) which is connected to the AC power source. The secondary winding is then connected to the load. For a typical distribution transformer the primary will be connected to the 11,000 volts (11 kV) 3-phase or 6,350 (6.35 kV) single phase network. The secondary winding will normally supply 415 volts 3-phase (240 V single phase) to any load connected to the secondary. Even if no load is connected to the secondary, the presence of flux in the core will require magnetising current, incurring energy losses.

Figure 9-1(a) shows the general features of the single phase transformer construction and the major relevant components (the magnetic core that contains the magnetic flux and the windings that carry the currents). Three phase transformers have three sets of primary and secondary windings, one for each phase, with each set wound on a separate leg of a multi-limb transformer core. (See for example Figure 9-2(c)).

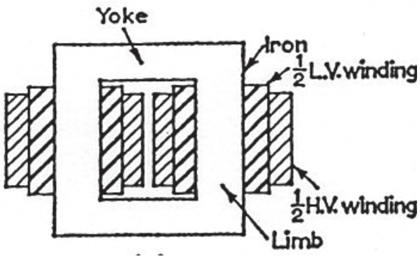
In a simple single phase transformer the windings are wound on the transformer core with the magnetic field coupling through both windings as in Figure 9 1(b). The primary winding is the high voltage (outer) winding. The power taken to the load is thus transferred from the primary to secondary winding and load via the magnetic flux generated in the core by the magnetising current. There are limits imposed by core material properties on the magnitude of the magnetic flux density in the core

Figure 9-1 Single phase transformer schematics

(a)



(b)



A.2.2 TRANSFORMER TYPES

Figure 9-2 shows examples of typical oil-immersed and dry type distribution transformers.

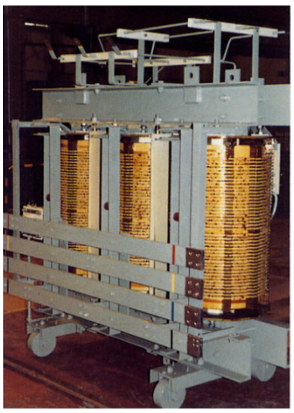
In oil-immersed transformers (see for example Figure 9-2(a)) the windings and core are immersed in insulating oil which provides both electrical insulation and thermal transfer to dissipate heat generated by transformer losses.

In dry type transformers (Figure 9-2(b) and Figure 9-2(c)) electrical insulation is provided only by solid insulation materials. Insulating paper is wound over the winding wire/conductor and then encased in a solid casting of epoxy resin as illustrated in Figure 9-2(c). Alternatively, in the open winding dry type (Figure 9-2(b)) the windings and paper insulation are given a thick varnish-type coating.

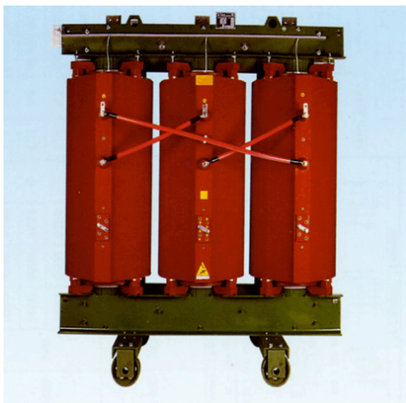
Heat produced by a transformer must be dissipated at a rate that maintains the temperature of its electrical insulation within allowable limits. In dry types heat generated by losses can be dissipated only by thermal conduction of heat from the core and windings to the outer surface of the solid insulation. Thermal conduction is much less effective than the convection process that occurs with oil heat transfer in oil-immersed types. As a result, dry types have lower power efficiencies than oil-immersed transformers.

Figure 9-2 Examples of oil-immersed and dry type transformers

(a) 1000 kVA oil-immersed



(b) 750kVA dry type: open winding



(c) 500 kVA dry type: cast resin

A.3 Transformer Losses

There are two quite different components of transformer energy loss. These are:

- no-load (or "core" or "iron") loss; and
- load (or "copper" or "winding") loss.

A.3.1 NO-LOAD (CORE) LOSS

Whenever an AC magnetic field is generated in the magnetic core, it will cause an energy loss in the core material. There are two components of no-load loss:

- hysteresis loss; and
- eddy current loss.

Hysteresis loss is generated by the alternating magnetic field on the soft magnetic steel of the core. As the magnetic domains in the steel try to follow the changing (alternating) orientation of the AC magnetic field they generate frictional heat in the core: this is the hysteresis loss. The level of hysteresis loss depends on:

- the magnetic field magnitude (the core flux density);
- the AC power frequency; and
- the specific material used for the core.

The level of magnetic flux density in the core is designed to be the maximum possible before magnetic "saturation" of the core occurs. However the hysteresis losses increase very significantly as the flux density level increases.

Hysteresis losses increase linearly with frequency. As the normal 50 Hz AC supply may have higher frequency harmonics imposed on it by non-linear loads, this will increase losses if such harmonics are present [25].

Transformer cores require soft magnetic materials and there are several possible choices. However their energy loss characteristics vary greatly. Cast iron has very high hysteresis loss while silicon-steel alloy has very low hysteresis loss. Modern production processes such as laser etching can reduce losses further.

Eddy current loss in the core steel arises from the intrinsic effect of the AC magnetic field on the electrically conducting core material. The AC magnetic field generates (induces) eddy currents in the core steel due to the magnetic interaction. These induced eddy currents generate heat (and energy loss) in the metal core material in the same way that any electrical current flow generates heat from the resistance of an electrical conductor. The magnitude of the eddy current loss depends on:

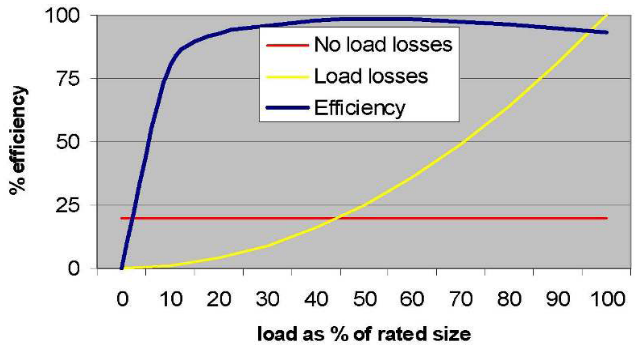
- the core magnetic flux density level;
- the AC power frequency; and
- the electrical resistivity of the core metal.

As in all eddy current generation, the loss increases as the square of the magnetic flux density. Losses also increase as the square of the power frequency and thus any harmonic content is very important in this loss mechanism. The loss varies inversely with the electrical resistivity of the core material or the overall resistance of the core, so that high resistivity/resistance material is better. Lamination of the core provides a simple way to increase resistance and reduce losses: the thinner the laminations the lower the losses. It is also possible to use a core material with an inherently high electrical resistance, such as amorphous magnetic metal.

The magnetising current is required to establish AC magnetic flux in the core. The magnetic field flux density in the core is always constant and independent of the load current. Thus the core loss is the same for all levels of transformer loading; whether there is no load, half load or full load. As shown in Figure 9-3, the no-load core losses are fixed losses. They will be produced and present within the core whenever the primary winding is connected to the distribution grid.

Figure 9-3 Transformer loss components and power efficiency versus loading

[Note that peak efficiency occurs when load loss and no-load loss are equal] [From [26]]



Core loss is voltage-dependent and also slightly temperature dependent. If the distribution grid voltage level changes, the core loss will also change; a higher voltage will generate higher losses.

Temperature dependence of the core loss is complex. Hysteresis loss will increase slightly with increased temperature but eddy current loss will decrease because resistance increases with temperature. Thus, measuring fixed losses in transformer efficiency tests requires test voltage and temperature to be specified and measured. Multiplying factors to adjust measured losses to the standard test conditions specified in test procedures may sometimes be required.

A.3.2 LOAD (COPPER) LOSS

Load loss is produced by the resistance to current flow in the windings. The magnetising current in the primary winding is very small compared to normal load current and will contribution very little to load loss. As illustrated in Figure 9-3, the load loss scales as the square of the load current (and the load level in kVA). For example, the load loss at 100% loading will be four times the load loss at 50% loading.

The primary determinant of load loss is the resistance of the windings. This can be reduced by using wires or conductors with larger cross-section area or by using a conductor material with lower resistivity. For this reason copper is the best material to use for windings, but aluminium is often used to reduce cost, even though it has 50% higher resistivity than copper. Winding resistance increases with temperature so load losses are very sensitive to temperature variation in the windings. Load losses are relatively insensitive to grid voltage change.

As can be seen in Figure 9 3, load loss becomes the dominant loss component when the transformer is more than about 50% loaded. The dependence on load also means that any overloading of the transformer (above 100%) will cause significant increase in load loss and a corresponding decrease in efficiency.

Load loss also depends on the harmonic content of the load current. When higher frequency harmonics are present in the load current due to non-linear loads eddy currents are generated in the windings and these cause higher levels of loss. The higher the harmonic frequency content, the greater is the load loss.

Stray loss in the metal structural parts of the transformer tank and similar metal components is another loss component generally included in load loss. Stray loss arises from eddy currents set up in the metal parts when the magnetic field of the secondary current in the transformer interacts with them. Eddy current flow causes heating in the tank and other metal structural components in the same way that they are caused in the core laminations. Stray losses are typically about 5-10% of load loss. Non-magnetic metals such as aluminium will have much lower stray loss than magnetic metals such as steel.

