Product Profile: Commercial Lighting

Fluorescent Lamps, Ballasts and Commercial Luminaires in Australia and New Zealand

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Contents

CONTENTS III

EXECUTIVE SUMMARY 1

Background 1
The commercial lighting market 1
Energy consumption 1
Current MEPS and international programs 2
Policy options 2

1 INTRODUCTION 3

1.1 Purpose 3
1.2 Context 3
1.3 The problem 4
1.4 Where to from here 5
1.4.1 Consultation on this Product Profile 5
1.4.2 After consultation on this Product Profile 5
1.4.3 Commercial lighting Product Profile – key questions 5

2 PRODUCT DESCRIPTION 7

2.1 Fluorescent lamps 7
2.1.1 Linear fluorescent lamps 7
2.1.2 Circular and U-shaped fluorescent lamps 8
2.1.3 Non-integrated CFLs 8
2.2 T8-T5 adapters 9
2.3 Ballasts 9
2.4 Basic commercial luminaires 10
2.4.1 Troffers and battens 10
2.4.2 Recessed canisters 11

3 MARKET CHARACTERISTICS 12

3.1 Manufacturers, importers and suppliers 12
3.1.1 Channel to market – new build of commercial buildings 13
3.1.2 Channel to market –refit of commercial buildings 13
3.2 Stock and sales 14
3.2.1 Linear fluorescent lamps 14
3.2.2 T8 to T5 linear fluorescent adapters 16
3.2.3 Other fluorescent lamps 16
3.2.4 Ballasts 16
3.2.5 Luminaires 17
3.2.6 Projected trends 17

4 ENERGY CONSUMPTION AND ENERGY EFFICIENCY 19

4.1 Energy consumption 19
4.1.1 Fluorescent lamps 19
4.1.2 Ballasts 20
4.2 Energy efficiency 21
4.2.1 Linear fluorescent lamps 21
4.2.2 Other fluorescent lamps 23
4.2.3 Ballasts 25
4.2.4 T8-T5 adapters 28
4.2.5 Luminaires 29
4.2.6 Other opportunities to achieve energy savings 33

5 RELEVANT STANDARDS AND REGULATIONS IN AUSTRALIA AND NEW ZEALAND ... 34
5.1 Testing and MEPS/labelling ... 34
5.1.1 Current test methods and test laboratory capability ... 34
5.1.2 MEPS regulations impacting on energy and performance ... 35
5.1.3 Luminaires ... 37
5.2 Other regulations and policies impacting on energy ... 37
5.2.1 Interior lighting ... 37
5.2.2 Australia ... 37
5.2.3 New Zealand ... 38
5.3 ENERGY STAR ... 39
5.4 Incentive schemes ... 40
5.4.1 Australia ... 40
5.4.2 New Zealand ... 40
6 OVERSEAS ENERGY EFFICIENCY PROGRAMS ... 41
6.1 Test methods ... 41
6.2 Mandatory programs ... 42
6.2.1 Fluorescent lamps ... 42
6.2.2 Fluorescent Lamp Ballasts ... 44
6.2.3 Luminaires ... 46
6.3 Voluntary programs ... 47
6.3.1 USA ... 47
6.3.2 New Zealand ... 49
6.3.3 Germany ... 49
7 POLICY OPTIONS ... 50
7.1 No action ... 50
7.2 Update Australian and New Zealand test standards for fluorescent lamps and ballasts to recent International Electrotechnical Commission standards ... 51
7.3 Increase MEPS levels for linear fluorescent lamps or harmonise with international standards in 2-3 years 51
7.4 Introduce MEPS for circular fluorescent lamps in 2-3 years ... 61
7.5 Reduce mercury content in lamps to meet international requirements ... 61
7.6 Harmonise Australia and New Zealand MEPS for ballasts by increasing Australian MEPS requirements . 62
7.7 Align with European stage 3 requirements for ballasts in 2-3 years ... 62
7.8 Introduce a voluntary or mandatory MEPS level for commercial luminaires ... 64
7.9 Product labelling and education initiatives ... 65
7.9.1 Linear fluorescent lamps ... 65
7.9.2 Ballasts ... 66
7.10 Voluntary labelling ... 66
7.10.1 Luminaires ... 66
7.11 Information, education, behaviour and controls ... 66
7.12 Summary of options ... 68
7.13 Potential Energy Benefits ... 69
8 REFERENCES ... 70
APPENDIX A – FLUORESCENT LAMP ENERGY CONSUMPTION MODELLING AND ASSUMPTIONS ... 72
APPENDIX B – OVERSEAS PROGRAMS AND SPECIFICATIONS ... 74
Efficiency Programs ... 74
Specifications ... 79
APPENDIX C – OTHER OPTIONS CONSIDERED ... 91

LIST OF FIGURES

Figure 1. A linear fluorescent lamp, also known as double-capped or tubular fluorescent lamp. 7
Figure 2. A circular fluorescent lamp. 8
Figure 3. Non-integrated CFLs, electronic fluorescent lamp ballastand a magnetic fluorescent lamp ballast. 8
Figure 4. T8-T5 linear fluorescent adapter typical installation circuit 9
Figure 5. A T8-T5 adapter.. 9
Figure 6. An electronic ballast. 10
Figure 7. Recessed troffers with louvers to direct light output and a pendant batten with diffuser. 11
Figure 8. A recessed canister with two non-integrated CFLs. 11
Figure 9. ABS import data for fluorescent lamps, 1995 to 2013 15
Figure 10. Sales trends of linear fluorescent lamps in New Zealand 16
Figure 11. Sales trends of ballasts for fluorescent lamps in New Zealand 17
Figure 12. Projected mix of lighting technologies to be used for commercial (non-industrial) lighting purposes 18
Figure 13. Initial efficacy of fluorescent lamps registered in Australia and New Zealand, 2014. Australia/New Zealand linear fluorescent MEPS levels shown. 21
Figure 14. Initial efficacy of fluorescent lamps available worldwide including E3 registered product, 2014. Australia/New Zealand linear fluorescent MEPS levels overlaid. 22
Figure 15. Initial efficacy of fluorescent lamps available worldwide. Australia/New Zealand linear fluorescent MEPS levels overlaid. 22
Figure 16. Initial efficacy of non-integrated CFLs available in Australia and New Zealand. 24
Figure 17. Initial efficacy of circular fluorescent lamp available on the Australian and New Zealand market. 25
Figure 18. Linear fluorescent ballasts registered with the E3 Program 26
Figure 19. T8-T5 adapter efficacy using T5 lamps 28
Figure 20. Examples of T8 to T5 adapters 29
Figure 21. Linear fluorescent troffers LER versus luminaire lumens. 29
Figure 22. Linear fluorescent troffers LER versus power consumption. 30
Figure 23. Linear fluorescent battens LER versus luminaire lumens. 31
Figure 24. Linear fluorescent battens LER versus power consumption. 31
Figure 25. CFL can LER versus luminaire lumens. 32
Figure 26. CFL can LER versus power consumption. 32
Figure 27. Minimum and maximum rated initial efficacy of E3-registered linear fluorescent lamps 52
Figure 28. Percentage of all lamps incremental increases in initial efficacy levels of 1 lm/W steps 54
Figure 29. Percentage of Australian and New Zealand registered linear fluorescent lamps that would be retained if initial efficacy requirements were increased 54
Figure 30. International MEPS for T8 linear fluorescent lamps 56
Figure 31. International MEPS for T5-HE (High efficacy) linear fluorescent lamps 57
Figure 32. International MEPS for T5-HO (High output) linear fluorescent lamps. 57
Figure 33. Efficacy range and average of T8 linear fluorescent lamp models registered in Australia and New Zealand based on wattage, and the EU efficacy requirement. 58
Figure 34. Efficacy range and average of T5 linear fluorescent lamp models registered in Australia and New Zealand based on wattage, and the EU efficacy requirement for HE and HO. 58
Figure 35. Efficacy range of T8 fluorescent lamp models, displayed with China's MEPS levels. 59
Figure 36. Efficacy range of High Efficiency T5 fluorescent lamp models, displayed with China's MEPS levels 59
Figure 37. Efficacy range of High Output (HO) T5 fluorescent lamp models, displayed with China's MEPS levels. 60
Figure 38. Percentage of E3 registered linear fluorescent lamp models that would be removed from the market if the Chinese or European MEPS were adopted in Australia. 60
Figure 39. Comparison of ballast efficiency requirements in Australia/New Zealand and Europe for ballasts with EEI classification A2. 63
Figure 40. The mandatory label for fluorescent lamps sold in Korea. 75
Figure 41. Star rating label and performance measures for linear fluorescent lamps in India. 75
Figure 42. An example of the 'recognition-type' energy efficiency label which can be issued for electronic ballasts in Hong Kong. 77
Figure 43. An example of the voluntary Thailand Energy Efficiency Label No. 5 and the Japanese Energy Saving Label. 79

LIST OF TABLES

Table 1. The major of brands and number of models available on the Australian and New Zealand market for selected commercial lighting products. 12
Table 2. Linear fluorescent lamp characteristics in Australia and New Zealand 14
Table 3. Approximate sales split of fluorescent lamp technologies in residential and commercial settings 14
Table 4. Estimated market size of New Zealand commercial lighting in 2007 16
Table 5. Annual electricity consumption and percent enduse share of lighting in Australian commercial buildings 19
Table 6. Indoor lighting electricity consumption and end-use share by commercial building type in New Zealand 20
Table 7. Average fluorescent lamp characteristics and energy consumption. 20
Table 8. 10-year cost benefit analysis of a lamp upgrade options (Business user) 23
Table 9. Double-capped fluorescent lamp efficacy and mercury requirements. 35
Table 10. Ballast performance MEPS for linear fluorescent lamps in Australia and New Zealand, 2014. 36
Table 11. Building Code Australia maximum illuminated power densities for select spaces in commercial buildings, and corresponding AS 1680 lighting levels and lumens per watt 38
Table 12. Selected overseas linear fluorescent lamp test methods. 41
Table 13. Selected overseas fluorescent lamp ballast test methods. 42
Table 14. Energy efficiency classes for EU fluorescent lamps and an example layout of the European energy label 43
Table 15. ENERGY STAR requirements for directional commercial luminaires, downlight luminaires (recessed, surface, pendant, SSL downlight retrofits). 48
Table 16. ENERGY STAR requirements of fluorescent lamps (integrated CFL (GU24) and non-integrated CFL) for all luminaires. 48
Table 17. Cost analysis for replacement of T12 halophosphate fluorescent fittings with a) single 1150mm T5 fluorescent fitting and b) single 1450mm T5 52
Table 18. Initial efficacy requirements for incremental 1 lm/W stepped increase in MEPS for linear fluorescent lamps. 53
Table 19. Estimated energy savings from revised linear fluorescent lamp MEPS in Australia. 69
Table 19a. Estimated energy savings from revised linear fluorescent lamp MEPS in New Zealand. 69
Table 20. Comparison of lamp characteristics and cost benefits. 72
Table 21. Cost benefit analysis of swapping to high efficiency T5-HE from less efficient T12 and T8 lamp models. 73
Table 22. Linear and circular fluorescent lamp efficacy requirements as per EC No 245/2009. 79
Table 23. Single-capped fluorescent lamp efficacy requirements as per EC No 347/2010 amendment to EC No 245/2009. 80
Table 24. Deduction percentages for rated minimum efficacy values for fluorescent lamps with high CCT, high colour rendering (Ra) and/or second envelope. 81
Table 25. Lamp lumen maintenance factors and lamp survival factors for double-capped fluorescent lamps. 81
Table 26. EEI requirements for non-dimmable ballasts for fluorescent lamps, EC No 347/2010. 81
Table 27. EEI requirements for non-dimmable ballasts for fluorescent lamps not included in Table 26. 83
Table 28. EEI requirements for dimmable ballasts for fluorescent lamps, as per EC No 245/2009. 83
Table 29. Minimum efficacy requirements for fluorescent lamps (manufactured after 14 July 2012) in the USA. 84
Table 30. Minimum efficacy requirements for fluorescent lamps in the USA to take effect from 2018. 84
Table 31. The ballast luminous efficiency and applicable fluorescent lamp ballasts subject to energy efficiency requirements in the United States as per 10 CFR 430. 84
Table 32. Minimum efficacy of fluorescent lamps as per CAN/CSA-C819-11. 85
Table 33. Minimum efficiency requirements for ballasts in Canada. 85
Table 34. Minimum efficacy requirements for linear fluorescent lamps in China, as per GB 19043-2013 86
Table 35. Minimum efficacy requirements for circular and non-integrated compact (single-capped) fluorescent lamps in China, as per GB 19415-2003. 86
Table 36. Energy efficiency requirements for linear fluorescent lamp ballasts in China, as per GB17896-2012. 87
Table 37. Minimum efficacy requirements for linear, U-shaped and circular fluorescent lamps in Hong Kong. 88
Table 38. Maximum allowable values of lamp control gear loss, as per the Hong Kong Code of Practice for Energy Efficiency of Lighting Installations. 88
Table 39. Performance levels for fluorescent lamps in Korea as per KSC 7601. 89
Table 40. Minimum performance requirements for linear fluorescent lamps in Thailand. 89
Table 41. Japan's Top Runner Program minimum requirements for fluorescent lamp luminaires. 90

Executive Summary

Background

This product profile provides an update on the state of commercial lighting technologies in Australia and New Zealand, their capacity for improved energy efficiency, current and projected markets, and potential policy options.

The scope of this product profile includes lighting primarily used in commercial premises in Australia and New Zealand. The products covered in this product profile are fluorescent lamps (excluding integrated compact fluorescent lamps (CFLs)), ballasts for fluorescent lamps, basic commercial luminaires (troffers, battens and CFL cans). It does not include light emitting diodes (LEDs) as these lighting products are being reviewed separately as part of the LED Product Profile.

Linear (double-capped) fluorescent lamps with a nominal length of 550 mm to 1500 mm (inclusive) and a nominal lamp wattage of 16 W or more have been subject to minimum energy performance standards (MEPS) and labelling requirements since 2002 in New Zealand and 2004 in Australia. Certain fluorescent lamp ballasts have been subject to MEPS since 2002 in Australia and New Zealand.

Non-integrated compact fluorescent lamps, circular and U-shaped fluorescent lamps and commercial luminaires are currently not subject to MEPS.

The commercial lighting market

No fluorescent lamps are manufactured in Australia or New Zealand – the majority are made in countries such as China, Germany and Hungary. Although some magnetic ballasts are still manufactured in Australia, the majority on the Australian and New Zealand markets are imported from China and Germany.

The main suppliers of commercial lighting products to the end-user are electrical contractors, electrical/lighting wholesalers, specialist lighting stores and energy efficiency programs (e.g. T8-T5 adapters). Most commercial lamps are provided to the business market via wholesalers and fitting manufacturers/importers that supply complete fitting/lamp solutions.

Summary of current import and sales

- Current linear fluorescent lamp stock in Australia is estimated at 70 million, with approximately 17 million units sold in 2013 (E3, 2015). The majority of these lamps sold are 1200 mm 36 W T8 lamps (Beletich, Page and Brocklehurst 2014) and the average weighted efficacy of the linear fluorescent lamp market is 74–91 lm/W. Sales of linear fluorescent lamps in New Zealand were about 2 million units in 2014.
- Ballast sales are estimated at 2.2 million units in 2013 for Australia and 200,000 units in 2014 for New Zealand, with the majority of ballasts being electronic.
- 2013 imports of non-integrated CFLs are estimated at 3.5 million to Australia and 1.9 million to New Zealand, and about 4 million circular and U-shaped fluorescent lamps to Australia. Data is unavailable for luminaires and T8-T5 adapters.

In the commercial lighting sector, there is anecdotal evidence of an increasing prevalence of LEDs for lighting needs (see the LED Lighting Product Profile for further information); in particular the choice of LED downlights over traditional CFL cans. Linear fluorescent lamps are more likely to be replaced with more efficient fluorescent lamps rather than switching to LEDs, especially where lighting designers are involved. However, a recent statement by the lighting industry suggests that a change to LED linear lamps may occur within the next 5 years (AFR 22/01/2015). As the move to more efficient linear and LED technology occurs, products such as T8-T5 adapters and circular and U-shaped fluorescent lamps are likely to be phased out of the market.

Energy consumption

Commercial lighting systems (lamp and ballast) account for between 18–40% of electricity end-use in Australian commercial premises or 33.5 PJ per year (MEA 2003; pitt & sherry 2012), and about 39% or 8.9 PJ per year in New Zealand (BRANZ/EECA 2015).There is also indirect energy use associated with the removal of heat generated by lighting, through increased demand on air-conditioning. Ballast energy use is estimated at 7.5 PJ in 2014 for

Australia. It is estimated that linear fluorescent lamps in the commercial sector account for 20.1 Mt CO_2-e of greenhouse gas (GHG) emissions and ballasts 23.5 Mt CO_2-e (E3 2014).

Due to the lack of data for stock and sales of commercial lighting products, only modelling of average energy consumption per lamp in Australia and New Zealand has been undertaken. Non-integrated CFLs have an average energy consumption of 61 kWh per annum, circular fluorescent lamps 120 kWh per annum and U-shaped fluorescent lamps 124 kWh per annum. The average linear fluorescent lamp energy consumption ranges between 91 kWh per annum (T5-HE) through to 160 kWh per annum (T5-HO).

The efficacy of linear fluorescent lamps has improved since the introduction of MEPS (ranging from a 2–13 lm/W improvement), as has the efficiency of ballasts – improving from primarily C and B1 energy efficiency index (EEI) classifications to A2 (i.e. magnetic to more efficient electronic). Total cumulative savings to 2012 for linear fluorescent lamps in New Zealand is 0.4 PJ since they were regulated in 2002.

Current MEPS and international programs

There are two relevant Australian/New Zealand standards for products within the scope of this Product Profile: *AS/NZS 4782 Double-capped fluorescent lamps – Performance specifications* and *AS/NZS 4783 Performance of electrical lighting equipment – Ballasts for fluorescent lamps*. Prior to development of AS/NZS 4782, MEPS for linear fluorescent lamps were regulated in New Zealand as per NZHB 4782.2:2001.

AS/NZS 4782.2:2004 specifies the MEPS for double-capped tubular fluorescent lamps, which includes initial efficacy (100 hours) and maintained efficacy (5000 hours) requirements (based on four length categories), minimum colour rendering index (CRI) and maximum permissible mercury content. AS/NZS 4783.2: 2002 specifies the requirements for the classification of ballasts for a range of fluorescent lamp types according to their EEI, the form of labelling of the EEI, and defines MEPS requirements for certain fluorescent lamp ballasts.

A number of other regulations and programs relevant to the products within scope of this Product Profile are the AS/NZS 1680 series for interior lighting, Building Code of Australia, Commercial Building Disclosure, New Zealand Building Code, ENERGY STAR and incentive schemes.

International test methods exist for double-capped fluorescent lamps and fluorescent lamp ballasts, however, there is no international energy efficiency performance standard or requirements. Instead, individual countries have developed their own specifications. Very few regulators internationally have developed MEPS for luminaires, largely due to the wide variety of applications and design objectives not completely related to efficacy. While Europe, Japan and the USA have some requirements for luminaires, the most widely used regulatory mechanism to promote luminaire efficacy is building standards (Beletich, Page and Brocklehurst 2014).

Policy options

A number of possible policy options for commercial lighting products within the scope of this Product Profile are discussed. More than one option could be implemented at the same time. The following policy options are considered, however further discussion with industry and government approvals would take place if any mandatory options were to be put in place. Possible policy options include:

- No action
- Update Australian and New Zealand test standards for fluorescent lamps and ballasts to recent International Electrotechnical Commission standards
- Increase MEPS levels for linear fluorescent lamps or harmonise with international standards in 2-3 years
- Introduce MEPS for circular fluorescent lamps in 2-3 years
- Reduce mercury content in lamps to meet international requirements
- Harmonise Australia and New Zealand MEPS for ballasts by increasing Australian MEPS requirements
- Align with European stage 3 requirements for ballasts in 2-3 years
- Introduce a voluntary or mandatory MEPS level for commercial luminaires
- Product labelling and education initiatives

Initial energy saving estimates can be found on p69, however all policy options for further consideration would be subject to thorough analysis of costs and benefits in a consultation Regulation Impact Statement (RIS).

1 Introduction

1.1 Purpose

This consultation document forms part of an investigation into the feasibility of increasing the MEPS for linear fluorescent lamps and ballasts, and establishing MEPS for basic commercial luminaires, circular and U-shaped fluorescent lamps, and non-integrated CFLs, under the *Greenhouse and Energy Minimum Standards Act 2012* (GEMS Act) in Australia and the *Energy Efficiency (Energy Using Products) Regulations (2002)* in New Zealand.

The objective is to improve the energy efficiency of commercial lighting products supplied in Australia and New Zealand by addressing market failures such as information failure and principal-agent problems (discussed below). This Product Profile serves two purposes:

1. To provide an update on commercial lighting technologies, their capacity for improved energy efficiency and the current and projected markets for sales in Australia and New Zealand. This information has been collected for the benefit of policy makers, however, stakeholder feedback is sought for verification.
2. To signal to stakeholders the options that will likely form the basis of initial stakeholder consultation should a regulatory proposal follow. Final policy options would be subject to detailed investigation and public consultation through a Regulation Impact Statement (RIS). In New Zealand, approval of Ministers is required before consulting on any proposed regulatory option that might be modelled by a RIS.

1.2 Context

Energy efficiency is widely accepted as a low cost approach to reducing energy intensity and greenhouse gas emissions. Modelling by the International Energy Agency (IEA) shows that as much as half the savings in greenhouse gas emissions required by 2050 can be achieved by adopting energy efficiency measures (IEA 2012). Improvements to energy efficiency can also help to reduce demand on electricity supply systems (such as during peak periods) with consequent savings in capacity requirements. The following benefits arise from use of more energy efficient technology:

- Enhanced economic growth through increased productivity;
- Improved energy security by reducing energy demand;
- Improved energy affordability by reducing consumer energy costs;
- Deferred need for more expensive energy supply by making better use of existing energy resources;
- Reduced greenhouse gas emissions from energy consumption.

Available energy efficiency measures include the use of new technologies and processes to reduce energy use in residential, business, industry and manufacturing applications. Use of high efficiency commercial lighting products would reduce greenhouse gas emissions and therefore the cost of carbon abatement.

A key mechanism to drive performance improvements in commercial lighting is to use MEPS on products manufactured in or imported into Australia or New Zealand. MEPS for commercial lighting help reduce energy use by ensuring inefficient lighting products are not available on the market.

MEPS are one of the tools used by the broader Equipment Energy Efficiency (E3) Program, which aims to deliver cost-effective increases in the energy efficiency of appliances and equipment used in residential, commercial and manufacturing sectors in Australia and New Zealand. The E3 Program has been in place for 21 years. In Australia the program came under single national legislation in 2012 when the Australian national GEMS legislation was introduced, replacing separate approaches by the states and territories. GEMS is supported by the states and territories through an intergovernmental agreement and is an action under the National Strategy on Energy Efficiency (NSEE). New Zealand takes part in the E3 Program under a trans-Tasman Arrangement (The Australia

New Zealand Policy Framework and Funding Arrangement for the E3 Program). In New Zealand, MEPS are an action in the NZEECS (New Zealand Energy Efficiency and Conservation Strategy). The Australian Government's recently released Energy White Paper (EWP) recognises energy productivity improvements can help reduce business and household costs and encourage economic growth. As part of the EWP, the Australian Government announced it will develop a National Energy Productivity Plan that includes a national energy productivity improvement target of up to 40 per cent by 2030.

Linear (double-capped) fluorescent lamps with a nominal length of 550–1500 mm (inclusive) and a nominal lamp wattage of 16 W or more, manufactured or imported into Australia or New Zealand, have been subject to MEPS since 2002 in New Zealand and 2004 in Australia. Certain fluorescent lamp ballasts, within the scope of ferromagnetic or electronic type used with fluorescent lamps with a rated lamp power from 10-70 W, for use on 50 Hz supplies of 230/240/250 V or a range that includes one or more of these voltages, have been subject to MEPS since 2002 in Australia and New Zealand. An intention to review MEPS levels sometime between 2008 and 2015 was signalled in the Greenlight Australia strategy (NAEEEP 2004).

