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PUBLIC DISCUSSION DRAFT

REGULATORY IMPACT STATEMENT:

Minimum Energy Performance Standards and Alternative Strategies for ELECTRICITY DISTRIBUTION TRANSFORMERS

Prepared for the Australian Greenhouse Office

by

George Wilkenfeld and Associates

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GEORGE WILKENFELD AND ASSOCIATES Pty Ltd
ENERGY POLICY AND PLANNING CONSULTANTS
92 Spencer Road, Killara NSW 2071 Sydney Australia
Tel (+61 2) 9418 2405 Fax (+612) 9418 2406 e-mail: geosanna@ozemail.com.au

Executive Summary

Electricity distribution transformers are essential for the operation of the electricity system. Their function is to step the supply voltage down from transmission voltages of 33,000 volts and above to the 415 volt three-phase supply which most electricity users receive (a single phase of this supply is 240 volts). Industry sources estimate that there are about 577,000 utility-owned distribution transformers in use in Australia, and their number is increasing at about 1.5% per annum.

Electricity distributors usually provide supply at higher voltages to larger electricity users such as factories, mines, shopping centres or hospitals. This enables users to operate any specialised equipment requiring higher voltages. In most cases the voltage must still be stepped down to 415V/240V for general use, so the owners of the premises in effect take over the last stage in the electricity distribution task, using their own transformers located on site. These are called "private transformers" as distinct from "utility transformers". It is estimated that there are about 100,000 private transformers in use, and the stock is increasing more rapidly than utility transformers.

A small proportion of the electrical energy passing through every transformer is lost as heat from the core and the windings. The percentage of energy lost depends on the design of the transformer (eg whether it is liquid- or air-cooled), the quality and quantity of materials used in its construction, the capacity and the power system operating conditions.

It is estimated that in 2000 distribution transformer losses were about 5865 GWh, or 3.2% of the energy supplied to transformers, giving an overall operating efficiency of 96.8%. The generation of the electricity lost led to emissions of nearly 6.0 million tonnes of carbon dioxide equivalent (CO_2-e). This was about two-thirds as great as the emissions associated with the operation of all domestic refrigerators and freezers.

There are at present no energy efficiency programs explicitly targeting distribution transformers in Australia. There are analytical tools for assessing lifetime operating costs – such as the Energy Suppliers Association of Australia's *Specification* – but the motivation for transformer purchasing organisations to apply them appears to be diminishing.

The changes in structure of the electricity industry have greatly reduced the ability of utilities to minimise costs across functions. According to distributors themselves and their regulators, the State-based regulation of distributor charges appears to be favouring first cost concerns above lifetime operating cost. Consumers of electricity are neither aware of the consequences of this emphasis by distributors on initial, rather than lifetime operating costs, nor in a position to directly influence it.

Consequently, the costs of electrical distribution services, and the emissions of greenhouse gases, are projected to be higher than would be the case if operators of electricity distribution transformers were to base investment decisions on lifetime operating costs.

The National Greenhouse Strategy states that “improvements in the energy efficiency of domestic appliances and commercial and industrial equipment will be promoted by extending and enhancing the effectiveness of existing energy labelling and minimum energy performance standards [MEPS] programs” (NGS 1998).

The prospect of MEPS for electricity distribution transformers was first raised within government in 1994, and an industry-Government Steering Group to advance the matter was constituted in early 2000.

The Proposal

The proposal is to introduce mandatory minimum energy performance standards for all electricity distribution transformers of up to 2500 kVA capacity, falling within the scope of a proposed new part of Australia Standard AS2374-1-2 2001: *Power Transformers: minimum energy performance standards for distribution transformers.* They are expressed in terms of minimum efficiency levels at half rated load.

The draft Standard containing the proposed levels was published in October 2001. It is intended to publish the final Standard shortly though possibly after governments decide on the proposal.

The proposal would be given effect if all States and Territories agreed to amend the schedule of products in the existing regulations governing energy labelling and MEPS in their jurisdictions. The proposed implementation date is 1 January 2003.

Regulatory Impact Statement

The Council of Australian Governments (COAG) requires that proposals of this type be subject to a Regulatory Impact Statement (RIS).[1] The present RIS estimates the benefits, costs and other impacts of the proposal and assesses the likelihood of the proposal meeting its objectives.

The main objective of the proposed regulation is to reduce greenhouse gas emissions related to energy losses from electricity distribution transformers below what they are otherwise projected to be, in a manner that is in the community’s best interests.

The following alternative options are considered in the RIS:

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[1] The COAG Guidelines state that:
“The purpose of preparing a regulation impact statement (RIS) is to draw conclusions on whether regulation is necessary, and if so, on what the most efficient regulatory approach might be. Completion of a RIS should ensure that new or amended regulatory proposals are subject to proper analysis and scrutiny as to their necessity, efficiency and net impact on community welfare. Governments should then be able to make well-based decisions. The process emphasises the importance of identifying the effects on groups who will be affected by changes in the regulatory environment, and consideration of alternatives to the proposed regulation.
Impact assessment is a two step process: first, identifying the need for regulation; and second, quantifying the potential benefits and costs of different methods of regulation. In demonstrating the need for the regulation, the RIS should show that an economic or social problem exists, define an objective for regulatory intervention, and show that alternative mechanisms for achieving the stated objective are not practicable or more efficient” (COAG 1997).

1. Status quo (termed business as usual, or BAU);
2. The proposed regulation (mandatory MEPS) which adopts all the requirements contained in Australia Standard 2374 applying to transformers;
3. An alternative regulation which only adopts those parts of the Standard that are essential to satisfy regulatory energy objectives (targeted regulatory MEPS);
4. Voluntary MEPS, where minimum energy efficiency levels for distribution transformers would be made publicly available, and industry is encouraged, but not compelled to adhere to the proposed levels;
5. Another regulatory option involving a levy imposed upon inefficient equipment to fund programs to redress the greenhouse impact of equipment energy use; and
6. A levy on electricity reflecting the impact it has on greenhouse gas emissions.

In addition to assessing whether the alternatives would meet the objective of the proposed regulation, they were also reviewed according to the following criteria:

1. Does the option address market failures, so that the average lifetime costs of transformers are reduced, when both capital and energy costs are taken into account?
2. Does the option address information failures, so buyers have ready access to product descriptions that are consistent and accurate with regard to energy efficiency?
3. Does the option minimise negative impacts on product quality and function?
4. Does the option minimise negative impacts on manufacturers and suppliers?

Projected energy and Greenhouse Savings

The energy and greenhouse savings from the proposed MEPS have been projected using detailed computer modelling of the Australian distribution transformer stock over the period 2002-30. Three main scenarios were developed, to cover the range of uncertainty concerning the starting efficiency of the existing stock. Table S1 summarises the projected reductions in greenhouse emissions for the mid-point scenario. Figure S1 illustrates the projected emission reductions by State.

Table S1 Projected greenhouse emissions and savings, 2002-2030

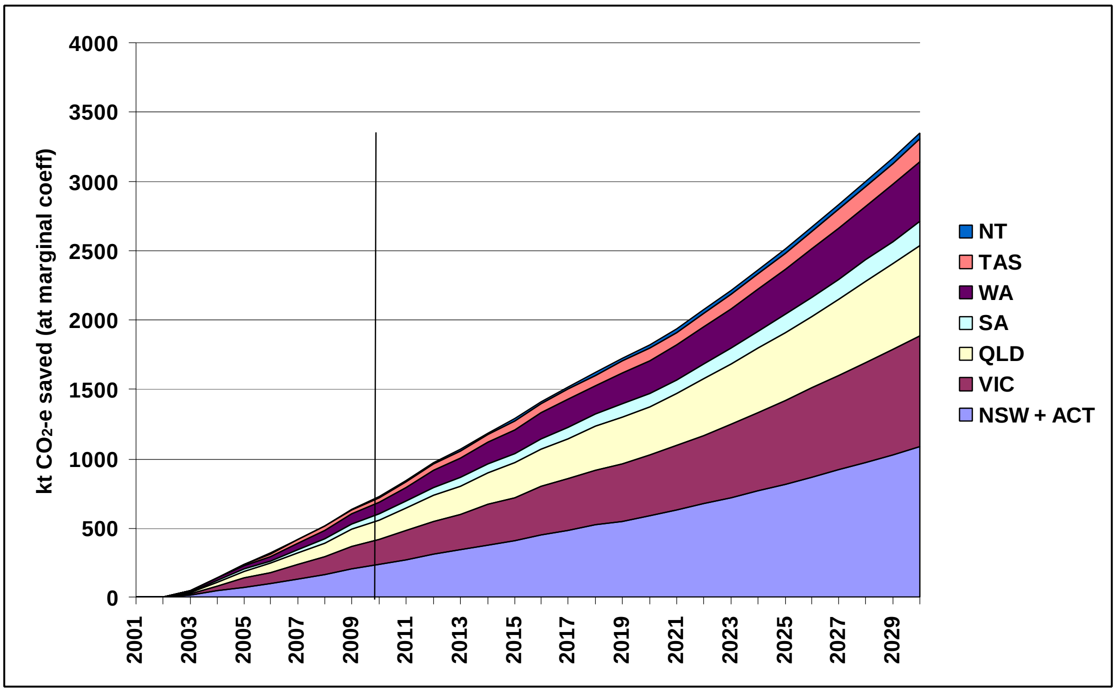
Trans-formers	BAU (No MEPS)			With MEPS			Reduction			Share of reduction
	2010	2020	2002-30	2010	2020	2002-30	2010	2020	2002-30	
Utility (a)	5230	6343	174444	4524	4483	131514	706	1859	42930	80.3%
Utility (b)	860	1104	29857	858	1097	29692	2	7	166	0.3%
Private (a)	1232	1540	42107	1072	1107	32074	161	433	10034	19.4%
Total stock	9332	11007	246409	8463	8707	193279	869	2299	53130	
Reduction below BAU							9.3%	20.9%	21.6%	

All value kt CO_2-e. (a) up to 2500 kVA capacity, and subject to MEPS. (b) Not subject to MEPS, but with some savings due to reduction in losses of downstream transformers.

The greenhouse reductions in 2010 from MEPS is estimated to lie in the range 1066 kt CO_2-e (10.7% below BAU) to 672 kt CO_2-e (7.8% below BAU), with a mean value of 869 kt CO_2-e (9.3% below BAU). The projected savings build up rapidly with the projected rise in electricity consumption. Over a 30 year horizon, the projected savings range from 64.9 Mt CO_2-e to 41.4 Mt CO_2-e.

MEPS-impacted utility transformers (Group A) account for over 80% of the projected emissions reductions, and MEPS-impacted private transformers for nearly 19%.

Figure S1. Projected emission reductions by State, 2001-30



Benefits and Costs

The benefit is the net present value (at 10% discount rate) of the projected reduction in electricity losses. No value has been given to greenhouse gas emission savings. The cost is the net present value of the projected increase in the price of transformers. There are no additional program costs, since transformer energy efficiency testing is already common and the administrative infrastructure for MEPS already exists.

The benefit/cost ratios range from 1.0 to 1.2 for utility-owned transformers, where the value of losses is related to the wholesale price of energy, and 3.3 to 4.0 for privately-owned transformers, which face much higher marginal electricity prices and for which the value of electricity saved is consequently higher. The mean estimates are summarised in Table S2. The projections embody a price/efficiency ratio of 0.5. For private transformers, MEPS remain cost effective up to ratios of 1.8 - ie if a reduction in energy losses of 10% were to lead to a unit cost increase of 18%.

Table S2 Projected national costs and benefits, MEPS options

	No MEPS			With MEPS			NPV Extra cost	NPV Saving	Benefit/ Cost ratio	Limit P/E ratio
	NPV cost of trans	NPV losses	Total NPV	NPV cost of trans	NPV losses	Total NPV				
Type A	$1,392.7	$2,003.4	$3,396.1	$1,688.5	$1,679.2	$3,367.7	$295.8	$324.2	1.1	0.55
Type B	$149.6	328.4	$1,828.8	$149.6	$327.2	$473.8	$0.0	$1.2		
Type C	$208.5	$1,080.5	$1,289.0	$255.8	$908.8	$1,164.7	$47.3	$171.7	3.6	1.81
All types	$1,750.8	$3,412.4	$6,514.0	$2,093.9	$2,915.3	$5,006.2	$343.1	$497.1	1.4	

All values $M net present value of transformer costs during the period 2002-30, at 10% discount rate

Supplier and Trade issues

Transformers are manufactured in nearly all developed countries and many of the developing countries in the Asia Pacific region, and are freely traded. There are over 20 manufacturers of transformers in Australia, five of which account for the majority of the market. Between 15% and 25% of the transformers sold each year are imported, in many cases by firms which also manufacture locally. In addition, there are several import-only firms. In 1999 Australia imported transformers from 25 countries.

One of these countries, Canada, has introduced MEPS for electricity distribution transformers with effect from 1 January 2002. The MEPS level proposed for Australia are based on and equivalent to the Canadian levels, adjusted for differences in electricity supply frequency. The USA and European Union are also considering MEPS, at somewhat more stringent levels, roughly equivalent to the "high efficiency" designation proposed for Australia.

In order to meet Australia's proposed MEPS, some domestic and some foreign manufacturers will need to review their design and manufacturing practices, and will need to upgrade designs (although in many cases not actually incur the additional costs of manufacturing to the more stringent efficiency level until orders are received).

The technologies required for the necessary efficiency improvements are widely available and accessible to all manufacturers. It should not be difficult for importers to source product of different price and efficiency levels, provided there is reasonable notice.

It is already industry practice to test each transformer unit at the factory, to ensure that it conforms to the type specifications for that model, and so that the characteristics of that specific unit, including its energy efficiency, can be certified to a prospective buyer if required. It is proposed that suppliers would continue to test their own products to determine compliance with the MEPS level, so no additional testing costs should be imposed in the normal course of business.

As with household appliances, tests done in the country of origin would be acceptable for imported products, provided those tests are carried out to the appropriate Australian Standard. There is at least one independent, accredited laboratory in Australia available for suppliers that may be unable to carry out the necessary tests, and to conduct check testing in case of dispute.

On balance the introduction of MEPS levels is not likely to significantly change the number of suppliers, nor the price competition between them. The current MEPS regime is not inconsistent with the GATT *Technical Barriers to Trade* Agreement, and there is no reason why more stringent MEPS would be so.

Assessment

Reduce greenhouse emissions below business as usual

The mandatory MEPS option is the only one for which the extent of likely reduction can be quantified, and the one where reductions have the highest probability of occurring.

Address market failures

The mandatory MEPS option would address market failure in the private transformer market, and the increasing risk of market failure in the utility transformer market, by enforcing investment in more efficient products so that the total life cycle cost of transformers to users would be lower than otherwise.

Address information failures

One consequence of the mandatory MEPS option would be to introduce consistency in declarations of transformer energy efficiency and in the designation of models as "High Efficiency". The introduction of MEPS would put reliable data on the energy efficiency of every transformer model in the public domain for the first time. Buyers could access this data via the State government registers of products (assuming these are made public, as is now the case of household appliances).

Minimise negative impact on product quality

MEPS are not expected to have any significant effect on product quality or function (ie apart from energy-efficiency). In fact, greater transformer energy efficiency should lead to lower heat gain in operation, and hence lower failure rates and higher overall network reliability.

Minimise negative impact on suppliers

The mandatory MEPS option would clearly prevent suppliers from manufacturing or importing non-complying products after the commencement date (although products lawfully manufactured or imported before the date could still be sold). The other options would have lower costs for suppliers to the extent that they were less effective in bringing about these outcomes. At the extreme, the voluntary MEPS option may have no impact on suppliers in the event that none take it up.

Matching World's Best Practice

Canada and Mexico have MEPS for transformers, and the European Union and the USA are considering implementing them. The proposed MEPS levels are based on, and equivalent to, the most stringent currently in place (those for Canada, which took effect January 2002) and so are consistent with the principle adopted by ANZMEC – matching but not exceeding the most stringent MEPS levels in force elsewhere.

The proposed criteria for designating transformers as "high efficiency" are roughly equivalent to the MEPS levels under consideration for the EU and the USA, and so are an indicator of the likely direction of world's best practice.

Conclusions

After consideration of the mandatory MEPS option and the provisions of the draft Standard, it is concluded that:

1. The mandatory MEPS option is likely to be effective in meeting its stated objectives;
2. None of the alternatives examined appear as effective in meeting all objectives, some would be completely ineffective with regard to some objectives, and some appear to be far more difficult or costly to implement;
3. The projected monetary benefits of the mandatory MEPS option appear to exceed the projected costs by a ratio of about 1.4 to 1, without assigning monetary value to the reductions in CO_2 emissions that are likely to occur;
4. If implemented in January 2003, the greenhouse gas reductions from the electricity saved by the proposed MEPS regulations could be as high as 0.87 Mt CO_2-e per annum by 2010;
5. The benefit/cost ratio for privately-owned transformers is significantly higher than for utility-owned transformers;
6. Given that the proposed MEPS levels were issued in a draft Australian Standard in October 2001, and that transformers are generally built to order rather than mass-produced, the proposed regulation could be implemented as early as 1 January 2003.

Recommendations

It is recommended that:

1. States and Territories implement the proposed mandatory minimum energy performance standards.

2. The mode of implementation be through amendment of the existing regulations governing appliance energy labelling and MEPS in each State and Territory.

3. The amendments should:
   – add electricity distribution transformers to the schedule of products for which minimum energy performance standards are required, and refer to the MEPS levels in Tables 1 and 2 of AS2374.1.2 (proposed part);
   – add electricity distribution transformers to the schedule of products requiring energy labelling, so that any transformer for which the claim of "high efficiency" or "energy efficient" are made must meet the energy efficiency criteria in Tables 3 and 4 of AS2374.1.2 (proposed part);
   – require registration of models, so invoking Appendix A of the proposed Standard.
   – allow transformers manufactured or imported prior to the date of effect of the regulations to continue to be lawfully sold indefinitely.
4. Governments make the register of electricity distribution transformer characteristics publicly accessible, so prospective purchasers can compare their energy efficiencies.

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Contents

Glossary

ABARE	Australian Bureau of Agricultural and Resource Economics
AEEMA	Australian Electrical and Electronics Manufacturers Association
AGO	Australian Greenhouse Office
ANZMEC	Australian and New Zealand Minerals and Energy Council
APEC	Asia-Pacific Economic Cooperation
AS	Australian Standard
BAU	Business as usual
COAG	Council of Australian Governments
DISR	Department of Industry, Science and Resources
EC	Council of the European Union
EES	Energy Efficient Strategies
ESAA	Electricity Supply Association of Australia
EU	European Union
GATT	General Agreement on Tariffs and Trade
GWA	George Wilkenfeld and Associates
GWP	Global warming potential
HE	High efficiency (eg meeting the criteria designated in AS2374).
HSE	High starting efficiency: one of the projection scenarios
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronic Engineers (USA)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organisation
kV	kilo-volt: measure of voltage at input and output sides of transformer
kVa	kilovolt-amps: measure of capacity of transformer
LSE	Low starting efficiency: one of the projection scenarios
MEPS	Minimum energy performance standards
MSE	Medium starting efficiency: one of the projection scenarios
MVA	thousand kVa
NAEEEC	National Appliance and Equipment Energy Efficiency Committee
NAEEEP	National Appliance and Equipment Energy Efficiency Program
NGGI	National Greenhouse Gas Inventory
NGS	National Greenhouse Strategy
NPV	Net present value
TTMRA	Trans-Tasman Mutual Recognition Agreement
UNFCCC	United Nations Framework Convention on Climate Change

1. The Problem

COAG Guidelines:

- ***Statement of the problem:*** *why is government action being considered in the first place? What is the problem being addressed? For example, this Section should state the market failure that the proposal seeks to remedy.*

1.1 Energy-Related Greenhouse Gas Emissions

In recognition of the risks and costs of climate change, the Australian government is cooperating with other countries on a global strategy to reduce greenhouse gas emissions below what they would otherwise be. The Commonwealth, State and Territory governments have adopted a National Greenhouse Strategy to give effect to this objective (NGS 1998).

The United Nations Framework Convention on Climate Change (UNFCCC) was agreed in 1992 and came into force in 1994. It places most of the responsibility for taking action to limit greenhouse gas emissions on the developed countries, including Australia, which are referred to collectively as Annex I countries. Annex I countries are required to report each year on the total quantity of their greenhouse gas emissions and on the actions they are taking to limit emissions.

The Kyoto Protocol to the UNFCCC was agreed in December 1997, but has yet to be ratified by its signatories, which include Australia. If ratified, it would place a legally binding obligation on Annex I countries to limit their average annual greenhouse gas emissions during the "first commitment period" 2008 – 2012 to agreed targets, expressed as a proportion of their 1990 emissions. Australia's target would be 108% of its 1990 emissions. While this is higher than the average for Annex 1 countries, it is nevertheless challenging, representing a reduction of more than 20% compared with business-as-usual projections (NGS 1998).

Table 1 summarises Australia's greenhouse gas emissions in 1990 and 1999, the latest year for which a national greenhouse gas inventory (NGGI) has been prepared. Net emissions increased by 17.4% over the period, and the energy sector accounted for nearly all of this increase.[2] The energy sector accounted for nearly all of the growth in national emissions, and electricity generation emissions represented nearly two thirds of the increase in energy emissions. The next highest contributor was road transport (19% of the total increase in energy emissions).

ABARE (2001) projects total electricity use to increase by a further 29% between 1999 and 2010, the mid-point of the Kyoto protocol commitment period. Electricity use in agriculture, mining and manufacturing is projected to increase by 22%, commercial sector electricity use by 32%, and residential electricity use by 9%. Slowing, and ultimately reversing the growth in electricity-related emissions is thus a high priority in Australia's greenhouse gas reduction strategy.

[2] By convention, emissions from land use change are reported separately. These were substantially lower in 1999 than in 1990.

Table 1 Change in Greenhouse Gas Emissions, 1990 to 1999

	1990 Mt CO_2-e	1999 Mt CO_2-e	Change 1990 to 99 Mt CO_2-e	Change 1990 to 99 %	% of Energy Sector change
1A Fuel Combustion	270.0	333.7	63.8	23.6%	98.0%
1A1 Energy Industries	142.3	188.8	46.5	32.7%	71.5%
Electricity generation	129.1	171.8	42.7	33.1%	65.7%
Other	13.2	16.9	3.8	28.6%	5.8%
1A2 Manufacturing & Construction	50.3	52.0	1.7	3.4%	2.6%
1A3 Transport	61.5	73.9	12.4	20.3%	19.1%
Road	54.8	66.6	11.8	21.5%	18.2%
Other	6.6	7.3	0.6	9.6%	1.0%
1A4 Small combustion	14.2	16.7	2.5	17.5%	3.8%
1A5 Other	1.7	2.3	0.6	38.3%	1.0%
1B Fugitive	29.5	30.8	1.3	4.4%	2.0%
Solid Fuels	15.9	18.3	2.4	15.3%	3.7%
Oil and Natural Gas	13.6	12.5	-1.1	-8.3%	-1.7%
Sector 1. All Energy (sum of 1A, 1B)	299.5	364.6	65.1	21.7%	100.0%
Sector 2. Industrial Processes	12.0	9.6	-2.4	-19.9%	
Sector 4. Agriculture	91.2	93.8	2.7	2.9%	
Sector 5 (part). Forestry and Other (a)	-27.3	-25.9	1.4	-5.1%	
Sector 6. Waste	14.9	16.0	1.1	7.6%	
Gross emissions	417.6	484.1	66.5	15.9%	
Net emissions	390.3	458.2	67.9	17.4%	

Source: AGO 2001c (a) Land use change excluded. Sector 3, Solvent and Other Product Use, contains only indirect greenhouse gases that fall outside the scope of the Kyoto Protocol.

1.2 Contribution of Transformers to Emissions

The National Greenhouse Gas Inventory does not indicate directly the contribution of economic sectors (eg the commercial or manufacturing sectors) or end uses (eg transformers) to national greenhouse gas emissions. Further analysis is required, especially the allocation of electricity use to sectors, end uses and technology types.

Transformers are essential to the operation of the electricity grid. The electricity generators and utilities use transformers to increase the supply voltage for energy transmission over long distances between the power stations and the areas of use (the "load centres"), and then to reduce the voltage for safe distribution to the premises of end users.

The higher the voltage, the lower the current necessary to transmit a given amount of energy, and the lower the line losses. Transmission voltages of 500,000 volts (500 kilo-volts, or kV) are common. The voltage is then "stepped down" in a series of transformers, by factors of between 3 and 30 at a time, until it reaches the supply voltage. Electricity utilities supply at 415V to domestic or small business customers.[3]

[3] This is the maximum voltage difference between the active carriers, the so called "three phase" voltage. Most household appliances operate at 240V, which is the difference between the active and the neutral, the so-called "single-phase" supply. Appliances taking more than about 2400W of power,

The utilities usually provide supply at higher voltages to larger electricity users such as factories, mines, large office buildings or hospitals. This enables users to operate any specialised equipment which requires higher voltages. In most cases the voltage must still be stepped down to 415V/240V for general use, so the owners of the premises in effect take over the last stage in the electricity distribution task, using their own transformers located on site. These are called “private transformers” as distinct from “utility transformers”.

Transformers can be characterised in a number of ways, the most important of which are voltage and capacity. Each transformer has an input voltage and an output voltage. These may be specified as a pair of values (eg 33kV/11 kV) or simply in terms of the higher value (eg 33 kV).

The capacity of a transformer indicates the amount of power it can handle (ie the rate of energy transfer). For example, a transformer with a rated capacity of 2500 kVA (kilovolt-amps) is designed to handle 2500kW (or 2.5MW) under standard operating conditions.[4] This is the “full load” rating. However, transformers must be designed to operate across the wide range of loadings they are subjected to in use, from zero load to twice the rated load or more.

By convention, the electricity supply system is divided into the “transmission” and the “distribution” networks, which tend to be carried out by different organisations. Transmission transformers generally operate in the voltage range from 500kV down to 66 kV, and with capacities of 45,000 kVA (45 MVA) to 2,000 kVA (2 MVA). Distribution transformers generally operate in the voltage range 33 kV to 415/150V, with capacities of 2,500 kVA to 10 kVA. However, neither the technical nor organisational differentiations are strict, and there is some overlap in functions and in transformer characteristics in some States.

Transformers are not 100% efficient – the output energy is always less than the input energy (the reasons for these losses and how they can be reduced are covered in the following section). The loss characteristics of each transformer under standard conditions are tested during manufacture, but operating conditions deviate widely from the standard used in testing and actual losses are rarely monitored.

It is possible to estimate total transformer losses by combining data from the Electricity Supply Association of Australia (ESAA) with overseas estimates. Table 2 summarises energy losses from the transmission and distribution systems in the year ended June 2000. Transmission losses amounted to about 5,150 GWh, or 2.8% of the energy sent out from power stations, and distribution losses amounted to about 10,500 GWh, or 5.9% of the energy sent out from the transmission system to the distribution system.

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such as cookers or water heaters, must be connected to the three-phase supply. Australia is planning to follow new European standards and move to 400/230V supply in 2003.

[4] The power rating of a transformer in kilowatts is the product of the kVA rating and the power factor The standard condition is a “power factor” of 1. Most utility supply deviates from this due to the characteristics of the end user devices connected to the supply.

As expected, the highest loss percentages are in the electricity systems which cover the largest geographical area (Queensland and WA) and lowest where the load centres are concentrated (Tasmania and SA). The ratio of distribution to transmission losses partly reflects historical institutional arrangements. In most States the ratio is between 2 and 3 to 1, but in Queensland it was 1:1 and in SA over 8:1.

Table 2 Summary of distribution and transmission losses by State, 2000

	NSW	VIC	QLD	SA	WA	TAS	NT	AUST
Available energy GWh	65896	41352	39613	11836	12626	10012	1678	183013
Transmission loss GWh	1468	1074	2081	86	299	94	45	5148
To distribution GWh	64428	40277	37532	11750	12327	9917	1633	177865
Distribution loss GWh	3479	2699	2027	705	961	545	83	10500
Sales GWh	60949	37579	35505	11045	11365	9372	1550	167365
Total losses GWh	4947	3773	4108	791	1261	640	128	15647
Transmission loss/available energy	2.23%	2.60%	5.25%	0.73%	2.37%	0.94%	2.68%	2.81%
Distribution loss/energy to distrib	5.40%	6.70%	5.40%	6.00%	7.80%	5.50%	5.10%	5.90%
Total loss/available energy	7.5%	9.1%	10.4%	6.7%	10.0%	6.4%	7.6%	8.5%
Ratio of dist to trans losses	2.4	2.5	1.0	8.2	3.2	5.8	1.9	2.0
Share national distribution loss	33.1%	25.7%	19.3%	6.7%	9.2%	5.2%	0.8%	100.0%

Source: Derived from ESAA (2001)

The share of energy lost in distribution in Australia appears to be static or increasing, but not declining. The trend reported by ESAA (Figure 1) suggests that losses levels are steady overall, despite large annual variations in some States. The data in Figure 2, however, which draw on a wider range of sources (including the series *Engineering and Financial Statistics of Electricity Supply Authorities in NSW*) suggest that loss levels in the largest State system are continuing to increase steadily.