A.3.3 NON-LINEAR LOADS AND HARMONIC LOSSES

Increasing use of power electronic loads by consumers reduces the quality of the supply voltage and current waveforms. Such loads are called non-linear because the shapes of the voltage and current waveforms they generate depart markedly from the 50 Hertz base frequency waveforms produced by rotating machinery or simple resistive loads such as incandescent lamps. Power electronic devices create very high levels of harmonics (components of voltage and current at frequency multiples higher than the base 50 Hertz frequency used in Australia and New Zealand). One of the major effects of the increased harmonic level is a significant increase in transformer losses to meet the same apparent load. Harmonic loads can increase transformer losses by up to 20% or even more.

Non-linear loads are increasing and thus harmonic losses will increase inexorably with time. A major contributor is the compact fluorescent lamp (CFL) which can generate harmonics up to the 50th level. While the intrinsic luminous efficacy and hence energy efficiency of the CFL is much better than the incandescent lamp, its benefit is offset to some extent by the increase in system losses caused by its high harmonic content. As incandescent lamps (which are linear loads and thus have no harmonic content) are phased out and replaced by more CFLs, these harmonic losses will increase.

Special transformer designs (K-Factor transformers) can reduce harmonic losses. They are much more expensive (up to two times) than standard distribution transformers of the same rating but are being increasingly specified in mining, commerce and industry to deal with the increased level of non-linear loads.

In many cases this may involve the purchase of K-Factor transformers specifically for use with non-linear loads. The design of a K-Factor transformer is based on reducing the additional losses caused by harmonics. One way of achieving this is to make the transformer inherently more efficient with larger conductors and windings with lower resistance and lower copper loss.Thus, although industry may not use MEPS to specify transformer purchases they nevertheless do use minimum efficiency performance standards indirectly by specifying K-type units. It should be noted that K-Factor transformers are currently excluded from MEPS compliance requirements.

Commercial buildings generally house major concentrations of information technology equipment that use power electronic energy supplies. In-house distribution transformers (normally dry types that do fall within the MEPS categories) should ideally be as efficient as possible to minimise additional losses caused by harmonics from IT equipment.

K–Factor transformers are not viable for purchase and use in the general distribution network. The practical avenue available to reduce these additional losses is to use standard design transformers with high efficiency levels.The harmonics will still be present but losses will be minimised if the base efficiency is as high as possible.

It should also be noted that the efficiency standard for MEPS2 (and for MEPS1) assume a pure single frequency electrical supply with no harmonics. The assessment of costs and benefits is based on an extrapolation of the current pattern of losses in the system, which does not fully account for the increment of losses due to the ever-growing harmonic content in the system. Thus the cost-benefit analysis presented is conservative.

APPENDIX B - DISTRIBUTION TRANSFORMERS IN AUSTRALIA AND NEW ZEALAND

B.1 Transformer Application and Supply

B.1.1 OVERVIEW

Most electrical energy must pass through a number of transformer stages on its way from the point of generation to the point of consumption. Some of these will be in the transmission network, some in distribution and some will be private sector transformers at large industrial manufacturing sites, large commercial sites, as well as in the mining industry. Transformers operating at 33kV are becoming more numerous as more wind farms are commissioned.

Small consumers, including small industry and all residential sites, will normally be supplied at 415 volts three phase or 240 volts single phase from the secondary windings of the main utility or private distribution transformers . In many cases larger consumers will take supply at higher voltage to feed through their distribution transformers into their internal distribution system.

The total number of transformer stages that may be traversed before electrical energy reaches the typical small consumer may be four or five. Usually, two of those transformers would be classed as distribution transformers, where the primary transformer voltages would be in the range of 6.6–33kV and the secondary voltage to the consumer at 415/240 volts.

Table 12 shows details of installed transformer numbers and power capacity in the various network voltage classes as at June 2007 [6], for the Australian electrical supply system.

The figures shown are for utility transformers only: they do not include any privately owned transformers installed in the private electrical systems of manufacturing and process industries or in the mining and commercial sectors.

The numbers in Table 12 have been broken down into four network categories:

- **Transmission transformers** with voltage levels between 220 kV and 500 kV. They are operated by the transmission utilities in Australia and NZ.
- **Sub-transmission transformers** with voltage levels between 66 kV and 132 kV. They are operated by the local DNSP.
- **Distribution transformers** with voltage levels between 6.6kV and 33kV. They are operated by the local DNSP reducing to under 1,000V (typically 415V).
- **Single Wire Earth Return (SWER) transformers:** These are low capacity single phase units used in rural areas. They are operated by the local DNSP.

Transmission and sub-transmission transformers are not included in the MEPS scheme. Their voltage is normally 66kV or higher. They make up only 0.058% of the total transformer population, but represent 61.9% of the total installed transformer capacity. Typically, a transmission transformer (say 330kV and 370 MVA in rating) will have an efficiency of 99.8%. A zone substation transformer (132 kV and 22.5 MVA) will have an efficiency of 99.6%. Most distribution transformers will be less than 99% and SWER efficiencies will be less than 97%.

Table 12 Transformer numbers & capacity - Australian electrical utility supply system in 2007

These numbers do not include units in private installations

Transformer number and capacity rating in the supply network	Transmission transformers (220-500kV)	Sub-transm. transformer (66132kV)	Distribution transformer (6.6-33kV)	33kV only	SWER distrib. Trans.	Number subject to MEPS	Total
Number of units installed (Fraction of the total number)	375 (0.058%)	2,902 (0.450%)	531,882 (82.47%)	8320 (1.29%)	109,776 (17.02%)	641,658 (99.49%)	644,935 (100%)
Total nominal installed capacity (MVA)	84,937	82,749	101,819	20,441	1,370	103,189	270,875
Average capacity per transformer (kVA/unit)	226,500	28,500	191	2,460	12.5	161	420

Source: ESAA-Electricity & Gas 2008: [6]

Distribution transformers (not SWER type) are also widely used in industrial and commercial sites and in mining. Such private transformers typically have quite different operational loading conditions to utility transformers. Their average loading is higher and this will cause losses to be higher than they are for utility transformers. Widespread use of power electronic devices also increases private sector transformer losses by degrading power quality.

B.1.2 INSTALLED TRANSFORMERS IN AUSTRALIA

Table 13 gives the numbers of utility distribution transformers in Australia in the years between 2000 and 2007 inclusive. The annual growth rate in number averages about 1.54% over that time and the rated power capacity increased at a rate of 4.08%. In recent years the increase in number has been much higher; it was 3.04% in 2007 representing almost 19,000 new transformers. The increase in installed transformer power capacity in 2007 was 5.93% or about 5800 MVA. The average, non-SWER, new unit size in 2007 was about 400 kVA.

Transformer numbers and installed capacity in the private sector are not well documented for Australia. If typical European figures [7] are applied to Australia, the number of distribution-type transformers in the industry, mining and commercial sectors would be about 25% of the utility numbers. Applying this to Australia, the total number of distribution transformers, including the private and utility sectors, is currently estimated to be about 802,000.

B.1.3 INSTALLED TRANSFORMERS IN NEW ZEALAND

EECA is researching the NZ market and hope to have more conclusive data in the near future. In the interim, this document assumes that the NZ market is proportionately similar to the Australian market. We welcome any feedback from stakeholders where the New Zealand market differs from our assumptions.

The only available recent figures have been determined by a review of " -- a wide range of network company asset management plans, plus information provided by a number of network companies –" [5]. Using this review suggests that there were about 175,000 distribution transformers in utilities in New Zealand in 2003. Using the same proportional increase as in Australia the number of utility transformers in 2007 is estimated at 190,400.

There is no information available about private transformers but Ellis [5] indicates that the private sector numbers would be a smaller proportion of total numbers than in Australia. A fraction of 15% of utility numbers was assumed for this RIS. This gives an estimated total number of distribution transformers in New Zealand of 219,000 in 2007.

B.1.4 TRANSFORMER SUPPLY IN AUSTRALIA AND NEW ZEALAND

Of all the electrical network equipment components, distribution transformers have the most extensive local manufacturing base in Australia and New Zealand. Expansion of utility distribution network capacity produces a steady demand for new transformers. As distribution transformers have a relatively small range of capacities with standard design requirements, they provide a good manufacturing base for local industry. About 85-90% of utility distribution transformer requirements are provided by local manufacturers.

The private transformer market has a much broader range of requirements that are specific to applications in industry, mining and commerce. As a result, the market size for particular sizes and designs is smaller. This drives the major transformer manufacturers in Australia and New Zealand to concentrate on the utility market. The private sector is supplied by imports and by smaller local manufacturing companies with specialised capabilities. Local manufacture is about 10% or less.

Table 13 Distribution utility transformer numbers & installed capacity in Australia 2000-2007

Includes 33kV units

Year	Standard Type		SWER Type		Total distribution transformers			
	Number	Capacity (MVA)	Number	Capacity (MVA)	Number	Increase (%)	Capacity (MVA)	Increase (%)
2000	466,841	76,190	110,209	1,965	577,050		78,155	
2001	481,477	77,959	98,425	2,071	579,902	0.49	80,030	2.40
2002	494,520	84,023	98,313	2,173	592,833	2.23	86,196	7.70
2003	488,536	85,095	101,220	2,178	589,756	-0.52	87,273	1.25
2004	543,798	92,886	58,021	786	601,819	2.06	93,672	7.33
2005	524,705	93,486	78,461	2,055	603,166	0.22	95,541	2.00
2006	517,328	96,074	105,416	1,341	622,744	3.24	97,415	1.96
2007	531,882	101,819	109,776	1,370	641,658	3.04	103,189	5.93

Source: ESAA Electricity and Gas 2001 to 2008: [6]

Transformer costs vary with power capacity. An average cost for a 400 kVA transformer would be about $10,000 in Australia. Based on 15,000 new utility transformers per year of average capacity 400 kVA, this corresponds to about $150 million per year turnover for the Australian utility transformer market.