1.3 The problem

Commercial lighting systems (lamp and ballast) account for between 18–40% of electricity end-use in Australian commercial premises or 33.5 PJ per year (MEA 2003; pitt & sherry 2012), and about 39% or 8.9 PJ per year in New Zealand (BRANZ/EECA 2015). Businesses are paying unnecessarily high electricity costs to power lighting that is not as efficient as it could be. This is because commercial lighting products are either installed by third parties (such as construction firms or building owners) who choose lower cost, inefficient products over those with lower lifetime cost (the principal-agent problem), or because there is insufficient information available to make purchase decisions based on lighting efficiency, running costs and ability of the product to deliver the necessary illumination (information failure).

While technological advancements mean higher efficiency models are available, the local commercial lighting market is likely to be biased toward cheaper models which only just meet the MEPS requirements, as lifetime costs are often not being considered in purchasing decisions. However there is anecdotal evidence that suggest that some elements of the market are moving towards LED technology due to perceived efficiency and lifetime benefits, particularly in can luminaires and downlights used in hotel foyers, retail premises and within office buildings,. However there has not been an overall shift in the market to LEDs, one reason being that they are not available for every application.

Market failures including principal-agent problems and information failures, are inhibiting the uptake of more efficient commercial lighting products and government intervention may be justified. Other barriers identified by the business sector to realising the energy savings potential of efficient lighting are time and resources, and financial (including capital) and organisational constraints (EECA 2009 market research).

The **principal-agent problem** arises when an agent does not act in the best interests of the principal due to 'split incentives'. For example, the majority of commercial buildings are tenanted and the tenants typically do not participate in the purchase and replacement of lamps, which is the task of the building managers. Since the tenants pay the electricity bills for lighting, there is little incentive for purchasers to buy efficient lamps if they have a higher capital cost (NAEEEC 2002).

Information failure can be a problem when buyers are not able to compare the lifetime costs of commercial lighting products and therefore make sub-optimal purchase decisions. For example, both suppliers and specifiers of lighting systems may lack sufficient knowledge of luminaires and their costs and benefits, to select the optimal fixture for the purpose of the lighting system.

The current MEPS on linear fluorescent lamps and ballasts are not adequately addressing the problem. Several commercial lighting products within the scope of this product profile are not subject to MEPS and there are no incentives for increasing their efficiency. If less efficient commercial lighting products were removed from the market, businesses would reduce their energy costs and associated greenhouse gas emissions.

1.4 Where to from here

1.4.1 Consultation on this Product Profile

Readers are asked for feedback on the information and proposed policy options in this document, and to assist by providing robust data where possible. Feedback from industry stakeholders will be important in formulating the most appropriate policy approach for improving energy efficiency. Responses to the key questions below would be of particular assistance.

Comments should be sent via e-mail and be received by 18 September 2015.

The subject should be clearly titled 'Commercial Lighting Product Profile' and sent to:

Australia EER-Lighting@industry.gov.au

New Zealand regs@eeca.govt.nz

1.4.2 After consultation on this Product Profile

The material in this Product Profile will be reviewed and supplemented in light of any written submissions made by stakeholders and/or issues raised at stakeholder meetings. Decisions will then be made on whether to proceed with some of the proposals to improve the energy efficiency and performance of commercial lighting, the reliability of information available to consumers and what other options may be available.

If the preferred options involve regulation (e.g. MEPS and/or labelling) then a RIS will be prepared to analyse the costs, benefits, and other impacts of the proposal. Consultation will be undertaken with stakeholders prior to any final decisions being made. Final decisions on policy will be made by the relevant Council of Australian Governments (COAG) Ministerial Council in Australia and by the New Zealand Cabinet.

Options for improving energy efficiency and performance of commercial lighting will be considered alongside options for LED lighting and incandescent, halogen and (integrated) compact fluorescent lamps, which are the subject of separate Product Profiles.

1.4.3 Commercial lighting Product Profile – key questions

Readers are invited to comment on any aspect of this Product Profile. Responses to the key items listed in the box below would be of particular assistance.

The problem

- To what extent do market barriers such as the principal-agent problem and information failure exist?
- Can you provide supporting information on how purchasing decisions are made for commercial lighting?

Market characteristics

- Is the major channel to market via electrical wholesalers, or do others play an important role?
- Who are the main wholesaler groups and specifiers for new builds and renovations?
- What are the sales and stock volumes of the major commercial lighting product categories? Where specific data on categories of lamps cannot be provided, any indication of the relative split between categories and estimated market share would be very useful.
- Can you provide an estimate of the penetration rate for each current lamp length category?
- Can you provide robust market share data on linear fluorescent lamps greater than 1500 mm in length?
- Would you be able to provide robust data for non-integrated CFLs, circular and/or U-shaped fluorescent lamps, and non-integrated CFLs, including sales, average wattage, light output and average efficacy?
- Can you provide robust data on the stock and sales of T8-T5 adapters in Australia and/or New Zealand?
- Can you provide information on the stock of commercial luminaires within the scope of this Product Profile?
- Can you comment on the projected trends for commercial lighting, including the use of LEDs?

Energy consumption and greenhouse gas emissions

- Stakeholders are asked to comment on the figures for electricity use and greenhouse gas emissions of commercial lighting and to provide robust supporting data where possible.

Policy options

- Can you comment on the policy options proposed in Section 7? Do you think they could feasibly address The Problem outlined in Section 2, in terms of market failures inhibiting improved energy efficiency of commercial lighting?
- Can you provide data / information on the potential impact of phasing out T12 linear fluorescent lamps in Australia?
- Can you comment on the terms defined in Section 7 that could be considered suitable for determining luminaire efficiency?
- Should a luminaire rating include in-built control systems, i.e. favour luminaires with in-built timers and motion/daylight sensors, or facilitate the ability of luminaires to be dimmable, where feasible?
- Does the quality of light (e.g. glare reduction) need to be included in any voluntary or mandatory requirements for commercial luminaires?
- Do you support voluntary or mandatory labelling for commercial lighting? Please explain.
- Can you provide any data to support in-depth cost-benefit analyses for any of these policy options?

2 Product Description

Commercial lighting generally refers to most lighting used for non-residential purposes. The commercial lighting products within scope of this report are fluorescent lamps (excluding CFLs with an integrated ballast), fluorescent lamp ballasts, T8-T5 adapters, and basic commercial luminaires (troffers, battens and CFL cans). While LED lighting is the subject of a separate Product Profile, it is briefly discussed in other sections of this Product Profile within the commercial lighting context.

2.1 Fluorescent lamps

The *AS/NZS 4782.1:2004 Double-capped fluorescent lamps- Performance requirements* defines a fluorescent lamp as a 'discharge lamp of the low-pressure mercury type, in which most of the light is emitted by one or several layers of phosphors excited by the ultra-violet radiation from the discharge'.

Fluorescent lamps require a ballast to operate and are available in a variety of shapes, including linear, circular, U-shaped and compact (integrated and non-integrated ballast) fluorescent lamps. This product profile applies to fluorescent lamps without an integrated ballast, which are detailed below.

2.1.1 Linear fluorescent lamps

Linear fluorescent lamps, also known as double-capped or tubular fluorescent lamps, have two separate caps and are straight in shape (Figure 1). These lamps have an International Lamp Coding System (ILCOS) code of FD with suffixes indicating power, starter (external or internal), cap type, diameter (mm) and length (mm) (MEA 2011).

Figure 1. A linear fluorescent lamp, also known as double-capped or tubular fluorescent lamp.

Historically, linear fluorescent lamps have consisted of two types based on the internal phosphor coating – halophosphate and triphosphate. Halophosphor lamps use a single calcium halophosphate and are less efficient than triphosphor lamps. They were effectively phased-out with the implementation of MEPS based on AS/NZS 4782, with the exception of those lamps greater than 1500 mm in length which are currently not within the scope of MEPS (see Section 5).

Triphosphor lamps use three phosphors to create light. As a result they are more efficient at converting ultraviolet light to visible light and generally have a higher colour rendering index than halophosphor lamps.

Linear fluorescent lamps are identified primarily by their designated 'T' number that defines the tube diameter in eights of an inch, based on the original American system. The most common linear fluorescent lamps in a commercial setting are T5 (16 mm), T8 (26 mm) and T12 (38 mm). T8 lamps are available in a range of lengths, and have a higher efficacy and better colour rendering index than T12 lamps. T8 and T12 lamps can operate with either magnetic or electronic ballasts.

T12 lamps are the oldest and least efficient linear fluorescent technology and have poor colour rendering. The lengths of some of these lamps are also outside the scope of the current MEPS, which only applies to linear fluorescent lamps with a length between 550 mm and 1500 mm, inclusive (see Section 5). Other lengths of T12 lamps generally do not meet the minimum efficacy requirements of MEPS and have been replaced with more efficient T8 lamps.

T5 lamps are the most efficient of the linear fluorescent lamps and only operate on high frequency electronic ballasts. They are available as high efficiency (HE) or high output (HO) – HE are better at converting the power used to light output, while the HO provides more light but at a higher wattage. T5 lamps require an adapter kit to retrofit T8 lamp fittings, as they have a different pin-base connection and are 50mm shorter. A specifically designed T5 luminaire also makes the overall use of T5 lamps more efficient, as the luminaires are designed to reflect more light out of the fixture so fewer lamps are required to light an area.

2.1.2 Circular and U-shaped fluorescent lamps

Circular (circline) and U-shaped fluorescent lamps are essentially a tubular fluorescent lamp in a circular (Figure 2) or U-shaped form, respectively. They have either a 2-pin or 4-pin base. The 2-pin base contains an integrated starter and is designed for use with a magnetic ballast; a 4-pin base is designed for an electronic ballast or magnetic ballast with an external starter.

Figure 2. A circular fluorescent lamp (© Dmitry G / Wikimedia Commons / CC-BY-SA-3.0 / GFDL).

2.1.3 Non-integrated CFLs

A CFL is defined as a single-capped lamp with a compact (e.g. folded or spiral) gas discharge tube. CFLs are amongst the most efficient lamps available, employing a gas discharge technology together with a phosphor coating to produce visible light. CFLs predominantly have a tube diameter the same as a T5 lamp and generate light in the same manner as linear fluorescent lamps. However, they connect to the power supply with a base or socket system.

A ballast is required to operate the lamp at the correct current and can be integrated with the lamp or a separate piece of equipment. Only non-integrated CFLs (ILCOS code FS; Figure 3) are within the scope of this product profile as these are the most common form of CFL used in commercial premises. Non-integrated CFLs, sometimes referred to as a CFLn, pin-based or plug-in CFL, have the ballast installed in the luminaire, separate to the lamp. These types of CFLs are found in a variety of shapes, including 2-tube, quad-tube, flat and double D/square.

Figure 3. Non-integrated CFLs (right and bottom of picture), electronic fluorescent lamp ballast (left top) and a magnetic fluorescent lamp ballast (left centre).

Similar to circular and U-shaped fluorescent lamps, non-integrated CFLs have bases with either 2 or 4 pins for making the electrical connections between the control gear (ballast, together with the ignitor and capacitor if installed) and lamp.

2.2 T8-T5 adapters

T5 linear fluorescent lamps can produce the same quantity of lumens using less power than a T8. This has led to a new energy-saving technological solution in the form of the T8 to T5 adapter, which is a plug-in fixture that allows replacement of fluorescent T8 lamps with the energy-efficient T5 lamp in the existing light fitting (Figure 4). These can be of a lamp-end type or baton type. Some models include a reflector and provide "underrunning" capabilities. Depending on the design of the T8-T5 adapter, the starter may need to be replaced (with the one supplied with the adapter).

Figure 4. T8-T5 linear fluorescent adapter typical installation circuit. EB = electronic ballast; L = live 240 V supply; N = neutral volts; S = starter.

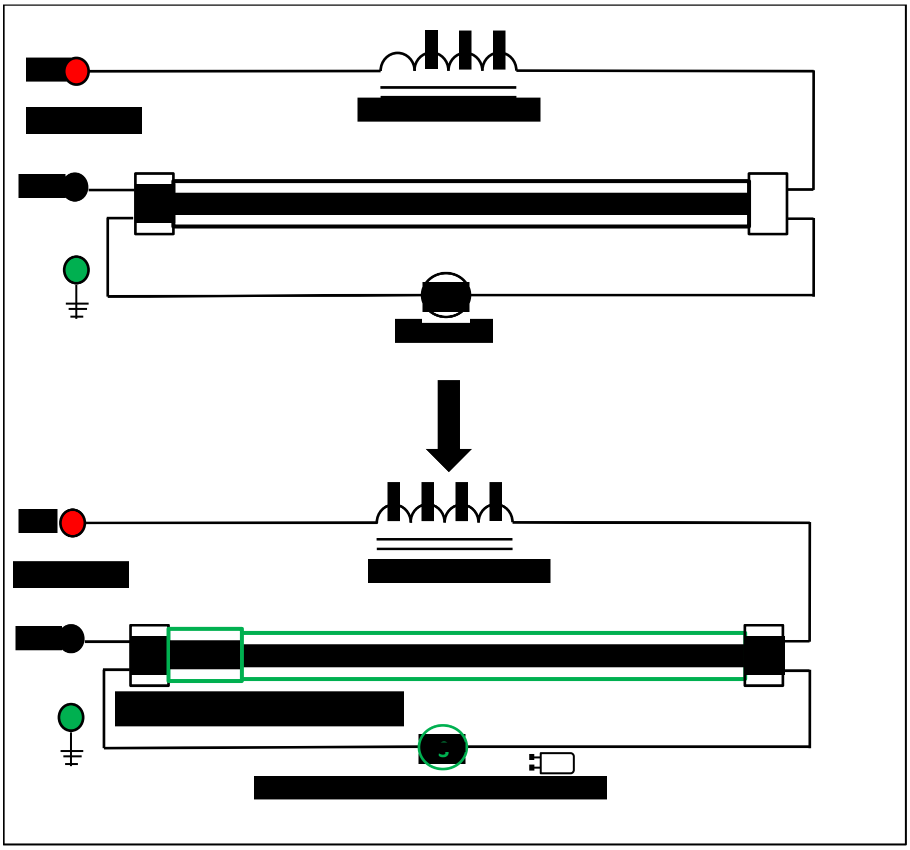


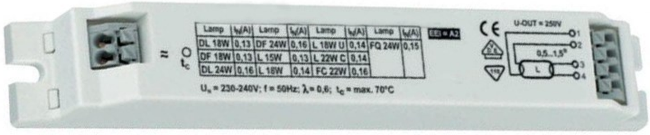
Figure 5. A T8-T5 adapter. Images sourced from Enduralight (www.enduralight.com.au/products/t5-adaptors).

2.3 Ballasts

A ballast controls the lamp current during operation, and may assist in the lamp starting process. AS/NZS *4783.1:2001 Performance of electrical lighting equipment – Ballasts for fluorescent lamps* defines a ballast as 'a unit inserted between the electricity supply and one or more discharge lamps which, by means of inductance, capacitance, or a combination of inductance and capacitance, serves mainly to limit the current of lamp(s) to the required value. The ballast may consist of one or separate components. It may also include means for transforming the supply voltage and arrangements which help provide the starting voltage, preheating current, prevent cold starting, reduce stroboscopic effects, correct the power-factor and/or suppress radio interference. The term includes the components in a variety of ballast circuits, e.g. rapid start, instant start, quick start, etc.'

Ballasts can be either wire-wound ferromagnetic (Figure 3) or electronic (Figure 3 and Figure 6). Ferromagnetic ballasts, often simply called magnetic ballasts, operate at 50 Hz which can lead to visible lamp flicker and audible noise from the ballast (Myer et al. 2009). Magnetic ballasts require a separate starter and along with the lamp itself, make up the lamp circuit.

Figure 6. An electronic ballast.



Most magnetic ballasts are very inefficient, with some of the lamp circuit energy lost as heat due to ballast wire electrical resistance and eddy currents in the magnetic core. The ballasts with lower electrical losses generally have higher quality electrical steel and copper coils with larger wire and fewer turns – although this makes ballast larger and heavier (GWA 2001).

Electronic ballasts use semi-conductor components to operate at high frequency (greater than 20 kHz) and are generally more efficient than magnetic ballasts. Other advantages of electronic ballasts are that they have a flicker-free start-up (as they do not require a separate starter), longer lamp life, dimming capability, and compatibility with light-sensing controllers (GWA 2001).

2.4 Basic commercial luminaires

A luminaire is an apparatus which distributes, filters or transforms the light emitted from the lamp(s). For the purposes of this Product Profile, it includes all the parts necessary for supporting, fixing and protecting the lamps, but not the lamps themselves. In some cases a luminaire also includes the circuit auxiliaries along with the means for connecting them to the supply.

Although the energy efficiency of linear fluorescent lamps and ballasts are already regulated through MEPS in Australia and New Zealand, neither the efficiency of light distribution by the luminaire or the total energy performance of the luminaire-lamp-ballast combination is regulated.

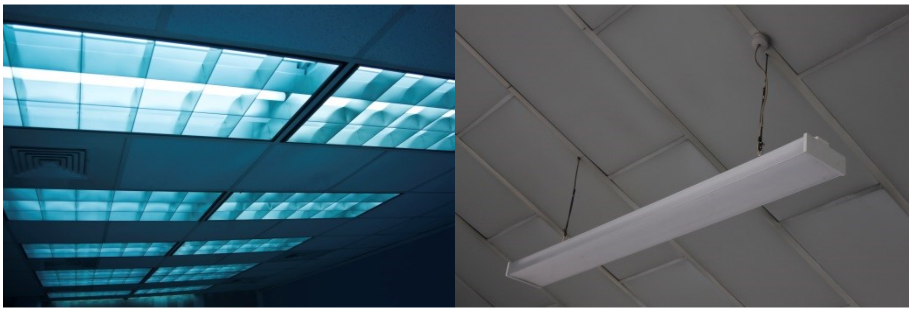
Commercial luminaires are those luminaires marketed and intended to be used in a commercial or business environment . The scope of this report is concerned with basic commercial luminaires – troffers, battens and recessed canisters. These are fixed installations that have the primary purpose of enabling people to perform visual tasks, but are also used for general lighting in corridors and foyers.

2.4.1 Troffers and battens

The most common linear fluorescent luminaires in commercial premises are troffers and battens. Both types of luminaires may incorporate various means of distributing light, including reflectors, louvers, lenses and diffusers.

A troffer is made of an inverted metal trough that holds the lamp-ballast system and acts as a reflector. Troffers can be either recessed into the ceiling (frequently used in suspended acoustic tile ceilings in offices due to their ease of installation (Figure 7); Myer et al. 2009) or suspended from the ceiling. Troffers use a louver, lens or diffuser to reduce glare and direct or diffuse light.

Figure 7. Recessed troffers with louvers to direct light output (left) and a pendant batten with diffuser (right).



A batten (Figure 7) can be broadly defined as a pipe, pole or wood strip which is used to support a lamp. However, battens can also comprise a metal 'box' containing the control gear and supports for the lamps. Battens can be either surface mounted or a pendant unit, and generally have either bare lamps, or a lens or diffuser to reduce glare.

Louvers are reflective blades which direct light output, reduce glare and prevent the lamp(s) from being seen directly at a low angle (Figure 7).

Lenses and diffusers are typically an acrylic or polycarbonate panel (troffers) or wraparound (batten; Figure 7) that reduce glare from the light source by blocking direct view of the lamp.

2.4.2 Recessed canisters

Recessed canisters (Figure 8) are referred to by a variety of names, including recessed cans, recessed reflector trim, high hats for CFLs and commercial compact fluorescent downlight. While in some cases directional lamps such as PAR lamps may be used in these luminaires, the interest here is where the luminaires are designed for use with non-directional lamps. Recessed canisters have a circular or square aperture and house one or more CFLs at the top of the dome-shaped housing/reflector unit (Green Seal 2000a). The CFL can be operated in either a vertical or horizontal position.

Light from a recessed canister is directed downwards and can be further controlled and directed by a combination of reflectors and lenses or louvers. However, the use of louvers on recessed cans can reduce the luminaire efficiency, or light output – Green Seal (2000a) reports a range from two to more than fifteen per cent reduction in light output. Recessed cans are generally used to provide ambient or accent lighting rather than light for fixed/visual tasks, and as such are most common in hallways, reception areas, foyers and meeting rooms.

Figure 8. A recessed canister with two non-integrated CFLs.

3 Market Characteristics

In 2013, market capitalisation of the 153 million lighting products sold in Australia for commercial and residential was estimated to be $3.2 billion. Of installed product, 13% is found in commercial spaces and the remaining 87% of lighting is used for residential (or non-commercial) purposes (information gathered from Commercial Stock Model, Lighting Naturally 2015).

In 2010, lighting products represented $247 million, or 2.5% of the value of the New Zealand Construction market. The commercial interiors market offers further opportunities through the lighting sector with an annualised value in excess of $42 million. New Zealand non-residential (commercial, industrial and retail) lighting is valued at $146 million, with offices accounting for $20.41 million and educational facilities $16.1 million (information provided by EECA from Forman Building Systems 2010).

The commercial lighting market is driven by new build installations and cyclical interior refurbishments by landlords and tenants. Major upgrades by landlords generally occur every 25 years, and fit-outs by tenants are on average every 6 years (information provided by EECA from Forman Building Systems 2010). Linear fluorescent lamps are generally replaced every 5 years based on estimated lifetime (although this can vary depending on use), with some businesses preferring to do bulk replacements of entire floors/buildings rather than replacing individual lamps.

3.1 Manufacturers, importers and suppliers

The major fluorescent lamp brands represented in Australia and New Zealand are Philips, Osram, Sylvania, General Electric and Narva NZ (Table 1). Manufacturing is predominantly in China, Germany and Hungary. A total of 618 linear fluorescent lamp models are approved on the E3 registration database.

Major brands and the total number of models (of these brands) of other commercial lighting products available in Australia and New Zealand are also listed in Table 1.

Table 1. The major of brands and number of models available on the Australian and New Zealand market for selected commercial lighting products.

Product	Major brands	Total number of models available in AU/NZ
Ballasts	Osram, Philips, AET, CMP	61
Linear fluorescent lamps	Philips, Osram, Sylvania, General Electric, Narva NZ	417
Circular fluorescent lamps	NEC, Osram, GE Lighting, Sylvania, Philips	108
U-shaped fluorescent lamps	GE Lighting, Osram, Sylvania	92
Non-integrated CFLs	Osram, GE Lighting, Sylvania, Philips	484
T8-T5 adapters	PAK, Pierlite, Vibe, Ultralamp, Carinda International, BPL LED Lighting, Ecobright Energy Solutions	8
Commercial luminaires	Cooper, Zumtobel, Thorn, Sylvania, Philips, Pierlite	1158

Note, for linear fluorescent lamps and ballasts, the major brands and number of models is based on approved registrations under MEPs in 2014. Not all models may be available on the market at the time of publication of this Product Profile.

The primary brands of ballasts registered for sale in Australia and New Zealand are Osram, Philips and AET (Table 1) with the majority made in China and Germany. No ballasts or fluorescent lamps are manufactured within Australia or New Zealand, with the exception of some magnetic ballasts manufactured in Australia by Custom

Mould Plastics Pty Ltd (CMP). Production of magnetic ballasts in Australia was estimated to decrease from 3 million per year in 2007 to 0.8 million per year in 2013 (Beletich, Page and Brocklehurst 2014).

The main suppliers of commercial lighting products to the consumer are electrical contractors, electrical/lighting wholesalers, specialist lighting stores and energy efficiency programs (e.g. T8-T5 adapters). Most commercial lamps are provided for the business market via wholesalers and through fitting manufacturers/importers that supply complete fitting/lamp solutions. Commercial light fitting suppliers in Australia and New Zealand that manufacture locally or import product include Philips, Osram, Thorn, Gerard Lighting and Gartner Superlux (NZ). There are also a large number of smaller fitting suppliers who manufacture locally and/or have the agencies for overseas suppliers and import into Australia and New Zealand. In Australia these include Aurora, Intralux, Eye Lighting and in New Zealand, Energy Light, Versalux, Halcyon and Infinity Lighting to name a few. A number also export their products as well as supply locally.