Figure 1 Distribution losses by State, 1995-2000

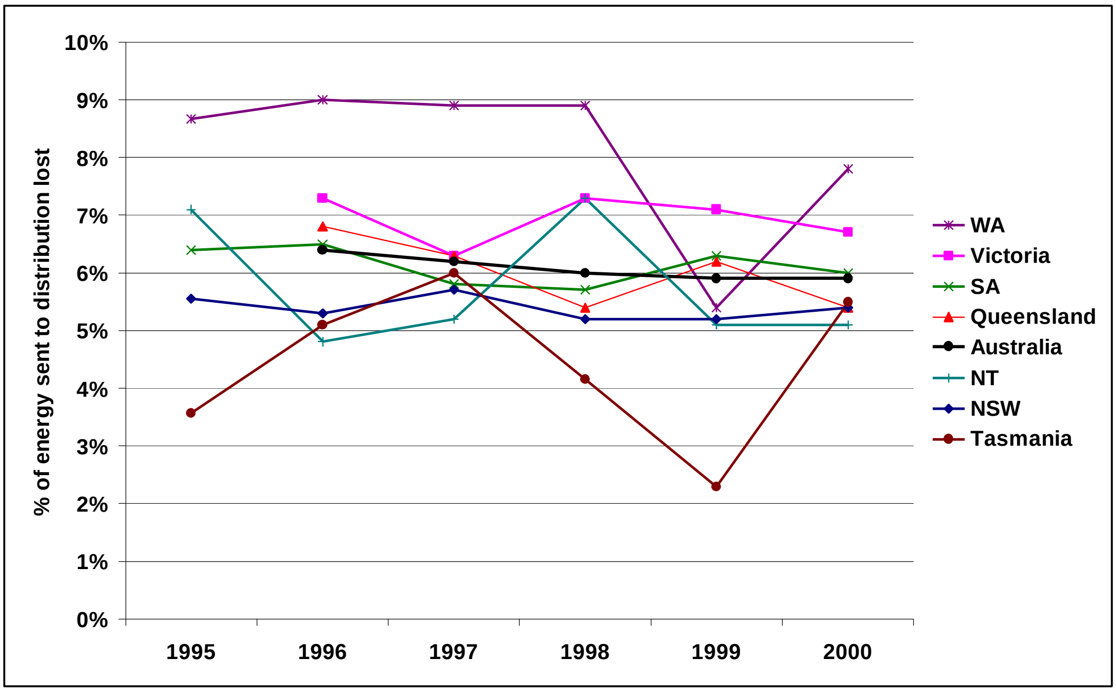
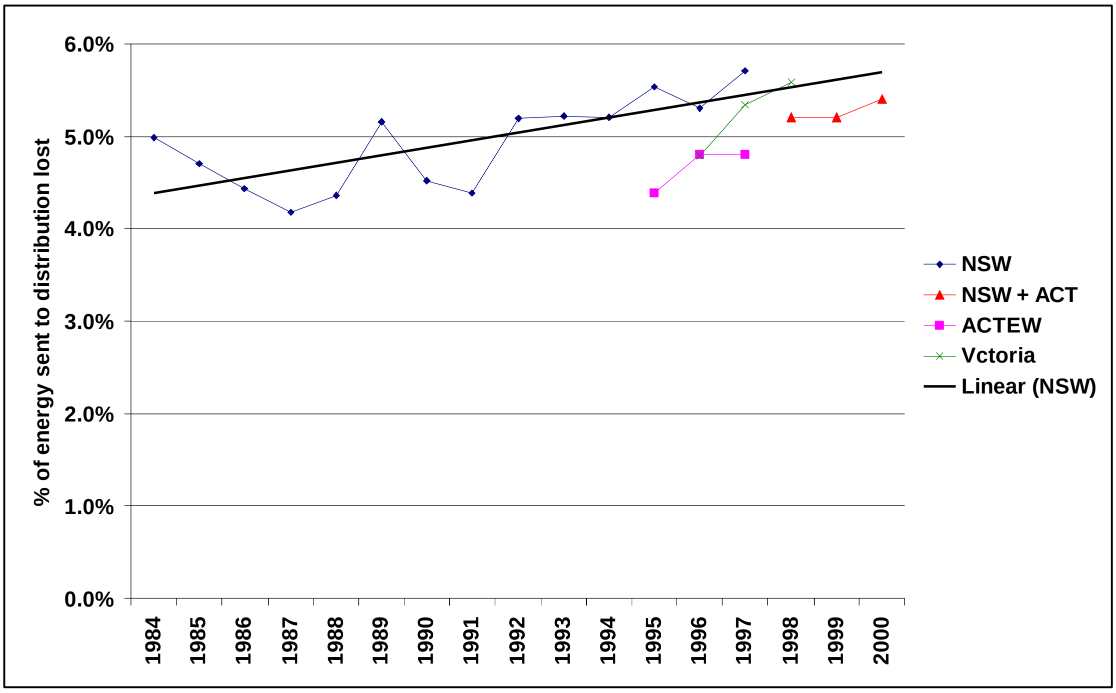


Figure 2 Distribution losses in NSW, ACT and Victoria, 1984-2000



There are two main contributors to transmission and distribution losses: line losses (energy lost as heat because of the resistance of conductors to the flow of current) and transformer losses. There is no direct information on the contribution of each of these losses the distribution losses in Table 2, but it is possible to make an estimate on the basis of data from the USA and the UK.

Table 3 indicates that on one large US network in 1985, transformer losses represented about 51% of distribution losses, and Table 4 indicates that transformer losses in the UK were about 42% of distribution losses. Comparison between networks is difficult, due to differences in technologies employed, voltages, distances and a range of other factors. The US network uses a far larger proportion of higher-loss single phase transformers than is the case in Australia, which is more similar to the UK network in this respect.

Table 3 Estimate of losses in Bonneville Power Administration, 1985

	Share of all loss	Share of Accounted loss		Share of Accounted loss	Share of distribution loss
Distribution Transformers	36.5%	40%	Transmission	23%	NA
Substation Transformers	2.2%	2%	Transformers	2%	NA
Transmission System	10.5%	11%	Cables	20%	NA
Secondary System	8.1%	9%	Distribution	77%	NA
Feeders (cables)	34.9%	38%	Transformers	40%	**51%**
Unaccounted 7.8%	7.8%	NA	Cables	38%	**49%**
Total losses	100.0%	100.0%	Total losses	100.0%	**100%**

Source: derived from BPA (1986)

Therefore the transformer share of distribution losses in Australia is estimated to be in the range 42% to 51% of distribution losses. At 42%, this would represent about 4,410 GWh per annum (2.4% of available energy), and at 51% about 5,355 GWh per year (2.9% of available energy). The higher value corresponds well with the estimate in Ellis (2001), which stated that:

> "Following consultation with the industry, we have assumed that distribution transformers in Australian electricity system account for around 25% of T&D losses, equivalent to 5,400 GWh."

It is estimated that private transformers account for about 15% of the total distribution transformer stock in Australia (Ellis 2001). These are likely to be built to different standards and with different average capacities than utility transformers, and may be loaded in different ways, so their average loss rates may be either higher or lower. However, if their losses were similar to utility transformers then private transformer losses would be a further 950 GWh.

Table 4 Estimate of losses in the UK, 1999

	Share of all energy	Share of all loss	Share of distribution loss
Transmission	1.7%	26%	
Distribution	4.8%	73.8%	
Transformers	2.0%	31%	**42%**
Cables	2.8%	43%	**58%**
Total losses	6.5%	100.0%	100%

Source: derived from EC (1999)

The greenhouse gas emissions associated with transformer losses can be calculated by multiplying the energy lost in each State by the fuel cycle greenhouse coefficients for electricity (ie including production overheads and fugitive emissions; see Appendix 3). For utility transformers, the appropriate coefficients are those for electricity supplied to the distribution system, and for private transformers the appropriate coefficients are those for electricity delivered. The weighted national average values in 2000 were 1.01 kg CO_2-e/kWh and 1.07 kg CO_2-e/kWh respectively.

Table 5 Estimated greenhouse gas emissions associated with distribution transformer losses, Australia 2000

Transformer share of distribution loss (a)	GWh loss – utility transformers(b)	kt CO_2-e emissions (c)	GWh loss – private transformers (d)	kt CO_2-e emissions (e)
42.0%	4,410	4,455	885	949
46.5%	4,882	4,932	980	1,050
51.0%	5,355	5,409	1,075	1,152

(a) Represents low, medium and high estimate of transformers share of distribution losses. (b) Includes transformers rated greater than 2500 kVA, which are outside scope of proposed MEPS. (c) Using fuel cycle coefficients for electricity sent to distribution system. (d) Based on flow model in Figure 5. (e) Using fuel cycle coefficients for electricity delivered.

As Table 5 indicates, the estimated greenhouse gas emissions associated with distribution transformers in Australia was in the range 5,360 kt to 6,560 kt CO_2-e. By comparison, the emissions associated with the operation of household refrigerators and freezers was 9,060 kt CO_2-e (GWA 2001b).

1.3 Transformer Energy Efficiency and Energy Loss

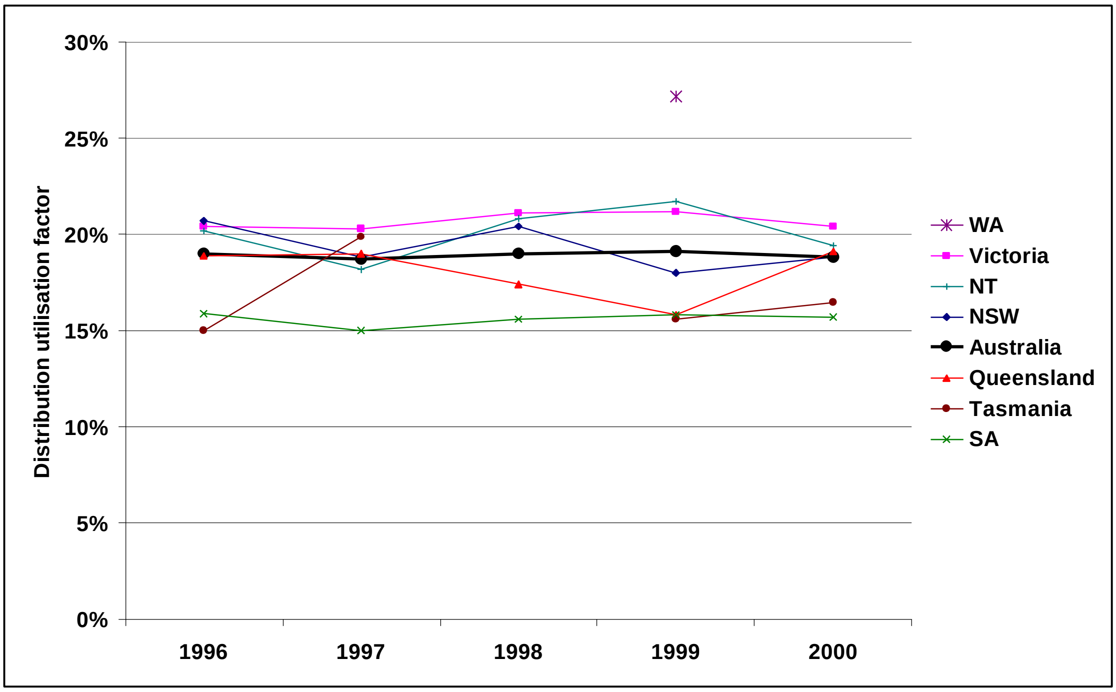
The technology of electricity distribution transformers, and the links between design, loading and energy efficiency are described in Appendix 1. The relationships between transformer operation and energy loss are complex, and it is necessary to make a number of assumptions about operating conditions in order to infer the consequences of changes in tested efficiency.

The method of test for distribution transformers is specified in Australian Standard AS2374.1 *Power transformers – Part 1: General*. The energy losses are measured at 50% of the rated load and a power factor of 1.0, which for typical designs is the point of optimum efficiency. The standard does not at present set limits for energy losses or energy efficiency, but a draft revision proposing such limits has been issued. The draft revision would also require information on energy efficiency be provided on the rating plate. The existing standard does not require such information.

If the distribution transformers in use in Australia actually operated at an average loading of 50% of their rated capacities, their utilisation factor would be 50%. The ESAA monitors the total installed capacity of distribution transformers, and calculates annual utilisation factors for each State and for Australia as a whole. The average utilisation factor has been about 19% over the period 1996-2000 (Figure 3), indicating that the rate of transformer capacity has increased at the same rate as energy sales.[5]

Figure 3 Utilisation factors for distribution transformers, Australia

[5] The transformer capacity utilisation at times of maximum demand on the distribution network is estimated by utility sources to be about 50%.



Using the information in Table 2 and Table 5, it is possible to infer that the actual operating energy efficiency of the existing utility transformer stock is in the range 97.0% to 97.5% (see Table 6). This is a broad weighted average: actual efficiency will vary over a wide range, depending on each transformer's loading, physical design and operating conditions.

If this broad average efficiency is attained at the average utilisation factor of about 20% reported by ESAA (see Figure 3), then the nominal efficiency of the existing stock at 50% load would be about 0.9% higher (see Figure 30). It is important to keep in mind this differential between nominal half load efficiency (the value given in AS2374.1 test results) and actual operating efficiency.

Table 6 Estimated efficiency of all distribution transformers, Australia 2000

Transformer share of distribution loss (a)	GWh loss – utility transformers	GWh loss – distribution lines	Energy sent to distribution transformers (b)	Effective transformer efficiency	Nominal half-load efficiency
42.0%	4410	6090	171775	97.5%	98.4%
46.5%	4880	5617	172248	97.2%	98.1%
51.0%	5355	5145	172720	97.0%	97.9%

(a) Represents low, medium and high estimate of transformers share of estimated 10,500 GWh distribution losses. The balance is line losses. (b) Energy sent to distribution less line losses

Additional modelling of the transformer stock was undertaken for the present RIS, which concentrates on the subset of distribution transformers for which Mandatory Energy Performance Standards (MEPS) are proposed: those with rated capacities up to 2500 kVA. Analysis of the stock data reported by ESAA suggests that more than half of utility 33 kV transformers have a capacity of greater than 2500 kVA, since the average capacity is well over that level (see Figure 4). Therefore the total capacity of utility distribution transformers of 2500kVA or less is estimated at 66,460 MVA (Table 7).

Figure 4 Average rated capacity of distribution transformers, 1998 - 2000

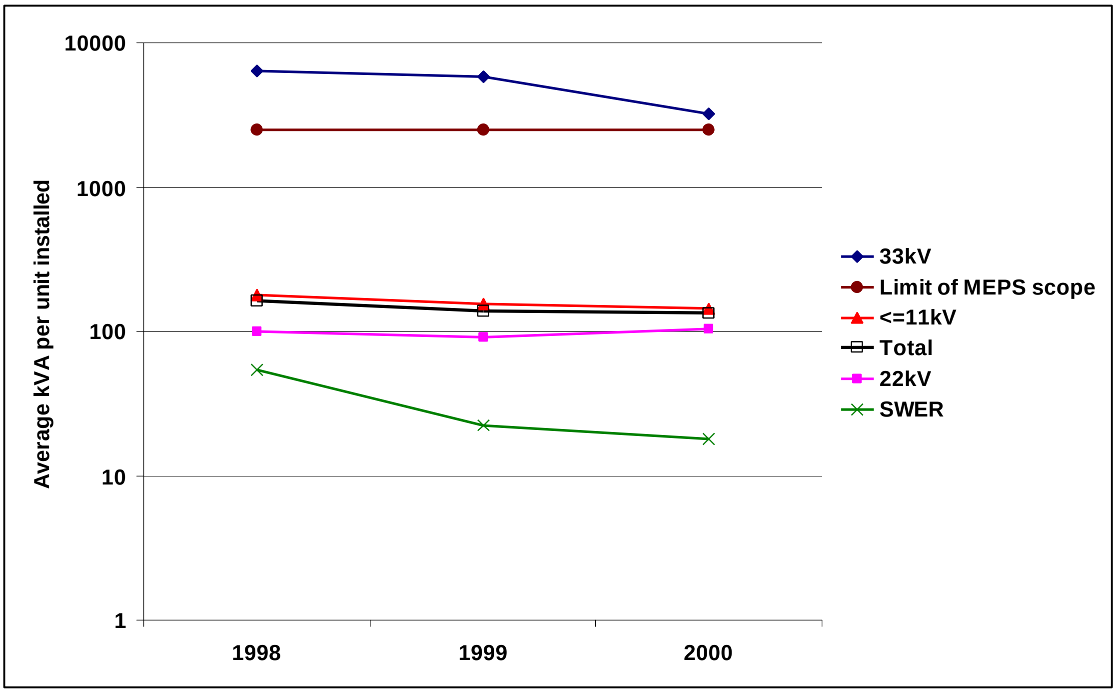


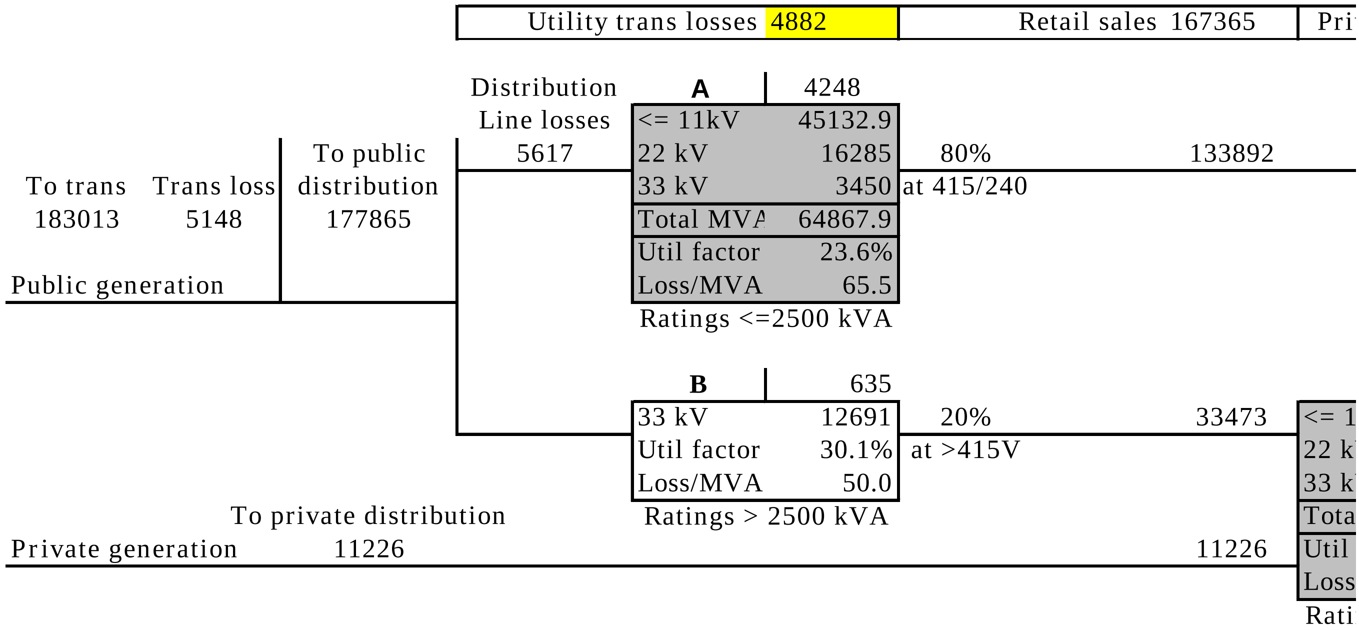
Table 7 Estimated capacity of distribution transformers with ratings up to 2500kVA, Australia 2000

	33kV	22kV	<=11kV	SWER	Total MVA installed	Number
Utility - modelled (a)	3450	16285	43183	1950	64868	576,050
Reported by ESAA (b)	16141	16264	43362	1965	77732	577,050
Modelled/reported	0.21	1.00	1.00	0.99	0.83	NA
Private - modelled	125	2402	11085	0	13612	100,400

All values MVA (a) Estimate only includes transformers with rating of up to 2500kVA. (b) Includes all transformers irrespective of rating.

There is also a large number of privately-owned transformers in addition to those owned by utilities. These are used to step down energy purchased from electricity retailers (it is estimated that about 20% of retail electricity in Australia is purchased at voltages over 415V), to step down power purchased directly at transmission level and also as part of private generation installations. Figure 5 summarises the estimates of electricity flows and losses used for modelling purposes in this RIS (corresponding to the medium efficiency point in Table 6). The shaded blocks correspond to transformers of 2500 kVA rating or less, which are the subject to the MEPS proposals. It is estimated that there was about 78,500 MVA of transformer capacity in this range in 2000, and about 17% of this was in private installations. The total energy lost from these transformers of 2500 kVA rating or less was about 5230 GWh, giving them an operating efficiency of 97.1%.

Figure 5 Schematic diagram of energy flows and losses in distribution transforn



1.4 The Transformer Market

Product Supply

Manufacture and Import

There are approximately 23 manufacturers of distribution transformers in Australia. The largest are:

- ABB Transmission and Distribution Ltd
- Alstom Australia Ltd
- AW Tyree Transformers Pty Ltd
- Schneider Electric
- Wilson Transformer Company Pty Ltd

These account for the majority of transformers manufacture in Australia. ABB, Alstom, Schneider and Wilson are subsidiaries of, or have strong associations with, major international electrical engineering companies.

The market for transformers is driven by the need to replace units at the end of their service life, by the need to augment utility distribution capacity to meet the continuing growth in electricity demand, and by industrial, mining, commercial and institutional construction.

The average life expectancy of transformers is approximately 30 years, although there is considerable variation depending upon the degree to which individual units have been loaded over their working life. Other reasons for retirement include lightning strikes and corrosion. In some cases transformers that are inadequate to handle load growth in one location may be reused elsewhere.

It is estimated that about 19,100 new distribution transformers with a total capacity of 3,100 MVA are sold to utilities each year in Australia, with a value of about $150m per annum (Ellis 2001). This indicates an average price of $48/kVA. Given that the stock of private distribution transformers is about 17% as great (Table 7), the private market is estimated to total about 660 MVA. Private transformers are on average somewhat larger and lower in quality, both of which indicate a lower value per kVA. This is estimated at $ 30/kVA, giving a value of about $20m for the private market.

Imports

Between 75% and 85% of new transformer capacity installed each year is produced in Australia. The major import-only brands are Toshiba (Japan) and Ealim (Austria), but most imports were via the larger local manufacturers, who imported units from their parent companies or associates.

Ellis (2001) estimates that 700 distribution transformers were imported during 1999, with a value of approximately $17m. This accounts for about 10% of total estimated annual sales by value. While the bulk of local manufacture is of liquid-filled types for utility use, the majority of imports were dry type for private use. The main sources of imports for liquid-filled transformers were France, Sweden and Canada, and the main source for dry type transformers were Germany, Japan, Sweden and South Africa.

Table 8 Estimated transformer imports, 1999

	Private Purchases	Utility Purchases	Totals
Liquid-Filled	145	33	178
Dry-Type	427	96	523
Totals	572	129	701

Source: Ellis (2001)

Refurbishment

Several companies undertake transformer refurbishment, including ABB, Alstom, Schneider, AMP Control & NPS. Refurbishment typically comprises inspection of windings, changing of oil, insertion of new gaskets, and repainting. Although no data is available on the numbers of units refurbished each year, industry sources suggest that it is a significant market, which may be growing as utilities try to drive their assets harder. Some utilities report that where transformers are reaching their capacity, they are replaced by larger units, but the original is refurbished and used elsewhere in the network, or kept in storage until wanted. There appears to be little economic scope for increasing the energy efficiency of units during the refurbishment process.

The impact of the proposal on the refurbishment market is considered in Chapter 4.

The Utility Market

Structure and Regulation of the Electricity Utility Industry

The Australian electric utility industry has four main components:

- Electricity generators
- Transmission organisations
- Distributors
- Electricity retailers

Up to the early 1990s, each State had a government-owned electricity sector, with most or all of the above functions vertically integrated in one or a few entities. During the 1990s there were major restructurings of the electricity sector, with the establishment of a unified wholesale electricity market across SA, Victoria, NSW, ACT and Queensland, and the sale of publicly owned assets to the private sector.

At present, only the jurisdictions outside the national market - WA, the NT and Tasmania - retain publicly owned utilities that remain fully or largely integrated (Table 9). Transmission remains in public ownership in each State. There are 16 distributors in all – 7 of them in private ownership.

Electricity transmission and distribution are considered natural monopolies, in that it is economic to have only one physical service provider in a geographical area. However, it is necessary to ensure that the service provider does not exploit its monopoly position through excessive prices, or through denial of access to generators, retailers or end users.

For this reason distributors in each State are subject to economic regulation, covering their pricing and access rules, and also their capital investment and operating practices. This regulation has several objectives, including:

- Fair and non-discriminatory pricing and access to network users (including entities that may be associated with the distributor, or competitors of its associates);
- Maintenance of appropriate levels of service: adequate to meet reliability and other standards, but not excessive and therefore too costly;
- In some jurisdictions, the regulations require distributors to consider alternatives to expansion or augmentation of the network, such as demand management.

Table 9 Number and ownership of electricity utility components

	NSW	Vic	Qld	SA	WA	Tas	ACT	NT
Generators(a)	7 Pu&Pr	8 Pr	6 Pu&Pr	6 Pr	1 Pu	1 Pu	None	1 Pu
Transmission	1 Pu	1 Pu	1 Pu	1 Pu		1 Pu	See NSW	
Distributors	4 Pu	5 Pr	2 Pu	1 Pr		1 Pu	1 Pr	
Retailers	19 Pu&Pr	17 Pu&Pr	20 Pu&Pr	9 Pu&Pr			15 Pu&Pr	

Source: ESAA (2001) (a) Major generators only. Pu = Public ownership Pr = Private ownership

The great majority of the utility distribution transformers currently in use were installed not under the present structure of the electricity utility industry but under the previous, vertically integrated model. The older model tended to favour cost recovery and optimised capital allocation throughout the vertically integrated utility. For example, the value of reduced losses in the distribution system could be realised through savings in the transmission network, a reduction in demand for generation and the ability to accommodate more of the (seemingly inevitable) growth in user demand before requiring additional investment.

Life Cycle Costs

To a fully integrated utility (or to an integrated distributor-retailer), the value of a kWh saved through greater distribution transformer energy efficiency is equal to the value of the revenue from selling that kWh to the end user, since no additional energy would have to be generated or transmitted to supply that kWh. There would be an additional value in the deferment of the capital cost of distribution network augmentation, although this value would vary greatly with load growth patterns, capital allocation practices and the configuration of the utility’s transformer stock.

The value of transformer losses was formally reflected in tender specifications developed by government-owned distributor-retailers in NSW in the 1980s. This is now incorporated in a non-binding industry standard *Specification for Polemounting Distribution Transformers* (AEEMA & ESAA 1998), which states:

When evaluating the tenders, the Purchaser will capitalise the guaranteed losses in order to make a fair economic comparison. The following values will be used for this purpose [Table 10]

Table 10 Value of losses for transformer tender price comparison

Transformer rating	Value of no load loss $/kW	Value of load loss $/kW
Up to and including 63 kVA	$ 6,300	$ 700
100 kVA and above	$ 6,300	$ 1,800

Source: AEEMA & ESAA (1998)

From this formula it is possible to estimate the value which distributors who adopt this specification place on energy saved through greater transformer efficiency. Table 11 gives an example, using typical characteristics, for a 63kVA transformer and two 2500 kVA transformers of different efficiency levels. The implied Net Present Value (NPV) of the energy lost, at a discount rate of 10%, has been calculated by assuming that the annual energy losses at the stated loadings (50% and 20%) persist for the 30 year operating life. Under these assumptions, the value of losses implied by the ESAA/AEEMA formula is 4.2 c/kWh for transformers rated up to 63kVA operating at 50% utilisation (4.7 c/kWh at 20% utilisation, when efficiency is lower). For transformers rated 100 to 2500 kVA, the corresponding values are 4.9 and 5.5 c/kWh.