Private transformers would be more expensive because of their special requirements, higher average capacity and lower numbers. Taking this into account, $60 million per year is a reasonable estimate of turnover for the new private transformer market, giving a total annual turnover for all new distribution transformers of about $210 million. This does not include replacement of retired aged stock. Taking this into account gives an annual turnover in the transformer industry in Australia of about A$250-300 million.

In New Zealand the corresponding annual turnover would be about A$68-82 million.

B.1.5 TRANSFORMER LIFETIME

Transformers have a nominal lifetime of about thirty years. However if they are well maintained, as they usually are in the utility sector because of reliability requirements, lifetime can be increased significantly. Fifty years is not uncommon. The low average loading of utility transformers also contributes to longer life. Figure 9-4 shows an age profile of utility transformers in New Zealand as determined in the 2003 survey [5].

In the private sector the average loads are higher and maintenance standards are perhaps less stringent than in the utilities. Also, many private applications may not last the 50 years of possible transformer life. The result is a somewhat shorter life expectation in the private sector, 30 years being a reasonable expectation.

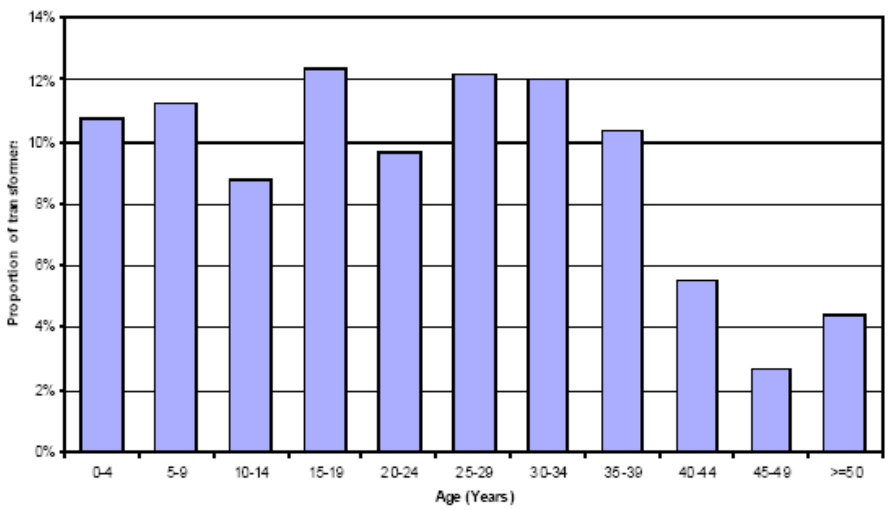
B.1.6 TRANSFORMER PURCHASING PRACTICE

As large and widely-used capital equipment, particularly by the utilities, transformers are generally purchased under a competitively tendered contract in significant numbers. The tender will specify technical requirements, usually including some specification for allowable losses. Technical specifications will be quite standard for utilities all over Australia and NZ, with only minor variations depending on location.

Selection of successful tenders is normally based on capital cost per unit and the amortized cost of losses over the transformer lifetime. Appendix C gives details of the total life capitalization procedures used when losses are included in consideration of tenders. However the primary selection criterion may simply be initial capital cost. This can occur because DNSPs do not directly share the benefits of reduced losses. While high efficiency transformers may be included in capital budgets for presentation to the regulator for approval, actual transformer purchases may be at lower cost. Regulatory procedures are intended to discourage such practices but may not be fully effective.

Major transformer manufacturers tend to leave the private transformer market to smaller manufacturers and importers, which are a major source. Reducing losses may not be a significant issue for the private sector except for some specific cases. In large commercial buildings, electricity costs are a major consideration. Even then, these buildings are often on-sold and buyers may not be informed of ongoing operating costs; a significant potential source of market failure. Another application where transformer efficiency is likely to be factored into purchase decisions is in commercial wind farms. This case is discussed in more detail in the body of this report.

Figure 9-4 Distribution of network distribution transformers in New Zealand in 2003



[Extracted from [5]]

Table 14 Transformers in MEPS range imported between Jul 1999 & Jun 2007

MEPS implemented on 1 Oct 2004.

Trans.Type & Rating (kVA) / Fin. Yr of Import	Oil-immersed S < 650 kVA	Oil-immersed 650 kVA< S < 10,000kVA	Dry Type 16kVA< S < 500kVA	Dry Type > 500 kVA
99-00	39,029	1038	136,335	15,416
00-01	72,100	288	84,247	9,919
01-02	18,093	584	101,726	159,846
02-03	30,382	104	97,296	34,630
03-04	21,095	1298	855,956	9,841
04-05	35,774	221	560,404	15,484
05-06	55,363	252	276,881	9,618
06-07	18,416	762	64,358	1,104

Data from Australian Bureau of Statistics data: 2007

B.2 Australia and New Zealand Market Players

B.2.1 TRANSFORMER MANUFACTURERS

There are about 26 manufacturers of distribution transformers in Australia and New Zealand. A number of transformer importers are also based in Australia. Larger manufacturers and importers tend to service the utility market while smaller manufacturers cover more specialised markets in the private sector. About 80-85% of utility distribution transformers in Australia and New Zealand are manufactured in Australasia and most of these by six companies:

- Wilson Transformers
- ABB T&D Australia
- Schneider Australia
- Tyree transformers
- ABB T&D New Zealand
- ETEL Transformers New Zealand.

Of the above companies, the ABB facilities and Schneider Electric are subsidiaries of large multi-national electrical companies. Tyree Transformers and the Wilson Transformer Company are Australian-owned and ETEL is New Zealand-owned. All of the major transformer manufacturers are long-established with good design and manufacturing capabilities. Some have subsidiary factories in SE Asia which also manufacture for the utility market in Australia. Most but not all of the major manufacturers in Australia are represented by the Australian Industry Group.

Two major transformer factories in Australia primarily service the private sector and manufacture product outside the MEPS range; Transformer Manufacturing Company (TMC) and Ampcontrol. Both are Australian owned companies. TMC has several overseas subsidiary factories; most of its transformer output is manufactured outside Australia.

B.2.2 TRANSFORMER IMPORTERS

Many companies based outside Australia supply distribution transformers into the Australian market in the range covered by the MEPS regulations. Countries of origin include, among many others, India, South Africa, Malaysia, Germany, UK, USA, Thailand, Taiwan, Korea, China and Indonesia. For the purpose of the MEPS proposal technical report [2], the Australian Bureau of Statistics provided information on distribution transformer imports from Australian Customs data. This covered all transformers within the MEPS range. The numbers and value of transformer imports were obtained for the years 1999 – 2007 and are summarised in Table 14. It should be noted that the first MEPS efficiency regulation proposal was issued in 2001 and the initial MEPS regulation came into operation in 2004.

The import numbers and the types of transformers indicate a large demand from the commercial and industrial (particularly mining) sectors. The transformer types used in those areas, particularly in commercial buildings and in mining applications, would be predominately dry type rather than oil-immersed transformers.

B.3 Electrical Energy Supply and Greenhouse Gas Emissions

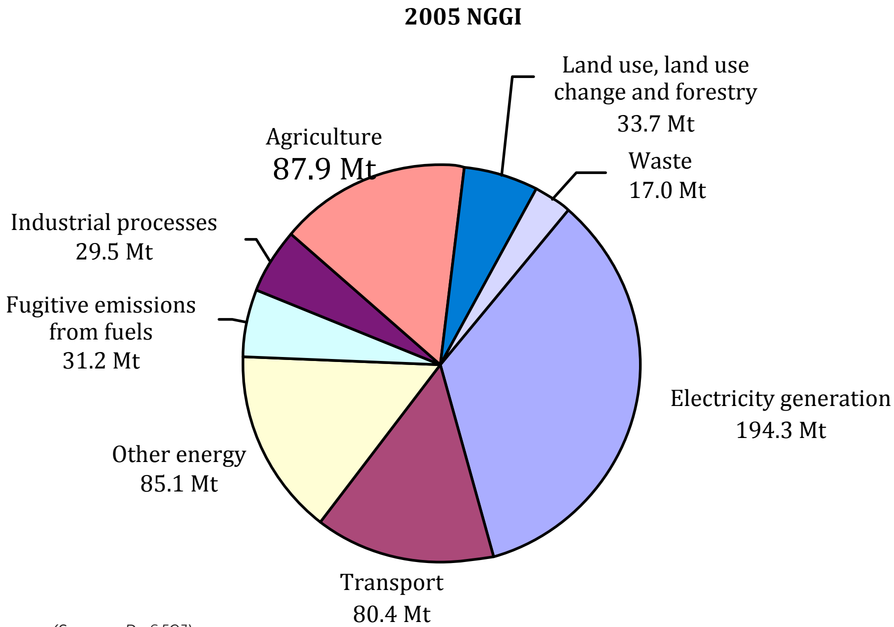
B.3.1 OVERVIEW

Figure 9-5 shows estimated Australian greenhouse gas emission by sector for 2005. Total greenhouse gas emissions for 2005 are estimated at 559 million tonnes (Mt) of CO_2 [9].