The lighting business market consists of the following components:

- Suppliers of services and products to develop a lighting system – design, lamps, fittings, and control gear (including drivers and lighting control systems). A small number of major suppliers provide all of these but the majority focus on one area of expertise such as fittings or control gear.
- Specifiers – identify what lighting system is required for the job (in the case of new builds and refurbishments), i.e. architects, consultants.
- Developers – own the buildings.
- Wholesalers – carry stock of lighting components for supply to electrical contractors.
- Electrical Contractors – install the lighting systems.

In New Zealand, the major channel to market for commercial lighting – both lamps and lamp/fitting combinations – is via the electrical wholesaler channel from three buying groups (very few sales happen outside the wholesale channel):

Australia has a much larger and more diverse commercial lighting market. The major channel to market would be via the electrical wholesaler. Most of the major manufacturers also have local supply outlets in Australia.

3.1.1 Channel to market – new build of commercial buildings

In general, the channel to market of lighting products when building new commercial premises follows these steps:

1. Suppliers advise specifiers / architects of what products are available. With this are provided the specifications of the performance of the products – such as light output and light distribution, or parameters of lighting control systems such as passive infra-red (PIR) sensor workable ranges.
2. The specifier specifies what will go into an installation – such as, 2 by 28 W troffers with need for lighting controls to integrate into building management system (BMS), or watts per m^2.
3. Tender issued for build based on the specification. The developer puts out the building specification to constructions companies who then put it out to subcontractors to develop their response to the tender back to the developer. The subcontractor (electrician) submits their response based on the specification.
4. Developer chooses best priced construction company and awards the contract.
5. Electrician sources products from wholesaler.

There is much discussion about who holds the power in this process and how that leads to inefficient lighting fittings and controls being installed. The tender process encourages lowest price and even though it may be specified to have efficient fittings and controls, once the contract is awarded there is generally pressure for the developer to extract more margin out of the electrician to maximise their profit. This can lead to product substitution which is often not picked up prior to commissioning.

3.1.2 Channel to market –refit of commercial buildings

For replacement of fitting, lamps and controls, the major channel to market is through electrical wholesalers. Typically the process is:

1. Facilities manager or maintenance person contacts electrician to arrange repair / replacement of lamps, fittings and or controls.
2. Electrician sources products from the electrical wholesaler and installs.
3. Electrician carries out the work.

In this model, the power is with the electrician, and to an extent the electrical wholesaler, to choose the product with the lowest cost.

3.2 Stock and sales

Where there are no readily available stock and sales figures for commercial lighting products within the scope of this Product Profile, import data (where this is available) is used as a proxy for sales.

3.2.1 Linear fluorescent lamps

A breakdown of linear fluorescent lamp characteristics and penetration rates in the Australian and New Zealand markets is provided in Table 2, based on lamp length (as per AS/NZS 4782.2:2004). The most popular lamp lengths are 1200 mm (4 foot) and 600 mm (2 foot). The weighted average wattage for T12 lamp is 35 W, T8 is 32 W, high efficiency T5 is 23 W and high output T5 is 44 W. The weighted average wattage and trade price for each lamp type has remained stable since 2003 (Table 2).

Table 2. Linear fluorescent lamp characteristics in Australia and New Zealand (data sourced from the E3 registration database and ABS import statistics).

		Lamp length (mm)					Weighted Average 2013	Weighted Average 2003
		600	900	1200	1500	1800		
Penetration rate for lamp lengths (2014)		15%	37%	42%	4%	2%		
T12	**Wattage (W)**	20	30	40	65	78	35	35.0
	Efficacy (lm/W)	68	66	78	75	73	72	61
	Trade price ($)	$6.52	$ -	$7.05	$ -	$ -	$3.94	$5.37
T8	**Wattage (W)**	18	30	36	58	70	33	32 (halophosphate) 32 (triphosphor)
	Efficacy (lm/W)	73	78	90	87	85	83	73 (halophosphate) 76 (triphosphor)
	Trade price ($)	$2.27	$5.30	$2.27	$4.17	$18.94	$3.80	$3.86 (halophosphate) $9.53 (triphosphor)
T5 (HE)	**Wattage (W)**	14	21	28	35	-	23	23
	Efficacy (lm/W)	87	94	96	93	-	92	89
	Trade price ($)	$4.55	$4.55	$5.38	$7.05	$ -	$4.90	$16.04
T5 (HO)	**Wattage (W)**	24	39	54	80	-	44	-
	Efficacy (lm/W)	73	86	84	85	-	81	-
	Trade price ($)	$2.27	$5.30	$2.27	$4.17	$ -	$3.42	-

NOTE: The 2003 weighted average for T5 lamps is not specific to HE lamps – Mark Ellis & Associates (2003) lists them as T5 triphosphor lamps.

Australia

The majority of linear fluorescent lamps are used in the commercial and industrial sectors, and the proportion of fluorescent lamp sales to the residential and non-residential sectors varies by the lamp type (Table 3). The small proportion of lamps used in the residential sector is primarily in areas such as the kitchen, garage, laundry and outdoors (E3 2013).

Table 3. Approximate sales split of fluorescent lamp technologies in residential and commercial settings (based on modelling conducted by Beletich Associates).

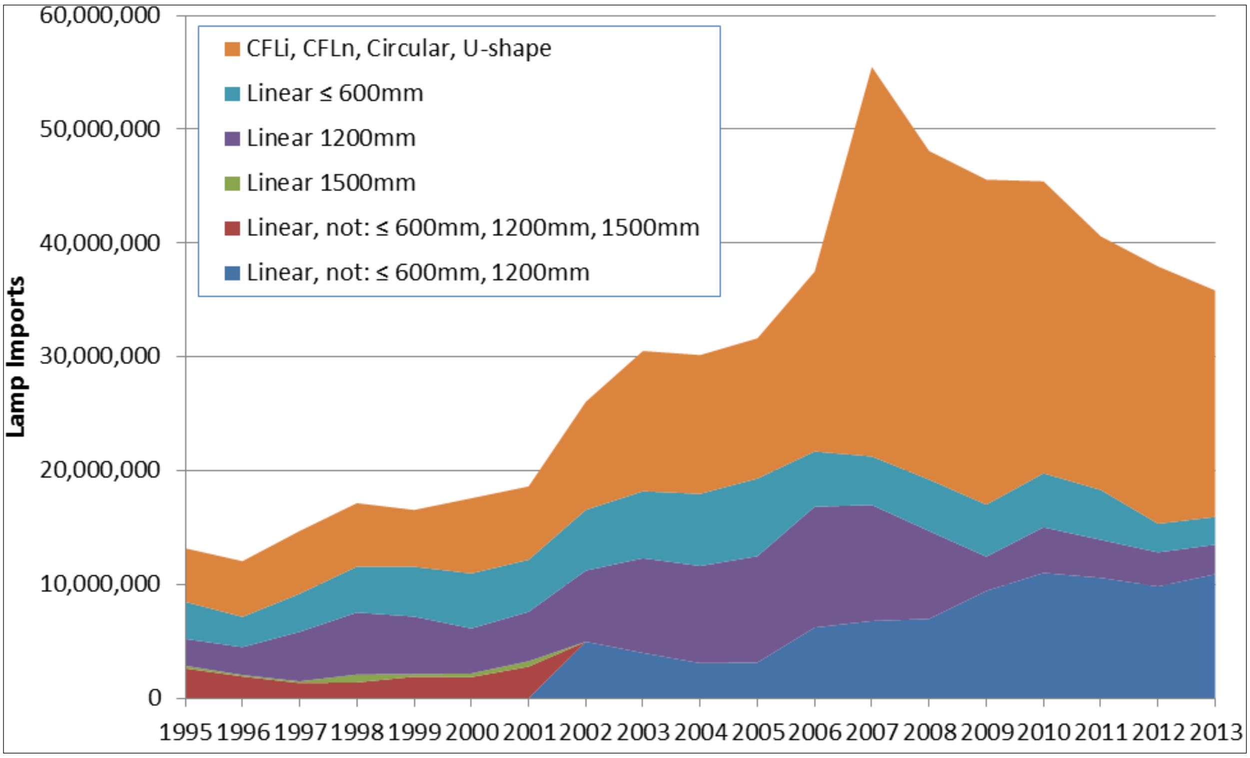
Sales split	T12	T8	T5 (HE)	T5 (HO)
Residential	0%	15%	10%	0%
Non-residential	100%	85%	90%	100%

In 2013, there was an estimated stock of 70 million linear fluorescent lamps, with estimated sales of 17 million in that year, with market capitalisation of $109 million. Linear fluorescent technology is estimated to account for 46%

of lighting used in commercial (non-industrial) spaces. Breakdown analysis suggests that linear fluorescents are employed for 67% of lighting in offices, 31% in hospitality, and 41% in a shop/retail setting (E3, 2015).

Australian import data shows a steady increase in imports of linear fluorescent lamps to a peak of about 21.2 million in 2007, followed by an overall decrease in imports to approximately 17 million in 2013 (Figure 9). Alternative lamp lengths appear to be gaining in popularity, as the "not: ≤ 600 mm, 1200 mm" category has increased significantly since 2005; based on the small proportion of 1500 mm lamps imported pre-2002 it could be concluded that this growth is *not* due to an increase in demand for 1500 mm lamps. There has also been a decrease in 1200 mm linear fluorescent lamps imported to Australia, from an average of 9.1 million per year (2003–2008) to around 3.3 million per year (2009–2013).

Figure 9. ABS import data for fluorescent lamps, 1995 to 2013. Note: CFLi are CFLs with an integrated ballast (e.g. the type used in residential premises) and CFLn are non-integrated CFLs.



Approximately 20% of all linear fluorescent lamp sales in Australia are 1200 mm 36 W T8 lamps in 2013 (based on ABS imports from 2012, which can be used as a proxy for sales). The most common wattage of T8 lamp is 36 W with an estimated lifespan of 16,000 hours, representing 75% of the commercial T8 market (Siddiqi and Lim 2013). Combined T8 and T12 lamp sales in 2012 are estimated at 3.5 million units (based on stock and sales model, and import data).

T5 lamp sales share has increased from 20% to 45% over the period 2007–2013 (Beletich, Page and Brocklehurst 2014). T5 lamp sales in 2012 are estimated at 1.5 million units (based on stock and sales model, and import data). The most common wattage of T5 lamp in Australia is 28 W, representing 80% of the commercial T5 market, with an average estimated lifespan of 24,000 hours.

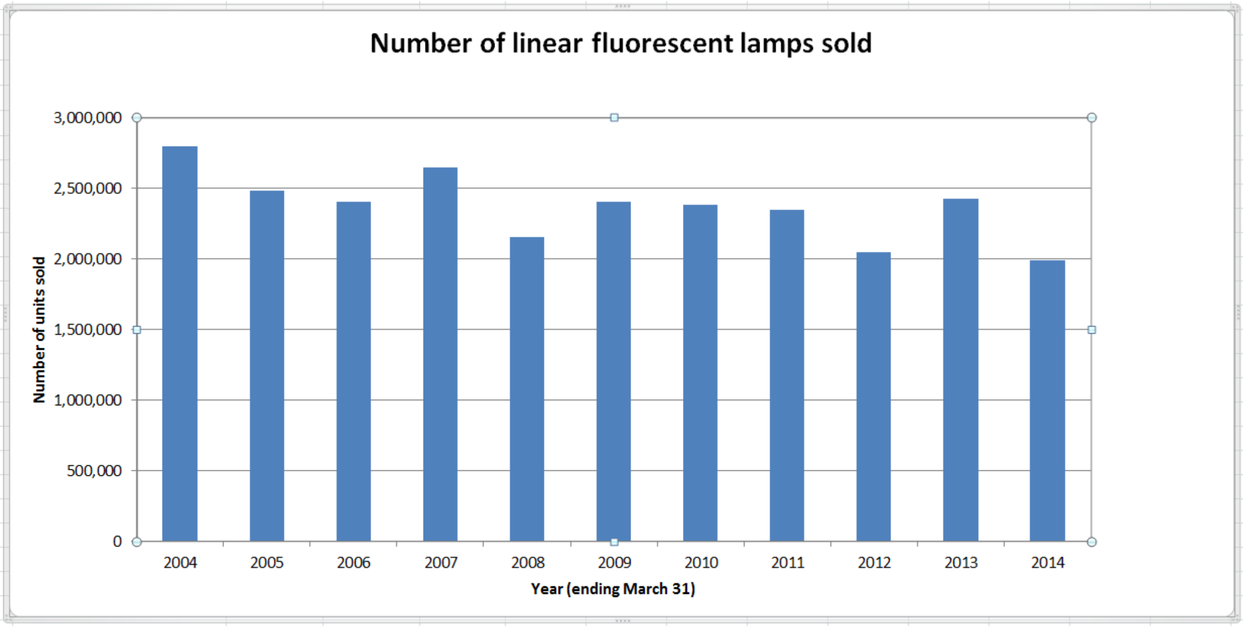
New Zealand

Linear fluorescent lamps account for around 65% of lighting technology in the commercial sector (KEMA 2007), with a total annual market size of 3.5 million lamps (Table 4). Sales data for linear fluorescent lamps has been collected by the New Zealand Energy Efficiency and Conservation Authority (EECA) since 2004. The general trend of sales has been a slight decrease overall from approximately 2.8 million units in 2004 to 2.4 million units in 2013 (Figure 10).

Table 4. Estimated market size of New Zealand commercial lighting in 2007 (Stewardship Solutions 2008).

Category	Estimated total annual market size	Percentage of market size represented by LCNZ members
Linear fluorescent lamp	3,500,000	93%
Non-integrated CFL	700,000	46%
Luminaires	1,000,000	Unknown
Control gear	1,000,000	Unknown

Figure 10. Sales trends of linear fluorescent lamps in New Zealand (adapted from EECA 2015).



The majority of linear fluorescent lamps sold were T8, although T12 lamps still accounted for a significant proportion of installed linear fluorescent lamps in 2007 despite no longer being sold in New Zealand due to MEPS introduced in 2001 (KEMA 2007). T5 lamps accounted for less than 5% of installed linear fluorescent lamps in New Zealand commercial premises (KEMA 2007).

3.2.2 T8 to T5 linear fluorescent adapters

No information on stock and sales of T8 to T5 adapters in Australia or New Zealand is available at this date.

3.2.3 Other fluorescent lamps

It is estimated that 3.5 million non-integrated CFLs were imported to Australia in 2013 (based on stock and sales model, and import data; Figure 9). All sales of non-integrated CFLs are assumed to be to the commercial sector (pers.com. Beletich Associates). Non-integrated CFLs account for about 3% of commercial lighting in New Zealand (KEMA 2007), with a total annual market of 700,000 (Table 4). Calculations from New Zealand import data and sales data suggest that around 1.9 million non-integrated CFLs were imported to New Zealand in 2013. The average wattage of non-integrated CFLs in Australia and New Zealand is estimated to be 22.8 Watts.

Based on a stock and sales model, and ABS import data, approximately 4 million circular and U-shaped fluorescent lamps were imported to Australia in 2013. Circular fluorescent lamp sales are assumed to be split 50% to the residential market and 50% to the commercial market (based on modelling by Beletich Associates). The average wattage of circular fluorescent lamps in Australia and New Zealand is estimated to be 33 W.

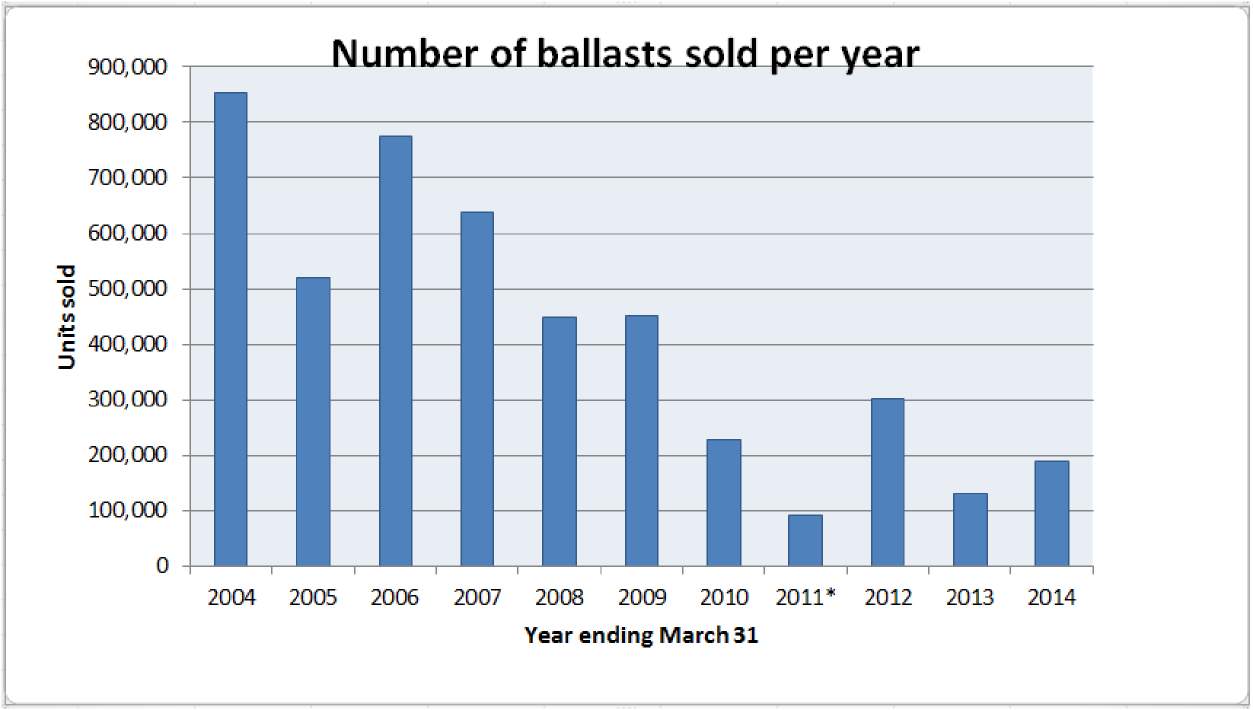
3.2.4 Ballasts

Based on the installed stock of linear fluorescent lamps in Australia, there are up to 70 million linear fluorescent ballasts in use in 2013 (the real number will be less that this as some luminaires contain more than one linear tube).

In 2013 it was estimated that luminaires with electronic ballasts had 80% of the market share with those using magnetic ballasts holding 20% (Beletich, Page and Brocklehurst 2014).

There has been a decrease of ballast sales in New Zealand (Figure 11), from around 850,000 in 2004 to about 190,000 in 2014. EECA 2015). A 2007 survey of LCNZ members combined with data by other companies and market knowledge, indicted that the estimated total annual market size for control gear was 1 million (Table 4).

Figure 11. Sales trends of ballasts for fluorescent lamps in New Zealand (EECA 2015).



There are 61 models of fluorescent lamp ballasts with approved registration on the E3 database (Australia and New Zealand), of which only five are magnetic. The majority of approved MEPS-registered ballasts are for use with 36 W (41%), 18 W (27%) and 28 W (26%) fluorescent lamps.

Ballasts can last for 15–20 years, although most are replaced earlier due to refurbishment of the property which typically occurs 10 to 30 years after commissioning (Energetics Pty Ltd and George Wilkenfeld & Associates 1994; NAEEEP).

3.2.5 Luminaires

Discussions with industry indicate that high-end new fit-outs of offices over the past 5-7 years typically have used a single lamp 28 W T5 luminaire. Prior to this the typical installation would have been a single lamp 36 W T8 luminaire. Retail premises generally use twin-lamp luminaires. Although more accurate data is not readily available, it is assumed that 50% of luminaires contain two fluorescent lamps; therefore luminaire stock is currently estimated to be 52 million.

A 2007 survey of LCNZ members combined with data by other companies and market knowledge, indicted that the estimated total annual market size for luminaires in New Zealand was 1 million (Table 4).

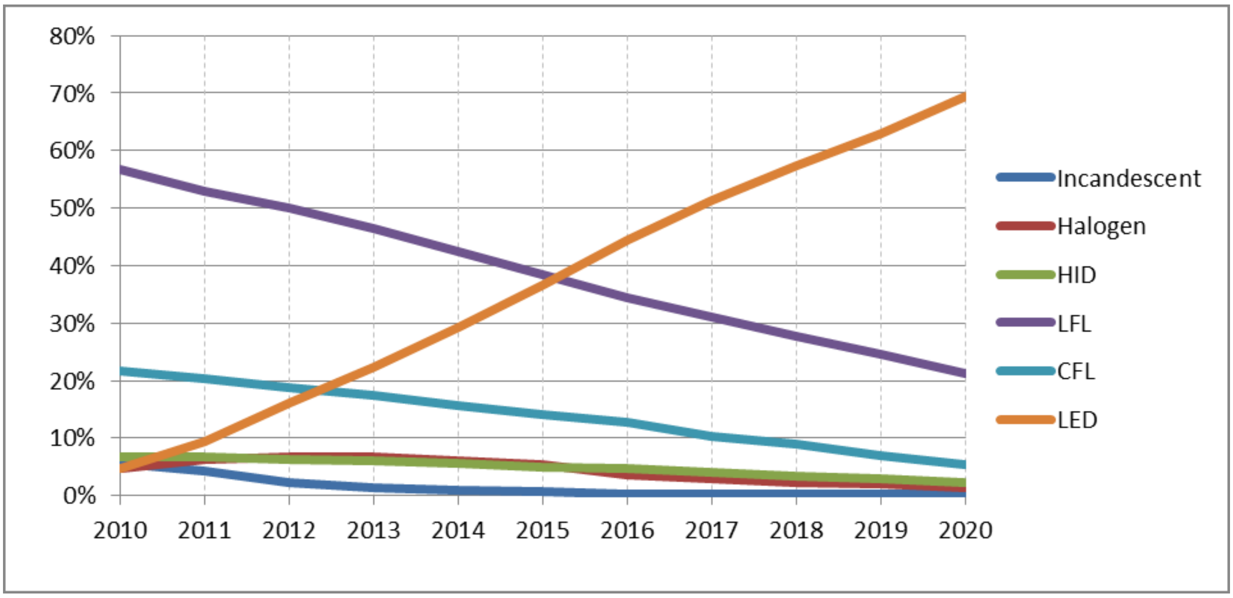
3.2.6 Projected trends

In the commercial building and retail store lighting market, there is an increasing prevalence to make a visible switch to LED technologies for lighting needs (for further information see the LED Lighting Product Profile due to come out in the near future). Anecdotal evidence from industry has indicated that many retail stores, hotels and commercial offices have changed most of their downlights to LEDs, and when provided with an option to choose CFL cans or LED module lighting in new buildings, the dominant choice is now LEDs.

Linear fluorescent lamps are more likely to still be replaced with more efficient fluorescent lamps rather than switching to LEDs where lighting designers are involved. Although there is a linear LED market for direct replacement in the original luminaire or for use in a modified luminaire, there are a number of safety issues which need to be considered including the risk of electric shock (see the Electrical Regulatory Authorities Council (ERAC) information bulletin (www.erac.gov.au/index.php?option=com_content&view=article&id=100&Itemid=547)). However, a recent statement by the lighting industry suggests that the change to LED linear lamps may occur within the next 5 years (AFR 22/01/2015).

According to the E3 internal commercial lighting stock model of the Australian market (E3, 2015) the overall proportion of linear fluorescent lamps used for lighting in a commercial setting is projected to fall from 46% in 2013 to 21% by 2020. This will be driven most significantly by adoption of LED lighting, which is approximated to have 22% market share for commercial lighting with this figure projected to rise to 69% by 2020. Other lighting technologies (incandescent, halogen, HID and CFL) are all projected to fall to a collective share of around 10% of the market (Figure 12).