Table 11 Calculation of NPV of losses – typical transformers

Transformer Rating	kVA	63	1500 Lower efficiency	1500 Higher efficiency
Full load (power factor = 1)	kW	63	1500	1500
Core loss	kW	0.315	4.5	3
Winding loss @ 50% load	kW	0.315	4.5	3
Efficiency at 50% load		98.0%	98.8%	99.2%
Efficiency at 20% load		95.5%	97.3%	98.2%
Value of no load loss (Table 10)	$/kW	6300	6300	6300
NPV of no load energy lost		$ 1,985	$ 28,350	$ 18,900
Value of load loss (Table 10)	$/kW	700	1800	1800
NPV of load loss		$ 221	$ 8,100	$ 5,400
NPV of all losses		$ 2,205	$ 36,450	$ 24,300
Purchase price	$/kVA	60	40	40
Purchase price		$ 3,780	$ 60,000	$ 60,000
Total capitalised cost		$ 5,985	$ 96,450	$ 84,300
NPV of loss/total cost		36.8%	37.8%	28.8%
Lifetime	years	30	30	30
Annual throughput @ 50% load	kWh	275940	6570000	6570000
Annual loss @ 50% load	kWh	5519	78840	52560
Annual throughput @ 20% load	kWh	110376	2628000	2628000
Annual loss @ 20% load	kWh	4939	70562	47041
Implied costs of losses, 50% load	$/kWh	0.042	0.049	0.049
Implied costs of losses, 20% load	$/kWh	0.047	0.055	0.055

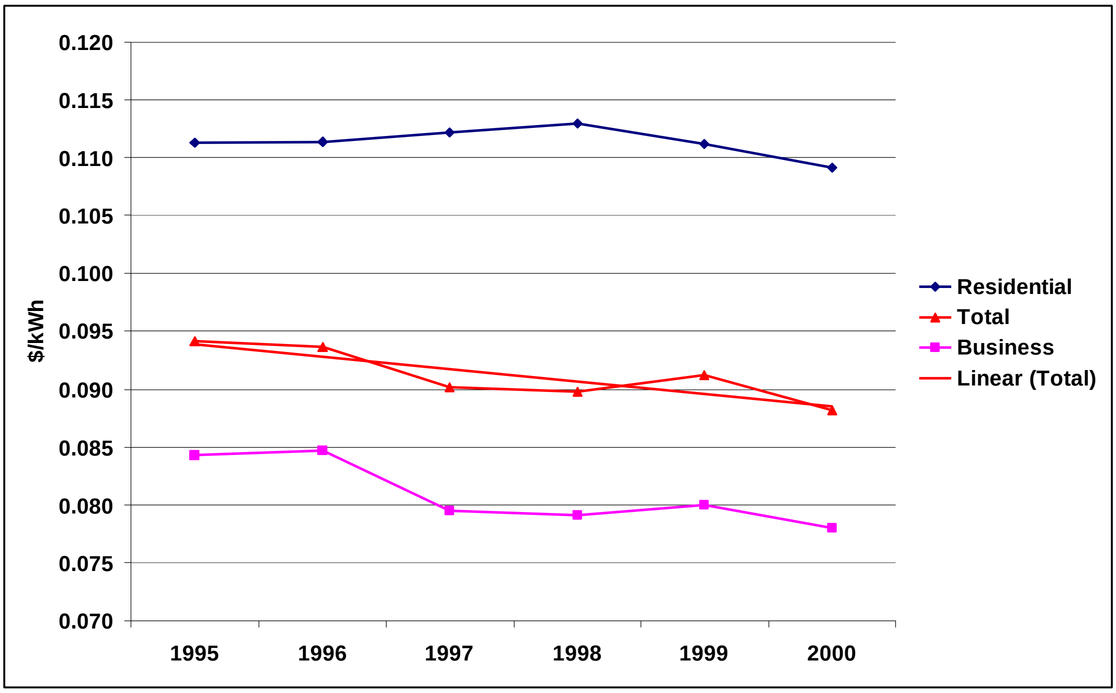
The implied value of loss is the same irrespective of the efficiency of the transformer, but will lead to the purchase of the more efficient unit, all else being equal. In the example in Table 11, the more efficient 1500 kVA transformer has a capitalised cost $12,150 lower than the less efficient model. Therefore the utility would prefer it so long as its purchase price was no greater than $ 12,150 (ie 20%) higher than that of the less efficient model.

At typical efficiency levels and transformer costs the NPV of the capitalised losses accounts for about a third of the initial cost of the transformer, so the use of the formula assigns significant value to energy efficiency in the selection process. However:

- The value of energy loss appears to be too low, given that the average sale price of electricity (which a distributor-retailer would gain in full as cost-free revenue) is about 8.8 c/kWh (Figure 6);

- The specification is advisory only, and there are indications that its use is declining as distributors (who are no longer distributor-retailers) respond to the new regulatory and commercial climate[6]; and

Figure 6 Real electricity prices, Australia 1995-2000 (1998 $)



[6] For distribution-only organisations, the appropriate value of losses is the marginal cost of supplying an additional kWh to the network, rather than the revenue to be gained from selling a kWh to end users. “For efficient capital investment to take place, the value assigned to losses needs to be a long range projection of the cost of generation, effectively the LRMC [long run marginal cost] of additional generation. In pre-electricity market days the Bulk Supply Tariff was based upon LRMC projections of Generation and Transmission costs and it was simply used by distributors as part of their investment analysis. What is now required is a broadly equivalent long run estimate of electricity pool prices at the market regional reference node. Each distributor should use the same value, with adjustment made by the distributor for the cost of transmission and distribution to the point of loss consumption” (IPART 1999).

- The specification applies to pole-mount transformers, not other configurations such as pad-mount (although there is no reason in principle why this or similar formulae should not apply to other types).

Distributor concern with energy efficiency

Firms which are solely distributors, as distinct from distributor-retailers, can only recover the costs of additional capital expenditure through charges to the users of the network – retailers and generators. Distributors which wish to incur higher costs to purchase more efficient transformers cannot be assured of being able to pass on those costs via their regulated charges.

Ellis (2001) analyses the impact of structural change in the UK electricity industry, where there is evidence that restructuring and privatisation has caused increased pressure to reduce capital expenditure and focus on the lowest ‘first cost’ options. Ellis reports industry sources suggesting a similar trend in Australia, and that this is affecting purchasing decisions with respect to transformers:

> Transformer purchases by utilities in Australia has traditionally placed considerable emphasis on quality, performance, longevity, low maintenance and low losses. Loss capitalisation has been extensively used by both utilities and Australian manufacturers as means to optimise designs, with the support of the Electricity Supply Association of Australia (ESAA). With the creation of distribution businesses to own and operate the network, and the introduction of private ownership, competition for capital has increased, and accountability for losses changed.
>
> In the UK, there is evidence that deregulation and privatisation has caused increased pressure to reduce capital expenditure and focus on the lowest ‘first cost’ options [EC 1999, and Appendix F]. Industry sources in Australia suggest that a similar trend is becoming prevalent here, and that this is affecting the purchasing decisions with respect to transformers. A number of utilities report that they have recently purchased transformers from overseas which have lower capital costs, higher losses and will probably not last as long as some other options. However, they argue that in the current regulatory regime, this is the action of aresponsible asset manager (Ellis, 2001).

The views of the regulators and utilities themselves appear to be consistent with this. A report prepared for the Office of the Regulator-General, Victoria, concludes:

> We note that the regulatory regime in Victoria does not at present provide for incentive measures to drive the Distribution Businesses to optimise distribution system losses. We also note that this situation would appear to be in contrast to the policy on the transmission system. VPX [Victorian Power Exchange, the transmission body], in section 2.3 of its Annual Planning Review 1999, states that the scope of its planning role includes the commissioning of extensions or modifications to the Victorian network, inter alia, to reduce the costs associated with losses in the existing network.

> A further point is that at present retailers (suppliers) and customers pay for the losses incurred (ORG 2000).

A report by the Independent Pricing and Regulatory Tribunal (IPART), the NSW counterpart of the Office of the Regulator-General, Victoria, quotes the following submission from the distributor EnergyAustralia:

> DNSPs [Distribution Network Service Providers] can be expected to make investment decisions on the basis of maximising the value to their shareholder. Such decisions all impact in some way upon the losses in their networks. However, under the present regulatory regime the cost of losses is external to the investment analysis and there is no incentive to include them. There is no financial benefit to a network in reducing losses.
> …DNSPs are faced with everyday decisions on transformer purchase. Traditionally, the cost of losses has been evaluated over the life of the asset using an energy value related to the Bulk Supply Tariff.
>
> The quotations for supply of transformers would be adjusted as follows:
> Supplier A – Purchase price $20,000, capitalised losses $20,000, total $40,000
> Supplier B – Purchase price $18,000, capitalised losses $30,000, total $48,000
>
> In the present regulatory environment, a rational DNSP would choose offer B, even though it increases total costs to customers. There is no incentive for the DNSP to take into account the cost of energy losses in the purchase decision. If the cost of losses is to be taken into account in investment decision making, as it must if economic (as opposed to merely financial) investment is to take place, an explicit direction is required to DNSPs to internalise this cost. With an appropriate value for the cost of losses incorporated in investment analysis, the Regulator should then have confidence that investment will take place to optimise (not minimise, as there is inevitably a cost tradeoff) capital investment (IPART, 1999).

Discussions with electricity distributors in the course of preparing this RIS confirm that there is now no direct financial or regulatory incentive for retailers to take energy losses into account in planning future transformer purchases.

The Private Market

Private purchasers of transformers fall into two groups: those who will bear the operating costs and those who will not. A large proportion of industrial and commercial development in Australia is built for resale or rental. The developer has little incentive to pay more for energy efficient equipment (whether transformers, air conditioners or lamps) since the premium is difficult to recover from the purchaser or tenant, who will in any case bear the running cost.

The second group of private owners of distribution transformers includes the operators of private mines and factories, who purchase energy at higher voltage for special equipment. These tend to have the engineering expertise to analyse the value of losses.

Ellis (2001) reports that the majority of private owners operate cheaper, less efficient transformers, and that many transformer manufacturers produce products specifically for this market. These models are in the region of 5%-10% cheaper, and have approximately 10% higher losses than those which have historically been supplied to the utility market.

In order to satisfy specific markets for electricity distribution transformers, most suppliers offer models of varying efficiency levels at each common capacity point: usually a less efficient one designed for the private market, a more efficient model optimised to the ESAA transformer specification formula and (in some cases) a still more efficient premium model.

Overseas Energy Efficiency Programs for Transformers

Transformer technology, and the general structure of the transformers market, is similar in all developed economies. The tendency of both utility and non-utility purchasers to select transformers of lower efficiency than is cost-effective from a life-cycle perspective has been addressed in a number of ways. The following summary of programs is taken from Ellis (2001).

United States

Distribution transformers in the USA are estimated to lose approximately 61,000 GWh of electricity per year, resulting in annual greenhouse emissions of 45 Mt CO_2. Utilities purchase over 1 million new units each year, and it is estimated that if the average efficiency of utility transformers was improved by one-tenth of one percent, greenhouse emissions reductions of 1.8Mt CO_2 per annum would be achieved over a 30 year period. As a result, the US has currently has a number of voluntary initiatives designed to increase the efficiency of distribution transformers (USEPA 1998b).

In the *Energy Star* transformer program, participating utilities agree to perform an analysis of total transformer owning costs, using a standard methodology, and to buy transformers that meet Energy Star guidelines when it is cost-effective to do so. The program provides technical assistance to partners to ensure that transformers are not oversized, and has developed a Distribution Transformer Cost Evaluation Model (DTCEM) to provide a standard methodology for the evaluation of multiple transformer bids. To compliment this tool, the program also labels transformers which conform to its targets (USEPA 1998a).

The US National Electrical Manufacturers Association (NEMA) publishes a *Guide for Determining Energy Efficiency for Distribution Transformers* (TP-1-1996), and a standard test method for the measurement of energy consumption in transformers (TP-2). The US Department of Energy (DOE) Federal Energy Management Program encourages government procurement of energy efficient distribution transformers.

The DOE is currently proceeding with industry-wide consultation and the development of test procedures with a view to the adoption of minimum efficiency performance standards (MEPS) for transformers by approximately mid 2003. No firm implementation commitment has been made as yet, however test standards under consideration include the ANSI/IEEE standards (C57.12.90-1993 and C57.12.91-1995) and the NEMA standard (TP-2 1998).

The Consortium for Energy Efficiency (CEE) has initiated a program aimed at the 6 million dry-type private distribution transformers in use. It is part of a consortium with NEMA, USEPA and others to increase information about and awareness of the potential for efficient transformers.

Canada

Natural Resources Canada (NRC) is proposing to introduce MEPS for dry-type transformers in January 2002 (NRC 2000). MEPS for liquid-filled types is also under consideration, but the processes for the two types have been separated. For dry type transformers, the MEPS are to be specified as minimum efficiency levels at both 5% and 35% loading.

NRC is proposing that the regulations will apply to single- and three-phase, 60 Hz, dry-type transformers with a primary voltage of 35 kV and below and a secondary voltage of 600 volts and below, rated 15 to 833 kVA for single-phase and 15 to 7500 kVA for three-phase.

NRC undertook benefit-cost analysis to determine the economic attractiveness of improving the energy efficiency of dry-type transformers. The economic analysis showed net benefits under all sensitivity scenarios. NRC projected the annual energy savings to be 132 GWh per annum.

It is also proposed that regulated transformers will have to carry a verification mark indicating that the energy performance of the product has been verified and complies with the relevant MEPS level.

Mexico

The Mexican standard, NOM-002-SEDE-1999, which covers energy efficiency and safety for distribution transformers, was made mandatory in 1999. This sets both the minimum efficiency levels for distribution transformers and the maximum allowed losses, although these are less stringent than those proposed for Canada and the US.

The regulation makes allowances for manufacturers whose annual total production is less than 9,000 kVA, who may appeal for a transitionary period before meeting the requirements.

Europe

Three levels of standards are applicable for distribution transformers purchased in the European Union:

- world-wide standards (ISO, IEC)
- European standards and regulations (EN, HD)
- national standards (eg. BSI, NF, DIN, NEN, UNE, OTEL)

A European Harmonisation Document (HD) is prepared if there is a need for a European standard. The draft HD is a compilation of the different national standards on the subject. The HD is finalised by eliminating as many national differences as possible. Among the many international standards for distribution transformers, two main European Harmonisation Documents specify energy efficiency levels:

- HD428: Three-phase oil-immersed distribution transformers 50Hz, from 50 to 2,500kVA with highest voltage for equipment not exceeding 36kV
- HD538: Three-phase dry-type distribution transformers 50Hz, from 100 to 2,500kVA, with highest voltage for equipment not exceeding 36 kV.

A separate HD is under consideration for pole-mounted transformers. Distribution transformers built to HD428 and HD538 have a limited number of preferred values for rated power (50, 100, 160, 250, 400, 630, 1,000, 1,600 and 2,500kVA). Intermediate values are also allowed. The two key figures for energy efficiency, the load losses and the no-load losses, are specified for each rated power.

HD428.1 and HD538.1 provide the limits for load losses and no-load losses for some important types of oil-filled and dry-type distribution transformers, for the preferred rated power range of the transformers. For oil-filled distribution transformers, the HD allows a choice of energy efficiency levels, A, B and C.

Loss values for transformers are usually declared as maximum values with a specified tolerance. If higher losses are found at the factory acceptance test, the transformer may be rejected or a financial compensation for exceeding the loss limit may be agreed between client and manufacturer (as is the case for the Australian ESAA specification for polemount transformers). In the same way, a bonus may be awarded to the manufacturer, mainly for large transformers, for a transformer with losses lower than the limits agreed.

HD428 therefore allows customers to choose between three levels of no-load losses and three levels of load losses. In principle, there are 9 possible combinations, ranging from the lowest efficiency, (B-A’) to the highest, (C-C’), which may be regarded as providing a high practical standard of energy efficiency for a distribution transformer.

The standards are not as yet mandatory.

Chinese Taipei

Since 1992, an eco-label program called “GreenMark” has been run by the Environmental Protection Administration (EPA) and currently covers over 50 products. For conforming products, the GreenMark logo label may be used on product packaging, brochures or on the products themselves. It is intended that distribution transformers will be covered by this program although the energy performance criteria have not yet been determined.

Conclusions

There are at present no energy efficiency programs explicitly targeting distribution transformers in Australia. There are analytical tools for assessing lifetime operating costs – such as the ESAA *Specification* – but the motivation for transformer purchasing organisations to apply them appears to be diminishing.

The Utility Market

The changes in structure of the electricity industry have greatly reduced the ability of utilities to minimise costs across functions. According to distributors and regulators, the State-based regulation of distributor charges appears to be favouring a concern with first cost above lifetime operating cost. The participation by many electricity distributors in voluntary programs such as the Greenhouse Challenge may counteract such trends to some extent.

However, there is evidence that some distribution utilities are now preferring less efficient and cheaper transformers (which have historically been produced mainly for the private market) and hence there is a real risk of deterioration of the efficiency of the utility transformer stock.

The Private Market

Some of the large industrial and commercial organisations which purchase transformers for private use are also member of Greenhouse Challenge, but are less likely than electricity distributors to take operating efficiency into account, because, unlike the distributors:

- The selection of transformers is not part of core business, and its significance to operating costs may be poorly understood;
- Electricity costs, and losses, are likely to be a small part of operating costs; and
- There is usually limited access to capital and revenue (since private purchasers are rarely in the position of regulated natural monopoly).

Furthermore, many developments such as shopping centres or industrial parks are built by speculative developers who are not concerned with lifetime operating costs – the “landlord-tenant” situation which has been documented in studies of MEPS for other industrial appliances, notably packaged airconditioners (GWA 2000b) and fluorescent lamp ballasts (2001a).

The technical information about the performance of transformers is not always available to private purchasers in a consistent form (eg tested to AS2374), and even where it is, there may be several intermediaries between the decision-maker who selects the transformer and those who bear the running costs. The specifier is frequently not the end user, but more commonly the builder or electrical engineer who designs the installation. Unlike household appliance buyers, who usually understand the function of the product, are responsible for the costs of purchasing and running it, and have access to information on life-cycle or running costs from the energy label, the ultimate end user of a transformer rarely knows what it does or even knows of its existence.

In practice, the nature of the existing market relationships between builders, electrical system designers, owners and tenants means that additional capital costs are very difficult to recover, and transformer options that are highly cost-effective over the lifetime of the installation are generally passed up.

Consequently,

- the cost of electrical distribution services to businesses and ultimately consumers will be higher than desirable; and

- emissions of greenhouse gases will also be higher than need be.

Options

There is scope for measures to maintain (in the face of possible pressures to reduce efficiency) and to increase the energy efficiency of Australia’s stock of electricity distribution transformers.

Ellis (2001) concluded that:

> On the evidence of the preliminary examination to date and with the information which has so far been forthcoming from the industry, it would appear that a case for improving transformer efficiencies through further regulation exists in Australia.
>
> Since the great majority of distribution transformers are manufactured locally, it is recommended that any new regulations provide sufficient lead times to enable existing suppliers to alter designs and manufacturing processes. This will enable manufacturers to maintain market share and minimise the economic impact.
>
> Another important factor with regard to MEPS and greenhouse reductions, is the relatively long lifetime of distribution transformers. An inefficient transformer is likely to be operational for 30 years or more, with little opportunity to replace it before it reaches the end of its life. Missing the opportunity of selecting an efficient transformer now, therefore represents a significant lost opportunity to reduce future greenhouse emissions.

Ellis (2001) advocates programs to assist private transformer buyers to evaluate lifetime operating costs, forms of labelling to assist buyers concerned with energy efficiency to readily identify more efficient models, and financing programs to assist with higher capital costs. All of these would rely on motivating private buyers to give weight to transformer operating costs.

As a related measure, Ellis recommends the promotion of analytical tools to assist transformer specifiers to select transformers which are not over-sized, and hence will operate closer to their optimum efficiency levels. The use of such tools by private purchasers, or engineers and specifiers acting on their behalf, also presupposes greater concern with transformer operating costs.

2. Objectives of the Regulation

COAG Guidelines:

- ***Objective:*** *the objective which the regulation is intended to fulfil must be stated in relation to the problem. The objectives of a regulation are the outcomes, goals, standards or targets which governments seek to attain to correct the problem.*

2.1 Objective

The primary objective of the proposed regulation is to bring about reductions in Australia's greenhouse gas emissions from the use of electricity distribution transformers below what they are otherwise projected to be (ie the "business as usual" case) in a manner that is in the community's best interests.

2.2 Assessment Criteria

The primary assessment criterion is the extent to which an option meets the primary objective.

The following secondary assessment criteria have been adopted:

1. Does the option address market failures, so that the average lifetime costs of electricity distribution transformers are reduced, when both capital and energy costs are taken into account?

2. Does the option minimise negative impacts on product quality and function?

3. Does the option minimise negative impacts on manufacturers and suppliers?

4. Is the option consistent with other national policy objectives, including the objectives of the National Appliance and Equipment Energy Efficiency Program to match " world best practice" standards?

3. The Proposed Regulation

COAG Guidelines:

- ***Statement of the proposed regulation and alternatives:*** *this should describe the proposed regulation and distinct alternatives in sufficient detail to allow comparative assessment and evaluation in the rest of the RIS.*

The following options for achieving the objectives were considered.

1. Status quo (termed business as usual, or BAU);

2. The proposed regulation (mandatory MEPS);

3. A regulation which only adopts those parts of the Australian Standards that are essential to satisfy regulatory objectives (targeted regulatory MEPS);

4. Voluntary MEPS;

5. Another regulatory option involving a levy imposed upon inefficient equipment to fund programs to redress the greenhouse impact of equipment energy use;

6. A levy on electricity reflecting the impact it has on greenhouse gas emissions abatement.

The following sections describe the options in more detail, and assess the non-MEPS options (5 and 6). The MEPS options (2,3 and 4) have been subject to detailed cost-benefit analysis, which is reported in the next chapter.

3.1 Status quo (BAU)

Transformer technology is fairly mature, and major improvements in materials or manufacturing processes are infrequent. Traditionally, transformers have used silicon steel as the magnetic material for cores in transformers. Over the last twenty years or so, "amorphous metal" (also called glassy metal) with magnetic properties has been tested for application as transformer core metal. Although there is a substantial decrease in losses when using amorphous metals for transformer cores, the cost is higher, and the types of transformers preferred in the Australian market offer less scope for the use of amorphous metals than is the case in North America and Europe.[7]

Even with conventional materials, there is a significant range in the efficiency of transformers on offer. Table 12 indicates the energy efficiencies and losses for the

[7] Because of the specialised process needed to manufacture amorphous metal (an extremely rapid cooling of molten metal is required) it can only be produced in very thin and long strips: typically, about 100 mm wide and about 0.02 mm thick. The material is relatively brittle and cannot easily be cut to shape. It can only really be used to make cores which are wound from helical layers of the continuous strip. While such wound-cores are suitable for single phase transformer cores, it is difficult to use them for three phase transformer core construction where there must be a number of legs of the core constructed, one for each phase (Ellis 2001, Appendix I).

range of a specific supplier, in this case one which offers higher quality transformers – there are also significantly less efficient models on the market. Although the efficiency range is narrow – between 99.24% and 99.41% - the actual energy losses for the least efficient are 29% higher than for the most efficient. The difference amounts to 7,500 kWh at half load, which would have a current value of $600 at a typical high voltage electricity cost of about 8c/kWh.

Table 12 Typical efficiency range: 1000 kVA liquid-filled transformer models

	% efficiency (50% load)	% loss (50% load)	Estimated kW loss(a)	kWh/yr loss (50% load)	kWh/yr loss (20% load)	Rating under proposal
A	99.24%	0.76%	3.80 kW	33,300	29,800	Fails MEPS
B	99.29%	0.71%	3.55 kW	31,100	27,800	Fails MEPS
C	99.36%	0.64%	3.20 kW	28,000	25,100	Passes MEPS
D	99.41%	0.59%	2.95 kW	25,800	23,100	Passes HE

(a) at 50% load, 1.0 Power Factor

Therefore, to project "business as usual" (BAU) energy losses from the distribution transformer stock, it is necessary to estimate whether there will be small increments or reductions in efficiency, in the absence of market intervention. Given the market conditions described in Chapter 1, it has been assumed that there will be a gradual *reduction* in average energy efficiency in both the utility and the private markets. The following assumptions have been made:

- The weighted average losses of new utility transformers installed from 2000 to 2030 will increase by 0.2% per annum (eg of the weighted average loss of new utility transformers is 3.0% in 2001, it is (3.0 x 1.002)=3.006% in 2002;
- The weighted average losses of new private transformers installed from 2000 to 2030 will increase by 0.5% per annum (eg of the weighted average loss of new private transformers is 4.0% in 2001, it is (3.0 x 1.005)=4.02% in 2002.

Each of the options for achieving the Government's objectives will now be assessed against the likely outcome under BAU (the status quo).

3.2 Mandatory MEPS

Background to Proposal

Development of the recommendations

The National Greenhouse Strategy states that "improvements in the energy efficiency of domestic appliances and commercial and industrial equipment will be promoted by extending and enhancing the effectiveness of existing energy labelling and minimum energy performance standards [MEPS] programs. This will be pursued by … developing minimum energy performance standards for a broader range of new appliances and equipment" (NGS 1998).

A high priority in the work program of the National Appliance and Equipment Energy Efficiency Committee is to “establish timetables for the introduction of MEPS for packaged air conditioners, electric motors and fluorescent lamp ballasts” (NAEEEC 1999). Each of these products has been the subject of detailed cost-benefit studies, which recommended that MEPS be introduced.

A study was carried out in 1994 of the market conditions in Australia for major energy using products used in large numbers in the industrial and commercial sectors (Energetics and GWA 1994). After applying several evaluation criteria, the study concluded that market intervention may be warranted for a range of products including distribution transformers, although the highest priorities were electric motors, fluorescent lamps ballasts, packaged airconditioners and office equipment.

In 2000 the Australian Greenhouse Office (AGO) established a Steering Group on Electricity Distribution Transformers, consisting of representatives from the five major transformer suppliers, the Australian Electrical and Electronics Manufacturers Association (AEEMA), State energy regulators, the Australian Competition and Consumer Commission (ACCC), ESAA, several distribution utilities and the AGO.

The Steering Group commissioned Mark Ellis and Associates, with assistance from Prof Trevor Blackburn of the University of NSW (UNSW), to undertake a study of Australian transformer technology and markets, and of MEPS and other overseas energy programs for transformers, to assess whether there was a case for the adoption of such programs in Australia. The study, completed in March 2001 (Ellis 2001) recommended the adoption of MEPS, to be based on the levels proposed for Canada, adjusted for differences between Canada’s 60Hz supply and Australia’s 50 Hz supply.

In October 2001 Standards Australia Committee EL008, which has much the same membership as the Steering Group on Electricity Distribution Transformers, endorsed the proposed MEPS levels and issued them as a draft Standard.

Approaches to MEPS

The objective of MEPS is to prevent products which do not meet prescribed levels of energy efficiency from coming into use. There are two main approaches to setting MEPS levels: the statistical and the engineering. The existence of test procedures for measuring energy consumption and data on the efficiency and other characteristics the market are prerequisites for either approach.

The statistical approach involves collecting efficiency data for the product of interest and setting a standard level based on eliminating some percentage of the models being offered at the time of the analysis. The results of such an analysis are both time-dependent and country-dependent, and reflect the particular costs and energy-efficiency characteristics of the range of models available at a specific time in a particular market.

The engineering analysis approach involves selection of a notional (or actual) "baseline" model which incorporates the features and technology typical of all products. A number of design options are then assessed, from the point of view of their projected energy impact (usually estimated with a computer simulation model) and their projected impact on manufacturing cost. The cost-effectiveness of each design option and of different combinations of options can then be assessed.

This approach has a number of advantages over the statistical approach:

- it explicitly analyses the relationships between energy consumption, product price and product capacity or level of energy service, and so allows estimates to be made of the effects of changing those relationships. In the statistical approach the existing relationships are considered to hold;
- there is no need to consider the number of existing models which meet the criteria found to be most cost-effective. This is not important provided the industry has a capacity to produce complying models within a specified time, without unacceptable adjustment costs (which are separately analysed);
- the approach is less sensitive to time and place, since it concentrates on product design and manufacture rather than market structure. However, it is still market dependent to the extent that the "baseline" models selected for analysis are typical of the market in question.

The major disadvantage of the engineering approach is that it is intensely data-intensive (including proprietary data from manufacturers) and resource-intensive.

In 1999 ANZMEC endorsed a new approach which in effect builds on the engineering and/or statistical analyses already carried out in other markets. The approach is summarised as follows in*National Appliance and Equipment Energy Efficiency Program: Future Directions 2002-04* (NAEEEP 2001b):

> "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 (eg 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."

There is no suggestion that cost-effectiveness criteria should be abandoned, or that MEPS cannot be applied to a product in Australia if that product is not subject to MEPS anywhere else. Nevertheless, the logic of this approach implies the following steps in considering new MEPS, or revisions to existing MEPS, for any given product:

1. establish what MEPS levels, if any, apply in the countries with which there is significant Australian trade;
2. take account of test method differences and other differences (eg climate, marketing and consumer preference variations), and adjust MEPS levels accordingly;
3. subject the adjusted MEPS levels to cost-benefit, greenhouse reduction and other appropriate analyses (working with key stakeholder representatives);
4. formally consult with stakeholders;
5. if the adjusted MEPS levels pass the appropriate tests, adopt them.

Proposal

The proposal is to introduce minimum energy performance standards (MEPS) for electricity distribution transformers within the scope of the forthcoming Australian Standard AS 2374.1.2 (probable publication year 2002) *Power transformers Part XX: Minimum energy performance standards for distribution transformers*. The Standard explicitly *excludes* the following transformer types:

- Oil filled transformers other than that on 11 or 22KV networks.
- Instrument Transformers;
- Auto transformers;
- Transformers for static converters;
- Traction transformers mounted on rolling stock;
- Starting transformers;
- Testing transformers;
- Welding transformers;
- Transformers with three or more windings per phase;
- Arc-furnace transformers;
- Earthing transformers;
- Rectifier or converter transformers;
- Uninterruptible power supply (UPS) transformers;
- Special impedance transformers (needs tighter definition);
- Regulating transformers (needs tighter definition);
- Transformers designed for frequencies other than 50 hertz.

For the types included (in effect, all the types commonly used by utilities and in private developments), the MEPS levels in Table 13 are proposed.

Table 13 Proposed MEPS levels for distribution transformers

Phase	KVA(b)	**Dry type transformers**	**Liquid filled transformers**
		Power Efficiency @ 50% Load	Power Efficiency @ 50% Load
Single Phase & SWER(a)	10	97.45	98.30
	16	97.63	98.52
	25	97.90	98.70
	50	98.20	98.90
Three Phase	25	97.13	98.20
	63	97.78	98.62
	100	98.03	98.77
	200	98.33	98.90
	315	98.52	99.01
	500	98.70	99.10
	750	98.80	99.20
	1000	98.90	99.30
	1500	99.00	99.40
	2000	99.05	99.40
	2500	99.10	99.40

Source: AS 2374.1.2 – 2001 Power transformers Part XX: *Minimum energy performance standards for distribution transformers* (draft). (a) Single Wire Earth Return. (b) For intermediate power ratings the power efficiency level shall be calculated by linear interpolation

The proposed MEPS would be implemented in the following way:

1. The proposed new Part of the Standard, when published, would specify dates in the future when the MEPS levels would come into force; the date currently proposed is 1 January 2003;

2. The MEPS requirements would be put into effect by amending the schedule of products in the regulations governing energy labelling and MEPS in each State and Territory (see example at Appendix 2). The amended schedules would refer to all parts of the forthcoming Standard, and so would make compliance with *all* the Standard requirements mandatory, for distribution transformers within the scope of the Standard manufactured or imported into Australia after that date. made or imported;

Grandfathering

The regulations would only apply to distribution transformers manufactured or imported after the commencement date declared in the regulations.