The electricity sector contributes most to Australia's greenhouse gas emissions. Electricity generation accounted for 194 Mt or 34.8% of total national emissions in 2005. Electricity generation emission increased by 0.7 Mt (0.4%) from 2004 to 2005, and by 64.8 Mt (50.1%) over the period 1990 - 2005. The Australian Bureau of Agricultural and Resource Economics projects total electricity use to increase by an average of 2.2% p.a. between 2004/05 and 2010/11 [10]. Slowing and ultimately reversing the growth in electricity-related emissions is thus a high priority in Australia's greenhouse gas reduction strategy.

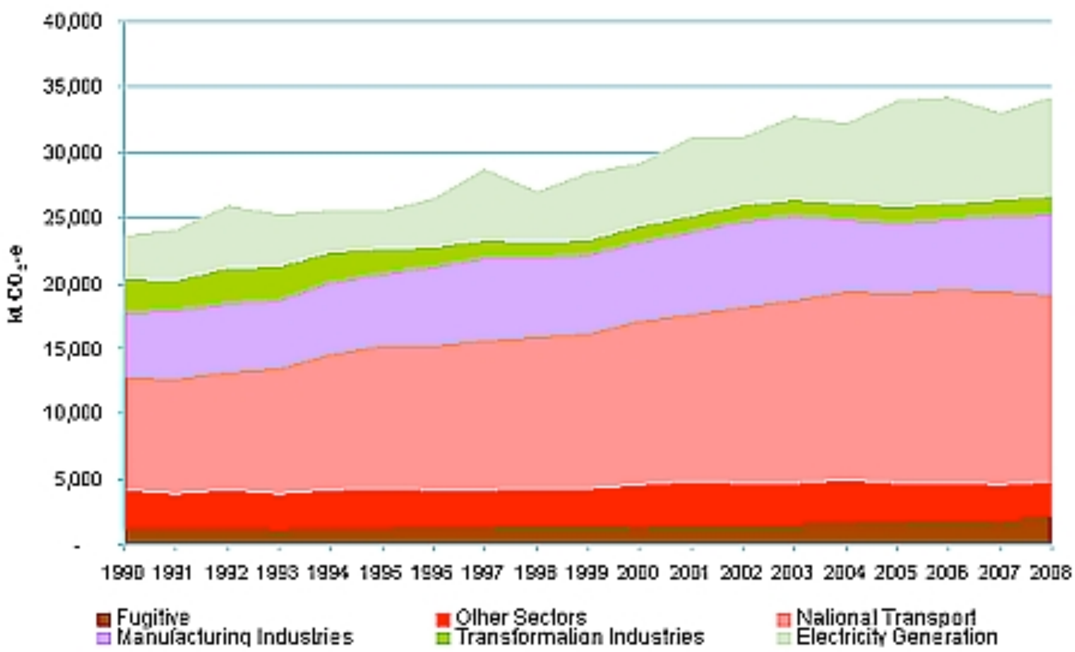
Greenhouse contributions in New Zealand are shown in Figure 9-6, which gives data for 2007 [12]. New Zealand's energy emissions are dominated by three main sectors: national transport, electricity generation and manufacturing industries. Emissions from national transport account for the largest share of total energy emissions, although in recent years the growth in emissions from this sector appears to have slowed. Emissions from manufacturing industries has seen some growth in recent years but has overall been declining since 2002 as a result of Methanex scaling back methanol production, which has historically been a large source of emissions.

Figure 9-5 Australian greenhouse gas emission by sector for 2005



(Source: Ref [9])

Figure 9-6 New Zealand energy greenhouse gas emission by sector for 2007



(Source: Ref [12])

Emissions from electricity generation have increased significantly since 1990 although there are large annual variations reflecting the cost and availability of hydro generation (on which New Zealand relies heavily). Thermal electricity generation accounts for 24% of CO_2 emissions from the energy sector. Emissions from this source increased by about 35% compared with those in 2004, due to increased consumption of coal [13]. In total, thermal electricity generation produced more than 8 Mt of CO_2 in 2007. Total greenhouse gas emission from the energy sector is projected to grow by about 30% between 2005 and 2030 [14].

It should be noted that sector splits are not as precise as by fuel type due to difficulties in allocating liquid fuel use to end uses. Sector breakdowns therefore need to be interpreted with some caution.

B.3.2 CURRENT TRANSFORMER LOSSES AND ASSOCIATED GREENHOUSE GAS EMISSIONS

Total network loss in the transmission and distribution networks can be as high as 10% of the total energy that is supplied to the networks by large power stations. Losses depend on the size and configuration of the network and on the spatial density of the load supplied and so can vary from country to country. Developed countries with small area and high load density have the lowest network losses. The network loss of all countries averages about 9%. The average loss in Australia is about 9.6% and in New Zealand about 8%.

Total network losses can be divided into transmission and distribution losses. Transmission networks transfer energy in bulk at very high voltage between generators and terminal substations near load centres. Distribution networks transfer energy from terminal substations to consumers. Often used is a sub-transmission stage, a high voltage network between the terminal substation and local substations distributed around the load area.

In Australia in 2007, total transmission and distribution network losses of about 9.6% represented about 21,100 GWh of energy loss. According to ESAA growth figures [6], this loss will increase at an average rate of at least 2.8% each year. An electrical energy loss of 21,100 GWh corresponds to about 20.8 million tonnes of CO_2 equivalent gas emission per year, using the NGA CO_2 equivalent figures for Australia as specified at January 2008 [3].

The distribution utility network loss component is, on average, about twice the transmission loss [18]. As can be seen in Table 15, the utility distribution loss in the Australian system has been relatively constant at about 5.9% in recent years although a figure of 5.6% is quoted for 2007 [6]. The 5.9% includes overhead line and underground cable losses and distribution transformer loss. Transformers account for 30-40% of utility distribution loss [3] and a similar proportion of the greenhouse gas emissions from losses. Private system losses will primarily be transformer losses because compact private networks incur little line loss.

Table 15 Distribution system loss in Australian states and territories as % of energy supplied. Loss is weighted by energy use in each state.

Distribution loss (% of energy handled):	97-98	98-99	99-00	00-01	01-02	02-03	03-04	04-05	05-06	06-07
NSW & ACT	5.2	5.2	5.4	5.5	5.7	5.6	5.1	5.1	5.7	5.1
Victoria	7.3	7.1	6.7	5.7	4.9	6.0	5.5	5.5	5.6	5.7
Queensland	5.4	6.2	5.4	5.5	6.0	5.8	5.6	6.2	6.1	6.6
South Australia	5.7	6.3	6.0	6.4	5.5	5.8	6.2	6.0	6.1	6.0
Western Aust.	8.9	5.4	7.8	8.0	9.0	7.8	9.1	7.5	N/A	5.4
Tasmania	N/A	2.3	5.5	5.4	5.4	5.4	4.3	6.6	7.2	4.3
Northern Territory	7.3	5.1	5.1	5.0.	6.6	6.7	5.8	7.5	7.1	7.4
Australian weighted av'ge	6.0	5.9	5.9	5.8	5.8	5.9	5.7	5.9	5.9	5.6

As illustrated in Ref [15]

New Zealand distribution losses were 5.3% for the year 2007 [15]. As shown in Figure 9-7 below, losses in the longer term have averaged 6.3% although there is wide variation between distribution companies.

The transformer loss contribution will be higher in urban and suburban distribution networks and lower in rural and sparsely populated areas where the line loss will be higher because of longer lengths and a lower number of transformers with the lower load density.

Transformer losses increase with load level. There will be a substantial difference between losses in identical transformers used in the utility and private sectors. Utility transformers tend to be more lightly loaded than privately operated transformers because of the high level of supply reliability required by the electrical regulator and because utility loads are much more variable than industrial loads.

B.4 Projected Energy Loss Reduction

The primary benefits expected from the proposed implementation of MEPS2 are a reduction in transformer energy losses over the life of each new transformer and an associated reduction in CO_2 emissions. The percentage loss reduction varies across the range of transformers specified in the Australian Standard. To estimate the effect of MEPS2 on losses and emissions, some analysis is required of power system growth rates, the numbers, types and ratings of transformers to be installed in the future and their average loading.

B.4.1 DATA AND ASSUMPTIONS

The number of transformers in the Australian utility sector is well documented by ESAA reports [6] and appears in Appendix B.1 (see Table 12). Some reasonable estimates of NZ transformer numbers were discussed previously. Table 16 shows the basic rates of change of transformer numbers used in the analysis.

Table 16 Transformer Numbers Variation (per annum)

Location	Utility sector		Private sector	
	Increase	Retirement	Increase	Retirement
Australia	2.5%	2.0%	2.5%	3.0%
New Zealand	2.5%	2.0%	2.5%	3.0%

The number of transformers in Australia subject to MEPS in 2010, the start of the modelling projection, was taken to be approximately 690,000 for the DNSPs and 173,000 for the private sector. The private industry proportion is about 20% of the total or 25% of the utility distribution transformer numbers (excluding the SWER population). The rates of net increase in numbers are taken as 2.5% per annum for both utilities and the private sectors, with a 2% retirement rate for the utilities and 3% retirement rate for the private sector.

For New Zealand, the base number of transformers used by utilities was 196,000 in 2010. The rate of increase in the numbers of installed transformers was 2.5%, the same rate as assumed for Australia. The New Zealand retirement rates per annum were assumed to be the same as for Australia; 2% for the utilities and 3% for the private sector. The private sector was assumed to have 15% or 32,000 of the utility numbers. This gave a New Zealand transformer population of 228,000 in 2010.