Figure 12. Projected mix of lighting technologies to be used for commercial (non-industrial) lighting purposes (E3, 2015).



These projections are based on the following assumptions:

- There will be no changes to the Building Code of Australia (BCA) National Construction Code (NCC), which outlines maximum power density limits for commercial properties in Australia
- "Business as usual" approach with regards to changes in performance requirement standards on lighting technologies in Australia
- The efficacies of each lamp technology will increase in a pattern conforming to historical improvements observed in the Australian and international lighting markets between 2009 and 2014; with data obtained through market analysis, E3 registration database, Australian Government lamp photometric testing 2009-2014.

T8-T5 adapters are mainly sold to facility managers as an interim rather than a designer's solution. Consequently, as new fit-outs occur with T5 luminaires and if the projected change to LED linear lamps occurs, adapters will eventually be phased out by market forces.

The circular and U-shaped fluorescent lamp market is small and projected trends are difficult to predict. In some instances these lamps may be replaced with recessed panel (planar) LED luminaires (discussed in the LED Lighting Product Profile).

Total sales of ballasts in Australia are projected to fall proportionate to any diminishing uptake of fluorescent (and HID) lamp technologies in the future. The New Zealand industry projects that total sales should remain relatively stable in the region of 200,000 per year, as recorded for 2014.

4 Energy Consumption and Energy Efficiency

4.1 Energy consumption

4.1.1 Fluorescent lamps

In Australia, lighting accounts for between 18–40% of electricity end-use in commercial premises (Pitt&Sherry 2012), with the highest users being office tenancies at 6.2 PJ in 2011 and schools at 5.6 PJ in 2011 (Table 5). The Commercial Building Disclosure (CBD) program data (www.cbd.gov.au/registers/cbd-downloadable-data-set) indicates the average nominal lighting power density in office buildings is 12.9 W/m².

Direct energy use of lighting systems was estimated at 33.5 PJ in 2000, comprising of 26.5 PJ by the lamps themselves and 7 PJ by the ballasts (MEA 2003). In 2014 it is estimated that linear fluorescent lamps account for 74.9 PJ of energy consumption in the commercial sector. As commercial buildings increase it is predicted to increase to 92.7 PJ per year by 2020 and 101.8 PJ per year by 2030 (E3 2104). However, since the introduction of MEPS for linear fluorescent lamps in 2004 in Australia, there has been an estimated cumulative saving of 6.4 PJ.

Table 5. Annual electricity consumption and percent end-use share of lighting in Australian commercial buildings (sourced from Pitt&Sherry 2012).

Building type	Electricity consumption (PJ/yr)	% electricity end-use share
Office tenancy	6.2	37
Office base building	2.9	15
Office (all)	9.4	26
Hotel	1.8	20
Hospital	1.5	17
School	5.6	40
University	2.5	18
Retail	No lighting breakdown was provided for the retail sector; however lighting was listed as a significant energy consumer – in supermarkets it was the third most intensive energy use after space cooling and refrigeration.	

In New Zealand, the commercial sector accounts for 23% of the total estimated energy consumption (KEMA 2007). Indoor lighting accounts for the largest portion of commercial electricity consumption at a 33% share, or approximately 10 PJ per year – the share varies from 15% in restaurants up to 60% in retail (Table 6; KEMA 2007). Total cumulative savings to 2012 for linear fluorescent lamps in New Zealand is 0.4 PJ since they were regulated in 2002.

There is also indirect energy use associated with the removal of heat generated by lighting, through increased demand on air-conditioning. About 90% of lamp heat in the commercial sector is released into air-conditioned spaces (Wilkenfeld and Associates 2001).

Due to the inability to estimate current stock of fluorescent lamps in commercial premises, only modelling of average energy consumption per lamp in Australia and New Zealand has been undertaken (Table 7; see Appendix for model assumptions). The average linear fluorescent lamp energy consumption ranges between 86 kWh per annum (T5-HE) through to 160 kWh per annum (T5-HO). Non-integrated CFLs have an average energy consumption of 83 kWh per annum, circular fluorescent lamps 120 kWh per annum and U-shaped fluorescent lamps 124 kWh per annum. **Note:** New Zealand has collected sales data for linear fluorescent lamps from 2004, and the average sales weighted wattage of these lamps in 2013 was 45 W, giving a unit energy consumption averaging 146 kWh per annum.

Table 6. Indoor lighting electricity consumption and end-use share by commercial building type in New Zealand (KEMA 2007).

Building type	Electricity consumption (PJ/yr)	% electricity end-use share
Office	1.5	35
Restaurant	0.1	15
Retail	2.0	60
Food store	1.0	18
Schools/colleges	0.9	35
Tertiary education	0.2	26
Hospital	1.1	26
Hotel/motel	0.8	42
Miscellaneous	2.4	33
Total	10.0	33

NOTE: Miscellaneous includes libraries, museums, cultural centres, childcare facilities, sports complexes, gambling facilities, religious assembly and other services.

Table 7. Average fluorescent lamp characteristics and energy consumption.

Weighted Average	Linear Fluorescent				Non-integrated CFL	Circular	U-shaped
	T12	T8	T5-HE	T5-HO			
Lamp wattage (W)	35.0	31.8	22.9	43.7	22.8	33	**34**
Circuit wattage (W)	43.0	39.8	26.6	47.4	29.8	39	40
Light output per lamp (lm)	3000	2700	2100	3500	1400	2400	2700
Lamp efficacy (lm/W)	74	83	91	79	61	73	79
Lamp energy consumption (kWh p.a.)	128	113	86	160	83	120	124
Lamp and ballast energy consumption (kWh p.a.)	157	145	97	173	109	142	146
Indirect energy consumption (kWh p.a.)	55	51	34	61	38	50	51
Total energy consumption (kWh p.a.)	212	196	131	234	147	192	197

4.1.2 Ballasts

Ballasts in the Australian commercial sector had an estimated energy usage of 6.9 PJ in 2000 (GWA 2001) and it is estimated to have only slightly increased to 7.5 PJ in 2014 (due to the implementation of MEPS in 2002 removing many magnetic ballasts from the market, resulting in a cumulative energy saving of 11.8 PJ; E3 2014). Based on these numbers and projection of fewer installations of linear and HID lamp technologies requiring use of ballasts, the total energy consumption is projected to decrease to 2.9 PJ per year by 2020 (Lighting Naturally 2015)

Magnetic ballasts have a power loss in the order of 8–10 W, while electronic ballasts only have a loss of 1–2 W. On average for all ballasts (i.e. magnetic and electronic), the energy consumption is 10% of the total fluorescent load. Average magnetic ballast consumption of the total fluorescent load is 20%, assuming an average ballast consumption of 9 W and average lamp power of 36 W, compared to 4% for the average electronic ballast (assuming an average ballast consumption of 1.5 W).

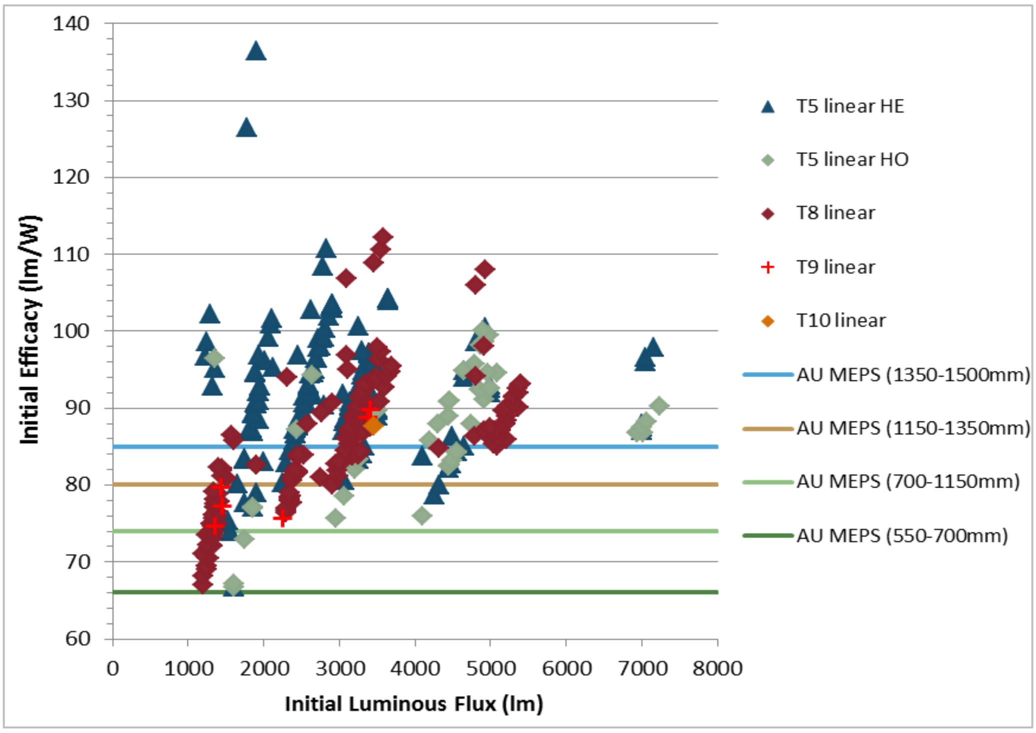
4.2 Energy efficiency

4.2.1 Linear fluorescent lamps

Since the introduction of MEPS in 2004, the energy performance of linear fluorescent lamps available on the Australian and New Zealand market has improved (Table 2 and Figure 10).

T8 lamps have increased from an average efficacy of 76 lm/W to 83 lm/W, T5 lamps have increased from 89 lm/W to 91 lm/W, and T12 lamps have also improved from 61 lm/W to 74 lm/W. Given the average lamp wattage has not changed between 2003 and 2013 (Table 2), the increased efficacy is being achieved through increased light output. However, the spread of (initial) efficacy within categories of lamps is still large (Figure 14).

Figure 13. Initial efficacy of fluorescent lamps registered in Australia and New Zealand, 2014. Australia/New Zealand linear fluorescent MEPS levels shown.



A comparison of the linear fluorescent lamp product available around the world to those lamps available in Australia and New Zealand (Figure 14 and 13) indicates that the introduction of a MEPS in Australia and New Zealand has led to significant efficiency improvements in the local market through the removal of less efficient products. However Figure 14 shows that many of these models remain in production elsewhere, presumably for supply to markets with less stringent or no regulation, suggesting the need for continued implementation of MEPS. It is notable that there are also numerous high performance lamp models available internationally. Thus there is the opportunity available to suppliers to import a range of alternative higher quality product in response to an upgrade to MEPS levels (Figure 15).

Figure 14. Initial efficacy of fluorescent lamps available worldwide including E3 registered product, 2014. Australia/New Zealand linear fluorescent MEPS levels overlaid.

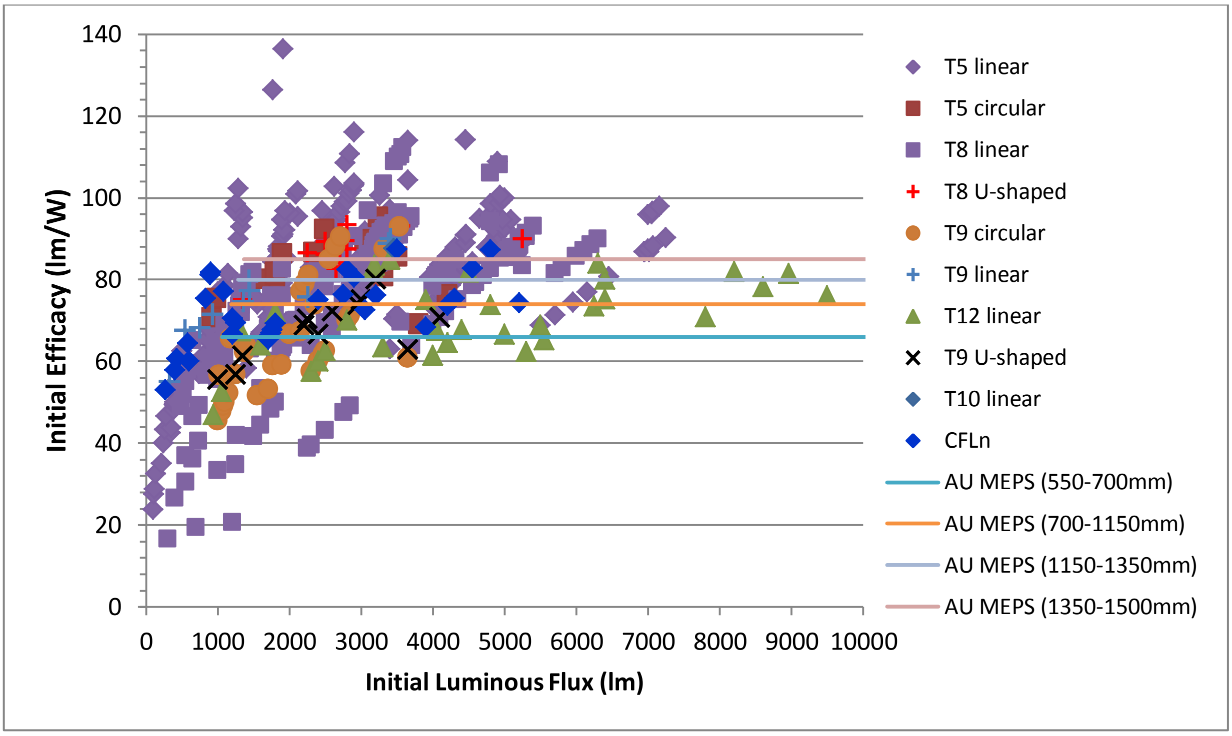
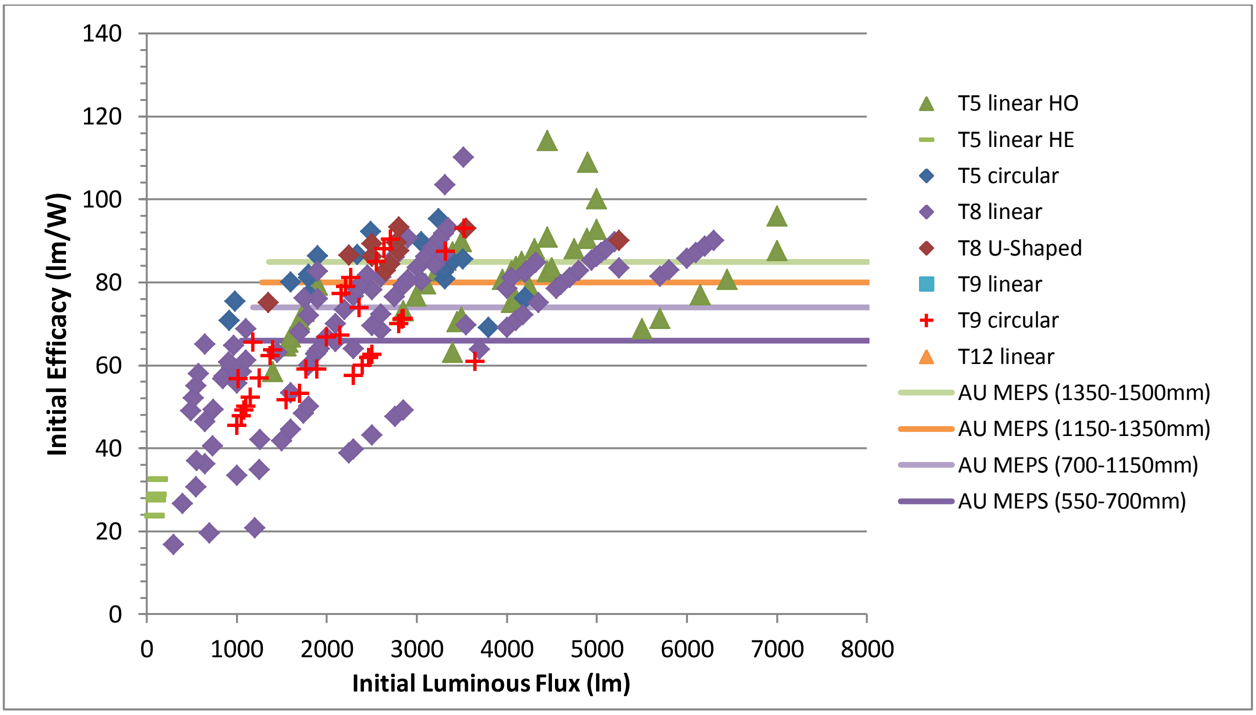


Figure 15. Initial efficacy of fluorescent lamps available worldwide. Australia/New Zealand linear fluorescent MEPS levels overlaid.



Specifically for New Zealand, sales data indicates that the overall average efficacy of linear fluorescent lamps has only increased marginally from 88.2 lm/W in 2004 to 89.7 lm/W in 2013 (EECA 2014). It is important to note that while linear fluorescent lamps have been regulated in New Zealand since 2002 (see Section 5) sales data has only been collected since 2004, so initial improvements in efficacy are not reflected.

There is also a known relationship between colour temperature and lamp efficacy for linear fluorescent lamps – lamps with higher colour temperatures (or cooler tones) are less efficient. This relationship is supported by data from testing undertaken by Beletich, Page and Brocklehurst (2014).

A simple example of cost benefit analyses to the average business by replacing less efficient T8 and T12 lamps with a more efficient 28 W T5-HE lamp is shown in Table 8. The calculations are shown over a 10-year period, and are based on calculations and assumptions outlined in the Appendix. The options involve retrofitting a 28 W high-efficiency T5 within a 3000 lumen, 1200 mm length fitting, in the place of both a 36 W T8 and a 40 W T12 (both of which produce approximately the same amount of lumens). Note: this does not take into account any changeover of fixture or need for a T8-T5 converter (see section 4.2.4 below).

A change from a 36 W T8 linear lamp to a 28 W T5-HE lamp is very cost effective, with a benefit:cost ratio of 13.2, whereby a small increase in initial capital outlay for the unit will enable much greater savings in energy usage and costs over the 10-year period. To change from a 40 W T12 to a 28 W T5-HE does not currently result in any negative cost sacrifices; the T5 lamp is cheaper to purchase, incurs less labour costs due to the longer lifetime of the lamp, and energy consumption and therefore running costs are significantly cheaper (therefore the benefit to cost ratio calculates to be negative, a non-applicable result).

Table 8. 10-year cost benefit analysis of a lamp upgrade options (Business user) (see Appendix A Table 21 for assumptions).

	Example 1: Swap 36W T8 for 28W T5-HE	Example 2: Swap 40W T12 for 28W T5-HE
Capital cost savings	-$3.10	$24.10
Replacement labour cost savings	$0.00	$5.30
Running cost difference (NPV)	-$40.90	-$54.10
Ratio of benefits : costs	13.20	(-1.8) 0.00

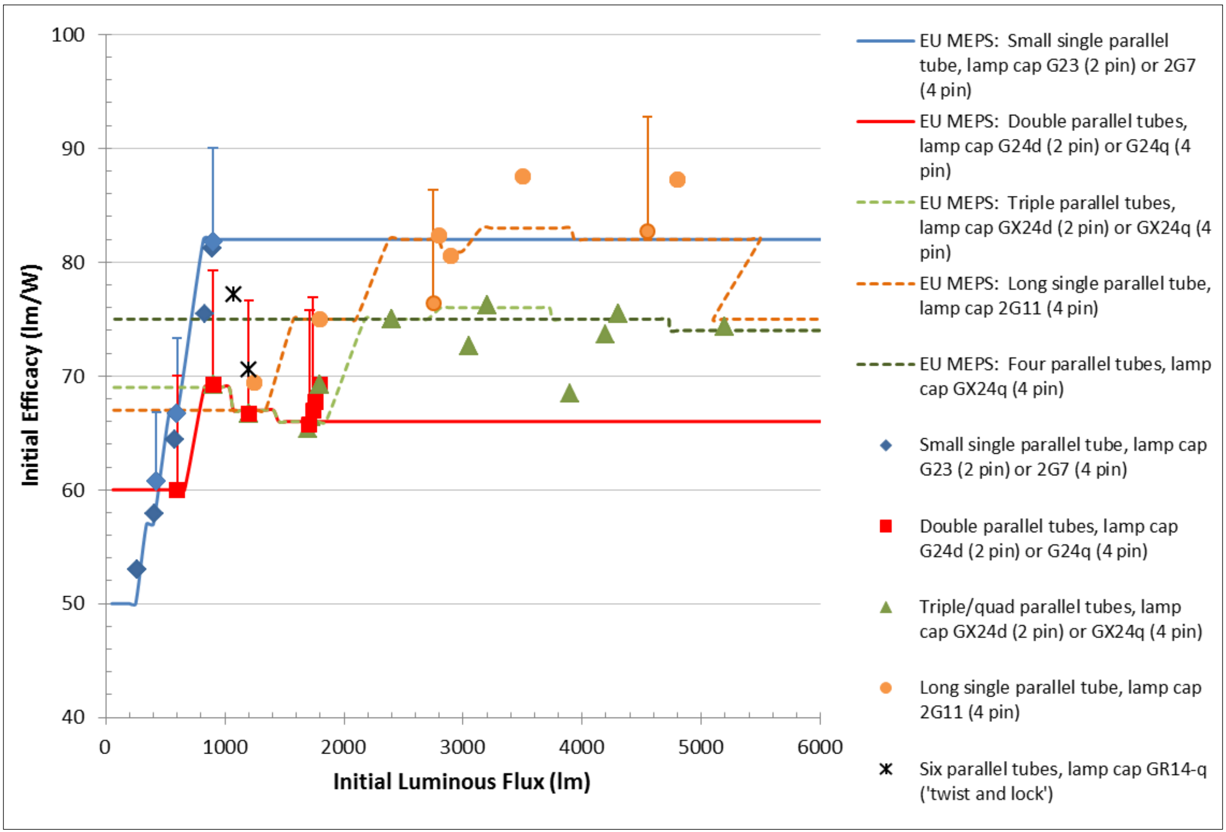
As discussed in Section 3, linear fluorescent lamps are currently more likely to be replaced with more efficient fluorescent lamps rather than LEDs. However, the lighting industry is predicting a change within the next 5 years to LED alternatives such as LED panel luminaires. This will lead to a further reduction in energy consumption, although it is difficult to estimate savings given the lack of data available on current stock.

4.2.2 Other fluorescent lamps

Market research of CFLs with non-integrated ballast that are available in Australia and New Zealand, finds an average rated efficacy of 61 lm/W (Table 7), with a range of 52–88 lm/W (Figure 14 and Figure 16) *(E3, 2015)*. Since there is no MEPS requirement for non-integrated CFLS in Australia or New Zealand, current market data has been plotted against the relevant European Union (EU) requirements (Figure 16) to indicate the potential for improvement in energy efficiency. The majority of non-integrated CFLs have a rated initial efficacy equivalent to or just exceeding the relevant EU requirement.