All products manufactured or imported prior to the commencement date could continue to be lawfully supplied for an indefinite period, provided of course that they meet any other regulatory requirements, such as electrical safety.

In order to take advantage of this grandfathering provision, suppliers would have to be able to link individual units to their date of manufacture or import. For equipment such as transformers, the date of manufacture is commonly stamped on the identification plate. For locally manufactured products this would be presumably be sufficient for grandfathering purposes. Imported products, however, will be landed in Australia some time after the date of manufacture, and documentation listing specific unit serial numbers and dates will have to be retained by the importer.

3.3 Targeted regulatory MEPS

"Targeted regulatory MEPS" may be defined as "a regulation which only adopts those parts of the Australian Standards that are essential to satisfy regulatory objectives". It needs to be established whether there are any parts of the proposed Standard which are not necessary to meet the objective of implementing MEPS.

The proposed part of the Standard refers to other parts clarifying the physical energy test procedures to which the MEPS levels would refer (ie Part 1 of the Standard), and as such are clearly essential.

Other aspects of the proposed Standard which would be made mandatory by the proposed regulation are the product marking requirement, the product registration requirements and the "High Efficiency" (HE) criteria.

Section 6.1 of the proposed Standard is as follows:

Declared Efficiency and Registration

Transformers within the scope of AS2374.1.2 (excepting exclusions) shall be registered for minimum energy performance standards (MEPS). Where the relevant regulatory authority requires, each transformer family [shall] have MEPS registration by way of an application, with the content shown in Appendix A of this standard. To register, contact the relevant state regulatory authority.

The transformer manufacturer shall also declare the power efficiency on the manufacturer's official test certificate. The test results shall be retained by the manufacturer for five years. The transformer rating plate shall contain a statement that the transformer complies with AS2374.1.2.

Appendix A sets out the required format for submitting an application for registration for MEPS where a test on the unit is undertaken to AS 2374.1 or AS 2735. The registration would cover a model type. Given the usual variations in manufacturing, the efficiency of individual units may differ slightly from the efficiency registered for that model. MEPS will apply to every unit supplied (within the testing tolerances set out in AS 2374.1). Section 6.2.2 of the proposed Standards is as follows:

HIGH EFFICIENCY CLASSIFICATION - All transformer designs

Transformers, which equal or exceed the power efficiency levels shown in the following tables [Table 14] will be classified as High Efficiency Transformers. As such they will be allowed to use the term 'High Efficiency Transformer' in any promotional or advertising materials pertaining to that particular transformer. Any transformer with a power efficiency lower than these levels contained in [Table 14] will not be permitted to be described as a 'High Efficiency Transformer'.

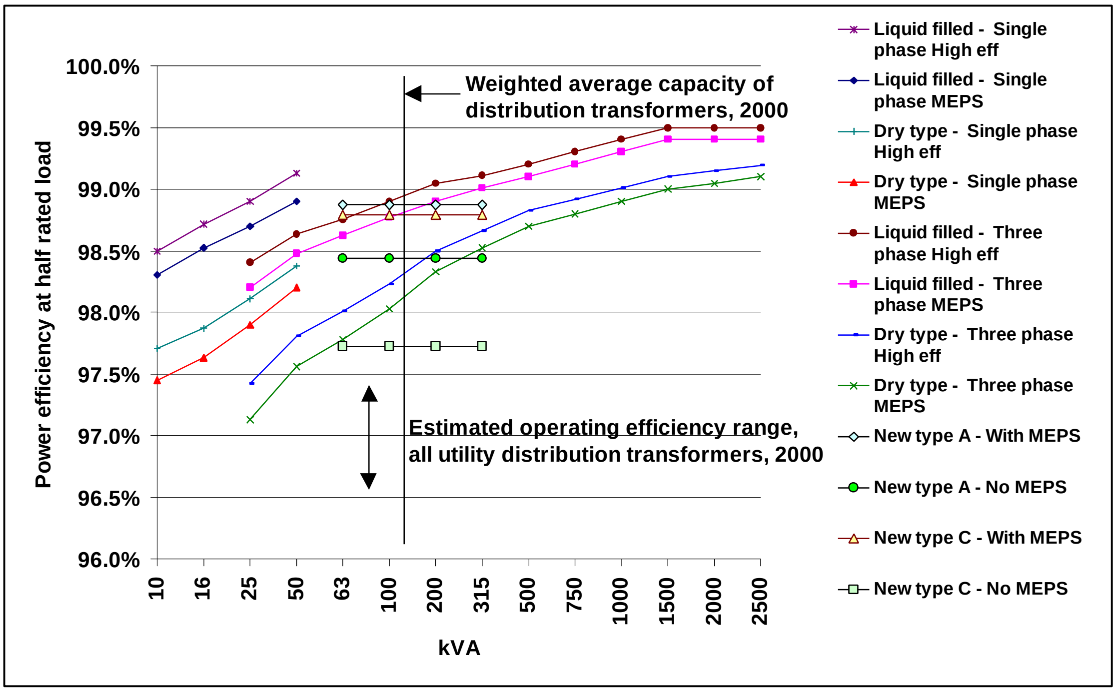
Table 14 Proposed "High Efficiency" levels for distribution transformers

Phase	KVA(b)	**Dry type transformers**	**Liquid filled transformers**
		Power Efficiency @ 50% Load	Power Efficiency @ 50% Load
Single Phase & SWER(a)	10	97.71	98.50
	16	97.87	98.72
	25	98.11	98.90
	50	98.38	99.13
Three Phase	25	97.42	98.40
	63	98.01	98.75
	100	98.23	98.90
	200	98.50	99.05
	315	98.66	99.11
	500	98.83	99.20
	750	98.92	99.30
	1000	99.01	99.40
	1500	99.10	99.50
	2000	99.15	99.50
	2500	99.19	99.50

Source: AS 2374.1.2 – 2001 Power transformers Part XX: *Minimum energy performance standards for distribution transformers* (draft). (a) Single Wire Earth Return. (b) For intermediate power ratings the power efficiency level shall be calculated by linear interpolation

The effect of making these provisions mandatory is considered in Chapter 4. Figure 7 illustrates the proposed MEPS and HE levels for new transformers, based on testing at half load, as well as the estimated actual operating efficiency range of the existing stock, which is lower than the nominal half-load efficiency (see Chapter 4).

Figure 7 Proposed MEPS and High Efficiency levels, distribution transformers



3.4 Voluntary MEPS

Under a voluntary MEPS regime, transformer suppliers would be encouraged to adopt certain minimum energy efficiency levels "voluntarily", ie in the absence of regulation. These levels would require them to incur the costs of changing their model range to eliminate less efficient models. Otherwise, "voluntary MEPS" is in effect "business as usual".

Suppliers would presumably only incur these costs if there were commercial incentive for them to do so. Whether such incentive exists or could be created is considered in Chapter 4.

3.5 Equipment levy

Another option involves "a levy imposed upon inefficient appliances to fund programs to redress the greenhouse impact of equipment energy use." Two variations of this option have been considered:

a) the proceeds from the levy are diverted to greenhouse-reduction strategies unrelated to transformer efficiency (ie the levy is "revenue-positive"); or
b) the proceeds are used to subsidise the costs of the higher efficiency transformers (say those meeting the HE criteria) so that any cost differentials between these less efficient models are narrowed or eliminated (ie the levy is "revenue-neutral").

Raising and disbursing the levy

Any levy would obviously have to be mandatory. A threshold question for both the "revenue-neutral" and "revenue-positive" options is whether the Commonwealth or State tax regimes could support the raising of the levy. The abolition of wholesale sales tax, which could be levied at different rates, in favour of a single-rate GST, removed the most likely vehicle for imposing a levy.

Once funds were raised, then under a "revenue-positive" option they would be applied to a greenhouse reduction activity determined by government – perhaps under competitive project bidding such as the AGO's current Greenhouse Gas Abatement Program (GGAP). The "revenue-neutral" option would be more complex, in that it would require a mechanism for applying the funds raised to the desired objective of narrowing the cost differential between more efficient and less efficient transformers.

Possible approaches include:

- scaling of tariffs and duties on imported transformers to energy efficiency (but this would not affect locally made products, which account for 85-90% of the market);
- payments to manufacturers or importers according to a formula based on sales and efficiency;
- rebates direct to the purchasers of energy-efficient transformers.

Because most suppliers offer transformers across a range of efficiencies, they may be largely unaffected by the levy (ie their required contribution to revenues may be close to their nominal receipt of benefits). Alternatively, where suppliers are net recipients they may use the revenues to support product prices in ways that conflict with the objectives of the levy. The only way to ensure that the funds are actually applied to the purchase price of the more efficient transformers would be to offer rebates direct to purchasers. However, this would create the following difficulties:

- high fixed costs to establish a publicity, verification and payment infrastructure;
- high administrative and transaction costs;
- "free riders": many buyers who would have bought the more efficient transformers in any case will claim payments.

Conclusions

There are no readily apparent means for raising the proposed levy. While expert legal advise would need to be obtained, it is not likely that differential taxation rates can be implemented under existing Commonwealth or State taxation or licencing laws. A levy would only become feasible if general provisions were introduced to enable import duties and other tax rates to be linked to specific product characteristics, in this case energy efficiency.

The product registration, check testing and ongoing administrative costs to business and government would be no less than under mandatory MEPS.

In the “revenue-positive” case, where the funds raised by the levy were applied to greenhouse gas reduction programs outside the distribution transformer sphere, there is no evidence that potential greenhouse gas reductions from other possible application of the funds would be more cost-effective, or even equally cost-effective, to the proposed transformer MEPS.

In the “revenue-neutral” case, where the funds raised were to be applied to reducing the cost differential between more- and less-efficient transformers, it would be difficult and/or administratively costly to ensure that payments to suppliers and/or purchasers were targeted as intended.

If the framework could be established, a “revenue-neutral” levy would act as a form of mandatory MEPS in which regulations would enforce the payment of the levy rather than prescribe characteristics to be met for lawful sale. Suppliers would be free to sell transformers less efficient than the reference level, but each sale would carry a financial cost. With the MEPS regime currently proposed, suppliers who sell non-compliant transformers would also be subject to financial penalty under the regulations. The main difference is that the levy provides an in-built mechanism for scaling the penalty to the extent by which MEPS is exceeded, whereas the proposed regulations do not. However, if such a feature is considered desirable it may be more straightforward to incorporate it into the regulations than to establish a levy regime.

The proposed levy, even if legally feasible, appears to offer no cost savings, no greater greenhouse gas reductions (in fact, probably less greenhouse gas reductions) and probably higher lifetime transformer costs to purchasers, compared with the MEPS proposals. Some form of levy *in association with* MEPS may produce greater energy savings, but more information about the form and design of a levy proposal would be necessary in order to form a judgement.

3.6 Electricity levy

At present, the electricity prices faced by consumers reflect – however imperfectly - the cost of the capital invested in the electricity generation, transmission and distribution system, operating and maintenance costs, and taxes (now including GST). They may also reflect the costs of controlling pollutants such as oxides of nitrogen and sulphur (NOx and SOx), for which emissions standards are currently in force in some areas. They do not reflect the value of greenhouse gas emissions, or rather they implicitly assign a value of zero to such emissions. In other words, greenhouse costs are not internalised in the electricity price.

It may be possible to introduce a levy on the price of electricity to reflect the cost of greenhouse gas emissions from the production and combustion of the fuels used to generate it – in effect, a carbon tax. Alternatively, if a cap and trade emissions permit scheme were implemented, electricity generators and other major emitters would have to obtain sufficient permits to cover their emissions. Some of these may be obtained free (ie by "grandfathering") and some may have to be purchased, but if there is an open market then all permits will ultimately have the same monetary value. The permit value would thus be reflected in the price of electricity and all greenhouse-intensive goods and services. The effect of a permit trading scheme would be similar to a carbon tax in its pervasiveness, but the magnitude of the electricity price impact would vary with the market price of permits.

The decision to introduce an electricity levy or an emissions trading scheme is a matter for the highest levels of Commonwealth, State and Territory Government. In that respect the options are not direct alternatives to the proposed mandatory MEPS regime.

However, the matter raises the following issues for consideration:

1. If an electricity levy were introduced, would market failures and information failures be corrected to the extent that the proposed MEPS were no longer necessary?

2. Alternatively, if the price of electricity reflected a value for emissions higher than zero, what would be the impact on the cost-effectiveness of the proposed MEPS?

4. Costs, Benefits and Other Impacts

COAG Guidelines:
- ***Costs and benefits:*** *there should be an outline of the costs and benefits of the proposal(s) being considered. This should include direct and indirect economic and social costs and benefits. There should also be analysis of distinct alternatives (including ‘ do nothing’) to the proposed regulation.*

The major economic benefit of MEPS is the value to the operator of the transformer of the electricity saved. The major economic cost is the increase in the average price of transformers. This chapter summarises the cost-benefit modelling carried out to estimate these benefits and costs. The likely impacts on manufacturers, importers and exporters are also covered.

A reduction in electricity consumption would also produce environmental benefits in the form of lower greenhouse gas emissions. These are estimated, but not given monetary value.

An increase in the efficiency of the distribution transformer stock is likely to create additional economic benefits such as greater system reliability (because temperature rise from heat dissipation is less) and a reduction in the rate of capital expenditure in system augmentation. Such benefits could not be modelled because the data are not available, but are likely to be significant.

4.1 Benefits and Costs of Mandatory MEPS

Modelling Approach

Stock Model

The existing stock of distribution transformers was modelled, based on data published by the ESAA and additional estimates in Ellis (2001). The stock was divided into three components, corresponding to the groupings illustrated inFigure 5:

- Group A comprises utility transformers of capacity up to 2500 kVA, and so would be affected by the proposed MEPS. This group is estimated to have accounted for 4248 GWh of energy losses nationally in 2000 (under the medium efficiency assumption – see Table 5);

- Group B comprises utility transformers of capacity greater than 2500 kVA. These would not be directly affected by the proposed MEPS, but there would be some indirect benefits. This group supplies a large part of the energy to private transformers (Group C). If the energy losses from Group C are reduced, the energy throughput of Group B would fall marginally. Group B is estimated to have accounted for 635 GWh of energy losses nationally in 2000;

- Group C comprises private transformers of capacity up to 2500 kVA, and so would be affected by the proposed MEPS. This group is estimated to have accounted for 980 GWh of energy losses nationally in 2000. (Most of these losses are part of utility sales reported by ESAA, and the balance occurs within private electricity generation systems, which do not appear in ESAA data).

It was necessary to estimate the number and aggregate capacity of transformers in each Group by capacity (eg 50kVA, 100 kVA etc) and type (liquid filled three phase, liquid filled single phase, dry type three phase, dry type single phase), since different MEPS levels apply to each of these categories. ESAA data are disaggregated by voltage (eg 33kV, 11kV etc) but not by capacity or type, so the allocations are somewhat arbitrary.

For Groups A and B, care was taken to match the total MVA installed reported by ESAA. Group C was configured so that private transformers comprised about 15% of the total stock, and matched the single/three phase and liquid/dry type profiles estimated by Ellis (2001).

Table 15 and Table 16 summarise the main disaggregations in Groups A and B. For simplicity, it is assumed that all the transformers in Group C are liquid-filled, three-phase units. Figure 8 to Figure 11 illustrate the composition of the utility and the private distribution transformer stock in more detail.

Table 15 Estimated split of distribution transformer stock numbers by type, Australia 2000

	Utility (Group A)		Private (Group C)		Total	
	Number	%	Number	%	Number	%
Liquid	498750	86.6%	57375	57.7%	556125	82.3%
Dry	77300	13.4%	42000	42.3%	119300	17.7%
Total	576050	100.0%	99375	100.0%	675425	100.0%
Three phase	451550	78.4%	68375	68.8%	519925	77.0%
Single phase	124500	21.6%	31000	31.2%	155500	23.0%
Total	576050	100.0%	99375	100.0%	675425	100.0%

Source: stock modelling by author

Table 16 Estimated split of distribution transformer installed capacity by type, Australia 2000

	Utility (Group A)		Private (Group C)		Total	
	MVA	%	MVA	%	Number	%
Liquid	58612	90.4%	5889	43.3%	64501	82.2%
Dry	6256	9.6%	7723	56.7%	13979	17.8%
Total	64868	100.0%	13612	100.0%	78480	100.0%
Three phase	62386	96.2%	12700	93.3%	75086	95.7%
Single phase	2482	3.8%	912	6.7%	3394	4.3%
Total	64868	100.0%	13612	100.0%	78480	100.0%

Source: stock modelling by author

Figure 8 Estimated split of utility distribution transformer stock numbers by capacity and type, Australia 2000

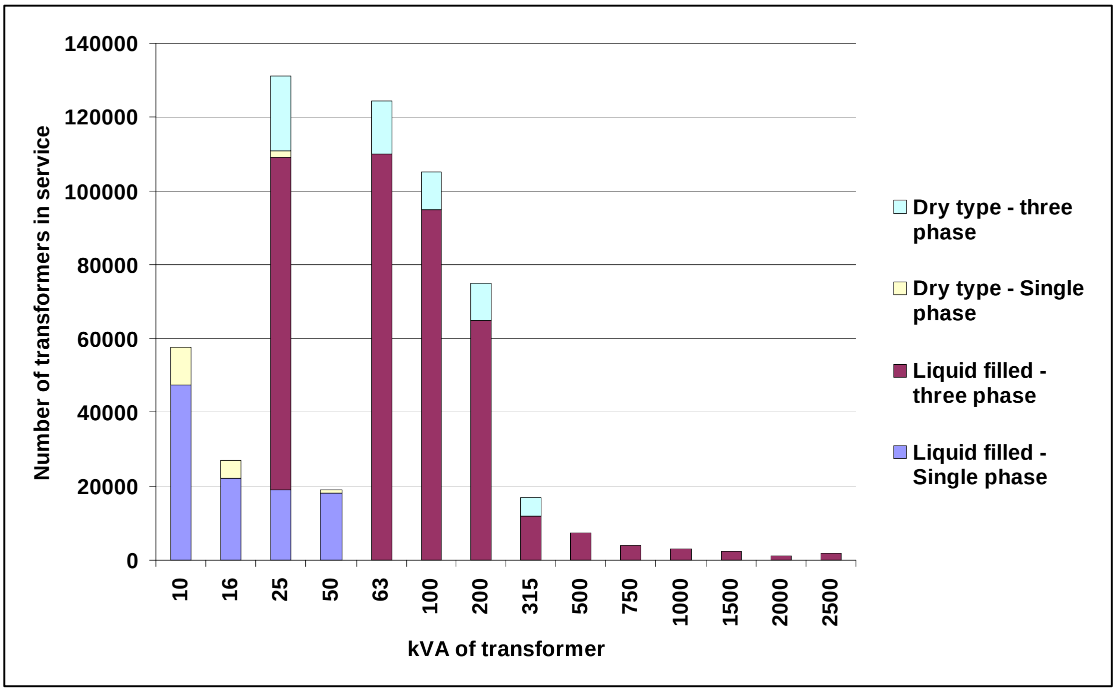


Figure 9 Estimated split of utility distribution transformer installed capacity by capacity and type, Australia 2000

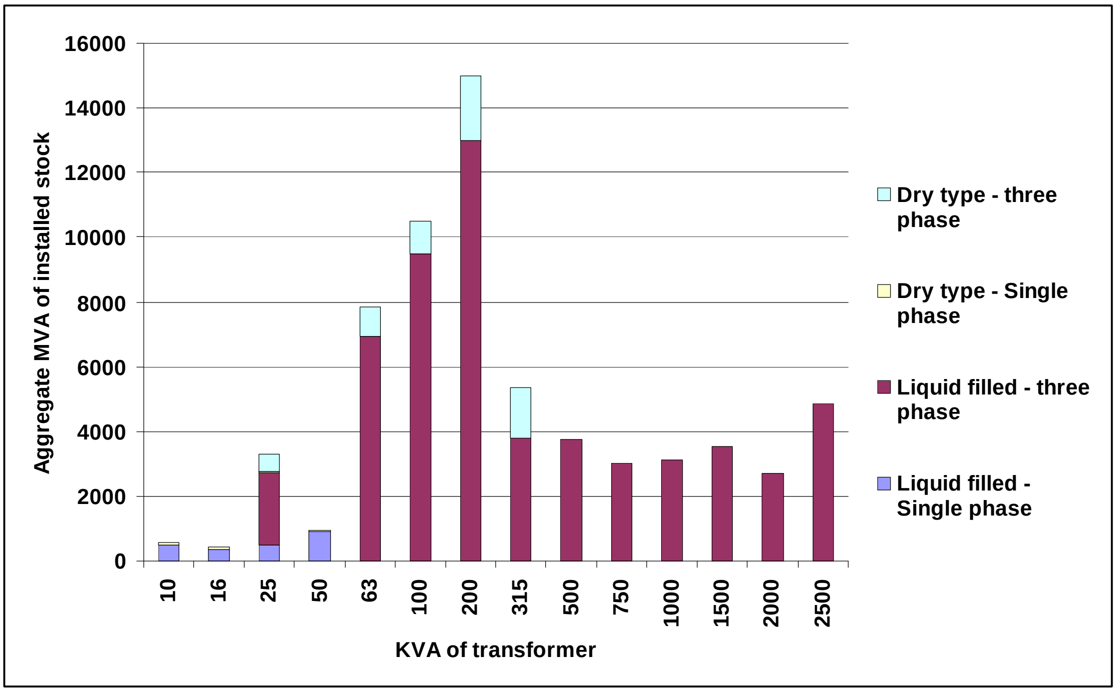


Figure 10 Estimated split of private distribution transformer stock numbers by capacity and type, Australia 2000

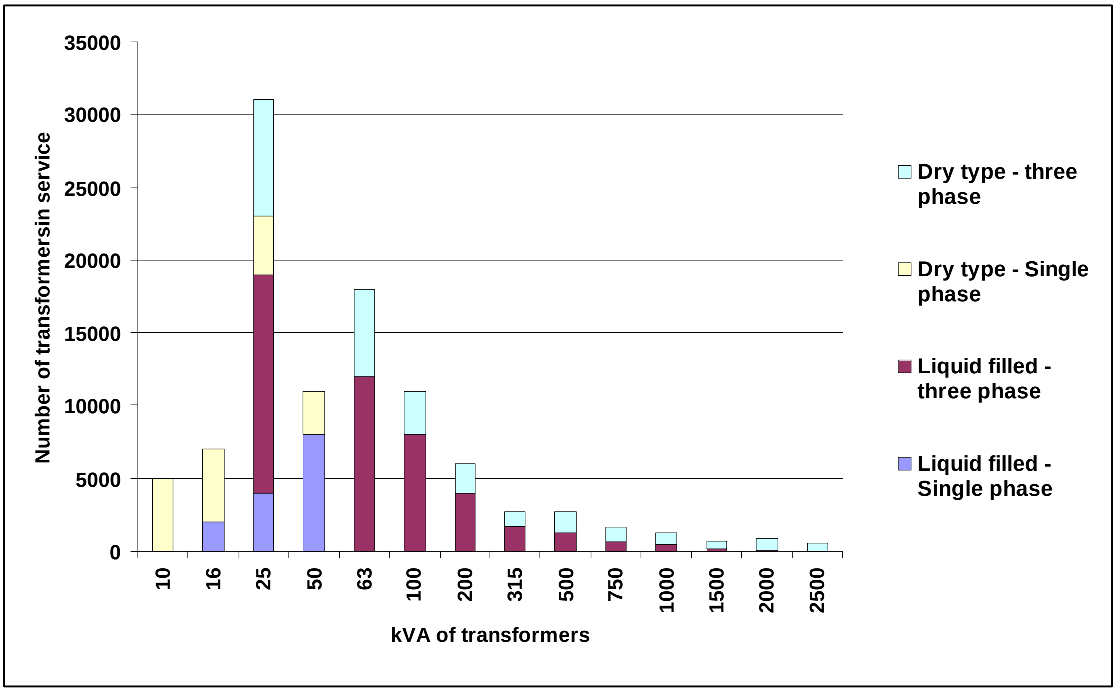
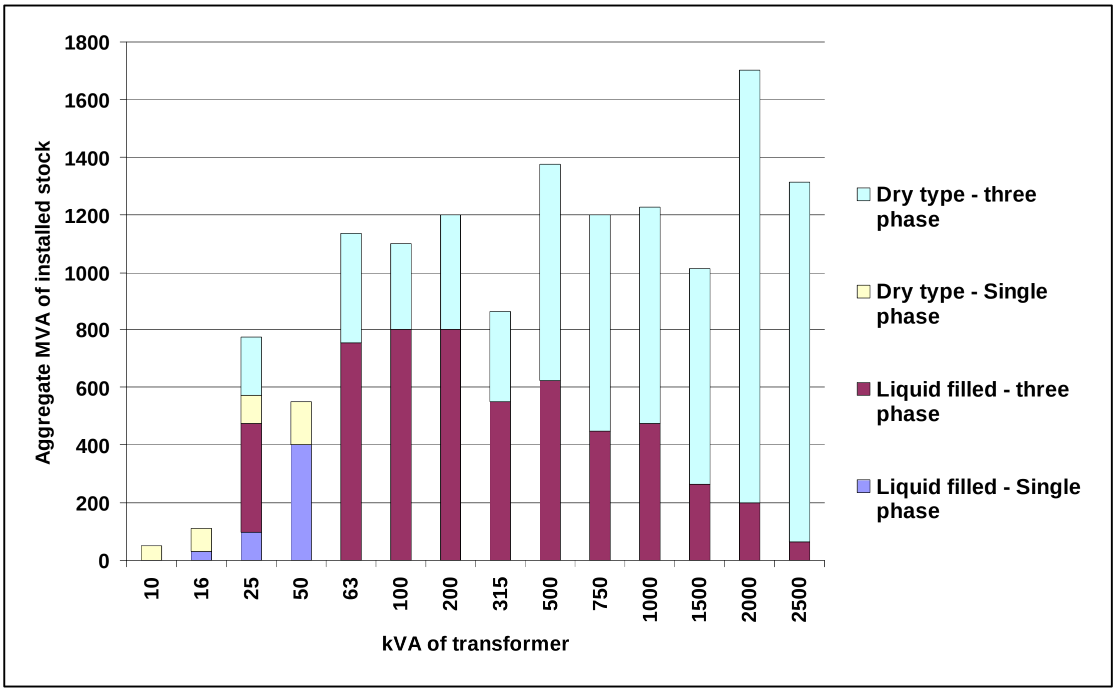


Figure 11 Estimated split of private distribution transformer installed capacity by capacity and type, Australia 2000



The energy lost by the existing transformer stock is uncertain, and depends on the allocation of the known distribution losses between transformer and line losses (see Chapter 1). The projection of the impact of MEPS are highly sensitive to the assumptions about the energy use and efficiency of the starting stock, so three separate scenarios have been used:

- High starting efficency (HSE): this assumes the lowest of the range of transformer losses in Table 5, the highest level of efficiency in the existing stock, and consequently the least impact from the adoption of MEPS;

- Medium starting efficency (MSE): this assumes the midpoint of the range of transformer losses in Table 5, a medium level of efficiency in the existing stock, and consequently tan intermediate impact from the adoption of MEPS;

- Low starting efficency (HSE): this assumes the highest of the range of transformer losses in Table 5, the lowest level of efficiency in the existing stock, and consequently the greatest impact from the adoption of MEPS.

Projection Model

A computer model has been constructed to project the energy losses from the distribution transformer stock. The model projects energy losses for 9 categories of transformer separately: four within Group A (liquid-filled three phase, liquid-filled single phase, dry three phase and dry single phase), the same four within Group C and Group B as a single category.

In addition to the starting efficiency (see above) the following input parameters can be set independently for each category:

a) The increase in MVA in each category in each year, expressed as a percentage of the stock;

b) The retirement of transformers in each category in each year, expressed as a percentage of the MVA installed;

c) The BAU change in average efficiency of new transformers, expressed as a rate of change in the percentage loss.

d) The ratio between weighted average loss percentages under the actual and weighted average loss percentages at half load (ie as if the distributor stock were tested to AS2743).

The projected increase in consumption of electricity (see below) guides the setting of parameter (a). Setting installed MVA to increase at the same rate as electricity use implies that the overall utilisation factor of the transformer stock will remain about the same. Setting MVA to increase at a lower rate implies that the overall utilisation factor (which is currently well below 50%) will increase, and that all else being equal the overall operating efficiency of the stock will probably be closer to the optimum half-load efficiency (although this will depend on the impact of demand growth on load shape).