Modelling for the MEPS2 case focussed on the impact of the new transformer population over the nominal life span of a transformer (i.e. over thirty years), assuming that all new transformers will be MEPS2 compliant. The BAU case assumed that all new transformers will be compliant with the existing MEPS1 efficiency levels only.

Modelling assumed that all utility transformers were oil-immersed with no dry types. For the private industrial, commercial and mining sectors the oil-immersed and dry types were equally represented. The average annual loading

Figure 9-7 Distribution loss for New Zealand utilities

Source: Ref [15]

of transformers was reasonably reliably determined by the transformer load utilization factor (LF). For the whole transformer population in Australia this is known from ESAA annual reports. An average LF of 25% was used for the utility transformers in the calculations. For the private sector an average load factor of 40% was estimated based on discussions with technical staff in the private sector.

The above data were used to determine the total annual loss of the various basic groups of transformers and combined to determine a weighting factor that could be applied to all new transformers installed by utilities and industry each year.

MEPS1 currently applies to four single phase and twelve three phase oil-immersed transformer types, and eight single phase and twenty two three phase dry type transformer types. The energy loss reduction achievable under MEPS2 varies for each transformer type and size and is also dependant on transformer loading. To calculate the effect of MEPS2 on total energy losses it is necessary to estimate the mix and loading levels of future installed transformers.

Details of this analysis are in Appendix B.5 and shown in Table 17 for the oil-immersed transformers and Table 18 for the dry type. For convenience, each group of oil-immersed or dry type transformers as tabled in the Australian Standard is called a cohort. The oil-immersed cohort is weighted by numbers that give an average kVA per transformer that is the same as the average kVA of the currently installed distribution transformers. Number weighting was not required for the dry type transformers, because the energy loss reduction % for MEPS2 is basically the same for all transformer sizes and voltages.

B.4.2 BAU CASE (RETENTION OF MEPS1)

Energy loss projections under MEPS1 (BAU) are shown in Figure 9 8. The figure shows total losses in Australia each year for new transformers installed, for the MEPS1 (BAU) case and the MEPS2 case. These are the two upper curves. The other curves are the utility and private industry losses under MEPS1 only. Also shown are the corresponding MEPS1 CO_2-equivalent gas emission levels. These curves show losses and emissions per year for transformers installed in that year. Ongoing losses are not accumulated in these curves. This is done in a later step in the analysis. Projected emissions assume a constant emission rate per unit of electrical energy generated, which is certainly an over-estimate to the extent that emission intensity declines over time as emission reduction policy takes effect.

Losses in industry are relatively large even though industrial transformer numbers are only about 25% of the utility numbers. This higher loss level for each unit is due to the higher average loading and the greater use of the more inefficient dry type transformers in industry. In 2010, for example, the ratio of utility transformer loss to private transformer loss is only about 3.1, but the ratio of utility transformer numbers to industry transformer numbers is 4.0 with SWER transformers included and 3.4 if excluding SWER units.

Figure 9-9 shows the projected energy losses that will accumulate from new transformer installations in Australia and New Zealand over the period 2010– 025 in the BAU case. These losses can be reduced by about 11-12% (about 2,770 GWh by 2025 for Australia and 540 GWh for NZ) if transformers complying with the voluntary high efficiency standards listed in the current AS2374.1.2 are used for all new and replacement transformers.

B.4.3 FULL IMPLEMENTATION OF PROPOSED MEPS2

Figure 9-10 shows estimates of the energy savings each year (relative to BAU case) if all new transformers installed by utilities and industry in Australia were to be MEPS2 compliant. These curves show losses and emissions per year for transformers installed in that year. Ongoing losses are not accumulated in these curves. This is done in a later step.

There is more potential for energy saving in the utility sector than in industry, commerce and mining. The ratio of utility energy savings to industry energy savings in 2010 is about 3.22. While industry in 2010 generates about 28% of the overall loss, the savings achieved in industry in that year are only 23%. This is because industry tends to use less efficient dry type units and operate them more highly loaded.

Modelling for this study takes into account only inherent transformer efficiency. Projections do not include any adjustment for the loss contribution arising from non-linear loads.

Total annual losses for the years modelled (with the impact of new transformers accounted for in the years after their installation) are shown in Figure 9-11 for both MEPS1 and MEPS2 efficiencies for all new transformers installed in Australia.

The modelling on which Figure 9-11 is based indicates that the cumulative energy loss reduction in Australia over 30 years under MEPS2 instead of MEPS1 would be 10,200 GWh of energy.

Using a CO_2-e figure of 0.925, the corresponding CO_2 loss reduction would be 9.43 megatonnes of CO_2-e. This figure is an overestimate to the extent that CO_2 intensity declines over time either spontaneously or as a result of explicit policy. It is an underestimate to the extent that some loss components, such as that increment of losses arising from non-linear loads, have not been included.

The calculated loss reduction for newly installed transformers is of the order of 10% of existing distribution transformer losses over the period of interest, reflecting the order of efficiency improvement specified under the proposed new MEPS.

Figure 9-8 Annual energy loss and GHG emissions for utilities & industry in Australia with all new transformers at MEPS1 efficiencies

[MEPS2 Total loss shown for comparison]

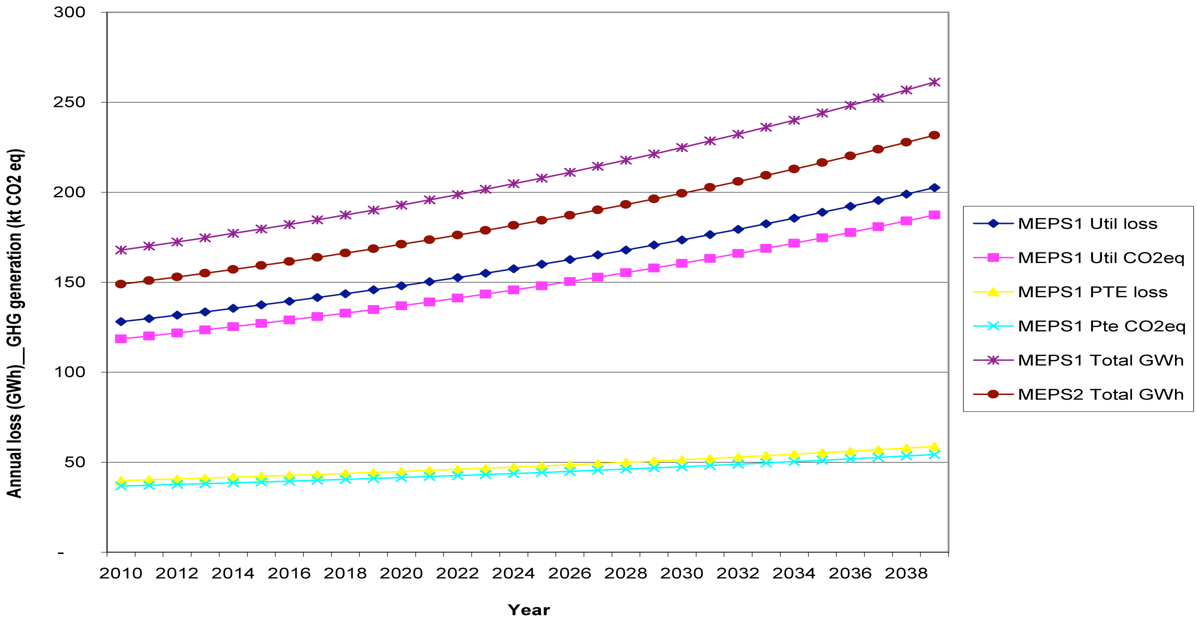


Figure 9-9 Total accumulating losses of new transformers with no improvement of transformer energy efficiency for Australia and New Zealand

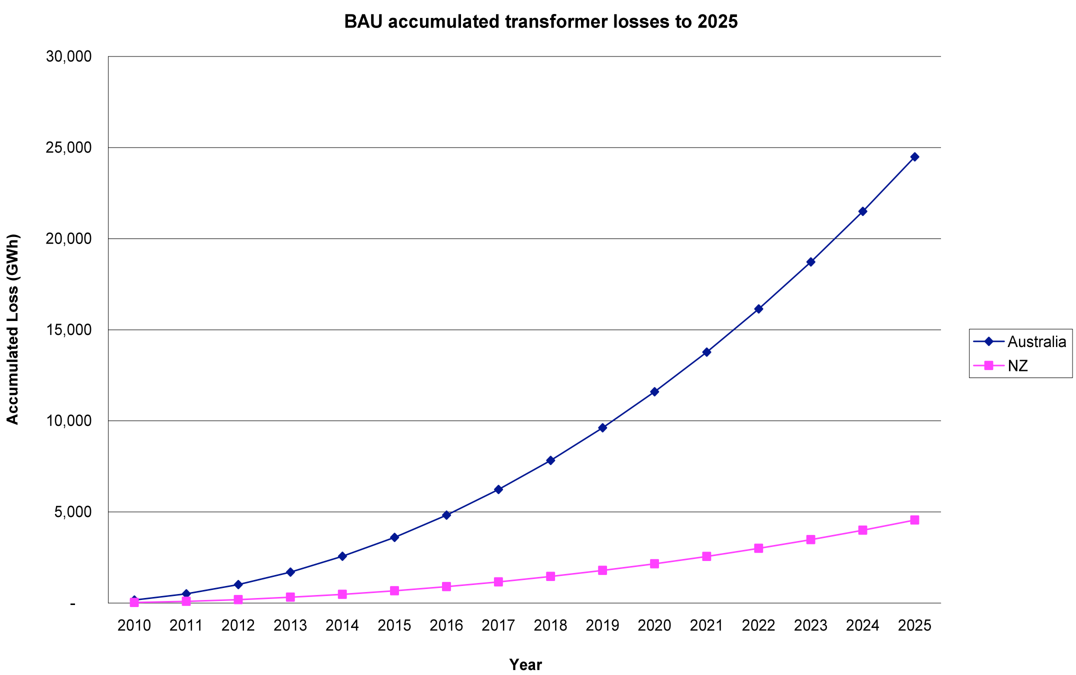


Figure 9-10: Annual energy loss savings with all new transformers in Australia at MEPS2 efficiencies, relative to MEPS1