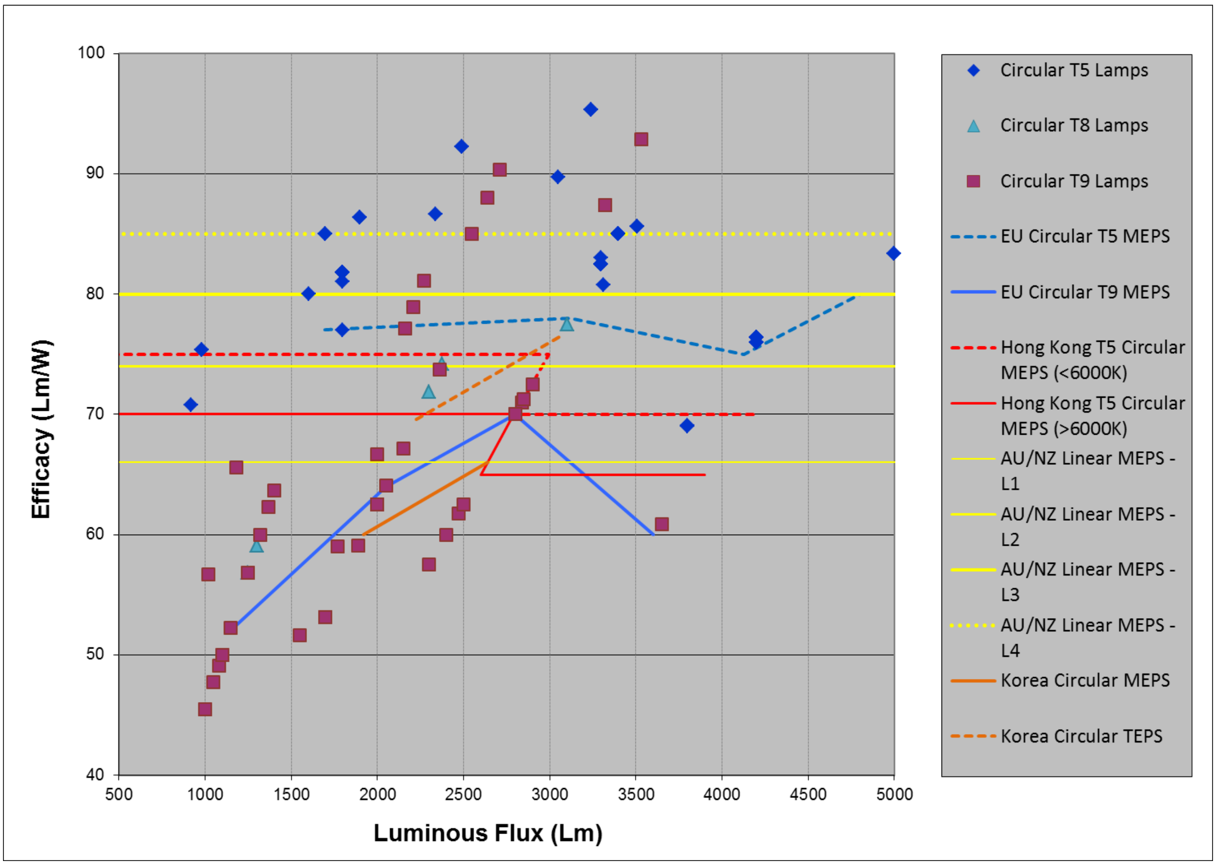
As previously discussed in Section 3, there is anecdotal evidence that non-integrated CFLs are being replaced with LED downlight fixtures, particularly in retail stores, foyers and hotels. However, there is currently no data available to indicate the market size or efficacy of existing and/or replacement products.

Figure 16. Initial efficacy of non-integrated CFLs available in Australia and New Zealand.



Circular fluorescent lamps have a weighted average rated efficacy of 73 lm/W (Table 7), with rated (initial) efficacy ranging between about 45–95 lm/W (Figure 14 and Figure 17). T9 circular fluorescent lamps have the largest range of initial efficacy and less than half would meet the linear fluorescent lamp MEPS (for L1 category). Currently available T8 and T5 circular fluorescent lamps achieve at least the lowest Australia/New Zealand MEPS for linear fluorescent lamps (with the exception of one T8 circular lamp). The majority of T5 circular fluorescent lamps have an initial efficacy within the range of 75–86 lm/W (Figure 17).

Figure 17. Initial efficacy of circular fluorescent lamp available on the Australian and New Zealand market.



U-shaped fluorescent lamps have weighted average rated (initial) efficacy of 79 lm/W (Table 7), with a range between 55–96 lm/W (Figure 14).

4.2.3 Ballasts

Prior to the introduction of MEPS in 2002, Australian ballasts were primarily of the Energy Efficiency Index (EEI) classification C and B1 (GWA 2001; see Section 5 of this Product Profile for explanation of the EEI). The majority of MEPS-registered ballasts now have an EEI of A2 (Figure 18). Most registrations are made in Australia (EECA 2015), so it can be assumed this improvement in EEI also applies to the New Zealand market.

This shift to more efficient electronic ballasts is mostly due to the gradual phase-out of magnetic ballasts in Australia and New Zealand (only 6% of registered ballasts are magnetic). On average, electronic ballasts consume 16% less of the total fluorescent load than magnetic ballasts.

In terms of the potential for further improvement in their design, electronic ballasts are comprised of electronic circuitry and are therefore partially dependent on the sophistication of the circuit design and the manufacturer's specification of quality components. Current research and development is primarily focussed on improvement of circuit power factor without affecting the overall energy efficiency level.

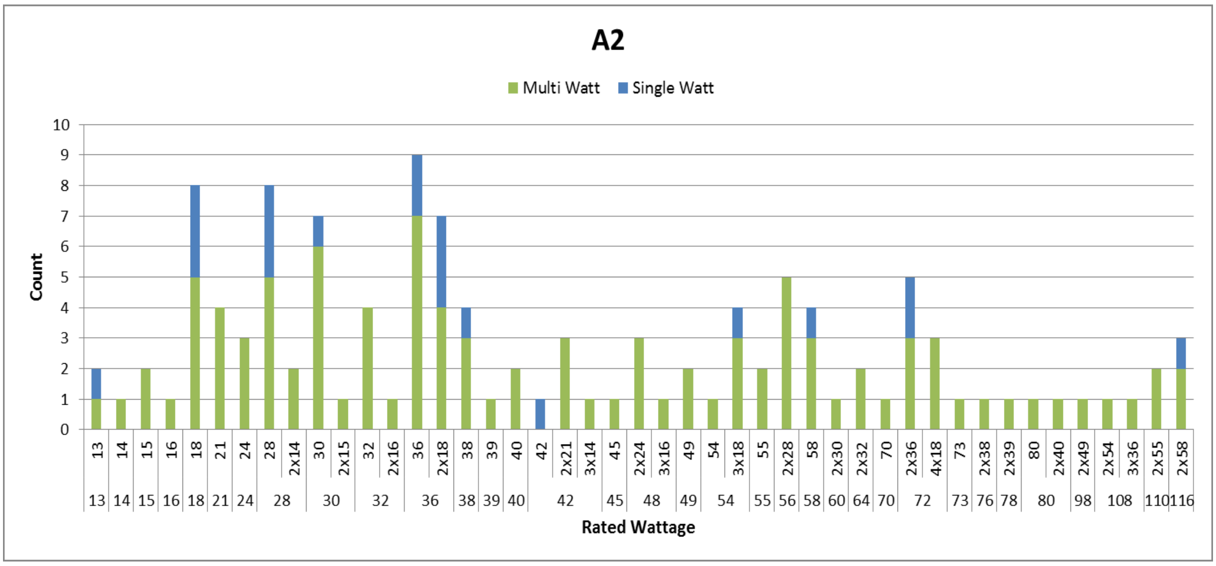
It is predicted that the market as a whole may shift towards A1 ballasts, as these are electronically more reliable and offer superior flexibility and dimming capability (discussion with industry).

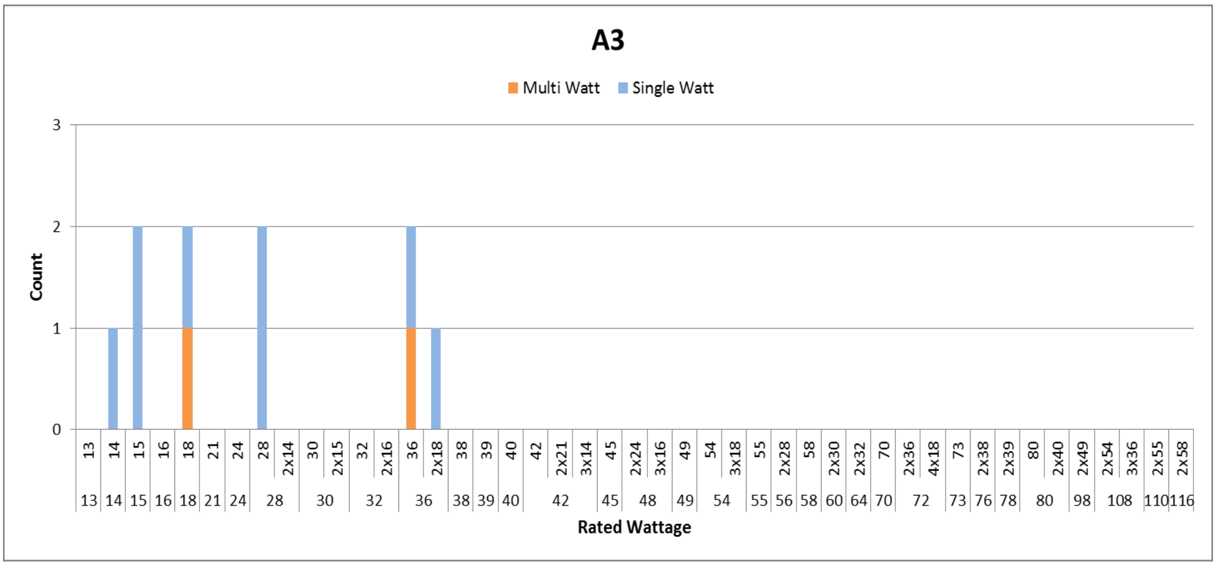
The following five charts show the range of lamp ballasts registered and approved with Australia/New Zealand E3 database, as identified by their EEI; A1 (dimmable), A2 and A3 (all electronic, in descending efficiencies); and B1 and B2 (magnetic, descending in efficiency). Each chart shows the number of available ballast models for a given wattage, and categorised as single or a multi-watt design (in which case, the ballast is counted for each wattage at which it has been rated to operate).

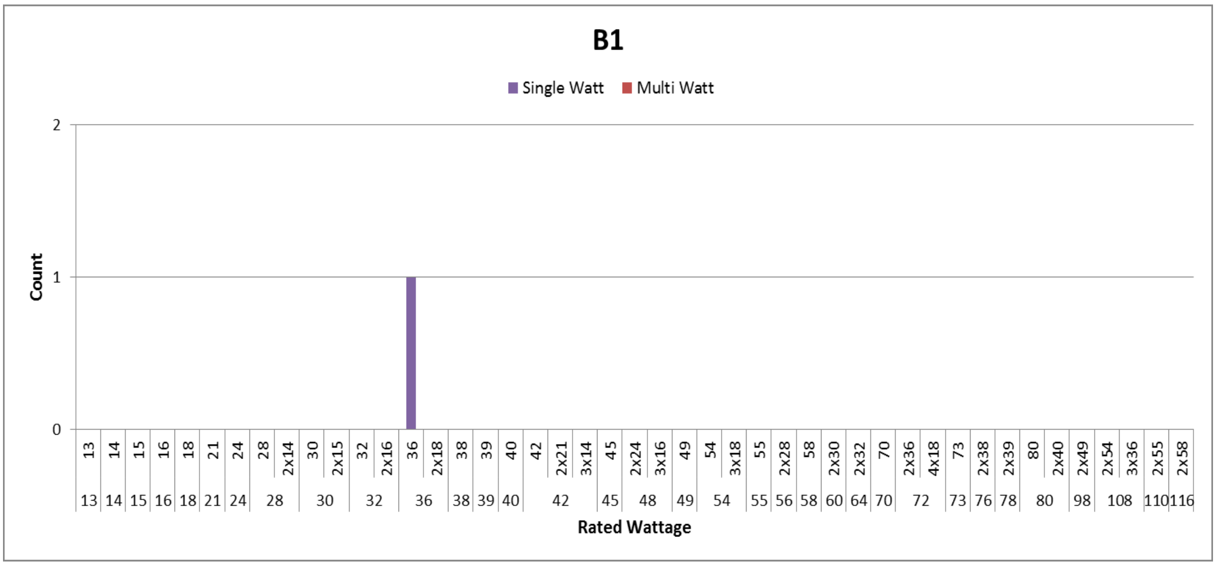
It is clear from these charts that manufacturers have put a major focus on developing ballasts at an A2 quality; with an option available across the whole wattage range. There are dimmable A1 ballasts across wattages from 18W to 2x58W (these can be used only with T5 fluorescent); while A3 ballasts are for lamps of wattage up to 36W.

Only four magnetic ballasts are currently registered for use in Australia and New Zealand; one B1 and three B2 quality.

Figure 18. Linear fluorescent ballasts registered with the E3 Program, indicating the Energy Efficiency Index (EEI) and total wattage of lamps with which they are designed to run.




A3
Multi Watt
Single Watt
Count
Rated Wattage
13 14 15 16 18 21 24 28 2x14 30 2x15 32 2x16 36 2x18 38 39 40 42 2x21 3x14 45 2x24 3x16 49 54 3x18 55 2x28 58 2x30 2x32 70 2x36 4x18 73 2x38 2x39 80 2x40 2x49 2x54 3x36 2x55 2x58
13 14 15 16 18 21 24 28 30 32 36 38 39 40 42 45 48 49 54 55 56 58 60 64 70 72 73 76 78 80 98 108 110 116


B1
Single Watt
Multi Watt
Count
Rated Wattage
13 14 15 16 18 21 24 28 2x14 30 2x15 32 2x16 36 2x18 38 39 40 42 2x21 3x14 45 2x24 3x16 49 54 3x18 55 2x28 58 2x30 2x32 70 2x36 4x18 73 2x38 2x39 80 2x40 2x49 2x54 3x36 2x55 2x58
13 14 15 16 18 21 24 28 30 32 36 38 39 40 42 45 48 49 54 55 56 58 60 64 70 72 73 76 78 80 98 108 110 116


B2
Single Watt
Multi Watt
Count
Rated Wattage
13 14 15 16 18 21 24 28 2x14 30 2x15 32 2x16 36 2x18 38 39 40 42 2x21 3x14 45 2x24 3x16 49 54 3x18 55 2x28 58 2x30 2x32 70 2x36 4x18 73 2x38 2x39 80 2x40 2x49 2x54 3x36 2x55 2x58
13 14 15 16 18 21 24 28 30 32 36 38 39 40 42 45 48 49 54 55 56 58 60 64 70 72 73 76 78 80 98 108 110 116

4.2.4 T8-T5 adapters

T8 to T5 adapters are marketed as a cost-effective, energy efficient replacement for existing T8 lamps (Lighting Council Australia). Products on the Australian market claim to provide energy savings of "up to 50%", "47%", "39%" or "35%" by using an electronic ballast in circuit with the existing T8 magnetic ballast.

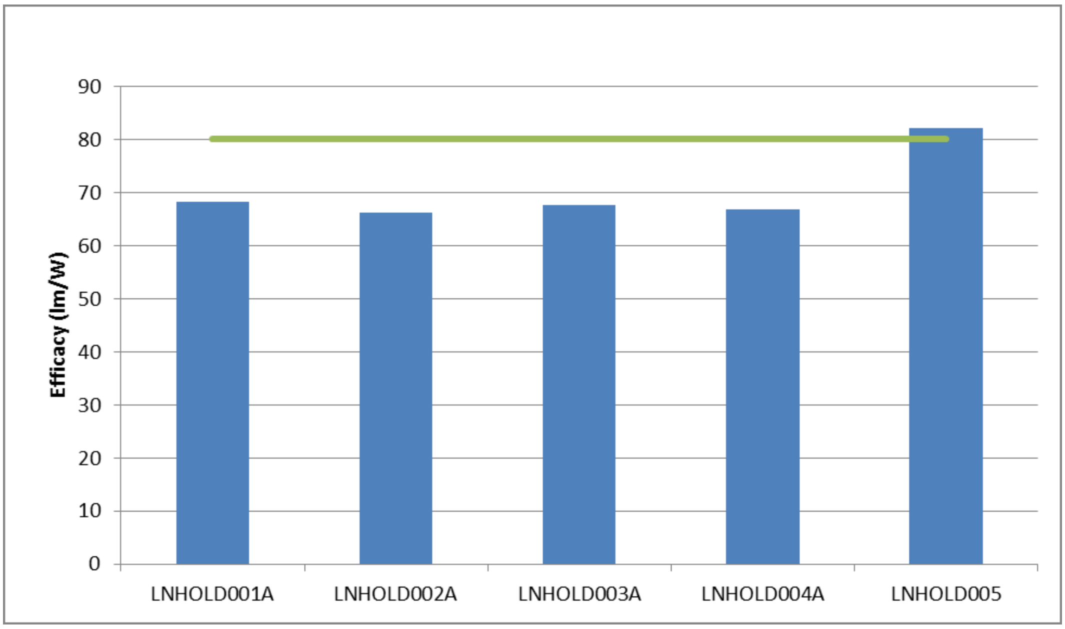
Five different models of T8-T5 adapter were purchased and tested for their performance by the Department of Industry in 2013. All were replacements for a 1200 mm length T8 fixture. Four of the five models came with a T5 linear fluorescent tube included as part of the purchase, however, only one T5 lamp was chosen to be a reference lamp for all five adapters.

The adapters reduce the amount of energy consumed by the whole light fixture and therefore do save energy. Using the adapter kit, T5 tubes work with the existing ballast and since the current required is much lower, losses in the ballast are minimised. Power consumed by the ballast drops from about 6 W for a T8 lamp to less than 1 W for a T5 lamp. Note however, that T8 fittings typically have a power factor correcting capacitor installed directly to the circuit, which brings the power factor up from around 0.4 to 0.9. Power factor of a T5 without the capacitor fitted is greater than 0.9. If the capacitor is left in place with the original ballast, this will cause the power factor to inversely decrease to around 0.4.

Although overall energy use can be reduced when using the T8-T5 adapters with the T5 lamp replacement, when examining the efficacy (total light output per watt consumed) of the adapter and lamp unit as though they were a bare lamp, four of the five models tested did not achieve the current MEPS requirement for a bare 1200 mm length linear fluorescent lamp (Figure 19).

The light output of a modified T8 luminaire can be different to the original when using a T8-T5 adapter. As such, the light is not reflected out of the luminaire as efficiently, and illumination levels, glare and task specific lighting requirements may not meet the minimum requirements of AS 1680.

Figure 19. T8-T5 adapter efficacy using T5 lamps (tested by the Department of Industry 2013). The green line indicates the current MEPS for 1200 mm T8 linear fluorescent lamps.



The four adapters that did not pass AU MEPS were the style of adapter shown [left] in Figure 20, where the T5 is held by a bare batten which itself is inserted into the luminaire in place of a bare T8 lamp (essentially a batten within a batten). The adapter 'LNHOLD005' is the style shown [centre] in Figure 20. This style of adapter does not cause any portion of the bare T5 light output to be absorbed by the adapter therefore it can achieve a higher lumen output. The adapter shown [right] Figure 20 (not tested) attempts to improve on the former problem by including a reflector in the design so that less light is lost to the batten and is distributed toward the intended area. From the three designs shown, it is clear that the light output of a modified T8 luminaire can be different to the original when using a T8-T5 adapter. As such, the light may not be reflected out of the luminaire as efficiently, and illumination levels, glare and task specific lighting requirements may not meet the minimum requirements of AS 1680.

Figure 20. Examples of T8 to T5 adapters. These are inserted into a T8 luminaire in place of a bare T8 lamp. [Left] shows bare batten style adapter; [centre] shows end cap style such that T5 is inserted bare; [right] shows batten style with inbuilt reflector.

4.2.5 Luminaires

Market research of luminaires currently sold on the international market, including Australia and New Zealand, has provided an indication of current efficacy. For the purpose of this section of the Product Profile, the efficiency of luminaires is determined by the luminaire efficacy rating (LER). This is a measure of the system as a whole (lamp, ballast, luminaire) and is measured in lumens per watt. This enables a categorisation of luminaire quality for a given room design which requires a specific amount of light to fall into the design space, in order to achieve lux levels recommended in AS1680. A detailed discussion on calculating the LER and other definitions for the photometric efficiency or lighting performance specifications of luminaires is provided in Section 7.

Troffers

The average LER is between 50 and 60 lm/W for both T5 and T8 troffers. However, the spread of efficiency between troffers containing 1, 2, 3, or 4 lamps is clearly shown in Figure 21. The most efficient troffer has two lamps, with an LER of 116 lm/W and light output of 7000 lumens.

The majority of single-lamp troffers have an LER of less than 90 lm/W and a light output between 1500 and 4000 lumens (Figure 21). In general, these troffers also consume the least amount of power (Figure 22). Most twin-lamp troffers have an LER of 100 lm/W or less and light output of 2000–6000 lumens (Figure 21). Both single-lamp and twin-lamp troffers were available with an LER of less than 10 lm/W.

Figure 21. Linear fluorescent troffers LER versus luminaire lumens.

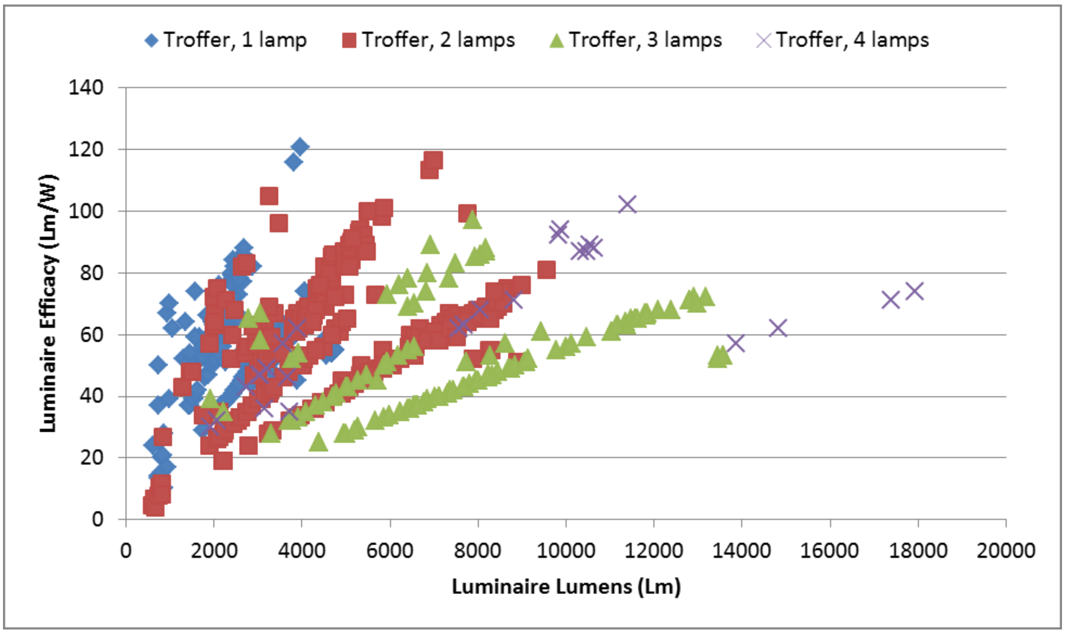
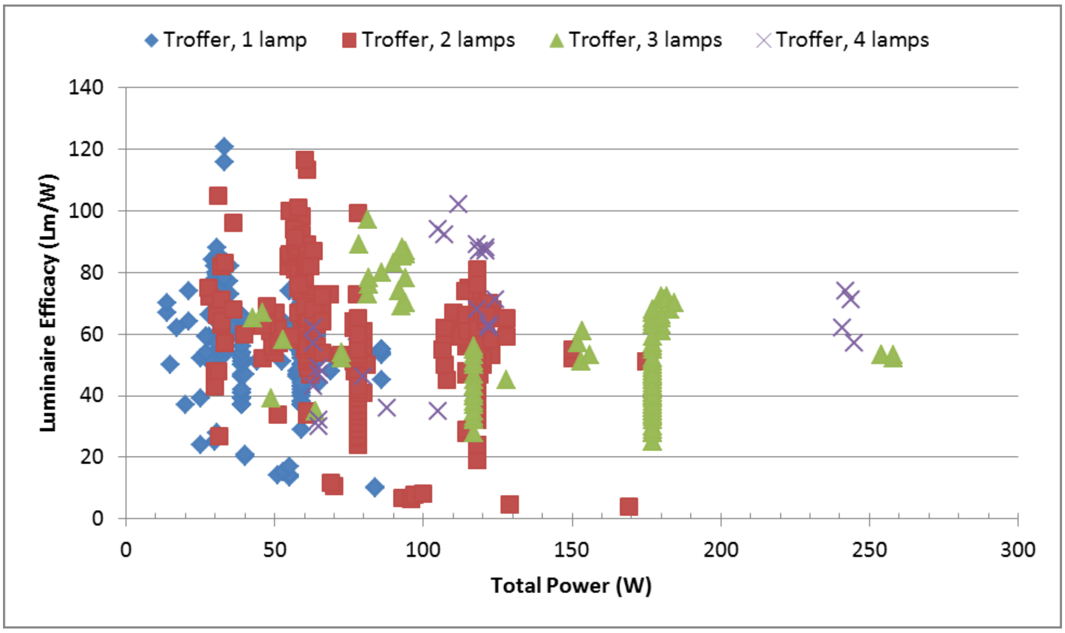


Figure 22. Linear fluorescent troffers LER versus power consumption.