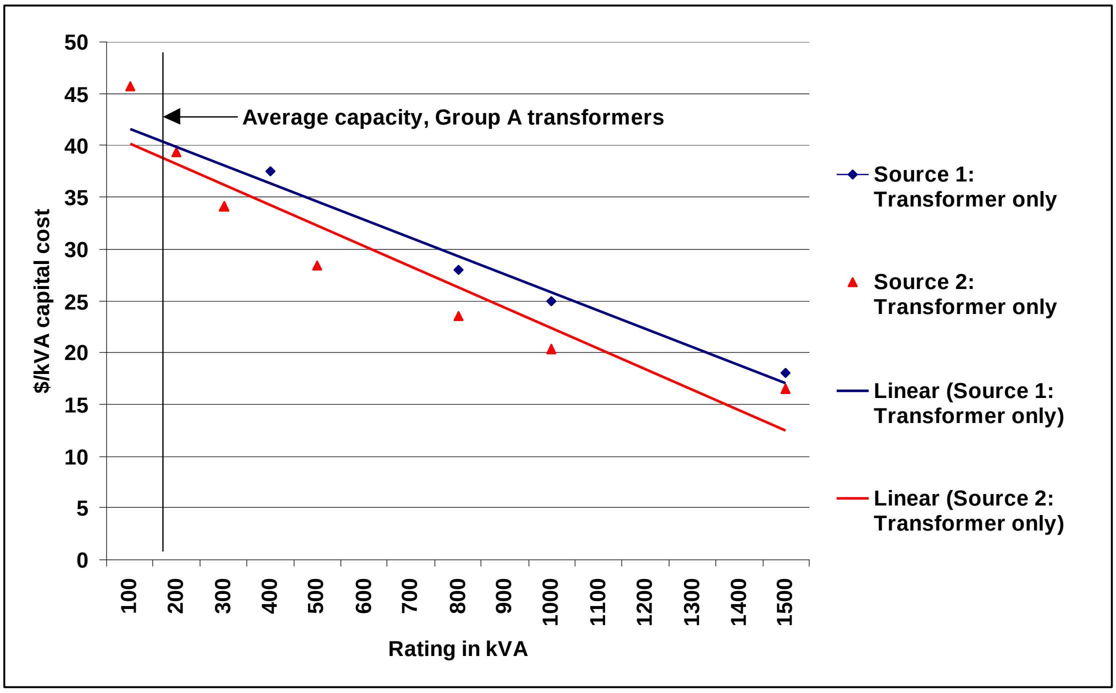
The retirement function (b) has been set so that 2.75% of utility MVA and 2.0% of private MVA installed retires each year. If the populations of transformers were steady, this would imply average service lives of 36 and 50 years respectively. However, given that utility MVA installed has been growing (at about 1.5% per annum in the decade to 2000), each year's retirements relate to a much smaller population of old transformers, and so correspond to a service life of well over 30 years. The retirement rate of private transformers has been set lower on the assumption that the stock has been growing more rapidly and hence is younger than utility transformers.

The settings for (a) and (b) automatically leads to the calculation of the MVA of new transformers entering service each year. Table 17 compares the transformer market modelled under these settings with the actual market for 2000 as reported by Ellis (2001). The modelled estimate for the cost of utility transformers is based on information from the industry, summarised inFigure 12. The estimated average cost of Group A utility transformers is $45/kVA, and the estimated average cost of the much larger Group B utility transformers is $25/kVA, giving a weighted average of $39/kVA for new utility transformers. There is a good fit in MVA and market value, but less so in the number of transformers, which is in fact a relatively unimportant variable, since the model works directly with total kVA and cost per kVA, rather than with unit costs of transformers.

Table 17 Comparison of actual and modelled transformer market

	Actual 2000			Modelled 2001		
	Public	Private	Total	Public	Private	Total
Number	19,100	3,100	22,200	25,720	4,400	30,120
MVA	3,100	660	3,760	3,450	660	4,110
Cost	$M 150	$M 20	$M 170	$M 142	$M 19	$M 161
$/MVA	$48	$30	$45	$39	$29	$39

Figure 12 Estimate cost per MVA, utility standard transformers, 2001



One of the most important parameters in the model is the relationship between nominal half-load efficiency and the actual efficiency in operation, which is generally significantly lower. It is essential to characterise the relationship between the two, since MEPS influences the half-load efficiency of new transformers, but the energy saved will depend on their operating efficiency.

For existing transformers, the average *operating* efficiency can be estimated (see Figure 5) but the *half-load* efficiency is not known and must be assumed: this would require test information about every transformer (of the kind that suppliers would have to obtain, disclose and keep on record for 5 years under the proposed regulation, but which has not been systematically collected in the past).

Conversely, for new transformers average half-load efficiency can be projected (especially in the MEPS scenario, under which all transformers would have to meet the efficiency level proposed) but assumptions must be made about the *operating* efficiency.

The utilisation factor is a guide to the relationship between half load and operating efficiency, but not a direct indicator. The ideal efficiency curve (Figure 30) only holds for transformers where core and winding losses are equal at half load, and it is not known how closely the stock as a whole conforms to this, or how far the average operating power quality and operating conditions deviate from the highly controlled settings in the AS2734 test. The parameters adopted for modelling that are summarised in Table 18. These are subject to sensitivity testing. In general, the lower the ratios (ie the closer the assumed fit between operating and ideal conditions), the higher the projected energy savings from MEPS.

Table 18 Relationships between half load and operating losses

	Estimated utilisation factor (a)	'Ideal' ratio of operating to half-load loss (b)	Ratio adopted for modelling
Utility owned, <=2500 kVA (Group A)	23.6%	1.30	1.6
Utility owned, > 2500 kVA (Group B)	30.1%	1.13	1.3
Privately owned, <=2500 kVA (Group C)	36.7%	1.05	1.1

(a) See Figure 5 (b) If core and winding losses were equal at half load and power factor were constant at all loadings

Figure 13 and Figure 14 illustrate the projected trends in the sales-weighted half-load and operating efficiencies of new transformers under BAU and with-MEPS assumptions. The step increases between 2002 and 2004 illustrate the impact of the introduction of MEPS in January 2003. MEPS would only impact on transformers up to 2500 kVA, so there is no impact on Group B (utility-owned transformers over 2500 kVA). The effect of a step increase in efficiency of new transformers would gradually increase the efficiency of the entire transformer stock as shown in Figure 15 and Figure 16.

Figure 13 Projected half-load efficiency trends, new transformers

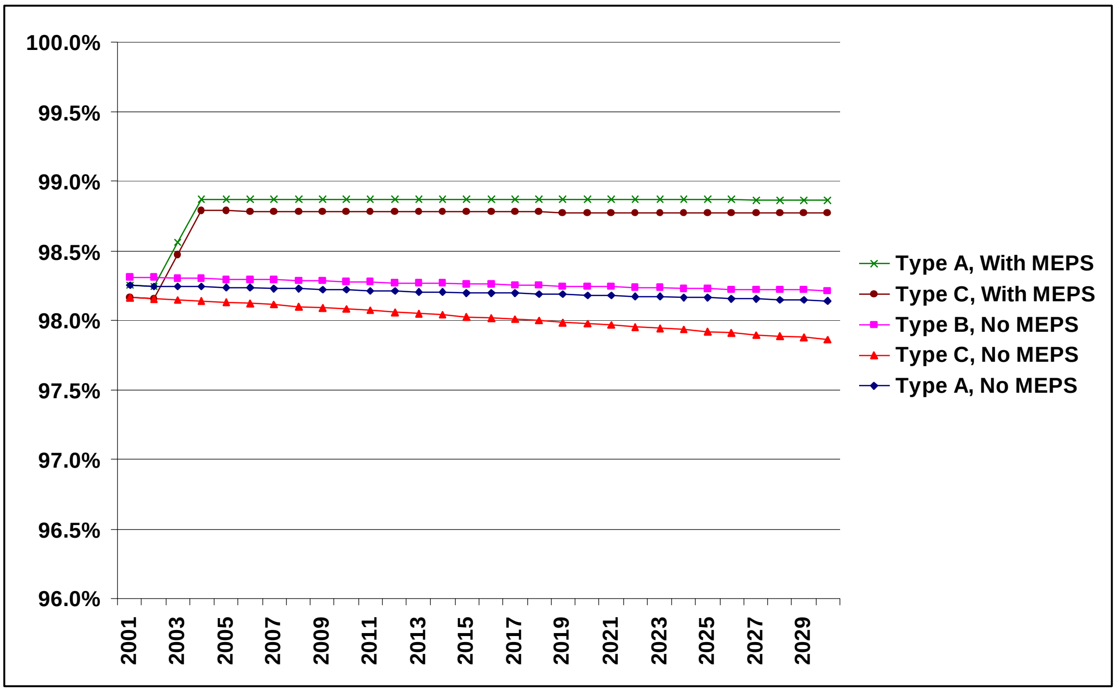


Figure 14 Projected operating efficiency trends, new transformers

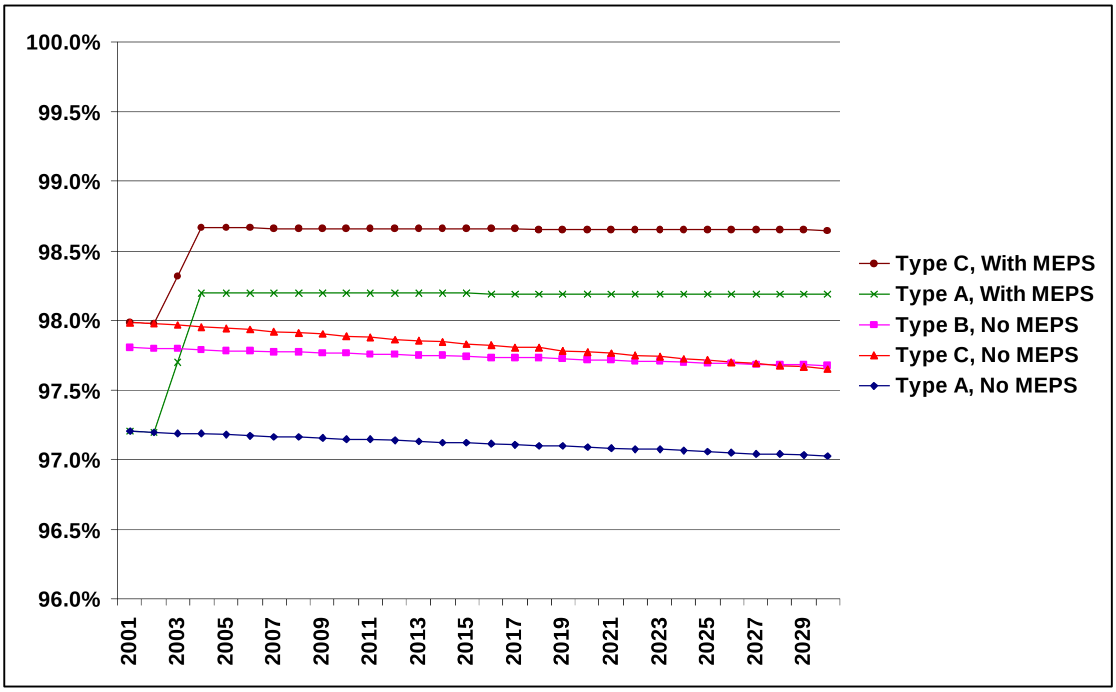


Figure 15 Projected half-load efficiency trends, entire transformer stock

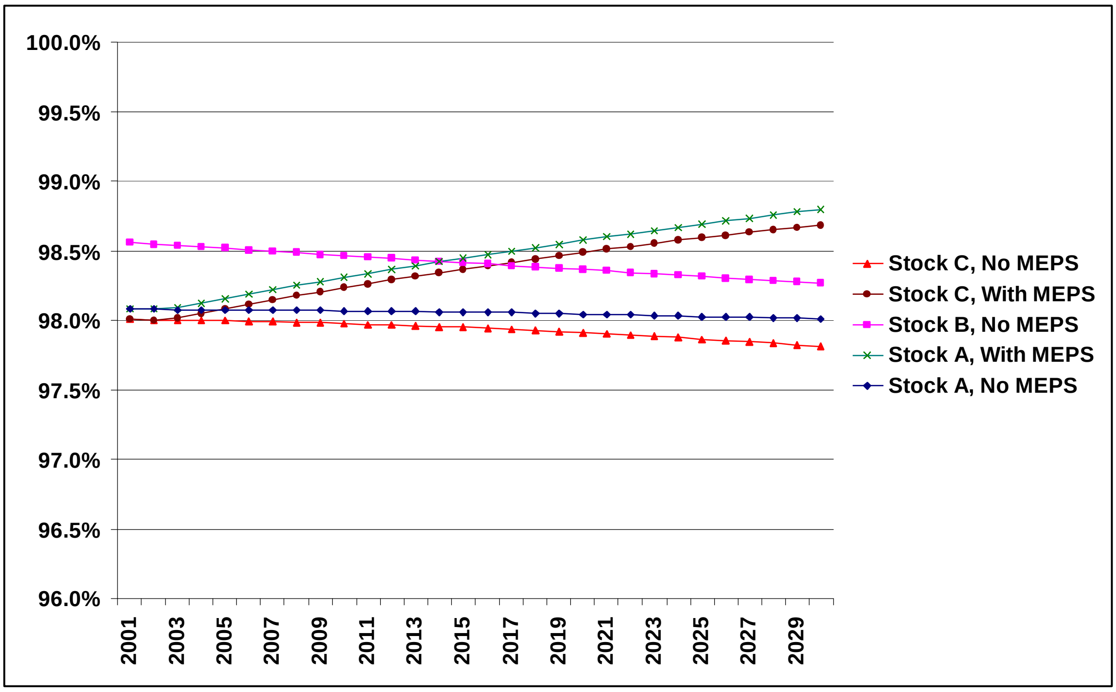
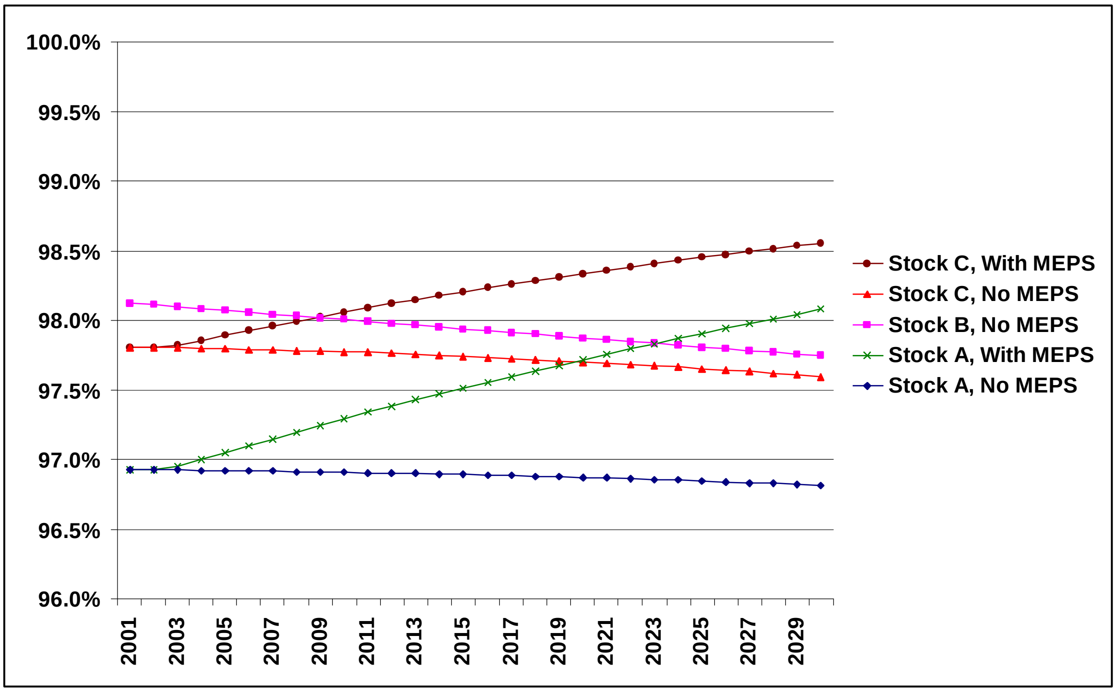


Figure 16 Projected operating efficiency trends, entire transformer stock



Energy Demand Growth

The basis for projecting the size of the transformer stock is the projected demand for electricity. The latest projection by published by ABARE (ABARE 2001) has been used. This is illustrated inFigure 17. The energy to end users is net of all Group A, B and C transformer losses, which ABARE accounts as part of the electricity generation sector. The energy lost be each group of transformers, and hence the energy supplied to them, is calculated by the model.

Figure 18 illustrates the rates of change from year to year in electricity consumption and energy demand. ABARE projects that the rate of growth in electricity use will be about 2.5% per annum until 2005, and will then fall to about 2.2% (the steps in the graph are an artefact of interpolation). The stock of private transformers is projected to grow at about 2.4% per annum, compared with about 1.6% per annum for utility transformers, on the assumption that the customer site transformer installations formerly undertaken by the utilities will in future be left to the customer.

Figure 17 Projected demand for electricity by end users, 2000-30

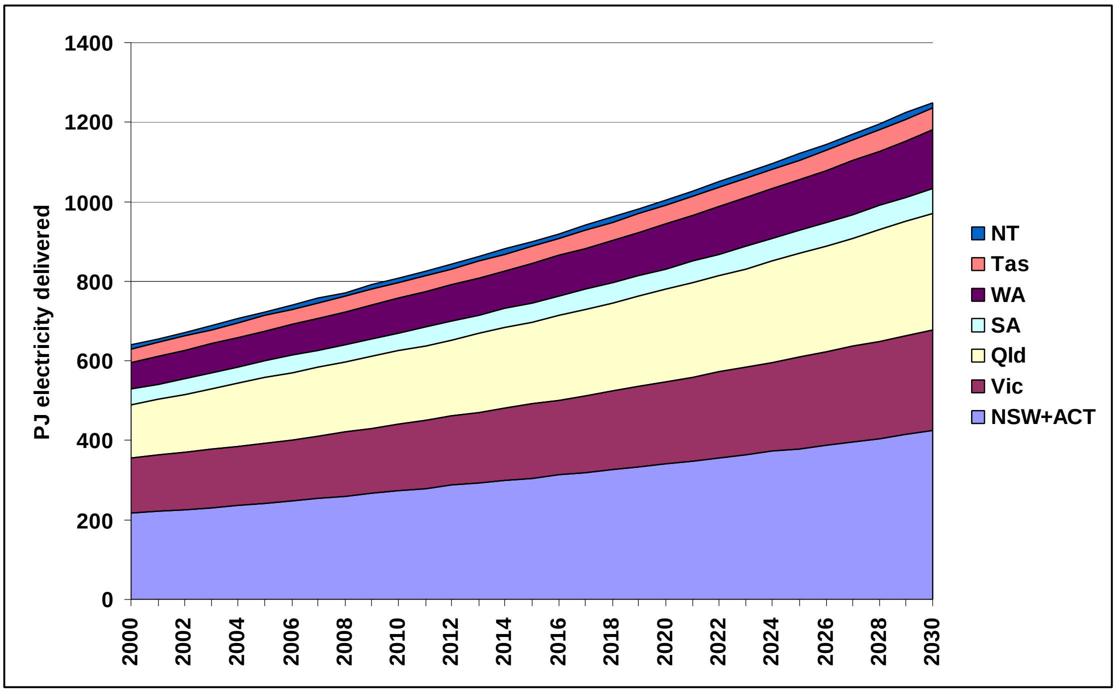
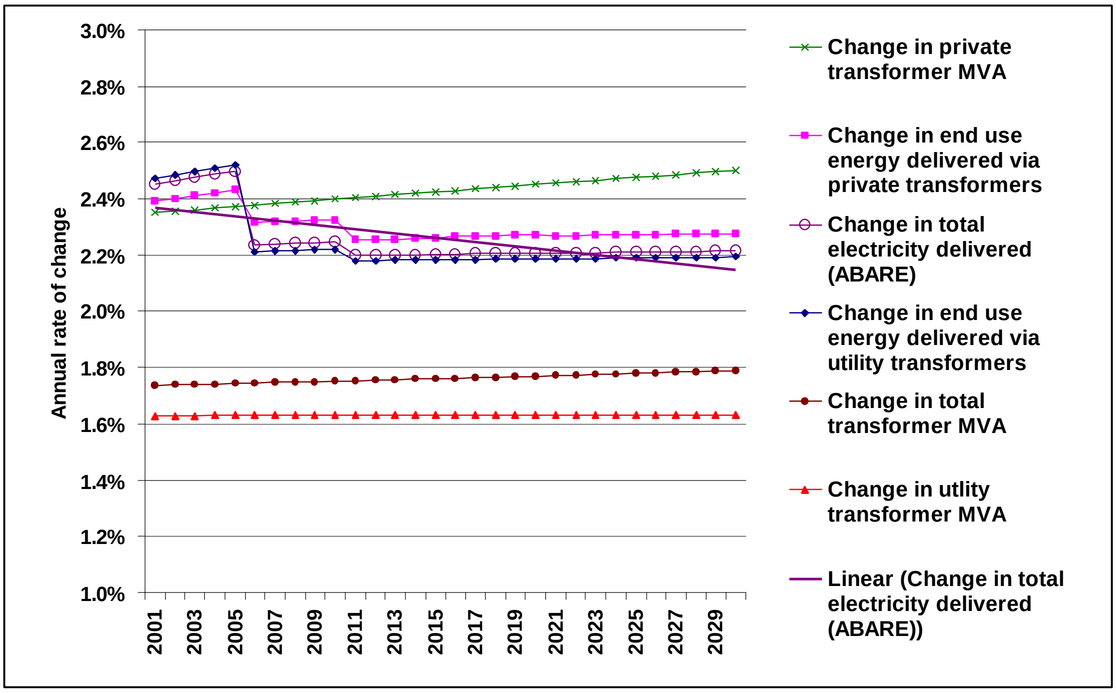


Figure 18 Projected growth rates for electricity use and the transformer stock



Transformer costs

The Price-Capacity Relationship

Transformer costs vary with type (eg liquid-filled or dry) and with capacity. In general, the smaller the capacity the higher the cost per kVA. Data on the relationship between price and efficiency for the most common type (liquid-filled three-phase) were obtained from two separate Australian industry sources. The relationship is illustrated in Figure 12.

The Price-Efficiency Relationship

It is generally assumed that if measures are taken that lead to an increase in the energy efficiency of products, the cost of those products will rise. This is usually true with products that are relatively simple in design, and where there is a direct relationship between material quality or quantity and energy efficiency: eg electric storage water heaters and ferro-magnetic ballasts for fluorescent lamps (GWA 2001a, 2001b). For such products, combination of simple engineering analysis and estimates of material costs will yield a value for expected additional cost to meet a given MEPS level. Transformers are also expected to be in this group.

For modelling purposes the relationship is expressed as the ratio of the percentage change in price per percentage change in energy *loss* at half load (not efficiency). A ratio of 1.0 would indicate that for each 1% reduction in energy loss there would be a 1% increase in transformer price, all else being equal. Information on the relationship between efficiency and price was obtained from Australian industry sources and from a study by the European Commission (EC 1999).

One aim of the EC study was to assess the cost-effectiveness of amorphous metal (AMDT) cores, but it also analyses the cost impacts of more efficient conventional types. The analyses for typical 100kVA, 400 kVA and 1600kVA transformers are summarised in Table 19, Table 20 and Table 21. These indicate that the price/efficiency ratios were in the range 0.26 - 0.35 for the first level of increase in efficiency, and in the range 0.48 - 1.0 for the next level of increase. The information obtained for Australia was more limited, in that it covers only one capacity from one supplier, but this indicated a price/energy ratio of about 1.

For modelling purposes a price-efficency ratio of 0.5 has been used, and outputs have been tested for sensitivity to different ratios.

Table 19 EC analysis – 100 kVA transformers

Efficiency level	Efficiency %	Loss %	Loss kWh (a)	% reduction in loss(b)	Cost Euro	% increase in cost(b)	Price/ energy Ratio(b)
A-A (Base)	94.71%	5.29%	3015		2538		
C-C	96.46%	3.54%	2018	33.1%	2799	10.3%	0.31
A-AMDT	98.71%	1.29%	735	75.6%	3456	36.2%	0.48
C-AMDT	98.77%	1.23%	701	76.7%	3567	40.5%	0.53

Source: EC (1999) (a) At 6.5% utilisation factor, 57,000 kWh throughput. (b) Compared with A-A

Table 20 EC analysis – 400 kVA transformers

Efficiency level	Efficiency %	Loss %	Loss kWh (a)	% reduction in loss(b)	Cost Euro	% increase in cost(b)	Price/ energy Ratio(b)
A-A (Base)	98.04%	1.96%	10251		4307		
C-C	98.64%	1.36%	7113	30.6%	4762	10.6%	0.35
A-AMDT	99.35%	0.65%	3399	66.8%	6332	47.0%	0.70
C-AMDT	99.40%	0.60%	3138	69.4%	6753	56.8%	0.82

Source: EC (1999) (a) At 14.9% utilisation factor, 523,000 kWh throughput. (b) Compared with A-A

Table 21 EC analysis – 1600 kVA transformers

Efficiency level	Efficiency %	Loss %	Loss kWh (a)	% reduction in loss(b)	Cost Euro	% increase in cost(b)	Price/ energy Ratio(b)
A-A (Base)	98.51%	1.49%	33376		9434		
C-C	98.94%	1.06%	23744	28.9%	10147	7.6%	0.26
A-AMDT	99.38%	0.62%	13888	58.4%	14953	58.5%	1.00
C-AMDT	99.45%	0.55%	12320	63.1%	15469	64.0%	1.01

Source: EC (1999) (a) At 16.0% utilisation factor, 2,240,000 kWh throughput (b) Compared with A-A

National Benefits and Costs

Electricity Prices

The value of electricity saved is different for utility transformers and private transformers. Electricity distribution businesses face the wholesale market price, scaled up for transmission losses, whereas private transformer users (other than those who are also generators) face a contract price negotiated with an electricity retailer. These prices vary by jurisdiction, as indicated inFigure 19. The average prices are derived from ESAA *Electricity in Australia 2001*, and the marginal wholesale prices are from projections for the period 2000-20 developed by the AGO for evaluating Greenhouse Gas Abatement Program (GGAP) projects.

For modelling purposes, the large user prices inFigure 19 have been assumed to remain constant throughout the projection period. The AGO's projections of marginal wholesale prices been used for the period 2000-20, and the 2020 price are kept constant for the remainder of the period. Transmission losses and distribution line losses have been factored into these projections, which are illustrated inFigure 20.

Figure 19 Electricity Prices, 2000

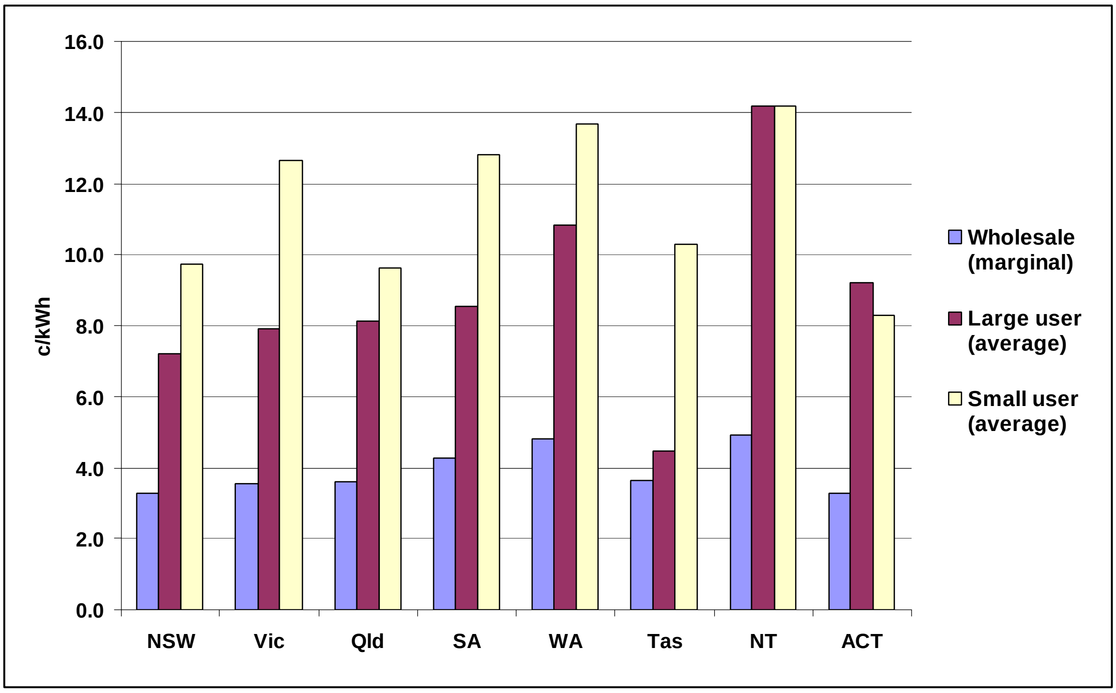
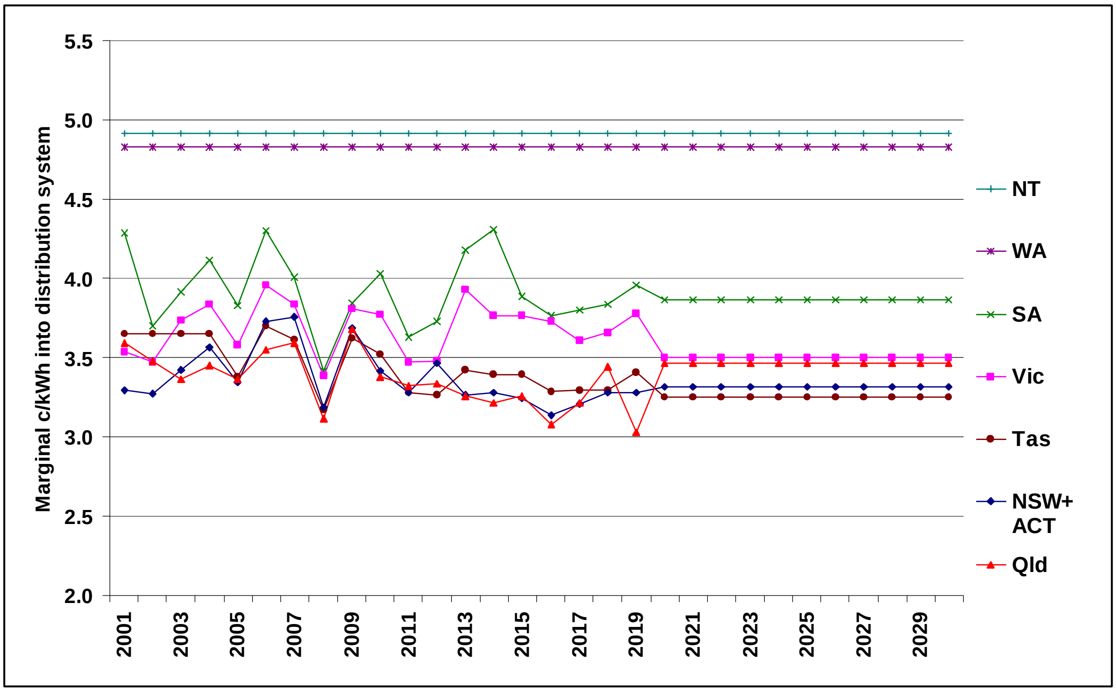


Figure 20 Projected marginal wholesale electricity prices, 2000-30



Projected Energy and Greenhouse Reductions

Three main projections have been developed:

- The HSE scenario assumes "higher" average energy efficiency in the existing transformer stock (but still somewhat lower, on average, than the proposed MEPS level), and so leads to the lowest projected reduction in energy loss;

- The LSE scenario assumes “lower” average energy efficiency in the existing transformer stock, and so leads to the highest projected reduction in energy loss;

- The MSE scenario is intermediate between the HSE and the LSE.