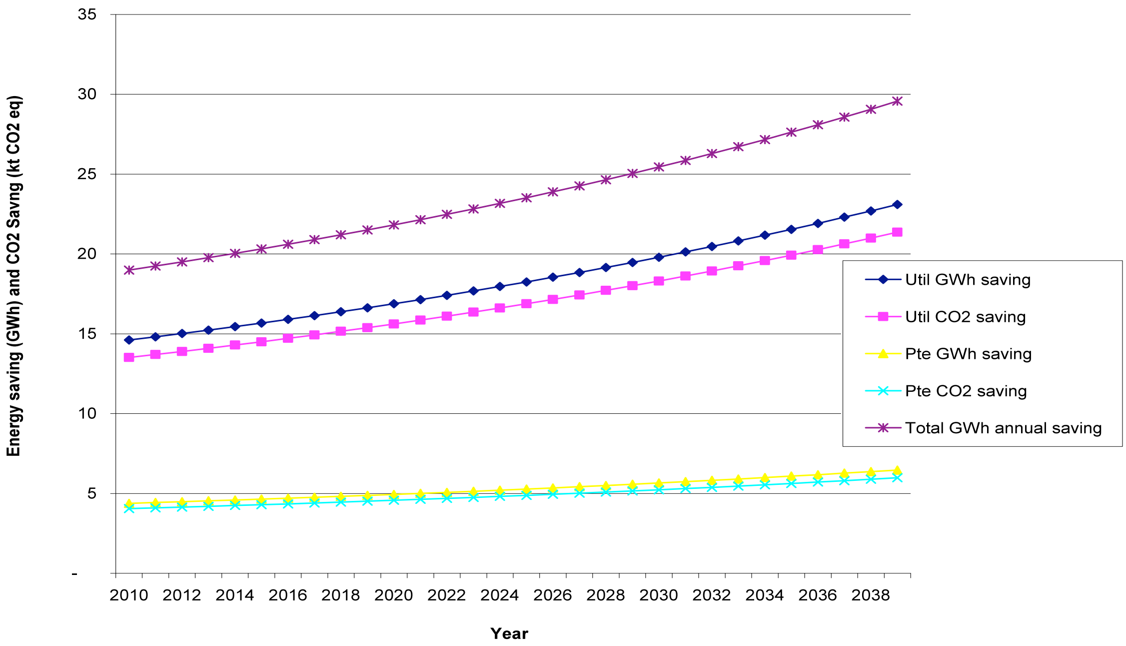
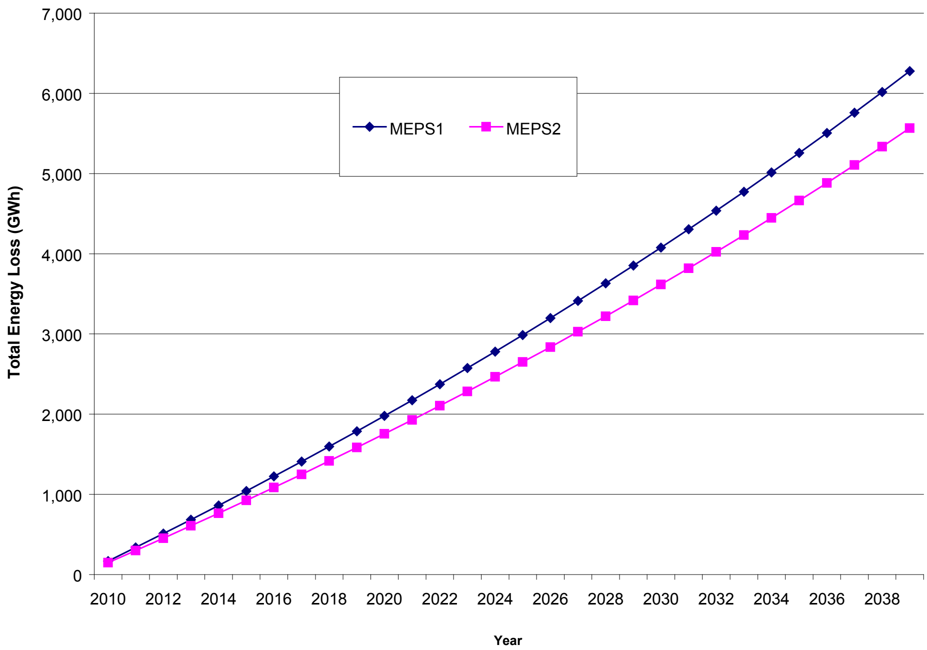


Figure 9-11 Annual losses of all newly installed transformers in Australia: MEPS1 & MEPS2



B.5 Details of Loss Reduction Calculation in Australia and New Zealand with MEPS2

MEPS1 currently applies to four single phase and twelve three phase oil-immersed transformers, and eight single phase and twenty two three phase dry type transformers. The energy loss reduction that will be achieved by the implementation of MEPS2 varies for each transformer type and size and also depends on transformer loading. To calculate the overall effect of MEPS2 on energy losses it is necessary to estimate the distribution of transformers that will be installed in the future, together with their loading levels.

Table 17 shows estimated loss reduction in Australia and New Zealand for oil-immersed transformers if MEPS2 is adopted. These are the transformer types usually used by the DNSPs. An overall load factor of 25% is assumed, consistent with load factors commonly achieved in utility distribution transformers.

There are 16 transformer sizes shown in the Table. Loss reduction varies across the range, with the single phase transformers varying between 7.17% and 9.18% loss reduction and three phase transformers varying between 19.55% and zero. As a result of this variation, it is necessary to estimate a weighted average loss reduction across the range. For convenience, the group of 16 transformer sizes is called a cohort.

The average rating of the cohort is 763 kVA. However, the average rating of the utility transformers actually installed across Australia by the DNSPs is much lower at 161 kVA, as calculated from ESAA statistics. So it is apparent that there are many more small transformers than large ones currently installed. In the Table, numbers are assumed for each transformer size so as to give average transformer ratings that are consistent with those already installed. Also, the proportion of total single phase to total three phase transformer ratings is also adjusted to be at an appropriate level. New transformer installations are assumed to match this pattern.

Table 17 shows that losses in single phase transformers will be reduced by 2.14 MWh (7.6%). The reduction for three phase transformers will be 136 MWh (11.5%), giving a total weighted loss reduction of 138 MWh (11.4%) for one cohort.

The results of a similar analysis for dry type transformers are shown in Table 18. Dry type transformers are usually used in the commercial and industrial sectors so a higher load factor of 40% is assumed. Information on the distribution of types and sizes currently installed is not available, so it was not possible to adopt the number weighting used in Table 17. Fortunately, the percentage loss reductions for the dry type transformers are similar; ranging from a low of 9.08% and a high of 12.19%, so a simple arithmetic average loss percentage is sufficiently accurate. The table shows that a cohort of dry type transformers has an average rating of 603.6 kVA and an annual loss reduction in moving from MEPS1 to MEPS2 of 73.2 MWh (11.0%).

Table 17 Annual energy loss reduction with MEPS2 for oil-immersed transformers – Australia and New Zealand

Loading 25.0%

Liquid Immersed Transformers				Efficiency Level at 50% Load		MEPS1 Annual Losses MWh			MEPS2 Annual Losses MWh			Loss Reduction	
Transformer Type	Rating (kVA)	Number	Total (kVA)	MEPS1 (%)	MEPS2 (%)	Iron	Copper	Total	Iron	Copper	Total	MWh	%
Single phase	10	39	394	98.30	98.42	14.94	3.73	18.67	13.87	3.47	17.33	1.34	7.17%
(and SWER)	16	10	154	98.52	98.64	5.05	1.26	6.32	4.64	1.16	5.80	0.52	8.22%
	25	2	50	98.70	98.80	1.44	0.36	1.80	1.33	0.33	1.66	0.14	7.79%
	50	1	50	98.90	99.00	1.22	0.30	1.52	1.11	0.28	1.38	0.14	9.18%
Sub Total	101	52	648					28.31			26.18	2.14	7.55%
Average	25.25		12.5										
Three Phase	25	120	3000	98.28	98.50	114.98	28.75	143.73	100.05	25.01	125.06	18.66	12.99%
	63	48	3024	98.62	98.82	92.67	23.17	115.84	79.08	19.77	98.85	16.99	14.67%
	100	30	3000	98.76	99.00	82.49	20.62	103.11	66.36	16.59	82.95	20.16	19.55%
	200	17	3400	98.94	99.11	79.77	19.94	99.72	66.86	16.72	83.58	16.14	16.18%
	315	13	4095	99.04	99.19	86.93	21.73	108.66	73.23	18.31	91.54	17.12	15.75%
	500	8	4000	99.13	99.26	76.88	19.22	96.10	65.31	16.33	81.63	14.47	15.05%
	750	6	4500	99.21	99.32	78.47	19.62	98.09	67.47	16.87	84.34	13.75	14.02%
	1000	4	4000	99.27	99.37	64.42	16.10	80.52	55.54	13.88	69.42	11.10	13.79%
	1500	3	4500	99.35	99.40	64.48	16.12	80.60	59.49	14.87	74.36	6.24	7.74%
	2000	2	4000	99.39	99.40	53.76	13.44	67.20	52.88	13.22	66.10	1.11	1.65%
	2500	2	5000	99.40	99.40	66.10	16.52	82.62	66.10	16.52	82.62	0.00	0.00%
	3150	2	6300	99.40	99.40	83.28	20.82	104.10	83.28	20.82	104.10	0.00	0.00%
Sub Total	12103	255	48819					1180.30			1044.57	135.73	11.50%
Average	1008.6		191.4										
Weighted Total	12204	307	49467					1208.61			1070.74	137.87	11.41%
Average	763		161.1										