The three-lamp troffers available on the market have an efficacy of 25–97 lm/W, the majority of which produce 4000–10,000 lumens. The most efficient three-lamp troffers have a lumen output of 6000–8000 (Figure 21). Three-lamp troffers have the largest variation in power consumption, from less than 50 W to more than 250 W, for a similar efficacy (Figure 22).

Four-lamp troffers are also highly variable in their efficacy, ranging from 30-100 lm/W. The most efficient four-lamp troffers have a light output of 10,000–12,000 lumens, while those that produce more than 14,000 lumens have a lower efficacy due to high power consumption (Figure 21 and Figure 19).

Battens

The average LER of battens available on the market is 45–55 lm/W, slightly lower than that for troffers. A particular range of T5 three-lamp battens have a much higher average efficiency at 72 lm/W, while a range of T8 four-lamp battens have a lower average of around 38 lm/W.

The LER range for single-lamp battens is very broad, from 10 to 80 lm/W, although most of that range is due to luminaires which produce less than 2000 lumens (Figure 23). Single-lamp battens which produce 2000–5000 lumens have an LER range of 45–80 lm/W. The variation in energy consumption is quite broad for single-lamp battens (9–86 W), across the whole range of efficacy (Figure 24).

Figure 23. Linear fluorescent battens LER versus luminaire lumens.

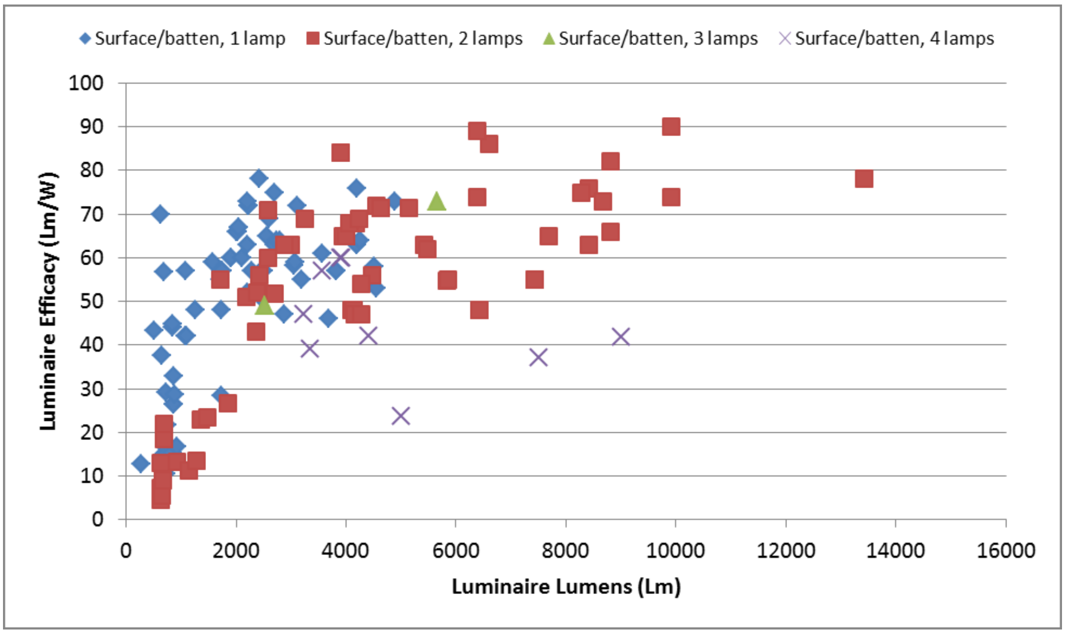
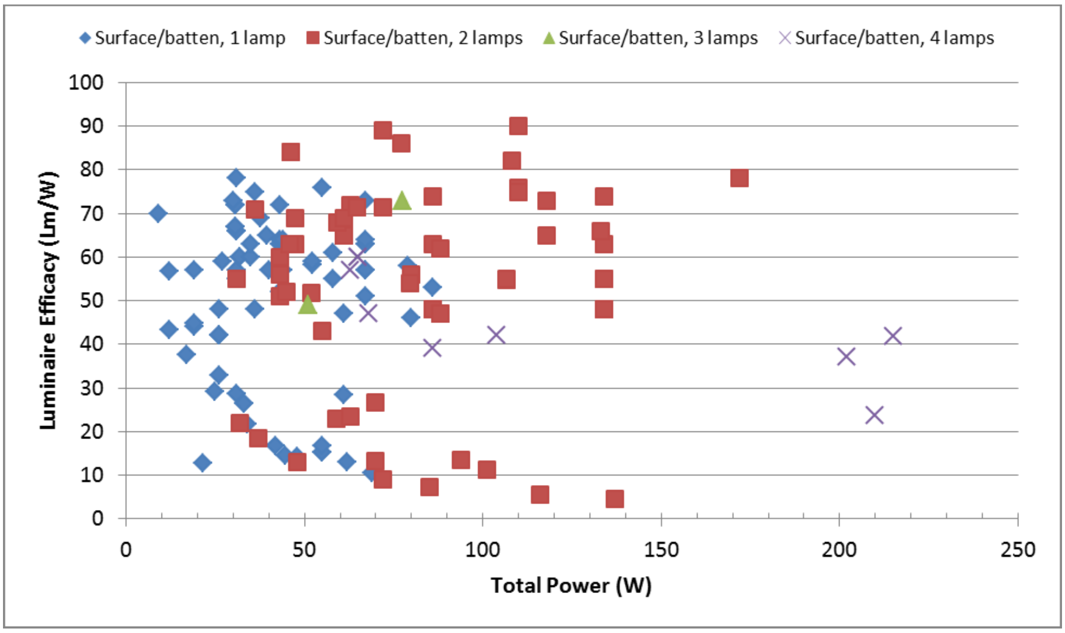


Figure 24. Linear fluorescent battens LER versus power consumption.



Twin-lamp battens also have a large variation in LER, from 4 lm/W to 90 lm/W (Figure 23). Similar to single-lamp battens, efficacy below 43 lm/W is restricted to fittings which output less than 2000 lumens. Twin-lamp battens have the largest range of light output, from 630 lumens to 13,400 lumens. They also have high variation in total power consumption – between 31 W and 172 W (Figure 24).

Only two three-lamp battens are available in the market and had efficacies of 49 lm/W and 73 lm/W (Figure 23). The efficacy of four-lamp battens is generally below the majority of single-lamp and two-lamp battens (less than 45 lm/W; Figure 23). The low efficacy for some of these battens is due to a very high power consumption of over 200 W (Figure 24), even though these battens had higher light output than other four-lamp batten (Figure 23).

From the above figures, it appears that there is scope for improvement to the efficiency of troffer and batten luminaires through the development and implementation of MEPS.

CFL cans

There is a clear difference in light output between single-lamp and twin-lamp CFL cans (less than 12,300 lumens), and three-lamp and eight-lamp CFL cans (greater than 12,300 lumens; Figure 25). A similar pattern is found for total power consumption, with single-lamp and twin-lamp cans consuming less than 200 W while three-lamp cans consume between 220 W and 350 W, and eight-lamp cans over 350 W (Figure 26).

Figure 25. CFL can LER versus luminaire lumens.

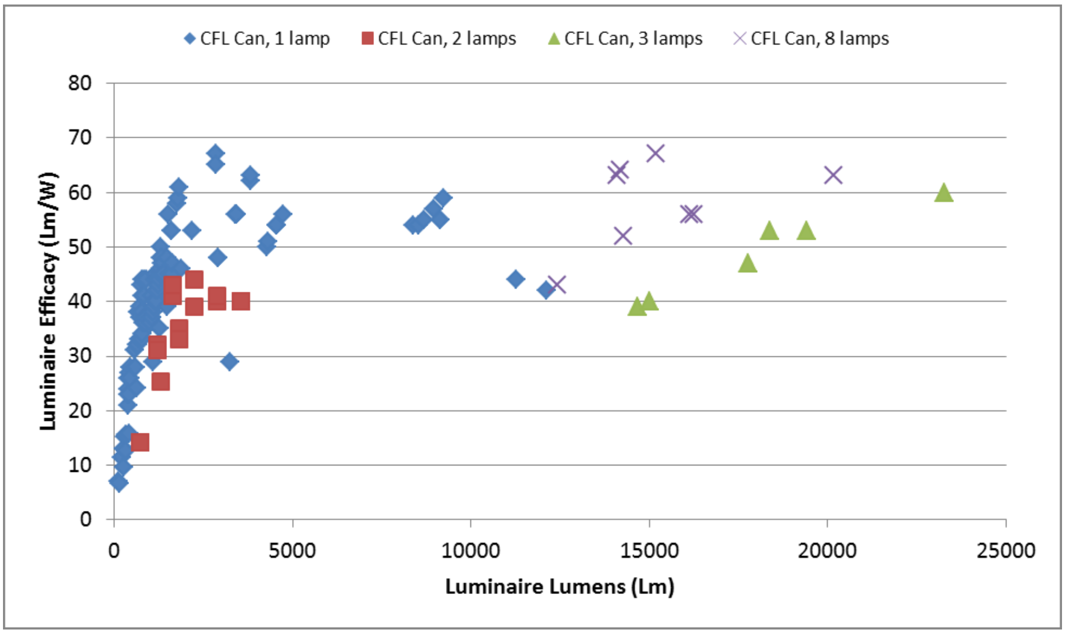
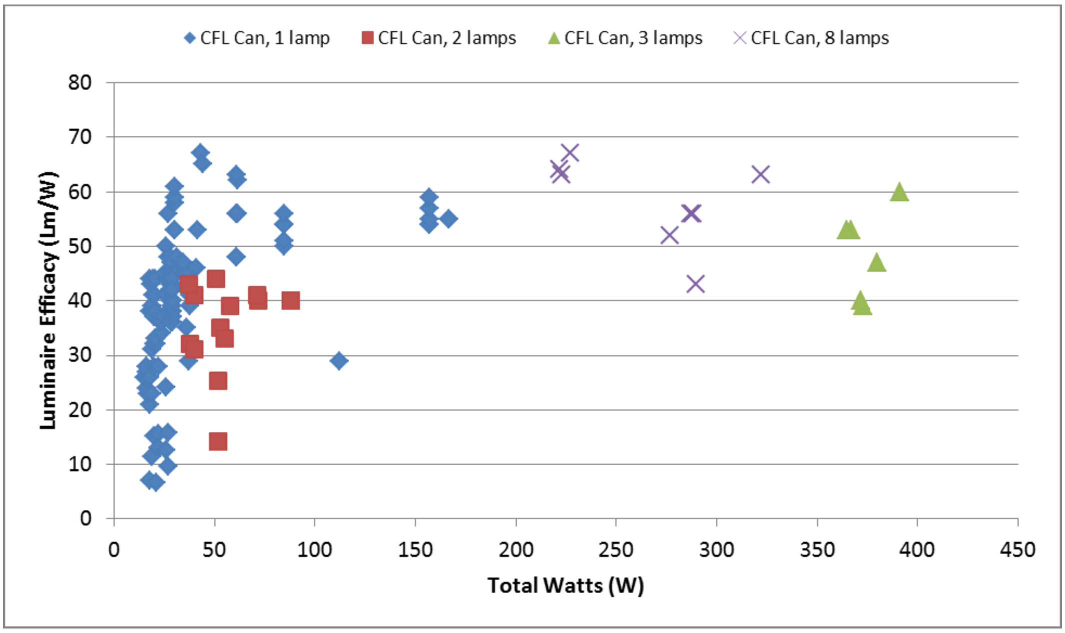


Figure 26. CFL can LER versus power consumption.



Single-lamp CFL cans generally have a higher LER (40 lm/W) than twin-lamp cans (33 lm/W). The LER of single-lamp CFL cans increases with lumen output, up to 5000 lumens (Figure 25). The data shows a general trend of decreasing LER for single-lamp CFL cans with light output greater than 2900 lumens and power consumption greater than 50 W (Figure 26).

Twin-lamp CFL cans currently available in the market only have a light output up to 3500 lumens, with most having an efficacy between 30–45 lm/W (Figure 25). The power consumption of these types of CFL cans ranges from 40–90 W (Figure 26).

Three-lamp and eight-lamp cans have an efficacy of 40–70 lm/W (similar to the top performing single-lamp cans) and a light output range of 12,000-23,000 lumens (Figure 25). Eight-lamp cans are more efficient than three-lamp cans for a given light output.

4.2.6 Other opportunities to achieve energy savings

A number of other opportunities exist to achieve energy savings from lighting in the commercial sector.

- Over-lighting is common in commercial buildings and has resulted from a number of factors including:

  - Advances in lamp technology that have reduced lumen depreciation and therefore the initial high light levels required to maintain end-of-life light levels.
  - Contractors selecting 3 by 36 W troffer systems as standard even though current systems produce significantly more light output than the older 3 by 36 W systems.
  - Uniformly high light levels in interior spaces to satisfy the most demanding visual tasks because detail of the use of the space is unknown at the design stage.

- Opportunities to reduce over-lighting are available through improved technology and lighting design. Better lighting design ensures that light is delivered to where it is needed and in the most efficient way.

  - Improvements in luminaire design and lamps means fewer lamps or lower wattage lamps can deliver the same or better light output than older fittings.
  - Use lighting controls such as occupancy sensors and/or daylight sensors so light levels are reduced or lights are turned off when there is sufficient daylight for the task.

Further opportunities to achieve energy savings include reducing operating hours of the lighting system and turning lights off when a room or area is not in use. Both of these can be achieved through a combination of modifying user behaviour and utilising lighting controls. Some provisions are already specified in the Building Code of Australia in relation to switching and lighting control in commercial buildings – see Section 5 of this Product Profile for further discussion.

5 Relevant Standards and Regulations in Australia and New Zealand

5.1 Testing and MEPS/labelling

The standards that are used in MEPS regulations usually consist of two parts, a test method, and a MEPS standard. These documents list the minimum energy efficiency, other minimum performance parameters and any labelling requirements that products must meet to be sold in Australia and/or New Zealand.

There are two relevant Australian/New Zealand standards for products within the scope of this Product Profile: *AS/NZS 4782 Double-capped fluorescent lamps – Performance specifications* and *AS/NZS 4783 Performance of electrical lighting equipment – Ballasts for fluorescent lamps*. Prior to development of AS/NZS 4782, MEPS for linear fluorescent lamps were regulated in New Zealand as per NZHB 4782.2:2001.

5.1.1 Current test methods and test laboratory capability

AS/NZS 4782.1 was published in 2004 by Standards Australia and provides the methods for starting, electrical, photometric and cathode characteristics, lumen maintenance and life. The Standard also provides chromaticity coordinates and information for ballast, starter and luminaire design. AS/NZS 4782.1 is adopted from IEC 60081:2000, with modifications to take into account Australian and New Zealand conditions. Part 2 of the Standard also specifies some test conditions for determining MEPS.

The procedure for analysing the mercury content of fluorescent lamps is detailed in AS/NZS 4782.3(Int):2006 and applies to both linear and compact fluorescent lamps. The technique is based on both the Japanese and European methods by wet chemical analysis, which involves acid digestion of the mercury contained within a lamp and the use of standard mercury solutions to accurately determine the lamps mercury content.

Standards Australia has published AS/NZS 4783.1:2001 that defines the methods of measurement for energy consumption and performance of fluorescent lamp ballasts. The test methods were derived from European (European Committee for Electrotechnical Standardization, or CENELEC) Standard EN 50294 and have been significantly restructured to allow the measurement method to be used for other classification systems. Together with AS/NZS 4783.2, the cumulative contents are equivalent to EN 50294. AS/NZS 4783.1 also references IEC 60921 and IEC 60929.

The scope of AS/NZS 4783.1 is ballast energy consumption and performance when used with their associated fluorescent lamp(s) that are within the scope of IEC 60081 (double-capped fluorescent lamps) and IEC 60901 (single-capped fluorescent lamps for general lighting service), including ballasts supplied as part of luminaires. Ballasts which are an integrated part of the lamp (e.g. self-ballasted CFL) are not within the scope of the test Standard.

Ballast energy consumption and performance is determined by the relative light output of the test ballast compared to the reference ballast operated with the same reference lamp. An alternative test method which does not require the measurement of light output is provided for magnetic ballasts that have a simple two-wire connection to the lamp. Details of test conditions, instrumentation and equipment are also given in the Standard, including the relevant reference ballasts and lamps.

Testing of linear fluorescent lamps and ballasts is carried out either by independent test laboratories, or by the manufacturers or importers at their own test facilities. Australia and New Zealand strongly recommend using an accredited third party testing facility such as an International Accreditation New Zealand (IANZ), National Association of Testing Authorities (NATA) or similar to test products.

There are a number of laboratories in Australia and New Zealand that are able to perform testing of linear fluorescent lamps and ballasts in accordance with AS/NZS 4782.1:2004 and AS/NZS 4783.1:2001. Some of these laboratories have the capacity to test luminaires as well as lamps. In general, this is limited by the maximum allowable physical size of the test object as a proportion of the dimensions of testing equipment.

5.1.2 MEPS regulations impacting on energy and performance

In Australia, Determinations under the GEMS Act set out specific product requirement. Requirements are described either directly in the Determination, or the Determination will refer to the applicable clause in a product standard – for lighting products the latter applies with some clarifications contained within the determination itself.

In New Zealand, lighting products are covered by the *Energy Efficiency (Energy Using Products) Regulations 2002* and must meet certain requirements before they can be legally sold. General requirements are set out in the regulations, and specific details for each product type, such as MEPS and labelling details, are described in product standards.

Linear fluorescent lamps

AS/NZS 4782.2:2004 specifies the MEPS for double-capped tubular fluorescent lamps (ILCOS code FD and FDH; linear shape and linear shape for high frequency ballasts only, respectively) with a nominal length of 550–1500 mm and nominal wattage of 16 W or greater, which operate in single-phase, 230 V 50 Hz supply. Lamps must meet initial efficacy (100 hours) and maintained efficacy (5000 hours) requirements, which are based on four length categories (Table 9). Length categories were used as a proxy for wattage categories, as there was only one wattage available for each length. This standard is structured to be broadly equivalent with *NZHB 4782.2:2001 Performance of Electrical Lighting Equipment - Tubular Fluorescent Lamps - Minimum Energy Performance Requirements*.

Circular and U-shaped double-capped fluorescent lamps, along with linear fluorescent lamps that are not for general illumination are excluded from AS/NZS 4782.2, in particular:

- lamps with a dominant colour or an output that is predominantly outside the visible light spectrum;
- lamps for colour matching and that have a CRI greater than 90 and a colour appearance approximating to a point on the black body locus;
- lamps that are specifically for use in an industrial or agricultural process;
- lamps for medical applications; or
- lamps that have been given written exemption by the relevant regulatory authority on the grounds that they are for a specific purpose other than general illumination and are clearly distinguishable from lamps for general illumination.

Table 9. Double-capped fluorescent lamp efficacy and mercury requirements.

Lamp nominal length '*l*' (mm) (mandatory)	550 ≤ *l* < 700	700 ≤ *l* < 1150	1150 ≤ *l* <1350	1350 ≤ *l* ≤1500
Lamp typical power (watts) (informative)	16–24	17–40	28–50	35–80
Initial efficacy (F_{100}) and Maintained efficacy (F_M)	$F_{100} \geq 66.0$ and $F_M \geq 57.5$	$F_{100} \geq 74.0$ and $F_M \geq 61.0$	$F_{100} \geq 80.0$ and $F_M \geq 70.0$	$F_{100} \geq 85.0$ and $F_M \geq 70.0$
Minimum colour rendering index (CRI)	79	79	79	79
Maximum mercury content (mg)	15	15	15	15

A minimum colour rendering index (CRI) of 79 and maximum permissible mercury content of 15 mg is also specified in the Standard. Furthermore, Appendix C of the standard provides details of a voluntary labelling scheme which indicates the energy efficiency class of the lamp, based on the European 'A–G' label established by the European Commission Directive 98/11/EC.

AS/NZS 4782.2 was developed to effectively phase-out halophosphate lamps from the Australian and New Zealand market. As a result, halophosphate lamps available as T12 and T8 models are no longer available in the market due to their inefficiencies. However, halophosphate lamps with a nominal length greater than 1500 mm are not within the scope of MEPS and as such some of these less efficient lamps are still available.

It is understood that at the time of the MEPS implementation, there was a concern about the availability of replacement lamps for some of the longer T12 models. This was addressed by excluding lamps with a nominal length greater than 1500 mm. As more than ten years have now passed it would be appropriate to revisit this restriction.

Fluorescent lamp ballasts

AS/NZS 4783.2 was published in 2002 by Standards Australia and specifies the requirements for the classification of ballasts for a range of fluorescent lamp types according to their Energy Efficiency Index (EEI), the form of labelling of the EEI (which is generally shown on the ballast rating plate), and defines MEPS requirements for certain fluorescent lamp ballasts. Within scope of this Standard are magnetic or electronic ballasts used with fluorescent lamps rated from 10–70 W, for use on 50 Hz supplies of 230/240/250 V or a range including one or more of these voltages. Ballasts supplied as separate components or as part of a luminaire are covered by the Standard.

The EEI in AS/NZS 4783.2 is based on the average performance (total circuit power) for the ballast model. At the time of publication, the labelling scheme was fully harmonised with the European Classification operated by CELMA, except that ferromagnetic ballasts with an EEI of B2 and rated at 240 V or 250 V and over had a small allowance added to the maximum permitted corrected total input power. Magnetic ballasts are within categories B1, B2, C and D, while electronic ballasts fall within the A1, A2 and A3 categories. Category A1 is specific to dimmable ballasts.

To comply with the MEPS, each unit tested must meet the relevant requirements (i.e. must not exceed the specified total circuit power; Table 10). In New Zealand, a minimum EEI of B1 is mandated for ballasts that are intended for use with or may be used with ILCOS code FD linear fluorescent lamps (type T), FSD compact 2-tube fluorescent lamps (type TC-L) or FSS compact 4 tube flat lamps (type TC-F), as listed in Table 3 of the Standard. Australia has a lower minimum EEI requirement of B2 for ballasts to be used with ILCOS code FD (type T) lamps, as specified in Tables 1 to 3 of the Standard. As the MEPS only applies to ballasts intended for use with specific ILCOS code lamps, ballasts for T5 lamps are not required to meet MEPS.

Table 10. Ballast performance MEPS for linear fluorescent lamps in Australia and New Zealand, 2014.
NOTE: MEPS for ballasts with ILCOS codes beginning with FSD and FSS (cells highlighted grey) in New Zealand only.