Both BAU and with-MEPS energy losses are different under each scenario. Figure 21, Figure 22 and Figure 23 illustrate the projected energy loss from the national stock of transformers under the LSE, MSE and HSE scenarios respectively. The losses from utility transformers (Groups A and B) and private transformers (Group C) are shown separately. Figure 24 illustrates estimated historical losses from utility transformers (ie Groups A and B combined) and the projected losses under the MSE BAU and with-MEPS scenarios.

Figure 25 illustrates the energy savings under the three Scenarios: in effect the differences between the BAU and with-MEPS trend lines. Most of the projected energy savings would accrue to utility-owned transformers (Group A), but the share of savings accruing to privately-owned transformers is greater than their share of the total stock, because it is assumed that they start at a lower average level of efficiency and hence are more impacted by MEPS.

Figure 21 Projected energy losses from transformers, 2000-2030, LSE scenario

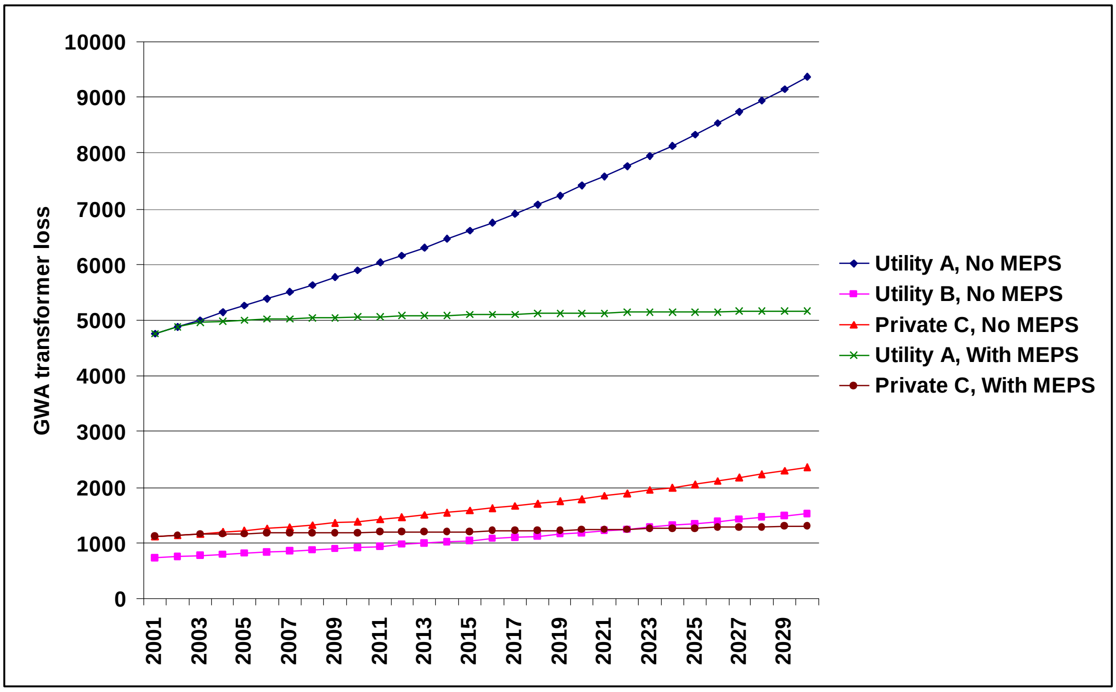


Figure 22 Projected energy losses from transformers, 2000-2030, MSE scenario

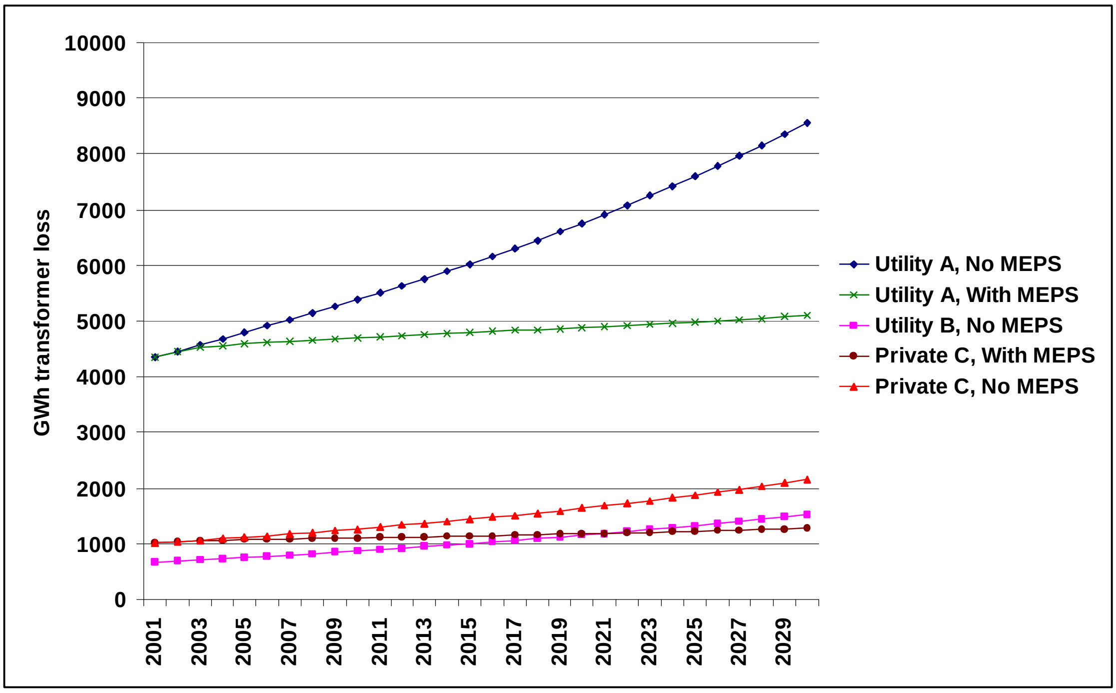


Figure 23 Projected energy losses from transformers, 2000-2030, HSE scenario

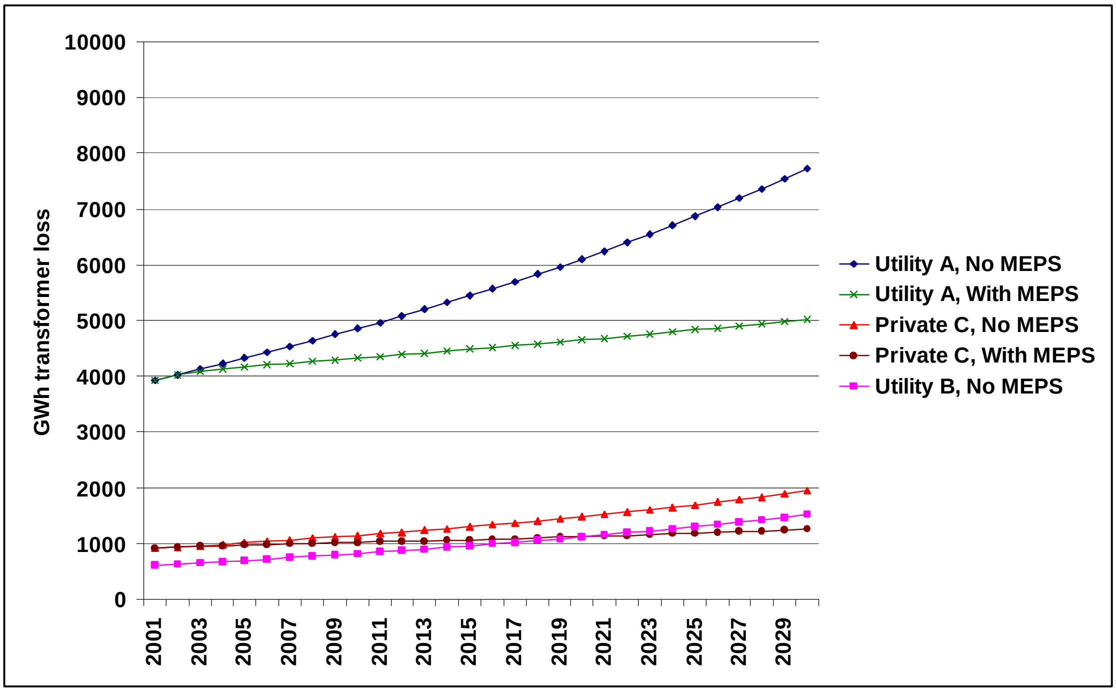


Figure 24 Historical and projected losses from utility distribution transformers

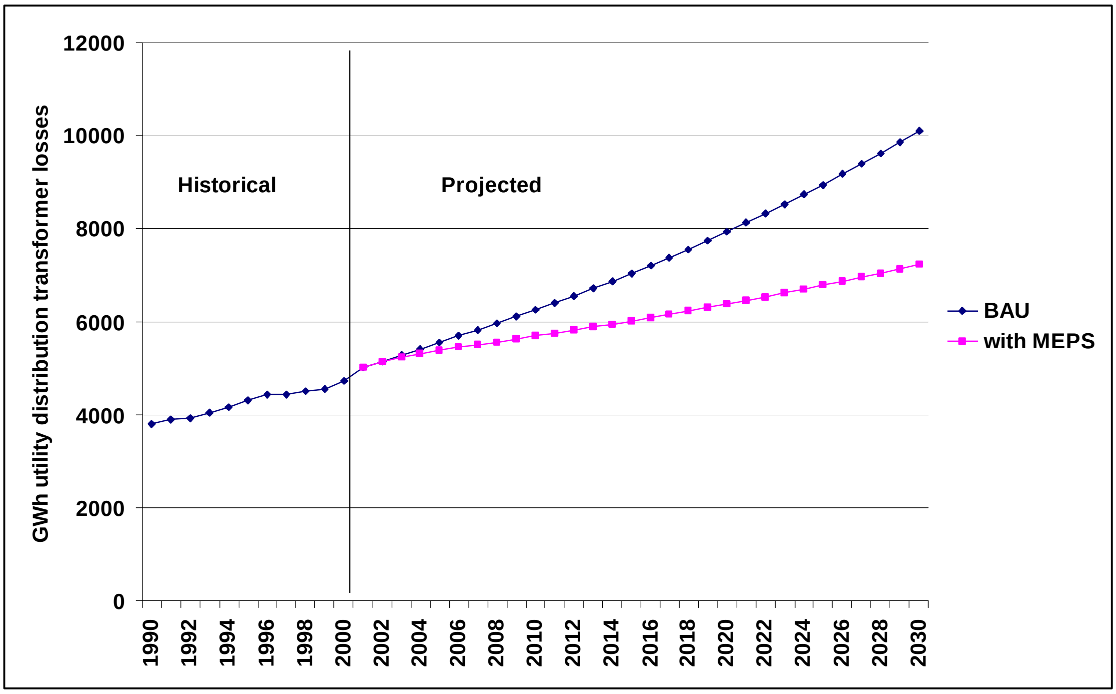
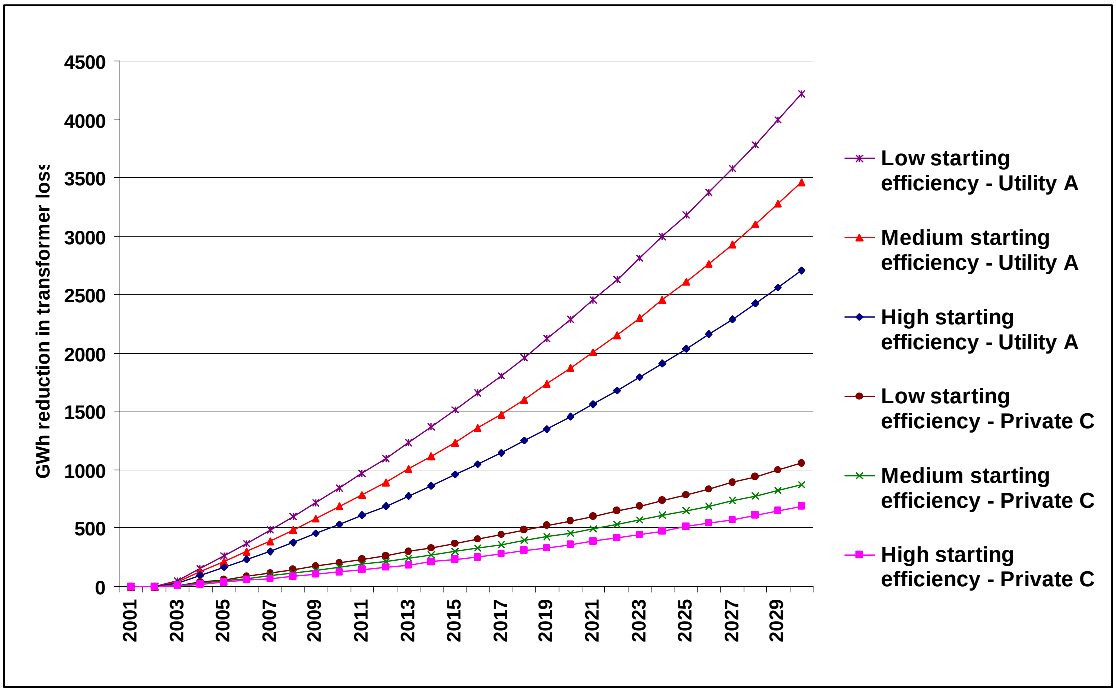


Figure 25 Projected annual energy savings under MEPS scenarios



The projected greenhouse gas reductions are calculated from the energy reductions using marginal greenhouse gas coefficients for electricity supplied in each State (see Appendix 2) and the share of transformer losses incurred in that State. Table 22, Table 23 and Table 24 summarise estimated BAU and with-MEPS emissions under the three scenarios. Table 25 indicate the projected reductions in emissions in 2010, the midpoint of First Commitment Period under the Kyoto Protocol, in 2020 and aggregated over the period 2002-2030.

The projected greenhouse reductions in 2010 from MEPS range from 1066 kt CO_2-e under the LSE scenario (10.7% below BAU) to 672 kt CO_2-e under the HSE scenario (7.8% below BAU), with a medium value of 869 kt CO_2-e (9.3% below BAU). The projected savings build up rapidly with the projected rise in electricity consumption. Over a 30 year horizon, the projected savings range 64.9 Mt CO_2-e to 41.4 Mt CO_2-e.

MEPS-impacted utility transformers (Group A) account for over 80% of the projected emissions reductions, and MEPS-impacted private transformers for nearly 19%. Although Group B is not subject to MEPS, there are minor energy savings and emission reductions as a result of the energy reductions in Group C.

Table 22 Summary of projected emissions and reductions – LSE scenario

Trans-formers	BAU (No MEPS)			With MEPS			Reductions			Share of reductions
	2010	2020	2002-30	2010	2020	2002-30	2010	2020	2002-30	
Group A	5735	6956	191308	4870	4683	138857	866	2273	52451	80.3%
Group B	909	1130	30858	906	1122	30652	3	9	205	0.3%
Group C	1351	1688	46161	1154	1160	33938	197	528	12224	19.4%
	10005	11794	268327	8939	8985	203447	1066	2810	64880	

All value kt CO_2-e.

Table 23 Summary of projected emissions and reductions – MSE scenario

Trans-formers	BAU (No MEPS)			With MEPS			Reductions			Share of reductions
	2010	2020	2002-30	2010	2020	2002-30	2010	2020	2002-30	
Group A	5230	6343	174444	4524	4483	131514	706	1859	42930	80.3%
Group B	860	1104	29857	858	1097	29692	2	7	166	0.3%
Group C	1232	1540	42107	1072	1107	32074	161	433	10034	19.4%
	9332	11007	246409	8463	8707	193279	869	2299	53130	

All value kt CO_2-e.

Table 24 Summary of projected emissions and reductions – HSE scenario

Trans-formers	BAU (No MEPS)			With MEPS			Reductions			Share of reductions
	2010	2020	2002-30	2010	2020	2002-30	2010	2020	2002-30	
Group A	4724	5730	157582	4178	4283	124155	546	1447	33427	81.2%
Group B	812	1077	28859	810	1072	28732	2	5	127	0.3%
Group C	1113	1392	38054	989	1054	30207	124	338	7848	18.5%
Total	8659	10219	224496	7987	8429	183094	672	1790	41402	

All value kt CO_2-e.

Table 25 Projected percentage reductions – all scenarios

Trans-formers	HSE Scenario			MSE Scenario			LSE Scenario		
	2010	2020	2002-30	2010	2020	2002-30	2010	2020	2002-30
Type A	11.6%	25.2%	21.2%	13.5%	29.3%	24.6%	15.1%	32.7%	27.4%
Type B	0.2%	0.5%	0.4%	0.3%	0.6%	0.6%	0.3%	0.8%	0.7%
Type C	11.1%	24.3%	20.6%	13.0%	28.1%	23.8%	14.6%	31.3%	26.5%
All types	7.8%	17.5%	18.4%	9.3%	20.9%	21.6%	10.7%	23.8%	24.2%

The shares of projected emissions reductions in the MSE scenario are disaggregated by State in Figure 26 and by Group (A, B and C) in Figure 27.

Figure 26 Projected emission reductions by State, 2001-30, MSE Scenario

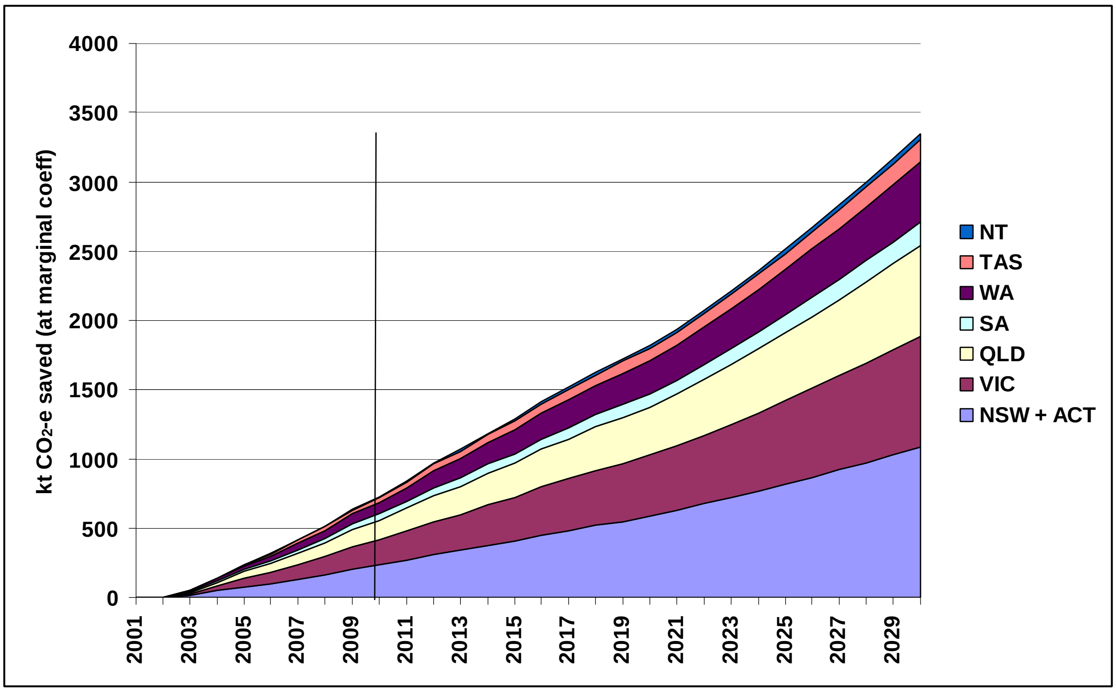
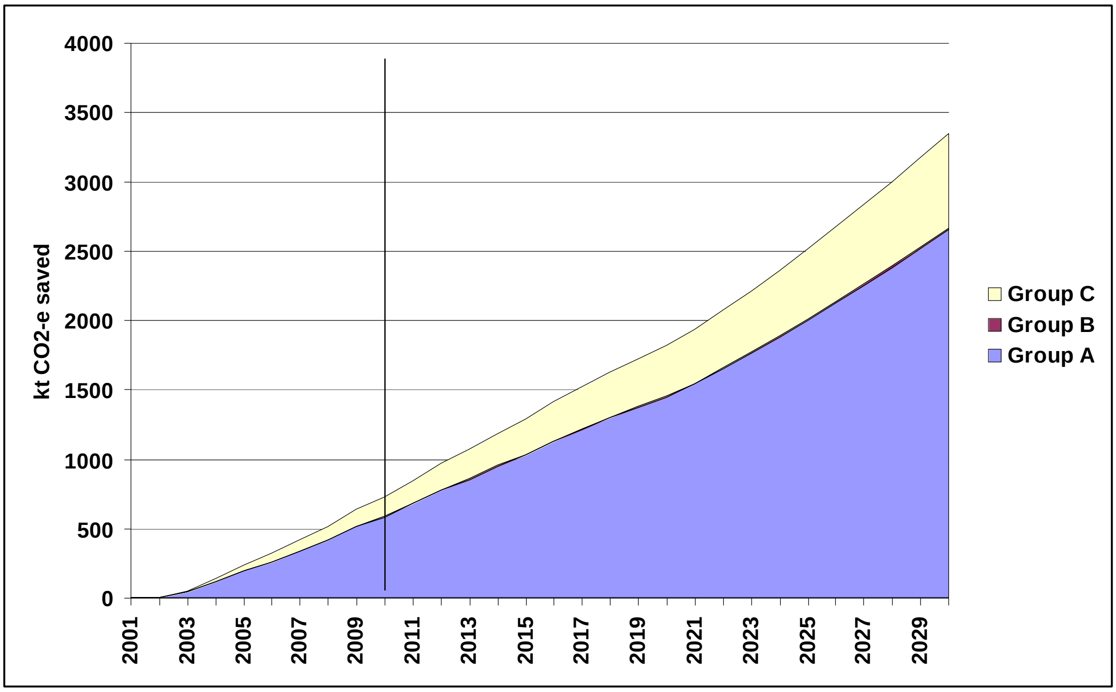


Figure 27 Projected emission reductions by State, 2001-30, MSE Scenario



Costs and Benefits

The projected national costs and benefits of the proposed MEPS options are summarised in Table 26, Table 27 and Table 28 for the LSE, MSE and HSE scenarios respectively. The benefit is the value of the reduction in electricity losses to transformer owners. No value has been given to greenhouse gas emission savings. The extra costs are the projected increase in the price of transformers. There are no additional program costs, since transformer energy efficiency testing is already common and the administrative infrastructure for MEPS already exists.

Table 26 Projected costs and benefits of MEPS proposal, LSE scenario

	No MEPS			With MEPS			NPV Extra cost	NPV Saving	Benefit/ Cost ratio	Limit P/E ratio
	NPV cost of trans	NPV losses	Total NPV	NPV cost of trans	NPV losses	Total NPV				
Type A	$1,392.8	$2,197.2	$3,589.9	$1,722.2	$1,800.4	$3,522.6	$329.4	$396.7	1.2	0.60
Type B	$149.6	345.0	$1,950.1	$149.6	$343.6	$546.3	$0.0	$1.5		
Type C	$208.5	$1,184.7	$1,393.2	$261.1	$974.9	$1,236.0	$52.6	$209.8	4.0	1.99
All types	$1,750.9	$3,726.9	$6,933.2	$2,132.9	$3,118.9	$5,305.0	$382.0	$608.0	1.6	

All values $M net present value of transformer costs over during period 2002-30, at 10% discount rate

Table 27 Projected costs and benefits of MEPS proposal, MSE scenario

	No MEPS			With MEPS			NPV Extra cost	NPV Saving	Benefit/ Cost ratio	Limit P/E ratio
	NPV cost of trans	NPV losses	Total NPV	NPV cost of trans	NPV losses	Total NPV				
Type A	$1,392.7	$2,003.4	$3,396.1	$1,688.5	$1,679.2	$3,367.7	$295.8	$324.2	1.1	0.55
Type B	$149.6	328.4	$1,828.8	$149.6	$327.2	$473.8	$0.0	$1.2		
Type C	$208.5	$1,080.5	$1,289.0	$255.8	$908.8	$1,164.7	$47.3	$171.7	3.6	1.81
All types	$1,750.8	$3,412.4	$6,514.0	$2,093.9	$2,915.3	$5,006.2	$343.1	$497.1	1.4	

All values $M net present value of transformer costs over during period 2002-30, at 10% discount rate

Table 28 Projected costs and benefits of MEPS proposal, HSE scenario

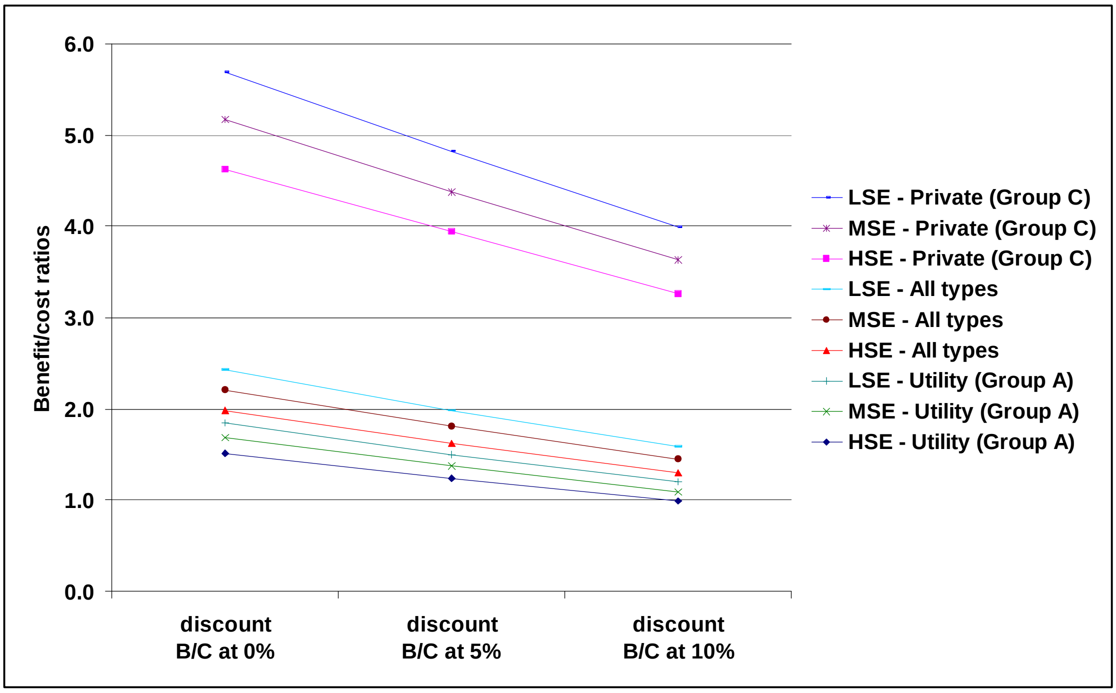
	No MEPS			With MEPS			NPV Extra cost	NPV Saving	Benefit/ Cost ratio	Limit P/E ratio
	NPV cost of trans	NPV losses	Total NPV	NPV cost of trans	NPV losses	Total NPV				
Type A	$1,392.6	$1,809.7	$3,202.3	$1,647.6	$1,557.8	$3,205.4	$255.0	$251.9	1.0	0.50
Type B	$149.6	311.8	$1,707.4	$149.6	$310.9	$401.5	$0.0	$0.9		
Type C	$208.5	$976.4	$1,184.8	$249.4	$842.7	$1,092.1	$40.9	$133.6	3.3	1.63
All types	$1,750.7	$3,097.9	$6,094.6	$2,046.6	$2,711.5	$4,699.1	$295.9	$386.4	1.3	

All values $M net present value of transformer costs over during period 2002-30, at 10% discount rate

The benefit/cost ratios range from 1.0 to 1.2 for utility-owned transformers, and 3.3 to 4.0 for privately-owned transformers, which face much higher marginal electricity prices and for which the value of electricity saved is consequently higher. The projections embody a price/efficiency (P/E) ratio of 0.5 (see preceding section). The "limit P/E ratio" is the highest ratio for which the MEPS proposal remains cost-effective. For private transformers, MEPS remains cost effective up to ratios of 1.8 in the MSE scenario: ie if a 10% reduction in energy lost leads to a cost increase of 18%.