Table 18 Annual energy loss reduction with MEPS2 for dry type transformers – Australia and New Zealand

Loading 40.0%

Dry Type Transformers				Efficiency Level at 50% Load		MEPS1 Annual Losses MWh			MEPS2 Annual Losses MWh			Loss Reduction	
Transformer Type	Rating (kVA)	Number	Total (kVA)	MEPS1 (%)	MEPS2 (%)	Iron	Copper	Total	Iron	Copper	Total	MWh	%
Single Phase 12kV	10	1	10	97.29	97.53	0.61	0.39	1.00	0.55	0.35	0.91	0.09	9.08%
	16	1	16	97.60	97.83	0.86	0.55	1.41	0.78	0.50	1.27	0.14	9.80%
	25	1	25	97.89	98.11	1.18	0.76	1.94	1.05	0.68	1.73	0.21	10.63%
	50	1	50	98.31	98.50	1.88	1.20	3.09	1.67	1.07	2.73	0.35	11.41%
Single Phase 24kV	10	1	10	97.01	97.32	0.67	0.43	1.11	0.60	0.39	0.99	0.12	10.65%
	16	1	16	97.27	97.55	0.98	0.63	1.61	0.88	0.56	1.44	0.17	10.51%
	25	1	25	97.53	97.78	1.39	0.89	2.27	1.24	0.80	2.04	0.24	10.35%
	50	1	50	97.91	98.10	2.34	1.50	3.83	2.12	1.36	3.48	0.36	9.27%
Three Phase 12kV	25	1	25	97.17	97.42	1.59	1.02	2.62	1.45	0.93	2.38	0.24	9.07%
	63	1	63	97.78	98.01	3.13	2.00	5.14	2.80	1.79	4.59	0.54	10.57%
	100	1	100	98.07	98.28	4.31	2.76	7.07	3.83	2.45	6.29	0.78	11.07%
	200	1	200	98.46	98.64	6.85	4.38	11.24	6.04	3.86	9.90	1.33	11.85%
	315	1	315	98.67	98.82	9.30	5.95	15.25	8.24	5.27	13.51	1.74	11.41%
	500	1	500	98.84	98.97	12.85	8.22	21.08	11.40	7.29	18.69	2.39	11.32%
	750	1	750	98.96	99.08	17.26	11.05	28.31	15.25	9.76	25.01	3.30	11.65%
	1000	1	1000	99.03	99.14	21.45	13.73	35.18	19.00	12.16	31.16	4.02	11.44%
	1500	1	1500	99.12	99.21	29.16	18.67	47.83	26.16	16.74	42.90	4.93	10.31%
	2000	1	2000	99.16	99.24	37.10	23.75	60.85	33.54	21.47	55.01	5.84	9.60%
	2500	1	2500	99.19	99.27	44.71	28.61	73.32	40.26	25.77	66.03	7.30	9.95%
Three Phase 24kV	25	1	25	97.17	97.42	1.59	1.02	2.62	1.45	0.93	2.38	0.24	9.07%
	63	1	63	97.78	98.01	3.13	2.00	5.14	2.80	1.79	4.59	0.54	10.57%
	100	1	100	98.07	98.28	4.31	2.76	7.07	3.83	2.45	6.29	0.78	11.07%
	200	1	200	98.42	98.60	7.03	4.50	11.53	6.22	3.98	10.20	1.33	11.55%
	315	1	315	98.59	98.74	9.87	6.31	16.18	8.80	5.63	14.44	1.74	10.77%
	500	1	500	98.74	98.87	13.97	8.94	22.92	12.51	8.01	20.52	2.39	10.44%
	750	1	750	98.85	98.98	19.11	12.23	31.34	16.93	10.83	27.76	3.58	11.42%
	1000	1	1000	98.92	99.04	23.91	15.30	39.21	21.23	13.59	34.81	4.40	11.22%
	1500	1	1500	99.01	99.12	32.85	21.02	53.87	29.16	18.67	47.83	6.04	11.21%
	2000	1	2000	99.06	99.17	41.56	26.60	68.16	36.66	23.46	60.12	8.04	11.80%
	2500	1	2500	99.09	99.20	50.28	32.18	82.46	44.15	28.26	72.41	10.05	12.19%
Total	18108	30	18108					664.63			591.42	73.21	11.02%
Average	603.6		603.6										

AS 2374.1.2 – 2003

APPENDIX B

LOSS CAPITALIZATION PRACTICES

(Informative)

This standard gives minimum power efficiency performance that must be achieved for distribution transformers. However it may be economically justified to go beyond these requirements. Efficiency is also an important issue with large power transformers and with special classes of transformers which are excluded from the requirements of this standard.

The approach taken is to evaluate the total cost of ownership, which includes both the capital cost of the transformer, and the cost of the losses. At the tendering stage, the evaluation formula is provided to all manufacturers, so they can optimize their designs on this basis. The purchaser uses the formula, plus the guaranteed losses, to help choose the best offer. Often it is economically better to initially pay more for a transformer with lower losses.

The final form of the formula is quite simple. The following example illustrates the principle:

For the purpose of this example, the electricity cost is assumed to be 10 cents per "unit", or 0.1 \$/kW-hour. Although most transformers will remain in service for over 30 years, in this case to allow for the cost of capital, a payback period of 7 years is assumed. The cost of electricity consumed over a 7-year payback period is:

0.1 × \$/kW-hour × 24 hours/day × 365 days/year × 7 years = 6,132 \$/kW

This figure is applied directly to the guaranteed no-load loss. The guaranteed load loss is defined at full load, but the actual loss varies as a function of load squared. (Power = I^2R) So if the transformer operates at ½ load on average, only ¼ of the guaranteed losses need to be costed. ¼ × \$6,132 = \$1,533. Hence we get the loss evaluation formula:

Total cost = Purchase price + \$6,132 × NLL + \$1,533 × LL

NLL = Guaranteed No-Load Loss (kW), LL = Guaranteed Load Loss (kW)

An alternative approach is to express the formula as an Assessed Annual Value (AAV), where the interest is placed against the purchase price and the cost of losses is given for a single year:

AAV = 0.07 × Purchase price + \$876 × NLL + \$219 × LL

For transformers that are not in continuous operation, such as testing transformers, the loss capitalization should be reduced by a factor equal to the fraction of time when the transformer is energized. For transformers with continual heavy loading, the load loss capitalization would be higher. Strictly, the load-loss capitalization should equal the no-load-loss capitalization multiplied by the time average of the square of the per-unit loading over the life of the transformer, which includes consideration of the variation of load over the day, over the week and seasonal variation over the year. It should also consider the expected change in load each year over its life. The expected life of the transformer and the cost of financing may be treated in more detail to also arrive at the figures.

The values of loss capitalization quoted above are typical for distribution and industrial transformers in the Australian market. For remote systems with expensive sources of generation, such as diesel generators, much higher values are appropriate.

Actual savings that can be achieved will vary with the transformer size and application, but the basic formula is a function of electricity costs, loading patterns and payback period only. It is applicable for the smallest distribution transformers through to the largest power transformers.

APPENDIX D ENERGY EFFICIENCY POLICY BACKGROUND

D.1 Australia

Australia's greenhouse abatement and climate change policies have evolved steadily since the release of the National Greenhouse Response Strategy in 1997. Energy efficiency has been, and remains, an important element in Australia's response to climate change. This is also the case internationally.

The Australian Government's climate change strategy is the mechanism through which Australia will meet its international commitments as a party to the United Nations Framework Convention on Climate Change (UNFCCC). The Government has an overall target of limiting Australia's emissions in 2008-2012 to 108% of its 1990 emissions. This is a 30% reduction on the projected BAU outcomes in the absence of interventions.

The Australian Government has made a commitment to introducing an emissions trading scheme, known as the Carbon Pollution Reduction Scheme (CPRS) as the key element in Australia's climate change response. While the CPRS is expected to be the major driver in Australia's strategic response to climate change, energy efficiency measures can be complementary to the CPRS.

A number of key studies have concluded that there is an important role for energy efficiency measures:

- The Australian Government's Green Paper on a Carbon Pollution Reduction Scheme (July 2008) [35].
- The Garnaut Review (June [33] and September [34] 2008) proposed a national emissions trading scheme as the key policy mechanism for Australia to achieve significant greenhouse emission reductions by 2050. Garnaut also noted that:

  "The role of complementary measures to the emissions trading scheme is to lower the cost of meeting emissions reduction trajectories, as well as adapting to the impacts of climate change by correcting market failures."