Nominal lamp power (W)	ILCOS code	Maximum corrected total input power (W) Energy Efficiency Index (EEI) classification								
		A1	A2	A3	B1	B2 (< 240 V)	B2 (≥ 240 V and < 250 V)	B2 (≥ 250 V)	C	D
15	FD-15-E-G13-26/450	≤18.0	≤16.0	≤18.0	≤21.0	≤23.0	≤23.5	≤24.0	≤25.0	>25.0
18	FD-18-E-G13-26/600	≤21.0	≤19.0	≤21.0	≤24.0	≤26.0	≤26.5	≤27.0	≤28.0	>28.0
30	FD-30-E-G13-26/895	≤33.0	≤31.0	≤33.0	≤36.0	≤38.0	≤38.5	≤39.0	≤40.0	>40.0
36	FD-36-E-G13-26/1200	≤38.0	≤36.0	≤38.0	≤41.0	≤43.0	≤43.5	≤44.0	≤45.0	>45.0
38	FD-38-E-G13-26/1047	≤40.0	≤38.0	≤40.0	≤43.0	≤45.0	≤45.5	≤46.0	≤47.0	>47.0
58	FD-58-E-G13-26/1500	≤59.0	≤55.0	≤59.0	≤64.0	≤67.0	≤67.5	≤68.0	≤70.0	>70.0
70	FD-70-E-G13-26/1800	≤72.0	≤68.0	≤72.0	≤77.0	≤80.0	≤80.5	≤81.0	≤83.0	>83.0
18	FSD-18-E-2G11	≤21.0	≤19.0	≤21.0	≤24.0	≤26.0	≤26.0	≤26.0	≤28.0	>28.0
24	FSD-24-E-2G11	≤27.0	≤25.0	≤27.0	≤30.0	≤32.0	≤32.0	≤32.0	≤34.0	>34.0
36	FSD-36-E-2G11	≤38.0	≤36.0	≤38.0	≤41.0	≤43.0	≤43.0	≤43.0	≤45.0	>45.0
18	FSS-18-E-2G10	≤21.0	≤19.0	≤21.0	≤24.0	≤26.0	≤26.0	≤26.0	≤28.0	>28.0

Nominal lamp power (W)	ILCOS code	Maximum corrected total input power (W) Energy Efficiency Index (EEI) classification								
		A1	A2	A3	B1	B2 (< 240 V)	B2 (≥ 240 V and < 250 V)	B2 (≥ 250 V)	C	D
24	FSS-24-E-2G10	≤27.0	≤25.0	≤27.0	≤30.0	≤32.0	≤32.0	≤32.0	≤34.0	>34.0
36	FSS-36-E-2G10	≤38.0	≤36.0	≤38.0	≤41.0	≤43.0	≤43.0	≤43.0	≤45.0	>45.0

In Australia, the EEI classification must be marked on ballasts that are within the scope of the MEPS, and EEI classification labelling may also be used on a voluntary basis for other fluorescent lamp ballasts outside the scope of MEPS and within the scope of the Standard. In New Zealand, labelling the EEI classification on fluorescent lamp ballasts is voluntary.

All ballasts that use the EEI classification label must meet the requirements of Clause 5 of the Standard (determination of corrected and average corrected total input power, determination of EEI classification and labelling of EEI) and comply with safety standards AS/NZS 60921 (ferromagnetic ballasts) and AS/NZS 60929 (electronic ballasts).

5.1.3 Luminaires

Annex F of AS/NZS 4782.1 provides (non-mandatory) information on luminaire design for linear fluorescent lamps. The Annex suggests that to ensure proper functioning of the lamps, consideration should be given to free space around the lamp, capacitor tolerance and distance between the surface of the lamp and the starting aid.

5.2 Other regulations and policies impacting on energy

5.2.1 Interior lighting

The AS/NZS 1680 series for interior lighting contain minimum recommended illumination levels for performing a range of visual tasks efficiently and without visual discomfort. Part 2 of the Standard provides recommendations for specific applications, while Part 4 provides recommendations for maintenance techniques of lighting systems. This includes cleaning, relamping and ensuring the luminaires are suited to the lamp to prolong operating time. While the AS/NZS 1680 series itself is not mandatory, parts of the Standard are referred to in other legislation as a mandatory requirement (e.g. *1680.0:2009 Interior lighting - safe movement* is mandatory as required by the Building Code of Australia).

5.2.2 Australia

National Construction Code and Building Code of Australia
The National Construction Code (NCC) is a performance-based system, where a proposal will achieve compliance with either a Deemed-to-Satisfy Provision or Alternative Solutions. Volumes One and Two of the NCC are the Building Code of Australia (BCA), which details technical provisions for building design and construction including energy efficiency.

Volume 1, Part J6 of the BCA prescribes energy efficiency measures for artificial lighting and power in non-residential buildings. The purpose is to avoid over-installation and excessive use of lighting, and improve the use of efficient lights and fittings. A number of elements are addressed in this part of the BCA, including:

- limits on the efficiency and power consumption of lighting installations;
- switching and control of lighting;
- interior decorative and display lighting control; and
- efficiency and control of building exterior lighting.

A lighting power allowance based on the illumination power density (watts per square metre) is set out in the BCA (Table 11). The illumination power density includes power loss through ballasts and control devices. The power densities given in Table 11 are based on lighting design that complies with the Australian Standard for interior lighting (AS 1680), however they also provide a safety margin, take into account physical limitations of lighting installations and are set at a level that can be achieved through a combination of practical surface reflectance, high efficacy lamps and efficient control gear and luminaires (ABCB 2010).

Table 11. Building Code Australia maximum illuminated power densities for select spaces in commercial buildings, and corresponding AS 1680 lighting levels and lumens per watt (ABCB 2010).

Building Space	W/m²	Recommended Lux Level (as per AS/NZS 1680 Interior Lighting)	lm/W
Board room and conference room	10	240	24
Corridors	6	160	27
Entry lobby from outside the building	15	160	11
Office – artificially lit to an ambient level of 200 lux or more	9	320	33
Office – artificially lit to an ambient level of less than 200 lux	7	160	23
School – general purpose learning areas and tutorial rooms	8	320	40

An adjustment can be applied to the maximum illuminated power density to recognise the use of energy control devices such as dimmers, timers and daylight sensors. The adjustment factor is a graduated scale, depending on the area of lights controlled by devices such as occupancy sensors.

Clause J6.3 of the Building Code Australia contains provisions for the switching and control of lighting in commercial buildings, with the intention that 'rooms are not unnecessarily lit or using power when vacant' (ABCB 2010). These provisions include:

- lighting in each space must be operated/switched separately from other spaces;
- the switch must be visible in the room being lit or be in a room where the lighting being switched can be seen;
- limiting the area of lighting that a single switch can control;
- Class 5 to 9 buildings larger than 250 m² must have 95% of their lighting automatically turn off after hours; and
- lighting in the natural light zone adjacent to windows must be separately switched to other general lighting in Class 5, 6 and 8 building larger than 250 m².

Appropriate design requirements for lighting and power control devices are contained in the Specification to Part J6. This includes corridor lighting timers, time switches, motion detectors, daylight sensors and dynamic control devices.

Commercial Building Disclosure

The CBD program is a national initiative designed to improve the energy efficiency of Australia's large office buildings. The program requires a current Building Energy Efficiency Certificate (BEEC) to be obtained and disclosed at the sale or lease of commercial office space of 2000 m² or more. The BEEC is comprised of a National Australian Built Environment Rating System (NABERS) energy star rating for the building, an assessment of tenancy lighting in the area of the building that is being sold or leased, and general energy efficiency guidance. The lighting provisions came into force in November 2011.

The tenancy lighting assessment measures the power density of the installed general lighting system by calculating the Nominal Lighting Power Density (NLPD) of the relevant functional space in the building as well as the capacity of installed lighting control systems. The assessment covers installed lighting, and where appropriate, proposed lighting systems.

5.2.3 New Zealand

Energy Efficiency and Conservation Act 2000

The *Energy Efficiency and Conservation Act 2000* provides the legislative framework for the New Zealand Energy Efficiency and Conservation Strategy (NZEECS), EECA and regulations pertaining to energy using products and services (discussed further below).

The NZEECS states the Government's policies, objectives, targets and the means to achieve those policies and objectives with respect to energy efficiency, energy conservation and the use of renewable sources of energy.

The Act established EECA, which is a standalone Crown Entity subject to the *Crown Entities Act 2004*. The function of EECA is to 'encourage, promote, and support energy efficiency, energy conservation and the use of renewable sources of energy'.

The *Energy Efficiency (Energy Using Products) Regulations 2002* are provided for under section 36(1) of the Energy Efficiency and Conservation Act. They are administered by the Ministry of Business, Innovation and Employment.

Building Act 2004 and Building Code
The *Building Act 2004* incorporates a movement towards sustainable building practices and includes energy efficiency in its guiding principles. Section 172 requires the chief executive of the Department of Building and Housing to appoint a building advisory panel that has members that specialise in a number of matters relating to the building industry. These include consumer, cultural, disability, energy efficiency, health and safety, heritage, or sustainable development issues. The purpose of the building advisory panel is to provide independent, specialist advice on trends in building design, quality and performance, building technology, sustainability, urban planning and consumer issues. This panel has the potential to influence the building industry in relation to the energy efficiency artificial lighting.

Section 400 provides powers to set minimum performance standards for new buildings in regulations called the Building Code. The Building Code is the first schedule of the *Building Regulations 1992* and continues in force via Section 415 of the *Building Act 2004*. The Building Code is a performance-based regulation that sets the standards building work must meet. It covers a variety of building aspects including structural stability, fire safety, access, moisture control, durability, services and energy efficiency.

Clause H1 of the Building Code prescribes energy efficiency performance standards. The objective of Clause H1 is to facilitate the efficient use of energy. One of the functional requirements is that "Buildings must be constructed to achieve an adequate degree of energy efficiency when that energy is used for … providing artificial lighting". This requirement only applies to commercial buildings with a floor area greater than 300 m^2. The provisions of the Building Code are that artificial lighting fixtures must be –

- located and sized to limit energy use, consistent with the intended use of space; and
- fitted with a means to enable light intensities to be reduced, consistent with reduced activity in the space.

Artificial lighting in commercial buildings must comply with *NZS 4243.2:2007 Energy efficiency – Large buildings – Lighting*, sections 3.3 or 3.4, to satisfy the above provisions.

5.3 ENERGY STAR

The ENERGY STAR program is a voluntary scheme which provides endorsement labelling for high efficiency products. New Zealand adopted the ENERGY STAR specification for luminaires which came into effect in November 2012 and was amended in December 2013. The objective of the specification is to save money on energy bills and lamp replacements and distribute light more efficiently and evenly than standard fixtures, with qualifying luminaires using only a quarter the energy of traditional lighting. The requirements are identical to those in the US ENERGY STAR specification, with the exception of some amendments (additional lampholder types and changes to the downlight types to meet New Zealand electrical safety requirements).

The ENERGY STAR luminaire specification is primarily for residential luminaires although includes some directional commercial grade luminaires. See Section 6 for inclusions and exclusions. An ENERGY STAR specification for commercial LED luminaires is currently under consideration (refer page 47).

The program uses an endorsement mark to indicate those models produced by participating manufacturers and suppliers that are performing at a high-efficiency level (top 25% most energy efficient products), as defined under the relevant specification. This provides an independent verification of energy efficiency to consumers, and provides a selling point that manufacturers, suppliers and retailers can use in their promotion of televisions.

The ENERGY STAR program has had significant success in New Zealand – the consumer brand awareness is measured at 78% (2012). ENERGY STAR has the opportunity to play a major role in promoting industry best practice and it is strategically significant in that it is an international program. The potential inclusion of the mark under government procurement criteria could also increase the program's impact. However, as this is a self-selecting program and only addresses energy performance at the high end of the scale, the program on its own is less effective in addressing the energy efficiency of products than when it is used to complement measures such as MEPS and comparative energy labelling.

5.4 Incentive schemes

5.4.1 Australia

The NSW Energy Savings Scheme (ESS) (www.ess.nsw.gov.au/Projects_and_equipment/Lighting) includes lighting retrofits in commercial or industrial facilities. Evidence is collected on the lighting configuration before and after an upgrade, and testing is conducted to ensure that the final lighting configuration meets relevant lighting standards so output and service levels are maintained. The Commercial Lighting Energy Savings Formula is used to calculate energy savings from an upgrade of general lighting in commercial premises. Energy savings certificates are created, which electricity retailers then buy these certificates from the business. Over 2.1 million certificates for commercial lighting upgrades have been surrendered since 2009 – this represents 2.1 million tonnes of CO_2e that has been abated.

The Victorian Energy Efficiency Target (VEET) (www.veet.vic.gov.au) scheme, entitles a commercial energy consumer to a discount on the product installed (an Energy Saver Incentive) when undertaking a commercial lighting upgrade using a business accredited under the scheme to make the energy efficiency improvements (similar to the NSW business lighting measure.). The accredited business creates a Victorian energy efficiency certificate (VEEC) for every tonne of greenhouse gas abated. Since the introduction of the lighting measure into the scheme in 2012 to mid-2015 it has seen the creation of 481,526 certificates (equivalent to 1 tonne of lifetime greenhouse gas abatement) at 1,725 sites.

The ACT Energy Efficiency Improvement Scheme (EEIS) (www.environment.act.gov.au/energy/energy_efficiency_improvement_scheme_eeis) began on 1 January 2013 and sets a Territory-wide energy savings target, including obligations for ACT electricity retailers to meet an individual Retailer Energy Savings Obligation (RESO). The EEIS is based on existing schemes such as VEET, ESS and the Residential Energy Efficiency Scheme (South Australia) but is not based on creating and trading certificates. The scheme was recently extended to include ACT business premises.

The South Australian Retailer Energy Efficiency Scheme (REES), began on 1 January 2009 as a residential only scheme, but was expanded from 1 January 2015 to include the commercial sector. Commercial lighting upgrades follow those specified under the NSW and Victorian schemes and the REES calculates energy savings using the NSW energy savings lighting calculator. Similar to the ACT scheme, the scheme obligation is on energy retailers who meet certain eligibility requirements, and does not include trading of certificates as yet.

5.4.2 New Zealand

EECA offers grants for lighting upgrades of up to 20% of the cost of energy efficiency projects, which are managed by a program partner. Projects must deliver a guaranteed level of cost-effective energy savings. However grants for lighting upgrades will be discontinued from 30 June 2015.

6 Overseas Energy Efficiency Programs

6.1 Test methods

The international test method for linear fluorescent lamps is *IEC 60081-2001 Double-capped fluorescent lamps – Performance specifications*. The EU, China, India and Thailand (along with Australia/New Zealand) have test methods based on this standard (Table 12). IEC 60081 gives technical requirements for linear fluorescent lamps with preheated cathodes for general lighting service, operated with or without a starter from AC mains. The Standard also describes the tests for lamps with non-preheated cathodes operated without the use of a starter, and testing methods to be used for checking quality and interchangeability for type testing, for individual lamp batches or for a manufacturer's entire production.

There is no international test method for other types of fluorescent lamps within the scope of this Product Profile, and the test method associated with overseas standards for these products is generally unclear.

Table 12. Selected overseas linear fluorescent lamp test methods.

Economy	Test method	Regulation	Test Method Origin
EU	IEC 60081 IEC 60901 IEC 50285	EC No 245/2009 EC No 32/2005	IEC 60081 IEC 60901
Canada	CAN/CSA-C819-95 (2001) references the following standards: American National Standards Institute (ANSI) C78.1, ANSI 78.3 ANSI C78.375 ANSI C82.3 International Commission in Illumination (CIE) 13.3-1995: Method of Measuring and Specifying Colour-Rendering Properties of Light Source Illuminating Engineering Society of North America (IES or IESNA)LM-9-1988: Approved method for Electrical and Photometric Measurements for Fluorescent Lamps LM-16-1984: Colorimetry of Light Sources LM-58-1983: Spectroradiometric Measurements	CAN/CSA-C819-11	
China	GB/T 10682-2010	GB 19043-2013	IEC 60081
USA	Appendix R to Subpart B of Part 430 - Uniform Test Method for Measuring Average Lamp Efficacy, CRI, and CCT of Electric Lamps	10 CFR 430.32(n)	
Korea	KS C 7601		
India	IS 2418 (Part 1) & (Part 2): 1977	Schedule – 2 Tubular Fluorescent Lamps	IEC 60081
Thailand	TIS 236-2548 (2005)		IEC 60960

The international test standards for fluorescent lamp ballasts are *IEC 60921-2006 Ballasts for tubular fluorescent lamps – Performance requirements* (magnetic ballasts) and *IEC 60929-2006 AC-supplied electronic ballasts for tubular fluorescent lamps – Performance requirements* (electronic ballasts). These standards, or minor variations of the standards, are used by the majority of countries around the world (Waide 2011), including China and the EU (Table 13). The Australian/New Zealand test method for ballasts also references these IEC standards, although it is largely based on *EN 50294 Measurement method of total input power of ballast-lamp circuits*. Hong Kong's test procedure for ballasts is as per EN 50294.

In 2011 the Collaborative Labeling & Appliance Standards Program (CLASP) undertook an assessment of test procedures and efficiency metrics, including ballasts (Waide 2011). The ballast test methods of China, Europe, Australia/New Zealand, Japan and the USA were compared. The conclusion was that although the countries use different names for the measured metric, the test methods were fundamentally similar or the same and there was no reason why there should be country-specific test standards for fluorescent lamp ballasts.

Table 13. Selected overseas fluorescent lamp ballast test methods.

Economy/Product	Test method	Regulation	Test Method Origin (harmonisation)
EU	EN 60921 EN 60929	EU Directive: 2005/32/EC and 2009/245/EC	IEC 60921-2002 (magnetic) IEC 60929 (electronic)
China	GB/T 717262-2002 GB/T 14044-1993 (magnetic ballasts) GB/T 15042-1994 GB/T 15144-1994; GB/T 17262-2002; GB/T13434-1992 (electronic ballasts)	GB 17896-1999	IEC 60923:2006; IEC 60901:2002; IEC 60921:2002 ANSI C78.389:2004 (for HID) CAN/CSA-C 654-M-91 (electronic ballasts) IEC 60929 (magnetic ballasts)
USA	Appendix Q to Subpart B of Part 430 -- Uniform Test Method for Measuring the Energy Consumption of Fluorescent Lamp Ballasts	10 CFR 430.32(m)	ANSI C82.2–1984 for Fluorescent Lamp Ballasts—Method of Measurement

6.2 Mandatory programs

6.2.1 Fluorescent lamps

There is no international energy efficiency performance standard for the fluorescent lamps within the scope of this Product Profile. Instead, individual countries have developed their own specifications.

Europe
EC No 245/2009: Ecodesign requirements for fluorescent lamps without ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps, amended by EC No 347/2010, is a mandatory performance requirement for fluorescent lamps without integrated ballasts and includes:

- T5, T8 and T9 double-capped (linear) fluorescent lamps;
- U-shaped fluorescent lamps;
- T5 and T9 circular fluorescent lamps; and
- single-capped CFLs (small single parallel tube, double parallel tubes and triple parallel tubes).

There are a number of exemptions including:

- double-capped fluorescent lamps having –

— a diameter of 7 mm (T2) or less,
— a diameter of 16 mm (T5) and lamp power P ≤ 13 W or P > 80 W,
— a diameter of 38 mm (T12), lamp cap G-13 medium bi-pin base, +/- 5 m (+magenta, -green) colour compensating filter value limit (cc), CIE coordinates x=0.330 y=0.335 and x=0.415 y=0.337, and
— a diameter of 38 mm (T12) and equipped with an external igniter strip; and

- single-capped fluorescent lamps having a diameter of 16 mm (T5) 2G11 4-pin base, CCT = 3200 K with chromaticity coordinates x=0.415 y=0.377 and CCT = 5500 K with chromaticity coordinates x=0.330 y=0.335.

EC No 245/2009 is set out in three stages. Stage 1 (2010) set the minimum performance requirements for T5-He, T5-HO and T8 double-capped fluorescent lamps, single-capped fluorescent lamps and T9 and T5 circular fluorescent lamps. The specified performance metrics are initial efficacy at 100 hours (see Appendix B Table 22 and Table 23), correction factors (Table 24) and colour rendering index (> 80).

From Stage 2 (2012), lamps must meet minimum lumen maintenance and lamp survival factors (Appendix B Table 25). From this date the Stage 1 T8 lamp minimum efficacy also applies to all double-capped fluorescent lamps of other diameters than those covered by Stage 1 and not exempt from the regulation.

Implementation of Stage 1 removed all halophosphate T8 and T4 linear, U-shaped and T9 circular fluorescent lamps from the European market, and Stage 2 removed T10 and T12 lamps from the European market.

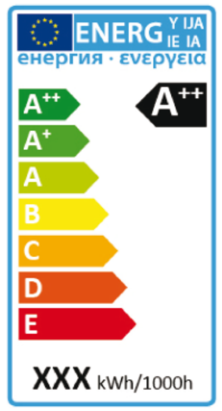
When Stage 3 comes into force in 2017, the Directive will require all non-integrated fluorescent lamps to operate with ballasts of energy efficiency class A2 or better.

U-shaped fluorescent lamps are not separately defined in EC No 245/2009. U-shaped fluorescent lamps must conform to the efficacy requirements for T8 linear fluorescent lamps, and the lamp survival factors and lamp lumen maintenance factors for T9 circular lamps.

Mandatory labelling of and provision of supplementary product information on electrical lamps, including fluorescent lamps and luminaires, is required under *EU No 874/2012 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires*. The label must include the energy efficiency class (A++ to E) and the weighted energy consumption in kWh per 1000 hours (unless specified elsewhere on the packaging). The energy efficiency class is based on the energy efficiency index (EEI), which is the rated power divided by the reference power (Table 14).

Table 14. Energy efficiency classes for EU fluorescent lamps and an example layout of the European energy label.

Energy efficiency class	EEI for non-directional lamps
A++	EEI ≤ 0.11
A+	0.11 < EEI ≤ 0.17
A	0.17 < EEI ≤ 0.24
B	0.24 < EEI ≤ 0.60
C	0.60 < EEI ≤ 0.80
D	0.80 < EEI ≤ 0.95
E	EEI > 0.95



USA

The Code of Federal Regulations (CFR) – Title 10, Part 430 (10 CFR 430) prohibits the production and sale of linear and U-shaped fluorescent lamps which are below the stated MEPS level. Luminous efficacy requirements for linear fluorescent lamps (manufactured after 14 July 2012) are specified firstly by tube diameter, then length and colour temperature categories, as per Appendix B Table 29. Increased efficacy requirements for general service fluorescent lamps were announced in January 2015 and will take effect from 2018 (Appendix B Table 30). The minimum efficacy requirements have been increased between 0–10.5%.

Other lamp efficacy and colour rendering index (CRI) standards (effective from 1 May 1994) for lamps manufactured before July 2012 are also listed in 10 CFR 430.

Regulations apply to T8, T5-HE, T5-HO and U-shaped fluorescent lamps as outlined below.

- Any straight-shaped lamp (commonly referred to as 4-foot medium bipin lamps) with medium bipin bases of nominal overall length of 48 inches and rated wattage of 25 or more;
- any U-shaped lamp (commonly referred to as 2-foot U-shaped lamps) with medium bipin bases of nominal overall length between 22 and 25 inches and rated wattage of 25 or more;
- any rapid start lamp (commonly referred to as 8-foot high output lamps) with recessed double contact bases of nominal overall length of 96 inches;
- any instant start lamp (commonly referred to as 8-foot slimline lamps) with single pin bases of nominal overall length of 96 inches and rated wattage of 52 or more;
- any straight-shaped lamp (commonly referred to as 4-foot miniature bipin standard output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 26 or more; and
- any straight-shaped lamp (commonly referred to 4-foot miniature bipin high output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 49 or more.

China

GB 19043-2013 Minimum allowable values of energy efficiency and the energy efficiency grades of double-capped fluorescent lamps for general lighting service is a mandatory performance standard which applies to

- cathode preheated lamps equipped with started and works on AC frequency circuits, and
- cathode preheated lamps which work on high frequency circuits.

The standard specifies the energy efficiency rating, energy efficiency limit values and test methods for evaluating values of energy conservation.

Lamps are categorised by diameter, wattage and CCT and can comply with three energy efficiency tiers – Tier 1 is the most efficient and Tier 3, the minimum energy performance requirement, is the least efficient (Appendix B Table 34). Linear fluorescent lamps must also satisfy the requirements for lumen maintenance (at 2000 hours must be a minimum 70%) and product life, as per *GB/T 10682-2010 Double-capped fluorescent lamps – Performance specifications*.

GB 19415-2003 Limited values of energy efficiency and rating criteria of single-capped fluorescent lamps is a mandatory performance standard for "single-capped fluorescent lamps that are with preheat type cathode and are installed with internal actuating device or used with external actuating device" (Code of China). The scope of the standard includes circular fluorescent lamps and double-tube, quad-tube, multi-tube and square CFLs.