The influence of the discount rate selected is illustrated in Figure 28. The value of the future stream of electricity savings is more heavily discounted than the capital costs, which are incurred in one lump. Hence the higher the discount rate, the lower the benefit/cost ratio.

Figure 28 Sensitivity of benefit/cost ratios to discount rates



At the highest discount rate, the projected benefits of MEPS for utility transformers are about equal to the projected costs. However the benefit/cost ratios for private transformers are so high that the overall benefits of MEPS as a whole significantly exceed the costs across the range of discount rates tested. This suggests that transformer owners as a group are highly likely to be better off with MEPS, but the benefits will accrue disproportionately to private transformer users.

The benefits of the proposed MEPS are underestimated because they do not value the reduction in transformer failure rates and improvements in system reliability that are likely to flow from the lower operating temperatures of a more energy efficient transformer stock. These benefits, like the deferment of capital investment to accommodate load growth, are very difficult to estimate.

On the other hand, the costs of the proposed MEPS may also be underestimated. It may be necessary to replace some poles, enclosures or mountings if the MEPS-complying replacement is larger or heavier than the existing transformer. This has some analogies to the dimensional constraint issue for water heater MEPS (GWA 2001b). However, there are dozens of potential suppliers of transformers, and individual units can be engineered to order, so the technological and competitive situation is far more conducive to low-cost solutions to such problems if they arise. With mains pressure electric storage water heaters, there are only two major suppliers and five models in the dimensionally-constrained market segments, so the tooling and inventory costs of meeting dimensional constraints is high.

4.2 Industry, Competition and Trade Issues

Supplier competition

The previous section examined the costs and benefits of the MEPS option from the perspective of transformer buyers and users. It was assumed that all compliance costs incurred by suppliers are eventually passed on to buyers in the normal course of business, so for the purposes of cost-benefit analysis the cost impact on suppliers as a group is neutral. However, it is likely that some suppliers will be more affected by the MEPS option than others. This section considers the impact on firms, with respect to both domestic and international competition.

There are over 20 manufacturers of transformers in Australia, five of which account for the majority of the market. Between 15% and 25% of the transformers sold each year are imported, in many cases by firms which also manufacture locally. In addition, there are several import-only firms.

Given the number of sourcing options, firms have a range of response options in the event that their products fail the MEPS level. Manufacturers will need to review their design and manufacturing practices, and will need to upgrade designs (although in many cases not actually incur the additional costs of manufacturing to the more stringent efficiency level until the order is received). An importer can request the overseas plant to change the design, to substitute more efficient models from the parent company's product range, or - if the importer is not tied to a particular brand – it could change suppliers.

Those suppliers with a higher numbers of non-complying models will clearly need to make more effort to obtain (or in the case of the local manufacturer, to design and construct) complying models.[8]

Transformers are manufactured in nearly all developed countries and many of the developing countries in the Asia Pacific region, and are freely traded – as evident from the wide range of countries of origin for Australian imports. It should not be difficult to source product of different price and efficiency levels, provided there is reasonable notice. Given the technical and financial resources of the transformer suppliers, their already wide model ranges and their proven ability to produce and source products of different efficiency levels, it is most unlikely than any firm will find the cost of compliance so onerous that it is forced to withdraw from the market. Any significant reduction in supplier or price competition is unlikely.

The product registration aspect of the mandatory MEPS option could enhance competition by helping to overcome information failure. The energy efficiency of all transformer models, determined under common test criteria, can be made available to specifiers if governments make the product register information publicly accessible, as is the case with electric motors.

[8] The industry has been asked to indicate the proportion of current models that would fail to meet MEPS. At the time of writing this draft the information was not yet available.

Competition with refurbished transformers

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

Although no data are available on the numbers of units refurbished each year, industry sources suggest that it is a significant market, which may be growing as utilities try to extend the service lives of transformers and other capital assets. Some utilities report that where transformers are reaching their capacity, they are replaced by larger units, but the original is refurbished and used elsewhere in the network, or kept in storage until wanted.

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

This may well be the case in the transformer industry, since the same firms are active in both manufacturing and in refurbishment. This places them in a better position to continue to maintain the market for new units through adjusting the price of refurbishment than is the case in the electric motor industry, where new product suppliers and rewinders are in direct competition.

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

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

Testing

Two forms of testing are relevant to the operation of the proposed MEPS regime: type (or "registration") testing and check testing. The position of Australian regulators with regard to testing these for all products subject to mandatory labelling and MEPS are set out in the *Administrative Guidelines Agreed by all Australian Regulators* (NAEEEC 2000a). A third form of testing – unit testing – is sometimes done by suppliers for quality control or in response to the requirements of customers.

It would be difficult to argue that the costs of correction of any existing testing inadequacies that may be exposed as a result of the administration of MEPS should be counted as a cost of the proposal. On the contrary, it would be an exposure and correction of information failure, and as such an incidental *benefit* of the proposal.

Type testing

Type testing is carried out on one or more samples of a type or a model family. Type testing is routinely undertaken by suppliers in order to publish specifications for the information of potential buyers and regulators (eg electrical safety regulators). Type tests are normally carried out to the test standards used in all the countries where the model is to be marketed. For the Australian market, this means AS 2374.1 *Power transformers – Part 1: General* or AS 2735. *Dry-type power transformers*.

Under the proposal, it would become mandatory to register a copy of the test report with one of the State energy labelling registries. The form of application for registration is appended to the proposed revision of AS 2374.1, and the test report would need to contain the following:

> *For products within the [model] family provide full details of measured voltage, current, load power factor, core and winding temperatures, core loss, load loss and temperature adjustment factors for normalising to 75^0C operation.*

The application for registration would also contain a declaration that the testing has been carried out in accordance with the requirements of AS2374.1 (and AS 2735 where appropriate) and that the model complies with the appropriate MEPS level.

Although the name and location of the test laboratory would have to be identified, there is no requirement for testing to be undertaken within Australia. The *Administrative Guidelines* (NAEEEC 2000a) lists the criteria for acceptability of the laboratories as follows:

> From 1 October 2004, regulatory agencies propose to approve only appliance registration that has been conducted by a laboratory accredited by the National Association of Testing Authorities (NATA) (or a laboratory that has been accredited by a body with a mutual recognition agreement with NATA).
>
> Prior to that data, regulatory agencies have agreed to consider approval of any 'inhouse' or third party laboratory that supplies a registration test report on the form specified in the relevant Australian Standard.

Whatever arrangements suppliers currently have for type testing would be acceptable, and there would be no significant additional costs either to importers or local manufacturers, until October 2004 at the earliest.

NATA is party to several international accreditation schemes, some of them covering laboratories in the countries from which transformers are imported. Within Australia, there is already one independent laboratory with NATA accreditation to AS 2374 – Testing and Certification Australia, in Sydney. The CSIRO high-voltage laboratory, also in Sydney, is capable of carrying out the tests, but is not currently NATA registered. The major manufacturers currently carry out their own tests but without NATA registration. They could continue to do this from the commencement of MEPS (proposed for January 2003) until October 2004, but if they wished to continue to supply registration type tests after that data, they would need to obtain NATA registration.

Unit testing

As with all manufacturing processes, there is a degree of variability in transformer production, and the operating characteristics of individual units may differ to some extent from the characteristics registered for that model. The higher the variability, the higher the risk that a randomly selected unit will depart significantly from its type with regard to its energy efficiency or other key characteristic.

This is of concern to the supplier to the extent that:

- Buyers may become aware of discrepancies between the characteristics of the type and of the items they have purchased, and seek compensation or replacement; and

- Regulators may be come aware of such discrepancies, and require the supplier to review the type description. If a condition of lawful sale is that the type meets certain criteria (eg MEPS) than the penalty may be withdrawal from sale.

This issue is relevant to all products subject to energy labelling or MEPS. Appliance suppliers address it by limiting the variability of the production process (which is in any case on of the objectives of quality control), by monitoring variability through their own random testing, and by ensuring that the type characteristics originally notified take production variability into account. (Testing and instrument variability is accommodated by the tolerances specified in the test standards).

Electricity distribution transformers differ from mass-produced appliances in that many manufacturers test every single unit, not just a random sample. This is because small variations can have major consequences, given the very large amount of energy handled by the typical transformers over its service life. Electricity utilities often have standing contracts for the supply of transformers of specified capacities and characteristics, and include in the contracts formulae by which the price will be adjusted for measured departures from the stated characteristics, as well as the limits beyond which units will not be accepted. The operation of these clause depends on the certification by the supplier of the characteristics of every unit supplied.

There would be no requirement for suppliers to advise regulators of the unit test results. However, unlike household appliances, buyers would be made aware in the event of any supply of a unit that fails MEPS.

Check testing

All State and Territory regulatory agencies participate in a national check testing program for products subject to mandatory energy labelling and/or MEPS. The procedures for check testing are set out in the *Administrative Guidelines* (NAEEEC

2000a). All check tests are conducted in NATA-accredited laboratories independent of the registration holder.

If an independent test of a single unit selected by regulators returns different results from the registered type test, and these differences cannot be explained by any "obvious operating defect", there is an option to have further check independent tests on additional samples conducted. If these additional tests return satisfactory results, the registration stands. This two stage process allows for the possibility that a sample at the extreme of production variability happens to be selected for the first stage test. Regulators meet the costs of the first stage, and suppliers the costs of the second stage. Suppliers who register correct type tests and who maintain low production variability will not incur stage two check test costs.

Trade Issues

GATT

One of the requirements of the RIS is to demonstrate that the proposed test standards are compatible with the relevant international or internationally accepted standards and are consistent with Australia's international obligations under the General Agreement on Tariffs and Trade (GATT)*Technical Barriers to Trade* (GTBT) Agreement. The relevant parts of the GTBT*TECHNICAL REGULATIONS AND STANDARDS Article 2: Preparation, Adoption and Application of Technical Regulations by Central Government Bodies* are addressed below.

The regulations would apply equally to imports and locally manufactured products, and so do not discriminate against imports.

It is a particular concern of the GTBT that where technical regulations are required and relevant international standards exist or their completion is imminent, Members should use them, or the relevant parts of them, as a basis for their technical regulations.

The Australian Standard for power transformers, AS2374, is based on the corresponding IEC standards (the 60076 series). Therefore use of an Australian test standard is not inconsistent with international practice. However, given the narrowness of the transformer efficiency range, and the need to report energy losses results to four significant figures (the level of precision required in all transformer standards), it is important that all products be tested to the Australian Standard. The results of tests carried out to the IEC standard, or other national standards based on the IEC standard, would not be acceptable. In this respect, the proposed MEPS regime would be similar to the Canadian and Mexican transformer MEPS regimes, which also require testing to the national standards.

The GTBT urges GATT members to give positive consideration to accepting as equivalent the regulations of other Members, even if these regulations differ from their own, provided they are satisfied that these regulations adequately fulfil the objectives of their own regulations. There would be scope for accepting the results of tests conducted in other countries provided that AS2374 were used as the basis of testing (see preceding section). However, there is no scope for accepting products that may comply with MEPS in their country of origin unless they also comply with the Australian MEPS levels. The GATT does not prevent countries from setting MEPS levels according to their own requirements, costs and benefits.

In summary, the proposed electricity distribution transformer MEPS are not inconsistent with the GATT *Technical Barriers to Trade* Agreement.

Other Trade Issues

It is estimated that the value of transformer imports is about A$17-20 million per year. Analysis of 1999 import data indicates that there were 12 countries of origin for imports of liquid-filled transformers, and 21 countries of origin for dry type transformers, grouped by region as in Table 29.

Table 29 Origin of imported transformers, 1999

	Liquid filled		Dry type	
	Number	%	Number	%
Europe	129	72.5%	400	76.5%
North America	22	12.4%	1	0.2%
Asia	12	6.7%	48	9.2%
NZ	13	7.3%	7	1.3%
Other	2	1.1%	67	12.8%
Total	178	100.0%	523	100.0%

Derived from Ellis (2001)

About 75% of imports come from Europe, and with the North American imports this means that nearly 80% of imports would be from countries where transformer MEPS are under consideration (see Table 30). This does not necessarily mean that all exports from those countries will meet their domestic MEPS levels, since – unlike mass-produced household appliances - there is no economic barrier to building different models for different markets. It is also possible that lower-efficiency transformers from other countries that would previously have been exported to Europe or North America will increasingly be diverted to countries without MEPS. The adoption of transformer MEPS in Australia would eliminate this risk.

Table 30 Economies with Transformer Energy Efficiency Programs

Economy	Comp-arison label	MEPS
Australia	UC	UC
Brazil	M	V
European Union	M	UC
Canada	M	M 2002
Mexico		M 1999
Chinese Taipei	V	
United States	V	UC

Source: CLASP (2001) M=Mandatory (with year of first effect) V=voluntary, U=Under Consideration.

TTMRA

Another trade issue is the Trans-Tasman Mutual Recognition Agreement (TTMRA). This states that any product that can be lawfully manufactured in or exported from either Australia or New Zealand may be lawfully sold in the other jurisdiction, unless an exemption is granted under the TTMRA legislation.

The New Zealand Government has endorsed the implementation of MEPS for a range of products, and Parliament has passed enabling legislation analogous to the legislation under which labelling and MEPS are implemented in Australian States and Territories (see Appendix 2). Although no regulations giving effect to MEPS for the targeted products have yet been passed, it is understood that a number of regulations including one requiring compliance with the current Australian MEPS levels for refrigerators and freezers, are imminent[9]. However, New Zealand does not currently have plans to implement MEPS for distribution transformers.

It would therefore be open for a New Zealand manufacturer to export to Australia NZ-made transformers that do not comply with the proposed MEPS. It would also be open for importers to bring non-complying products from their country of origin to New Zealand and then re-export them to Australia to avoid MEPS. However, this would add substantially to shipping costs: where re-export occurs now it is generally in the other direction because of the relative size of the markets.

Therefore it is concluded that the chance of the MEPS regime being avoided via the provisions of the TTMRA are small. Nevertheless this is a source of commercial risk to those suppliers who comply, and it would clearly be advantageous for suppliers in Australia for the transformer MEPS regimes in be harmonised. The costs and benefits from the viewpoint of transformer suppliers and buyers in New Zealand are beyond the scope of this RIS.

4.3 Targeted and Voluntary MEPS

The provisions of the proposed revision of AS2374 that would be made mandatory by the proposed regulation are reviewed below, to determine whether they are in fact necessary to achieve the objectives of the regulation. If this is not the case, the proposed regulation would need to be targeted more narrowly to avoid introducing unnecessary requirements.

Registration

Section 6.1 of the proposed Standard states:

> *Declared Efficiency and Registration*
>
> Transformers within the scope of AS2374.1.2 (excepting exclusions) shall be registered for minimum energy performance standards (MEPS). Where the

[9] Personal communication, EECA, September 2001.

> relevant regulatory authority requires, each transformer family [shall] have MEPS registration by way of an application, with the content shown in Appendix A of this standard. To register, contact the relevant state regulatory authority.

Appendix B sets out the required format for submitting an application for registration for MEPS where a test on the unit has been undertaken to AS 2374.1 or AS 2735.

It might be feasible for suppliers to satisfy themselves that their transformers meet the MEPS provisions in the Standard, but not notify or register that information with any party. However, the administration of the appliance and equipment labelling and MEPS program has historically been based on State-level registration. A product for which mandatory energy labelling or MEPS is required can only be lawfully sold in a State or Territory if an energy label and/or test report is registered for it in that or another State or Territory. All jurisdictions recognise each other's registrations. NSW, Victoria, Queensland and SA maintain an active registration capability, but the other States and Territories do not. The fees are fairly modest: eg in NSW, $150 for registration and $50 for transfer of registration to a new supplier. Registrations last for 5 years, and are renewable.

Applications for registration must be accompanied by copies of the energy test results. This provides some initial quality control over the testing, and errors are often picked up at this stage.

These provisions increase the likelihood that suppliers will test their products accurately and ensure the veracity of statements about efficiency. There have been some instances of "compliance shopping" where some suppliers have registered appliances in States with apparently lower standards of initial scrutiny, but if problems are detected in check testing, the other States apply pressure to withdraw or modify the registration.

Compliance under a self-certification regime is not likely to be as high as under a registration regime. The possibility of model deregistration is a powerful sanction against a supplier, and has been found in practice to promote compliance.

Another area where registration has clear advantages is in the ability of regulators to support public information programs. The Australian Greenhouse Office's www.energyrating.gov.au website has a complete list of labelled household appliances, taken from the State registers, to assist consumers. By contrast, prior to the adoption of mandatory product registration for electric motors, registration for the Australian Motor Systems Challenge website was voluntary, and covered only about a third of the market.

With complete product information, the AGO is also able to carry out annual tracking surveys which match sales to registrations to allow calculation of sales-weighted energy efficiency trends. These data are used for purposes such as cost-benefit modelling of enhanced MEPS levels. Without registration, the responsible authority would not even necessarily know about the existence of a product unless it was brought to its attention.

On balance, the requirement for mandatory registration of transformer test data is not onerous for suppliers, and is of considerable value for administration of the regulation and for obtaining information for consumers which may not otherwise be accessible.

Labelling and Marking

Section 6.1 of the proposed Standard continues:

> The transformer manufacturer shall also declare the power efficiency on the manufacturer's official test certificate. The test results shall be retained by the manufacturer for five years. The transformer rating plate shall contain a statement that the transformer complies with AS2374.1.2.

This requirement combines a form of energy labelling with a measure intended to enhance compliance. Since type testing would be required in any case, the mandatory declaration of the information to the user by way of a certificate involves negligible cost.

In the transformer industry, it is common practice to test all units, so if the test certificate relates to the specific unit then the energy efficiency stated could relate to the specific unit. The proposed provision would not make it mandatory to test every unit, only to include a value for power efficiency that is based on an AS2374 test of either the type *or* the unit.

The statement on the rating plate that the transformer complies with AS2374.1.2 (with the year of the standard being the version in force at the time of manufacture or import) is a form of permanent marking to the effect that the transformer meets the MEPS levels in the proposed Standard. This form of compliance marking has long been used in the Canadian MEPS program, and has been found to enhance compliance by requiring the supplier to make a statement that is subject to trade practices as well as energy efficiency legislation (CLASP 2001).

High Efficiency Designation

In some energy equipment and appliance markets, suppliers have begun to designate some models or model ranges as "high efficiency" (HE) to attract those buyers who place greater value on operating costs in their purchase. Such models typically command a premium in the market.

However, it has been observed that where there are no generally accepted criteria for designating a product as HE, suppliers will adopt the criteria which best suit their own products. In the electric motors market, for example, the criteria varied so widely that some suppliers' "High Efficiency" models were less efficient than others' standard efficiency models. This meant thatmotor buyers had no consistent means of identifying true HE motors. Therefore it was decided to adopt a standard set of HE criteria at the same time as introducing MEPS (GWA 2000a).

There is no additional cost involved for suppliers, since they would have to test for MEPS compliance in any case. Furthermore, there is no obligation on any supplier to designate a product as "High Efficiency", even if it meets the criteria.

Ellis (2001) does not report a tendency to use the HE designation as a selling point in the transformer market, or indeed to misuse it as was the case in the motors market. Consequently the immediate benefits of adoption of mandatory HE criteria are not clear. However, there is no cost or disadvantage in adopting such criteria, and this could forestall the type of confusion that became evident in the electric motor market.

The adoption of consistent HE criteria will also assist the operation of the programs recommended by Ellis (2001): to make private transformer buyers more energy-aware, and to assist them to select transformers with the lowest lifetime cost. If buyers have a quick way to narrow their search criteria by selecting the "HE" category, rather than searching through lists of models along a continuous efficiency band, they are more likely to follow the process through.

A further use of the HE criterion is as an early indicator of MEPS levels that may possibly be adopted in future, subject of course to future cost-benefit analysis and RIS. It is understood that the regulators and industry representatives who prepared the proposed AS2374 selected the HE levels to correspond to the MEPS levels under consideration, but not yet implemented in the USA and Europe. If these are adopted, then they would form the benchmark for World's best practice at such time as the levels of Australian MEPS (if adopted) were reconsidered.

The publication of these HE levels at this stage would not imply any undertaking to review MEPS levels, nor would they ensure that in the event of a review the HE levels would necessarily be the new MEPS level.

Voluntary MEPS

Under a voluntary MEPS regime, transformer suppliers would incur the costs of changing their model range to eliminate less efficient models and/or introduce more efficient models sooner than they would otherwise have done.

Suppliers would presumably only take such action if there were commercial incentive for them to do so. Such incentive might perhaps come from the industry association to which suppliers belong (in this case, AEEMA). If all suppliers belonged to the association, suppliers considered membership of the association a commercial advantage, and the association perceived adoption of MEPS to be in the collective interest of all suppliers, it may be feasible for the association to urge or require its members to adopt some level of MEPS. These conditions do not appear to be present in the transformer industry.

Alternatively, incentives for voluntary adoption of MEPS might conceivably come from customers themselves. This has historically been the case with utility buyers of transformers, who have maintained a certain level of energy efficiency through application of their purchase criteria, some of which have been adopted by the ESAA.

The restructuring of the electricity supply industry is however discouraging utility buyers from their previous focus on life-cycle cost.

The State regulations governing electricity distributors could help to create a new set of incentives for retailers to take due account of efficiency in their transformer purchases, but there are no signs that this is happening. If such incentives were created, transformer suppliers would need to be assured of a high level of uniformity in the consequent purchasing requirements of distributors in all jurisdictions before committing themselves to a voluntary MEPS level.

The private transformer market, which is largely driven by first cost considerations, is even less conducive to the adoption of voluntary MEPS than is the utilities market. Since this group of buyers gives energy efficiency a low priority, a proprietary "MEPS compliance mark", or use of the Standards Australia compliance mark, would have little value unless it were very heavily promoted.

There have been instances of successful introduction of compliance marks with the support of government or other agencies. The US Environment Protection Agency introduced the *Energy Star* label, initially for office equipment, in the early 1990s. The label now has high recognition in the USA and low to moderate recognition in Australia (GWA et al 1996). Most office equipment suppliers have products that qualify for the label. However, the greatest force for compliance was the decision of the US Government, the single largest corporate purchaser of office equipment in the world, to give tender preference to qualifying products, so establishing a form of "Government MEPS". This is clearly only feasible for products where government represents a large proportion of the market. This is not the case with the transformer market in Australia.

There is no example of a successful voluntary MEPS program for transformers anywhere in the world, and there is no reason to believe that voluntary MEPS would be effective in Australia. On the contrary, it is likely that compliance would be low.[10]

In short, it appears that:

- The chances of a successful voluntary implementation of MEPS for electricity distribution transformers in Australia appears remote; but
- if a voluntary MEPS program could be implemented successfully, the ultimate outcome for competition and consumer choice may be equal to a mandatory MEPS regime, and at lower cost.

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[10] While energy cost savings under a voluntary MEPS scenario would be lower than in a mandatory one, average product costs should also be lower, so long as consumers were still free to prefer less efficient and less costly products. However, the product range and the extent of competition in the market may ultimately be no different under a mandatory or a (successful) voluntary regime. If a high level of voluntary compliance were achieved, suppliers may rationalise their product ranges and reduce inventory costs by withdrawing non-compliant sub-MEPS models in any case. This occurred with the quasi-voluntary WaterMark labelling program for electric water heaters in NZ (Energetics and GWA, 1994).

5. Consultation

COAG Guidelines:

- ***Consultation:*** *a RIS must outline who has been or will be consulted, and who will be affected by the proposed action. On a case by case basis, this may involve consultation between departments, with interest groups, with other levels of government and with the community generally.*
- ***Review:*** *there should be consideration of how the regulation will be monitored for amendment or removal. Increasingly, sunset provisions are regarded as an appropriate way of ensuring regulatory action remains justified in changing circumstances.*

5.1 Consultations

The issues related to MEPS for distribution transformers have received considerable exposure over the past years. The possibility of market intervention to increase the energy efficiency of transformers was first raised in 1994 (Energetics and GWA 1994).

In 1999, the development of strategies to improve the energy efficiency of distribution transformers was listed as a medium priority program by the National Appliance and Equipment Energy Efficiency Committee in 1999 (NAEEEC 1999). The priority was raised to "high" in 2001 (NAEEEP 2001b).

The Steering Group on Electricity Distribution Transformers, established in 2000, Standards Working Group, which endorsed the proposed MEPS levels in October 2000 after a year of consultation and research, is itself a consultative body since it involves suppliers, purchasers, industry associations and regulators

Chronology of Reports and Consultations

1994	Distribution transformers identified as product types suitable for MEPS, in Energetics and GWA (1994)
1999	Energy efficiency measures for distribution transformers included in NAEEEP work program
2000	AGO establishes Steering Group on Electricity Distribution Transformers; commissions market study
March 2001	Market and technology study completed (Ellis 2001).
October 2001	Standards Australia Committee EL008 endorses the proposed MEPS levels and issues them as a draft Standard

Proposed consultations

The following further consultations are planned in early 2002.

- AGO will send out copies of this draft RIS to known interested parties, advertise its availability, and in February hold public meetings in Sydney and Melbourne, at which the consultant will make presentations.

- Written comments will be received up to a date to be nominated.

- The consultant will review and address written comments received, propose responses, discuss them with the AGO and revise the final RIS as agreed.

5.2 Comments

Comments received prior to publication of draft RIS

Some comments from utility personnel were received during the course of preparing this RIS. Apart from detailed technical comments on the text of the draft Standard (which the utility concerned has passed to ESAA and the AGO) the major concern was the risk that MEPS-complying transformers could be too large or too heavy for existing enclosures and poles.

It is understood that the Steering Group considered this matter, and came to the view that there are already sufficient MEPS-compliant models of various configurations on the market so that this problem is unlikely to arise. Further, the proposed MEPS would apply to new transformers only, so as a last resort in a difficult installation there would be an option of refurbishing the existing transformer, or one like it.

Comments on draft RIS

[This section will address comments received on the draft RIS]

6. Evaluation and Recommendations

COAG Guidelines:

- ***Evaluation:*** *there should be an evaluation of the relative impacts of the proposal and any alternatives, to show that the desired policy objective cannot be achieved at a lower cost to business and the community at large.*

6.1 Assessment

The following alternative options have been considered in the RIS:

1. Status quo (termed business as usual, or BAU);

2. The proposed regulation (mandatory MEPS) which adopts all the requirements contained in the proposed new part of Australia Standard AS2374-1-2 2001: *Power Transformers: minimum energy performance standards for distribution transformers*;

3. An alternative regulation which only adopts those parts of the Standard that are essential to satisfy regulatory energy objectives (targeted regulatory MEPS);

4. Voluntary MEPS, where minimum energy efficiency levels for distribution transformers would be made publicly available, andindustry is encouraged, but not compelled to adhere to the proposed levels;

5. Another regulatory option involving a levy imposed upon inefficient equipment to fund programs to redress the greenhouse impact of equipment energy use;

6. A levy on electricity reflecting the impact it has on greenhouse gas emissions.

A summary assessment of the six alternatives considered in this RIS against the objectives of the mandatory MEPS option is given in

Reduce greenhouse emissions below business as usual

The mandatory MEPS option is the only one for which the extent of likely reduction can be quantified, and the one where reductions have the highest probability of occurring.

Address market failures

The private electricity distribution transformer market has been characterised by an increasing emphasis on first cost and reduced concerns with operating cost, largely because of the split incentives between purchasers of equipment on the one hand, and owners/operators and users on the other.

The utility market has historically been more concerned with minimising lifetime owning costs, but changes in the structure of the electricity industry are changing the basis of distribution system asset management, in a way that is less conducive to the selection of energy efficient transformers.

The mandatory MEPS option would address by forcing investment in more efficient products.

An efficiency-related levy on appliances could address the market failure by making more efficient products cheaper than less efficient ones. If such an option were to be implemented – and there is no obvious legal or taxation mechanism - the cost to suppliers would be no lower, and the administrative costs higher than under the proposed regulations.

An emissions-related levy on electricity prices would be less effective than the efficiency-related levy on appliances, since it addresses running costs rather than capital costs. It would also have economy-wide implications that are beyond the scope of the present analysis. Given that any decision to implement such a levy would need to be taken at the highest levels of Government, it is not considered a direct alternative to the proposed regulation.

Address information failures

One consequence of the mandatory MEPS option would be to:

- introduce consistency in the designation of models as "High Efficiency"; and
- place reliable data on the energy efficiency of every transformer in the public domain for the first time.

Buyers could access this data via the State government registers of products (assuming these are made public, as is now the case of household appliances). Some of the other options could also achieve this objective, though not necessarily as efficiently or as effectively.

Minimise negative impact on product quality

None of the options are expected to have any significant effect on product quality or function (ie apart from energy-efficiency). In fact, greater transformer energy efficiency should lead to lower heat gain in operation, and hence lower failure rates and higher overall network reliability.

Minimise negative impacts on suppliers

The mandatory MEPS option would clearly require suppliers to withdraw, replace or improve non-complying products. The other options would have lower costs for suppliers to the extent that they were less effective in bringing about these outcomes.