- The Garnaut Review [34] (page 355) noted that: "While an emissions trading scheme will address the primary market failure of unpriced greenhouse gas emissions, other market failures have the potential to raise the economic cost of the structural adjustment process", therefore increasing the economic cost of implementing emissions trading. Garnaut argued that there were three market failures which needed to be "vigorously addressed".
- The Australian Government established the Strategic Review of Australian Government Climate Change Programs [32] ('the Wilkins Review') in February 2008 to determine whether existing climate change programs are efficient, effective and complementary to the CPRS - so that climate change can be addressed at least cost to the economy.

  The Wilkins Review states:

  "If there were a broad-based perfectly functioning emissions trading scheme in Australia, there would be no need for any complementary policies. The trading scheme would deliver the most efficient outcome for Australia. But markets do not work perfectly."

  – (Executive Summary page 1).

  "Addressing significant market failures, or other rationales for government intervention, has the potential to help the ETS work more efficiently thus ensuring that the overall cost of reducing Australia's emissions is lower than it would be otherwise. However, this is not guaranteed – energy efficiency programs are not costless.

  As with any Government intervention the potential benefits need to be weighed against a rigorous assessment of the potential costs and action should only be taken where there are likely to be net benefits for the economy as a whole".

- The Government's response to the Wilkins Review stresses that "with the planned introduction of the CPRS, there is an opportunity to streamline and better target Government policies and measures."

On 12 May 2009 "The Australian Government Climate Change Strategy" was released, following from the work and recommendations of the Garnaut Review [34], the Governments' Green Paper on a Carbon Pollution Reduction Scheme (July 2008) [35] and the Wilkins Review (Feb 2008) [32].

The Wilkins Review identified eight programs to be genuinely complementary to the emissions trading scheme and these include "energy efficiency – National Energy Efficiency Program". In response, the Government announced eight energy efficiency measures as part of the National Strategy on Energy Efficiency in the 2009-10 Budget. These eight include an expansion of minimum performance standards for appliances and equipment.

CoAG has remained the primary forum for progressing Australian, state and territory government collaboration on climate change issues requiring inter-jurisdictional attention. In June 2005 CoAG agreed to establish a new Senior Officials Group to consider ways to further improve investment certainty for business, encourage renewable energy and enhance cooperation in areas such as technology development, energy efficiency and adaptation. In addition, climate change issues requiring national coordination have been managed through a number of inter-governmental ministerial councils including the Ministerial Council on Energy.

In summary, the Australian Government is strongly committed to reducing Australia's carbon pollution and believes the Carbon Pollution Reduction Scheme (CPRS) is the cheapest and most effective way of tackling climate change. However, due to a lack of bipartisan support on the CPRS, combined with slow progress on reaching a credible global agreement to limit carbon emissions, at this stage the Government has delayed the introduction of the CPRS. In the short term the Government intends to boost existing investments in clean and renewable energy and support greater energy efficiency measures in order to bring down greenhouse gas emissions.

D.2 New Zealand

D.2.1 NEW ZEALAND AND THE RESPONSE TO CLIMATE CHANGE

New Zealand ratified the Kyoto Protocol in 2002, and is committed to reducing its greenhouse gas emissions back to 1990 levels, on average, over the period 2008 to 2012 (or to take responsibility for any emissions above this level if it cannot meet this target). More recently New Zealand adopted a provisional and conditional emission reduction target of 10-20% below 1990 levels in 2020 and a longer term target of 50% below 1990 levels in 2050.

Measures that reduce energy-related greenhouse gas emissions make an important contribution to meeting this target. Implementing energy efficiency is widely regarded to be amongst the most cost beneficial ways to reduce greenhouse gas emissions.

Revised New Zealand Emissions Trading Scheme (NZETS) legislation was passed in November 2009. It forms the centrepiece of New Zealand's response to climate change by introducing a market price on greenhouse gases. The equipment energy efficiency program is one of a raft of measures which complement emissions pricing.

Minimum energy performance standards and labelling act to reduce energy costs which will include a price on greenhouse gas emissions.

D.2.2 NEW ZEALAND POLICY CONTEXT FOR THE EQUIPMENT ENERGY EFFICIENCY PROGRAM

Improving the energy efficiency of energy-using products and appliances has important benefits for New Zealand.

National benefits include:

- increased economic growth – from improvements in productivity and international competitiveness of New Zealand businesses;
- enhanced security of supply - from reduced energy demand;
- deferring the need for more expensive energy supply infrastructure and reducing peak demand - with consequent reductions in costs and environmental impacts;
- reductions in the absolute amount of renewable electricity required for New Zealand to achieve its target of 90% renewable electricity generation by 2025;
- reductions in greenhouse gas emissions - consistent with New Zealand's medium and long term reduction targets, cited below; and
- reductions in national health costs and improved overall wellbeing of New Zealanders – by making energy services more affordable.

Benefits directly to end-user include:

- improved competitiveness of individual businesses - from reduced energy costs;
- lower cost energy services to householders – which improving their ability to afford higher quality lifestyles and/or make energy cost savings; and
- better informed energy users are more capable of managing the impact of future energy prices, which will incorporate a price on greenhouse gas emissions.

The New Zealand Energy Strategy (NZES) and its companion document, New Zealand Energy Efficiency and Conservation Strategy (NZEECS) are being revised and drafts will soon be publicly released for consultation. These strategies are expected to maintain a focus on energy efficient equipment, consistent with maximising the benefits cited above.

D.3 Impact of Electricity Sector Reform in Australia and New Zealand

The electricity supply industry in Australia and New Zealand has been reformed in a way that, whatever its other benefits, removes any incentives for optimising transformer efficiency.

The Australian National Electricity Market (NEM) began operations in 1998. As part of the electricity sector reform, generation, transmission, distribution and retail entities were separated and in many cases sold to private operators. In many important respects, the reform has led to markedly improved efficiency, for example, by encouraging improvements in generation plant performance and stabilising wholesale electricity cost and price.

On the other hand, the so called "wires" businesses of transmission and distribution (Transmission and Distribution Network Service Providers, or TNSPs and DNSPs) remain as local monopolies and their operations and pricing are subject to regulation. Initially, state regulatory bodies controlled DNSPs but all these powers were handed over to the Australian Energy Regulator (AER) commencing on 1 January, 2008.

With the split between DNSPs and retailers, clear responsibility for the management of losses in the distribution network has been lost. This is evident from the way the businesses are separated, as described below:

- Retailers buy energy wholesale from generators and sell it retail to end use customers. Some very large customers may operate directly in the wholesale market and essentially act as their own retailers.
- TNSPs and DNSPs charge a fee for the use of the wires to deliver energy to customers; this fee is regulated and applies to all customers of a given type in a given area.
- In addition, the amount metered to the customer is adjusted to account for losses according to a fixed formula set from time to time by the regulator. The effective outcome of the basic formula is that the costs of distribution losses are passed through directly to customers; DNSPs see no financial consequences from the pattern of losses in their network and competing retailers all see the same loss adjustments. Retailers cannot directly influence distribution losses.

The New Zealand electricity market is similar in design to that in Australia (and in fact preceded it). It suffers the same disincentives for efficient loss management because of the separation between the parties that pay for transformer purchases (the DNSPs) and the parties that pay for transformer losses (the Retailers in the first instance).

A DNSP plan presented to a regulator may include equipment that meets good industry practice, but, under a "light regulation" philosophy, the equipment actually installed may be different, and is likely to be lower in capital cost if that would immediately improve the DNSP bottom line.

Regulators are aware of the risk of such behaviour and attempt to devise schemes that encourage DNSPs (and TNSPs) to behave in ways more closely aligned to good long-term practice. In 2009 the AER proposed an Efficiency Benefit Sharing Scheme (EBSS) whereby the DNSPs would be rewarded for any improvement in operating and capital efficiency [26]. Matters addressed by the proposed EBSS included:

- the need to provide DNSPs with a continuing incentive, so far as is consistent with economic efficiency, to reduce operating and capital expenditures (if included in the scheme); and
- the desirability of both rewarding DNSPs for efficiency gains and penalising DNSPs for efficiency losses.

Under the AER scheme the cost savings through greater efficiency would be split, with 30% going to the DNSP and 70% to the consumer. The consumer (through the retailer) would have a reduced tariff and the DNSP would be able to keep 30% of the cost saving for five years after the initiation of efficiency improvement.

However, in its final decision on the EBSS of June 2008 [26], the AER decided to omit distribution losses from the scheme altogether. In Section 5.6.2 its conclusion is brief:

"Given the lack of evidence showing the distribution losses are deviating from efficient levels, the AER considers it appropriate not to apply the EBSS to distribution losses."

In an earlier AER discussion paper there was reference to the complication of such a scheme. It is noteworthy that most DNSPs chose not to comment on the draft recommendation proposing to omit electrical losses from the EBSS.

As a result of the AER decision, the incentives to maintain appropriate efficiency levels in distribution remain muted. At present, DNSPs in NSW and Queensland remain in public hands while those in Victoria and South Australia have been sold off. As more DNSPs are sold and as both existing and new ownership devolves to enterprises that may have easier access to low cost but inefficient transformers, the risk of efficiency loss in Australian distribution networks increases.