Table 31 Assessment of alternatives against objectives

Objective and assessment criteria	A. Status quo	B. Mandatory MEPS	C. Targeted Regulatory MEPS[(a)]	D. Voluntary MEPS
Objective: Reduce emissions below BAU	No	Significant reduction projected	Retention of supporting features in standard contributes to this objective	Extent of reduction uncertain – most likely far less than under proposed regulation
Address market failures	No	Yes – projected to reduce lifetime costs of distribution transformers	Retention of supporting features in standard contributes to this objective	May not fully address market failure; relies on raising consumer and supplier concern with energy
Address information failures	No	Potentially – makes comparable data available, relies on regulators to disseminate	Retention of HE and registration requirements contribute to this objective	No effect
Minimise negative impact on product quality	No effect	No negative effect, possibly positive effect. Could lead to some additional costs for replacement transformers	As for mandatory MEPS	No effect
Minimise negative impacts on suppliers	No effect	Most suppliers will have some non-complying models, so costs are fairly widely distributed. Costs of improving products likely to be moderate. Range of supplier responses possible.	Cost impacts of other elements are negligible.	Would minimise supplier costs
Other issues				Voluntary MEPS have not been tried/introduced successfully anywhere in the world

(a) "Targeting" implies omission from regulation of the following elements: High Efficiency Transformer criteria, disclosu
product information with regulatory authority.

Costs and Benefits

The implementation of the proposed MEPS would lead to a lower lifetime operating cost for both utility-owned and privately-owned transformers than would otherwise be the case.

Table 32 Summary of projected impacts of transformer MEPS

Product and proposed MEPS implementation	**NPV of costs $M(a)**	**NPV of benefits $M(a)**	**Net benefits $M(a)**	**benefits /costs**	**CO_2-e saving Mt (b)**
Proposed 2003 MEPS for distribution transformers	343	497	154	1.4	0.87

(a) Net Present Value of costs and benefits compared with BAU case, at 10% discount rate, under MSE scenario – see Table 23 and Table 27. (b) Average annual reduction below BAU during Kyoto Protocol commitment period. Calculated using marginal greenhouse coefficients (Appendix 3).

Matching World's Best Practice

The proposed MEPS levels are consistent with the principle adopted by ANZMEC – matching but not exceeding the most stringent MEPS levels in force elsewhere. They are roughly equivalent to the Canadian MEPS levels that are to take effect in January 2002, so there would still be a time lag of one year.

Conclusions [DRAFT]

After consideration of the mandatory MEPS option and the provisions of the Standard in this RIS, it is concluded that:

1. The mandatory MEPS option is likely to be effective in meeting its stated objectives

2. None of the alternatives examined appear as effective in meeting all objectives, some would be completely ineffective with regard to some objectives, and some appear to be far more difficult or costly to implement.

3. The projected monetary benefits of the mandatory MEPS option appear to exceed the projected costs by a ratio of about 1.4 to 1, without assigning monetary value to the reductions in CO_2 emissions that are likely to occur.

4. If implemented in January 2003, the greenhouse gas reductions from the electricity saved by the proposed MEPS regulations could be as high as 0.87 Mt CO_2-e per annum by 2010.

5. The cost-benefit ratio for privately-owned transformers is significantly higher than for utility-owned transformers.

6. Given that the proposed MEPS levels were issued in a draft Australian Standard in October 2001, and that transformers are generally built to order, the proposed regulation could be implemented as early as 1 January 2003.

6.2 Recommendations

It is recommended that:

1. States and Territories implement the proposed mandatory minimum energy performance standards.

2. The mode of implementation be through amendment of the existing regulations governing appliance energy labelling and MEPS in each State and Territory.

3. The amendments should:
   – add electricity distribution transformers to the schedule of products for which minimum energy performance standards are required, and refer to the MEPS levels in Tables 1 and 2 of AS2374.1.2 (proposed part);
   – add electricity distribution transformers to the schedule of products requiring energy labelling, so that any transformer for which the claim of "high efficiency" or "energy efficient" are made must meet the energy efficiency criteria in Tables 3 and 4 of AS2374.1.2 (proposed part);
   – require registration of models, so invoking Appendix A of the proposed Standard; and
   – allow transformers manufactured or imported prior to the date of effect of the regulations to continue to be lawfully sold indefinitely.

4. Governments make the register of electricity distribution transformer characteristics publicly accessible, so prospective purchasers can compare their energy efficiencies.

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7. Review

An increase in the stringency of electricity distribution transformer MEPS would be implemented under the same State and Territory regulations as existing MEPS, and so be subject to the same sunset provisions, if any. Victoria and SA have general sunset provisions applying to their labelling/MEPS regulations as a whole, while NSW has sunset provisions applying to the inclusion of some (but not all) items scheduled.

Once the States and Territories agree to mandatory requirements, their removal in any one jurisdictions would undermine the effect in all other jurisdictions, because of the Mutual Recognition agreements between the States and Territories (GWA 1999a). Under the cooperative arrangements for the management of the National Appliance and Equipment Energy Efficiency Program, States advise and consult when the sunset of any of the provisions is impending. This gives the opportunity for fresh cost-benefit analyses to be undertaken.

The Australian Standards called up in State and Territory labelling MEPS regulations are also subject to regular review. The arrangements between the Commonwealth, State and Territory governments and Standards Australia provide that the revision of any Standards called up in energy labelling and MEPS regulations are subject to the approval of the governments.

Therefore any proposal to make the MEPS levels in Australia Standard AS2374-1-2 2001: *Power Transformers: minimum energy performance standards for distribution transformers* either more or less stringent would need the cooperation of both the Standards bodies and of the regulators.

NAEEEC has adopted the principles that there should be a MEPS "stability period" of at least 4 years, and that a cost-benefit analysis would be undertaken before any revisions are proposed (NAEEEC 1999). The earliest possible timing of any change to the MEPS regulations discussed in this RIS would therefore depend on date of their implementation. If they are implemented on 1 January 2003, the earliest possible revision would be January 2007.

It would be necessary to commence studies well in advance of any proposed revision, so that adequate notice could be given to industry in the event that a change were justified.

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Appendix 1 Transformer Technology

Transformer technology

The main components of a transformer are:

- a core made of magnetically permeable material;
- two sets of conductors, or windings, typically made of a low resistance material such as aluminium or copper;
- an insulating medium such as oil ("liquid type") or air ("dry-type") surrounding the core and conductors. This medium must conduct heat away from the core and electrically insulate the transformer;
- connectors and switches to link the transformer to the network and to isolate it when necessary; and
- for transformers mounted in accessible areas, a casing to physically protect the transformer and to act as a barrier to human and animal contact. The casing may be a metal kiosk (typical of "pad-mount" transformers installed at ground level in public areas). Many transformers are mounted high on distribution poles ("pole mount") and rely on inaccessibility for protection.

Since smaller distribution transformers do not generate as much heat, a higher proportion of these tend to be dry-type. Dry types are also less flammable, and are therefore often selected for use when they must be located in confined spaces on a customer's premises. A higher proportion of privately-owned than utility-owned transformers is of the dry type

Energy efficiency

Loading

Alternating current in the primary winding induces a magnetic flux in the core, which in turn induces a voltage in the secondary winding. A voltage step-down results from the exchange of voltage for current, and its magnitude is determined by the ratio of turns in the primary and secondary windings. A transformer with 50 primary turns and five secondary turns would step the voltage down by a factor of 10, for example from 13,500 volts to 1,350 volts. The current in the secondary windings would be nearly 10 times as high as in the primary windings, so the total power would be the same, except for energy losses in the core and the windings.

Core losses (also called "no load" losses) remain constant so long as the transformer is connected to the AC supply ("energised"), while winding losses increase with the square of the load. A typical transformer design will seek to have core and load losses about equal when the unit is loaded to half its rated capacity, and the total energy losses at that point would be less than 2%. Figure 29 illustrates the loss curve for a typical 100 kVA transformer with 2% losses at half load, operating with a power factor of 1.0. At half load the input power is 50 kW, the core losses 0.5 kW and the winding losses also 0.5 kW, giving an efficiency of (50-1)/50 = 98%. This point, where core and winding losses are equal, represents the optimum efficiency point.

Efficiency declines as loading shifts from the optimum efficiency point, falling off more rapidly with low loadings than with high loadings (Figure 30). At 100% loading, for example, efficiency is (100-2.5)/100 = 97.5%. At 200% loading, which transformers often attain in actual use, the efficiency is (200–8.5)/200 = 95.8%. At 20% loading, efficiency is (20-0.58)/20 = 97.1%.

Figure 29 Loss curve for typical 100 kVA Transformer

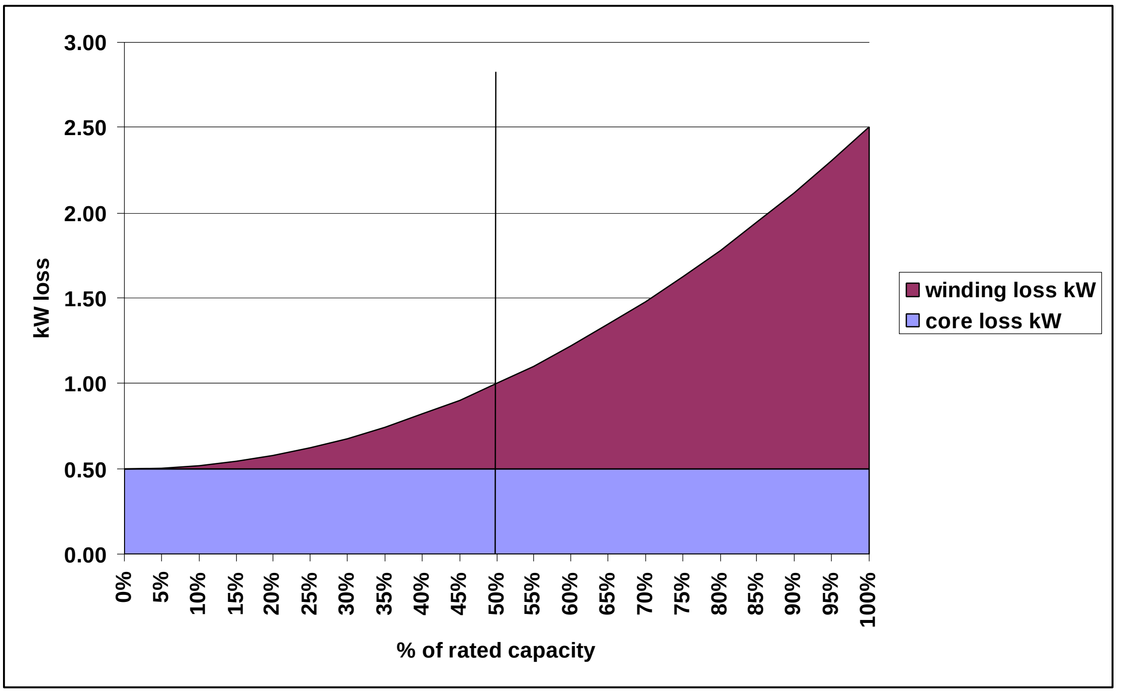
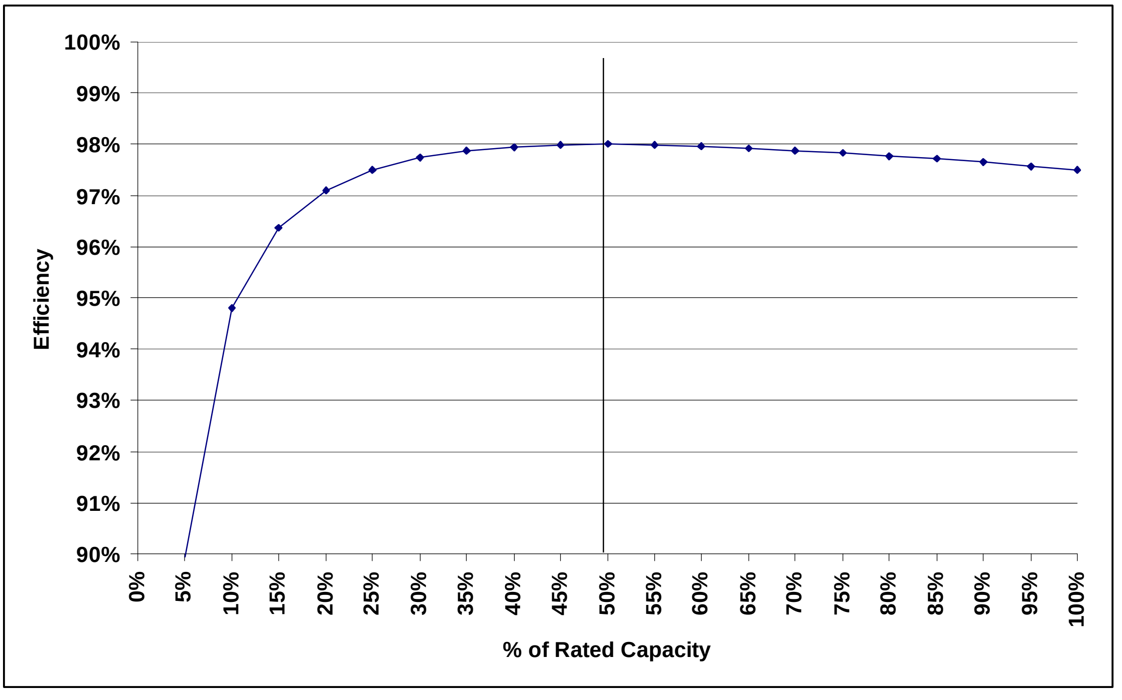


Figure 30 Efficiency curve for typical transformer



In determining the efficency of a given transformer, or group of transformers, it is therefore necessary to specify the point in the load curve at which the efficiency is being measured.

The actual efficiency of transformers in the field depends critically on how heavily they are loaded, or their "utilisation factor".[11] Transformers need to be sized to cope with expected peak loads, rather than average loads, and therefore where there is a large disparity between these two, the utilisation factor will be low. For example, distribution transformers serving primarily residential loads regularly carry average loads that are only 15% to 20% of the transformer's rated capacity but also must be able to support peak morning and evening loads, which may be 200% of rated load.

Because of the wide gap between peak and non-peak loads, and the relatively limited amount of time that the transformer is peak-loaded, average transformer loading tends to be fairly low. In this case, total losses may be mainly attributed to core losses. Larger distribution transformers, used more often in transforming power for commercial or industrial customers, tend to be loaded at higher average levels over the course of the year. Transformers that serve businesses operating from 9:00 am to 5:00 pm, for example, typically experience a consistent and relatively higher load throughout the day. In this circumstance, it is likely that load losses will make the major contribution to total losses.

In addition, transformer loading patterns tend to change over time. Homeowners may accumulate more appliances and equipment (or new houses built in the area), or businesses may expand and consequently increase the load on the transformer. Generally, utilities estimate load growth when sizing and purchasing transformers. In the US it has been calculated that, on average, utilities size single-phase transformers so that transformer peak load at installation is approximately 88 percent of its capacity, and 157 percent of capacity at the end of its service life (Ellis 2001).

Physical Design

Of course, there are many physical attributes and design characteristics which influence losses, so two transformers of the same rated capacity can have different losses and hence efficiencies at the same point in their load curves. Many different distribution transformer designs are available, depending on the loading patterns and needs of the end-user. Transformer engineers modify transformer design and vary material depending upon circumstances.

Transformer design includes variations of:

- the material used for the core;
- the material used for the windings;
- the material that insulates the core and the winding; and
- the number of phases of the current that passes through the transformer.

The following sections describe these factors in more detail.

[11] The "utilisation factor" is the ratio of actual energy throughput to the energy throughput if the transformers were operating at their full rated capacity at all times.

Core Material

Transformer cores are usually made of grain-oriented silicon steel, which comes in a variety of grades, each with its own conductive and efficiency characteristics. Amorphous metal, a more costly but highly efficient material, can significantly reduce core losses, but its manufacturing and structural limitations restrict its use to certain transformer configurations. Constructing the core of laminated sheets, insulated from each other, also reduces losses, but adds to the cost, weight and volume of the transformer.

Since the majority of transformer losses at low load levels are due to core inefficiencies, much of the research on reducing transformer losses has concentrated on building more efficient cores. Core losses result from cyclic changes in the magnetic state of iron, and "eddy-current" losses caused by the flow of small currents in the iron. Core losses can be reduced by improving the magnetic permeability of the core material or by using a core material that offers less magnetic resistance.

Considerable progress in reducing core losses has been made over the past twenty years, primarily through material improvements. In the early 1970s, manufacturers introduced more efficient silicon-steels. The four main grades of silicon-steel used in transformers are M2, M3, M4, and M6 (decreasing in efficiency). Differences are due mainly to the chemical composition and the rolling techniques used in manufacture of the core. The increased domestic availability of higher grades of silicon-steel (M2 and M3) and new manufacturing processes has led to the improved efficiency of silicon-steel distribution transformers.

Amorphous metal, a highly efficient material used in transformer cores, possesses good magnetic properties, low inherent magnetic resistance losses, and high resistivity. Due to its ability to be constructed into very thin sheets, "eddy-current" losses are significantly reduced. Amorphous metals have been found to reduce core losses by as much as 70%. However, the cost of transformers with more efficient cores increases due to the following factors:

- increasing core efficiency requires the use of more core material;
- the larger core size associated with the energy-efficient transformer necessitates the use of additional winding material, generally resulting in lower winding efficiencies and other costs;
- the thin lamination of amorphous metal tends to make the core material more difficult to handle; and
- larger and heavier transformers may encounter specific problems in replacement applications, where the new transformer must fit into an existing physical enclosure or meet the weight-carrying limitations of an existing pole.

Winding Material

Generally, copper and aluminium are used for transformer windings. As with silicon steel, these materials are available in a variety of grades and thicknesses, each with their own efficiency characteristics. The types of windings chosen by the transformer designer are also dependent on the cost of a specific utility's losses and on assumed transformer loading levels.

Winding losses, or load-losses, arise from the conducting material's inherent resistance to the flow of electrical current. Winding losses increase with the square of the transformer load. Efficiency gains can be achieved by using materials with lower resistivity or greater diameters. For example, distribution transformer coils made with low resistivity conductors, such as copper, can have considerably lower load losses than those made with other materials. However, low resistivity conductors often cost more than other conducting materials.

Insulating Material

The majority of utility distribution transformers are liquid filled. The non-conducting liquid (mineral oil is most commonly used) serves to electrically insulate and cool the transformer. As the core temperature of the transformer rises, the efficiency decreases, so an efficient cooling method improves performance. Typically, transformers perform best at temperatures within 55ºC above the ambient temperature. Liquid-filled transformers transfer heat more efficiently than dry-type transformers and are generally preferred for larger applications. Most liquids used in transformers now are non-flammable.

Phase

Transformers may be designed to step down a single alternating current from one voltage to another, called single-phase transformers, or contain three primary and three secondary windings and therefore provide the output in three phases. Three-phase transformers induce a more constant magnetic flux and output voltage necessary for motors, heating, ventilating, air-conditioning (HVAC) and other large equipment. Technically, the three-phase transformer is equally efficient to the single-phase transformer.

Appendix 2 Extract from Typical State Regulations

NSW Electricity Safety Act (1945)
Electricity Safety (Equipment Efficiency) Regulation 1999

Part 2 Standards

5 Minimum standards

(1) An electrical article listed in Schedule 2 must comply with the performance criteria set out in Part 2 of the relevant standard when tested, in accordance with Part 1 of that standard, by an accredited laboratory.

(2) An electrical article listed in Schedule 3 must comply with the energy efficiency requirements set out in the relevant standard.

(3) In this clause, accredited laboratory means a laboratory:

(a) accredited by the National Association of Testing Authorities, or

(b) approved by the Corporation.

Part 4 Labelling of electrical articles

15 Electrical articles to be appropriately labelled when sold

(1) A person must not sell an electrical article listed in Schedule 2 unless an approved energy efficiency label is displayed on the article in accordance with Part 2 of the relevant standard. Maximum penalty: 20 penalty units.

(2) In the case of an air conditioner that is sold in a package, the approved energy efficiency label may instead be displayed on the package.

(3) This clause applies in respect of the sale of new articles, whether by wholesale or retail, but does not apply to the sale of second-hand articles.

SCHEDULE

(Clauses 7 and 19)

Item	Fee
For registration of an electrical article	$150
For transfer of registration of an electrical article	$50
For provision of an extract from the Register	$50

Schedule 2 Standards for electrical articles that require registration and labelling

Article: (Clause 5 (1))

Relevant standard:

Clothes washing machine Australian/New Zealand Standard, "Performance of household electrical appliances Clothes washing machines Part 1: Energy consumption and performance", AS/NZS 2040.1:1998, and Australian/New Zealand Standard, "Performance of household electrical appliances Clothes washing machines Part 2: Energy labelling requirements", AS/NZS 2040.2:1998.

Dishwasher Australian/New Zealand Standard, "Performance of household electrical appliances Dishwashers Part 1: Energy consumption and performance", AS/NZS 2007.1:1998, and Australian/New Zealand Standard, "Performance of household electrical appliances Dishwashers Part 2: Energy labelling requirements", AS/NZS 2007.2:1998.

Refrigerating appliance Australian/New Zealand Standard, "Performance of household electrical appliances Refrigerating appliances Part 1: Energy consumption and performance", AS/NZS 4474.1:1997, and Australian/New Zealand Standard, "Performance of household electrical appliances Refrigerating appliances Part 2: Energy labelling and minimum energy performance standard requirements", AS/NZS 4474.2:1997.

Room airconditioner Australian/New Zealand Standard, "Performance of household electrical appliances Room airconditioners Part 1.1: Non-ducted airconditioners and heat pumps Testing and rating for performance", AS/NZS 3823.1.1:1998, and Australian/New Zealand Standard, "Performance of household electrical appliances Room airconditioners Part 2: Energy labelling requirements", AS/NZS 3823.2:1998.

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Schedule 3 Standards for electrical articles that require registration only

Article: (Clause 5 (2))

Relevant standard:

Storage water heater unvented without an attached feed tank Australian Standard, "Storage water heaters Part 1: General requirements", AS 1056.1:1991, Clause 2.4 "Thermal Insulation".

Appendix 3 Greenhouse Gas Emissions

There are two ways of calculating the greenhouse gas intensity of electricity systems:

- average intensity: total annual emissions divided by total annaual electricity produced, sent out, or delivered; and

- marginal intensity: the additional emissions that would be created (or avoided) by adding or saving an additional kWh.

Both intensity measures vary over time, but the marginal intensity takes into account the merit order of generators. In Australia, the base electricity load is met by coal-fired power stations (which are the cheapest – so long as greenhouse emissions costs are externalised - and the most CO_2-intensive) while intermediate and peak loads are met by more expensive but less CO_2-intensive natural gas and zero-intensity hydro. Thus a measure that reduces overall electricity demand – such as MEPS - will tend to reduce the operation of power stations that are less CO_2-intensive than the average; ie the CO_2-intensity per kWh avoided should be calculated using the marginal coefficients.

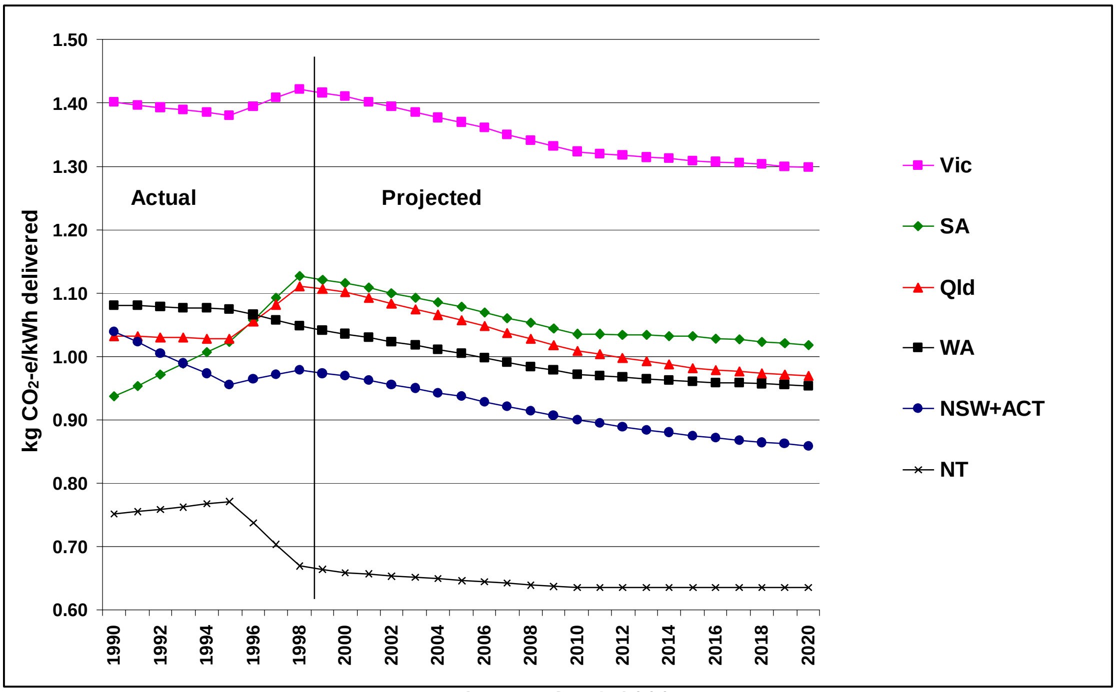
However, when estimating the emissions associated with existing electricity uses which are more or less continuous (as distinct from time-controlled loads such as off-peak water heating, or seasonal loads such as airconditioning) any ranking of loads in priority order would be arbitrary. Therefore, it is more appropriate to use average rather than marginal coefficients when estimating the share of national emissions associated with electricity distribution transformers.

The average electricity system CO_2–e intensities used in the RIS, illustrated in Figure 31, are taken from GWA (2000a). The intensities are projected to decline due to an eventual preference for natural gas, and the impacts of two Commonwealth initiatives, the “2% renewables” measure and power station efficiency standards.

The marginal electricity system CO_2–e intensities used in the RIS, illustrated in Figure 32 were supplied by the AGO (personal communication, April 2000). These embody specific assumptions about the scheduling of future generation and transmissions projects. For example, the projected completion of Basslink in 2003 would harmonise the marginal coefficient for Tasmania and Victoria, and both would converge to the intensity of natural gas generation.

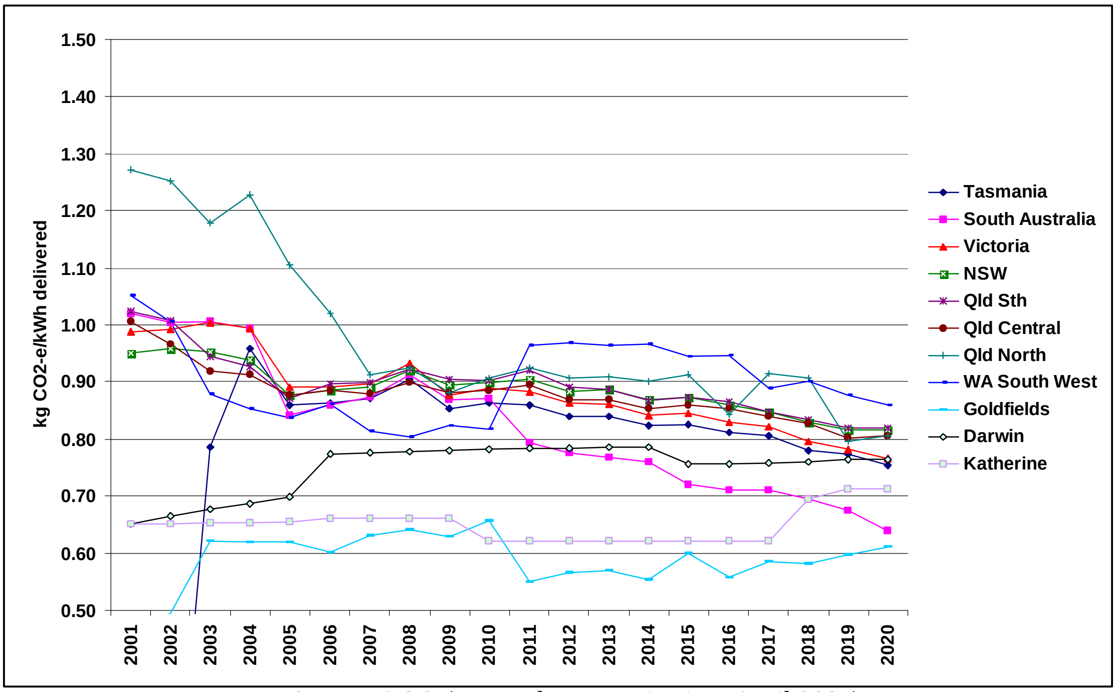
In order to derive a single marginal State coefficient for household electricity use, the three Queensland zone coefficients supplied by AGO were weighted on the basis of population in 200 as follows: 80% south Queensland, 8% central Queensland, 12% north Queensland. The WA coefficient was weighted 98% southwest WA and 2% Goldfields. The NT coefficient was weighted 90% Darwin and 10% Katherine. The weighted coefficients are illustrated in Figure 33.

Figure 31 Projected average emissions-intensity of electricity supply by State, 1990-2020



Source: GWA 2000a

Figure 32 Projected marginal emissions-intensity of electricity supply by State (sub zones), 2001-2020



Source: AGO (personal communication, April 2001)

Figure 33 Projected marginal emissions-intensity of electricity supply by State (weighted averages), 2000-2020