Circular fluorescent lamps and non-integrated CFLs must meet minimum efficacy requirements (Appendix B Table 35) and the luminous flux tested at 2000 hours should not be less than 80% of the initial value (at 100 hours).

Programs in other countries can be found in Appendix B.

6.2.2 Fluorescent Lamp Ballasts

Europe

EC No 245/2009 Ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps is a mandatory requirement (amended by EC No 347/2010) which applies to fluorescent lamp ballasts for linear, circular, U-shaped and non-integrated compact fluorescent lamps sold in Europe.

The following ballasts are excluded from the regulation:

- Reference ballasts for the use in laboratories for lighting measurement techniques.
- Integrated ballasts as a non-replaceable part of a luminaire – in this case all the requirements shall be fulfilled from the luminaire. Integrated ballasts are not usable within a luminaire or a special enclosure.
- Ballasts intended for use in emergency lighting luminaires and emergency sign luminaires and designed to operate the lamps in emergency conditions (the regulation at this point is un-clear, however the lighting industry interprets this to mean that ballasts capable of operating both in non-emergency luminaires and in emergency luminaires are not exempted).

EC No 245/2009 specifies an EEI for ballasts, which is calculated as the lamp power divided by the system power. The classes for dimmable ballasts are A1 BAT (Best Available Technology) and A1, and for non-dimmable ballasts A2 BAT, A2, A3, B1 and B2 (descending order of efficiency).

The requirement is implemented in a staged approach – Stage 1 (implemented in 2010) set the minimum EEI class at B2 for non-dimmable ballasts designed to operate with the specified lamps in Appendix B Table 26, or other lamps designed to be operated by the same ballasts as those lamps. Non-dimmable ballasts not included in this Table must meet a minimum EEI class of A3 based on the Efficiency Base ballast (EBb; Appendix B Table 27). EBb means the relationship between the rated lamp power (P_{lamp}) and the ballast efficiency. For ballasts for single and double capped fluorescent lamps, the EBb_{FL} is calculated as follows:

When $P_{lamp} \leq 5\ W:\ EBb_{FL} = 0.71$

When $5\ W < P_{lamp} < 100\ W:\ Ebb_{FL} = \dfrac{P_{lamp}}{\left(2 \times \sqrt{\dfrac{P_{lamp}}{36}} + \dfrac{38}{36 \times P_{lamp}} + 1\right)}$

When $P_{lamp} \geq 100\ W:\ EBb_{FL} = 0.91$

Dimmable ballasts must have a minimum EEI of A1 (Appendix B Table 28). Stage 1 also established the maximum input power of the lamp-ballast circuit at the dimming position corresponding to 25% of the lumen output of the operated lamp:

$$P_{in} < 50\% \times \frac{P_{Lrated}}{\eta_{ballast}}$$

where

P_{Lrated} = rated lamp power

$\eta_{ballast}$ = minimum energy efficiency limit of the respective EEI class.

In addition, the power consumption of fluorescent lamp ballasts must not exceed 1 W when the connected lamps are switched off and other possible connected components are disconnected.

Stage 2 requirements (from April 2012) decreased the standby loss to less than or equal to 0.5 W per ballast. In 2017, Stage 3 requirements will come into effect and ballasts for fluorescent lamps shall have the efficiency of

$$\eta_{ballast} \geq EBb_{FL}$$

At Stage 3, non-dimmable ballasts must meet an EEI of A2 or A2 BAT, and dimmable ballasts must meet an EEI of A1 BAT. This stage will effectively mandate electronic ballasts in the EU.

Ballasts must be labelled with the EEI class, and manufacturers must also provide this information on free-access websites and in other forms they deem appropriate for each of their ballast models.

USA

Energy efficiency standards currently apply in the USA to ballasts for T12 lamps and are specified in 10 CFR 430.32(m). The standard was amended in November 2011 to include ballasts for other fluorescent lamps, effective from November 2014. The amended standard applies to fluorescent ballasts designed to operate at nominal input voltages of 120 V or 277 V, with an input current frequency of 60 Hz. The product classes are:

- instant start and rapid start ballasts (not classified as residential) that are designed to operate 4-foot medium bipin lamps, 2-foot U-shaped lamps, 8-foot slimline lamps;
- programmed start ballasts (not classified as residential) that are designed to operate 4-foot medium bipin lamps, 2-foot U-shaped lamps, 4-foot miniature bipin standard output lamps, 4-foot miniature bipin high output lamps;
- instant start and rapid start ballasts (not classified as sign ballasts) that are designed to operate 8-foot high output lamps;
- programmed start ballasts (not classified as sign ballasts) that are designed to operate 8-foot high output lamps;
- sign ballasts that operate 8-foot high output lamps;
- instant start and rapid start residential ballasts that operate 4-foot medium bipin lamps, 2-foot U-shaped lamps, 8-foot slimline lamps; and
- programmed start residential ballasts that are designed to operate 4-foot medium bipin lamps, 2-foot U-shaped lamps.

The ballasts must have a power factor of 0.9 or greater (or a power factor of 0.5 or greater if it is designed and labelled for use only in residential applications) and have a ballast luminous efficiency (BLE – the ratio of lamp arc power to ballast input power as defined in Appendix Q1 of 10 CFR 430) not less than that specified in Appendix B Table 31.

10 CFR 430.32(m) does not apply to:

- a ballast that is designed for dimming to 50 per cent or less of its maximum output (except for those specified below);
- a low-frequency ballast that is –

— designed to operate T8 diameter lamps,
— designed, labelled, and marketed for use in EMI-sensitive environments only,
— shipped by the manufacturer in packages containing 10 or fewer ballasts; or

- a programmed start ballast that operates 4-foot medium bipin T8 lamps and delivers on average less than 140 milliamperes to each lamp.

China
Ballasts for linear fluorescent lamps sold in China must comply with the requirements of *GB 17896-2012 Minimum allowable values of energy efficiency and the energy efficiency grades of ballasts for tubular fluorescent lamps*. The standard applies to electronic and magnetic ballasts with rated power between 4 W to 120 W, operating on a 220 V and 50 Hz AC power supply. The energy efficiency rating, energy efficiency limit and test methods are specified.

MEPS requirements differ between magnetic and electronic ballasts for linear fluorescent lamps (Appendix B Table 36). The MEPS for electronic ballasts without brightness control is split into three tiers, with Tier 3 being the minimum requirement. Electronic ballasts with brightness control must meet additional maximum system input requirements.

Note, only MEPS requirements for linear fluorescent lamp ballasts are listed in Appendix B Table 36. GB 17896-2012 also applies to ballasts for a number of other lamps, including non-integrated CFLs, circular fluorescents and 2D-type fluorescents.

Programs in other countries can be found in Appendix B.

6.2.3 Luminaires

Very few regulators internationally have developed MEPS for luminaires, largely due to the wide variety of applications and design objectives not completely related to efficacy. While Europe, Japan and the USA have some requirements for luminaires (discussed below), the most widely used regulatory mechanism to promote luminaire efficacy is building standards, in particular maximum power density (see Table 11 for the Australian requirements) (Beletich, Page and Brocklehurst 2014).

Europe
Mandatory performance standards for luminaires in Europe are detailed in *EC No 245/2009 Ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps*. Luminaires are defined by EC No 245/2009 as “an apparatus which distributes, filters or transforms the light transmitted from one or more light sources and which includes all the parts necessary for supporting, fixing and protecting the light sources and, where necessary, circuit auxiliaries together with the means for connecting them to the supply, but not the light sources themselves.”

Luminaires must be compatible with EC No 245/2009 Stage 3 ballasts (a minimum EEI class of A2); this is in order to have a changeover to the ballasts in 2017 without delay. From 2017 luminaires may only use Stage 3 ballasts.

There is no mandatory labelling requirement for luminaires in Europe. However, manufacturers of luminaires for fluorescent lamps without integrated ballast with total lamp luminous flux above 2,000 lumens must comply with mandatory disclosure of information requirements. At minimum the following information must be provided on free-access websites and in other forms the manufacturers deem appropriate for each of their luminaire models

a) if the luminaire is placed on the market together with the ballast, information on the efficiency of the ballast (EEI) in accordance with the ballast manufacturer’s data;

b) if the luminaire is placed on the market together with the lamp, lamp efficacy (lm/W) of the lamp, in accordance with the lamp manufacturer’s data;

c) if the ballast or the lamp are not placed on the market together with the luminaire, references used in manufacturers' catalogues must be provided on the types of lamps or ballasts compatible with the luminaire (e.g. ILCOS code for the lamps);

d) maintenance instructions to ensure that the luminaire maintains, as far as possible, its original quality throughout its lifetime; and

e) disassembly instructions.

Japan
Japan’s Top Runner Program for energy labels and standards is unique and set apart from the general trends of the world. The program establishes the current highest energy efficiency levels as the target efficiency standards and implements various measures to obtain the efficiency target within a specified time period.

Top Runner sets target efficacy standards for lighting equipment using fluorescent light as a main light source (Appendix B Table 41). Fluorescent luminaires with lamps less than 40 W or self-ballasted compact fluorescent lamps are excluded from the program specifications. The target year for fluorescent luminaires to reach a fleet average efficacy level was 2012.

The energy consumption efficiency of fluorescent luminaires is obtained by dividing the total luminous flux of the fluorescent lamp when mounted on the fluorescent luminaire by the power consumption of the fluorescent luminaire, giving an efficiency in lm/W, where:

$$\begin{aligned} Total\ luminous\ flux \\ &= (Rated\ total\ luminous\ flux\ value\ of\ lamp\ in\ luminaire) \\ &\times (Ballast\ light\ output\ coefficient) \times (Temperature\ compensation\ coefficient) \end{aligned}$$

The ballast light output coefficient calculation method and the temperature compensation coefficient are specified in *Japanese Industrial Standard C 8020 Method of calculation on fluorescent luminaire efficacy index*. The measurement method for power consumption of the fluorescent luminaire is specified in *Japanese Industrial Standard C 8105-3 Luminaires – Part 3: General requirements for performance*.

USA
The USA Government has a mandatory efficiency requirement for federal purchasing of linear fluorescent luminaires used in commercial buildings. Products must meet a minimum luminaire efficacy rating (LER) measured in lm/W given on the Department of Energy's website (energy.gov/eere/femp/covered-product-category-fluorescent-luminaires). The LER is calculated as:

$$LER = \frac{luminaire\ efficiency \times total\ rated\ lamp\ lumens \times ballast\ factor}{luminaire\ watts\ input}$$

Product performance is measured in accordance with *NEMA LE 5-2001 Procedure for Determining Luminaire Efficacy Ratings for Fluorescent Luminaires*, using IESNA LM-41, ANSI C82.2-2002 for fluorescent ballasts, and ANSI C78.81-2005 for fluorescent lamps.

6.3 Voluntary programs

6.3.1 USA

In the USA, the ENERGY STAR Program run by the EPA aims to encourage industry best practice by forming partnerships with manufacturers and setting performance targets for appliances.

ENERGY STAR is a voluntary program and includes specifications for mostly residential and some commercial luminaires. Specifically:

- accent lights (includes line-voltage directional track lights);
- downlights – recessed, pendant, surface mount (includes SSL downlight retrofits and excludes troffers or linear form);
- under cabinet shelf-mounted task lighting; and
- portable desk task lights.

The scope of the specification does not include outdoor lighting (e.g. commercial street and area, wall packs, canopy), high bay, recessed troffers or other types used for general office illumination, adapters or converters.

The ENERGY STAR specification defines luminaires as a complete lighting unit, including lamp(s) and ballast(s), and luminaire efficacy as the 'luminous flux delivered by a luminaire, divided by its input power':

$$LER = \frac{luminaire\ efficiency \times total\ rated\ lamp\ lumens \times ballast\ factor}{luminaire\ watts\ input}$$

The specification details photometric, electric and thermal performance, safety, product labelling, packaging, shipment requirements, lighting toxics reduction and warranty requirements. Some specifications are based on the luminaire type while others are based on the light source (i.e. CFL , halogen, SSL). Requirements that are specific to commercial luminaires with CFLs are detailed in Table 15 and Table 16, respectively.

Labelling requirements relevant to commercial luminaires within the scope of the ENERGY STAR specification include:

- For luminaires shipped with lamps – CCT and mercury content.
- For luminaire not shipped with lamps – a list of lamp types and recommendation that consumers select a lamp with rated life of 10,000 hours or more.
- For luminaires marketed as dimmable – dimming capability and range.
- For recessed downlight luminaires – if insulation-contact (IC) type, clearly state rated for direct contact with insulation; if airtight (AT) certified clearly state airtight as per ASTM E283-04.

Table 15. ENERGY STAR requirements for directional commercial luminaires, downlight luminaires (recessed, surface, pendant, SSL downlight retrofits).

Criteria	Requirement
Luminaire efficacy (initial)	42 lm/W
Luminaire minimum light output (initial)	≤ 4.5" aperture: 345 lumens > 4.5" aperture: 575 lumens
Luminaire zonal lumen density	Luminaire shall deliver a minimum of 75% of total lumens (initial) within the 0-60° zone (axially symmetric about the nadir).

Table 16. ENERGY STAR requirements of fluorescent lamps (integrated CFL (GU24) and non-integrated CFL) for all luminaires.

Criteria	Requirements
Light source life	For lamps shipped with luminaires, average rated life of source must be ≥ 10,000 hrs. If the lamp is not shipped with the luminaire, product packaging shall meet the Product Labelling and Packaging Requirements section of the specification. *Exception*: covered and dimmable versions of GU24 based integrated lamps are required to meet reduced life requirements as outlined in qualification requirements for those lamps. Conditional qualification may be granted if testing has been completed for at least 40% of rated life AND a date for testing completion has been established by the test laboratory. Conditional qualification shall be immediately withdrawn if final testing results do not meet the above requirement.
Lumen maintenance	For lamps indicated on the luminaire packaging or shipped with the luminaire, the lamp average rated lumen maintenance shall be at least 80% of initial lamp lumens at 40% (4000 hrs minimum) rated lamp life.
Correlated colour temperature (CCT)	Lamps shipped with luminaires shall have one of the following nominal CCT (in Kelvin): (a) 2700; (b) 3000; (c) 3500; (d) 4000/4100; or (e) 5000 (commercial only). If the lamp is not shipped with the luminaire, product packaging shall meet the requirements set forth in Product Labelling and Packaging Requirements.
Colour rendering	Lamps shipped with luminaires $R_a \geq 80$
Source start time	≤ 1 second
Source run-up time	Elapsed time for lamps to reach 90% of stabilised lumen output after application of electrical power shall be ≤ 1 minute for non-amalgam lamps and ≤ 3 minutes for amalgam lamps.
Dimming	The luminaire and its components shall provide continuous dimming from 100% to 35% of total light output. Step dimming, if employed, shall provide at least two discrete light output levels ≥ 50% of total light output and not including 100% output.
Power factor	Commercial: ≥ 0.9
Operating frequency	20 to 33 kHz or ≥ 40 kHz

Criteria	Requirements
Lighting toxics reduction requirements	Luminaires and lamps shall not exceed hazardous substance concentrations set for in the EU Restriction of the Use of Certain Hazardous Substances (RoHS) Directive, 2003. Unless otherwise stated below, fluorescent lamps of all types shall not exceed 5 mg of mercury (per burner). RoHS exemptions that will be accepted by the ENERGY STAR program that may be relevant to luminaires and lamps are detailed below: 1. Mercury in single capped (compact) fluorescent lamps not exceeding (per burner): a. For general lighting purposes ≥ 150 W: 15 mg b. For general lighting purposes with circular or square structural shape and tube diameter (< 17 mm): currently no limit 2. Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp): a. Tri-band phosphor with long lifetime (≥ 25,000 hr): 8 mg 3. Mercury in other fluorescent lamps not exceeding (per lamp): a. Linear halophosphate lamps with tube > 28 mm (e.g. T10 and T12): 10 mg b. Non-linear halophosphate lamps (all diameters): 15 mg c. Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9): currently no limit Limits are given for mercury, lead, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), and RoHS exemptions are provided for lead and cadmium in the ENERGY STAR specification.

6.3.2 New Zealand

The ENERGY STAR Programme in New Zealand is currently developing a commercial lighting specification specific to SSL technology. The types of luminaires covered under this new specification include:

- Panel Fittings
- Downlights
- Linear
- Bulkheads
- Spotlights/Track lights
- Floodlights
- Pendants
- High Bays

The specification includes indoor and outdoor rated luminaires, but excludes street lights. The criteria requires laboratory tests to qualify for ENERGY STAR within a strict criteria outlined for Efficacy, Photometric, CRI, Chromaticity, Colour Maintenance, Colour Angular Uniformity Lumen Maintenance, Correlated Colour temperature, Power Factor, EMC and Transient Protection. Additionally all products must meet the current New Zealand electrical safety requirements.

6.3.3 Germany

In Germany, the Blue Angel eco-label is found on about 125 product categories, including electronic ballasts, and is administered by four institutions – the Environmental Label Jury, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Federal Environment Agency, and RAL gGmbH.

Within scope are electronic ballasts for fluorescent lamps designed for mains voltage 220-240 V, high frequency operation greater than 25 kHz, applying to fluorescent lamp diameter categories T4, T5, T8 and T12. The allowable maximum power consumption values for lamps of given wattages are detailed in the specification. The performance metrics for label eligibility are:

- service life greater than 50,000 hours;
- mortality less than or equal to 2.5% per 1000 lighting hours;
- voltage variations of 10% must not change the luminous flux more than 2%; and
- ballast lumen factor (BLF), the ratio of luminous flux produced by the lamp when run with the test ballast as compared to when it is run by a reference ballast, must be between 0.95 and 1.00 inclusive.

Programs from other countries can be found in Appendix B.

7 Policy Options

A number of possible policy options for commercial lighting products within the scope of this Product Profile are discussed. More than one option could be implemented at the same time. The following policy options are considered; however further discussion with industry and government approvals would take place if any mandatory options were to be put in place. All policy options for further consideration would be subject to thorough analysis of costs and benefits in a consultation RIS.

Possible policy options include:

- No action (business as usual);
- Update Australian and New Zealand test standards for fluorescent lamps and ballasts to recent International Electrotechnical Commission standards;
- Increase MEPS levels for linear fluorescent lamps or harmonise with international standards in 2-3 years;
- Introduce a MEPS for circular fluorescent lamps in the next two to three years;
- Reduce mercury content in lamps to meet international requirements;
- Harmonise Australia and New Zealand MEPS for ballasts by increasing Australian MEPS requirements;
- Align with European stage 3 requirements for ballasts with an implementation date in 2-3 years;
- Introduce a voluntary or mandatory MEPS for commercial luminaires;
- Product labelling and education initiatives.

7.1 No action

This scenario assumes no changes to policy. The commercial lighting market would continue to operate as it does now, with linear fluorescent lamps and ballasts in scope of the current MEPS required to meet lower efficiency requirements than overseas markets. As major markets (including the EU, US, China and Japan) either already exceed or have schedules in place to exceed our MEPS requirements, there is a possibility that as a result of their action products worldwide will improve and Australia and New Zealand may passively benefit. However the survey of the international market conducted for this product profile indicates a significant range of models available that would not comply with MEPS in place in the major regulated markets, suggesting that the broader market does not automatically follow this lead. A decision to not change linear fluorescent MEPS policy change presents a risk that the Australian or New Zealand markets will be supplied with less efficient and potentially poorer quality products, a situation that has been shown to occur in countries that lag in the adoption of appropriate MEPS (for example, the Chinese market experienced this scenario in the wake of Energy Star and the EU introducing minimum performance standards for CFL products[1]). This scenario lacks any stimulus within the market to source more efficient products.

For linear fluorescent lamps and ballasts outside of scope of the current MEPS, along with those other product types not currently subject to MEPS, there will be no pressure for lighting performance to enhance; improvement in the efficiency of these products would be industry-driven. They would not be required to provide labelling information and consumers would be unable to effectively compare products.

No action would be a lost opportunity to achieve significant energy savings to contribute to the Australian energy productivity plan improvement target of up to 40 percent by 2030 (outlined in the 2015 Energy White Paper, http://ewp.industry.gov.au/sites/test.ewp.industry.gov.au/files/EnergyWhitePaper.pdf).

[1] Ton, My; du Pont, Peter (2008). *An inconvenient truth: the reality of "shoddy" CFLs in developing Asia, and a plan for eliminating them.* ACEEE Summer Study on Energy Efficiency in Buildings. Sourced 15/06/2015 from http://aceee.org/files/proceedings/2008/data/papers/9_729.pdf.

Option 1: Existing MEPS for linear fluorescent lamps and fluorescent lamp ballasts remain unchanged, and no new policy is adopted for other products within the scope of this Product Profile.

7.2 Update Australian and New Zealand test standards for fluorescent lamps and ballasts to recent International Electrotechnical Commission standards

Australia and New Zealand test methods for photometric and electrical characteristics of linear fluorescent lamps are contained in AS/NZS 4782.1:2004, *Double-capped fluorescent lamps – Performance Specifications*. The standard is an adoption, with national modifications, of IEC 60081:2000, *Double-capped fluorescent lamps – Performance Specifications*, and its amendments 1 and 2, released 2000 and 2003. There have been a number of further amendments to the IEC standard since this time, the latest is Amendment 5, released in 2013.

Similarly, AS/NZS 60921:2002, *Ballasts for tubular fluorescent lamps – Performance requirements* is an adoption with national modifications, of IEC 60921:1988, *Ballasts for tubular fluorescent lamps* and includes Amendment 1:1990 and Amendment 2:1994. This IEC standard has been revised in 2004 and amended in 2006; the current version is IEC 60921:2004/Amd1:2006.

As there have been a number of changes to the basis IEC standards since the adoption of the Australia/New Zealand test standards, and good practice dictates that standards are to be reviewed at least every ten years, therefore it is recommended that this review process is initiated with the objective to align with the current IEC test standard.

Option 2: Update Australian and New Zealand test standards for fluorescent lamps and ballasts to recent International Electrotechnical Commission standards;

7.3 Increase MEPS levels for linear fluorescent lamps or harmonise with international standards in 2-3 years

There are a number of options for revising the double-capped fluorescent lamp MEPS, relating to initial efficacy, maintained efficacy, including lamps greater than 1500 mm in length, or aligning with overseas standards.

For any policy option specific considerations must be taken regarding T12 lamps in Australia, since a phase-out of all remaining T12 tubes or some lengths may potentially incur additional costs due to the need to replace luminaires or purchase converter kits, depending on market penetration of this technology. These costs would however be offset by ongoing energy savings. In states where white certificate schemes are in place additional support may be available for the transition. T12 to T8 or T5 converter kits, which can also include a conversion from magnetic to electronic ballasts, are also available. Several companies are manufacturing these products since the USA mandated a T12 phase-out from July 2012. The present quantity of installed stock in Australia is predominantly in NSW schools. In New Zealand, T12 lamps were phased out in 2002.

Modelling on the cost of changeover from T12 to alternative T5 linear fluorescent with electronic ballasts finds a typical installation will be cost-effective. Modelling is shown in Table 17 for a 100 square metre space using 1,680 lighting hours per annum, a project lifetime of 20 years, average lifetime electricity cost (per kWh) of $0.20 and ESC certificate value at $20 each, with a stipulation that replacement fittings meet or exceed the light output of the existing fittings. In Table 17a, the total lighting power falls from 2,407 W to 735 W and offers a simple payback period of 3.4 years; Table 17b models the 3,565 W total lighting power installation falling to 910 W solution with a payback of 2.1 years. Note that these figures represent 2013 energy cost and payback time will be linearly shorter with any rise in electricity prices.

Without utilising a white certificate program, the outcomes in Table 17 would be:

- Case 1: Simple payback of 5.1 years with a Return on Investment of 288% and Internal Rate of return of 19%
- Case 2: Simple payback of 3.9 years with a Return on Investment of 414% and Internal Rate of return of 26%

Table 17. Cost analysis for replacement of T12 halophosphate fluorescent fittings with a) single 1150mm T5 fluorescent fitting [top] and b) single 1450mm T5 [bottom]. (Source: Beletich and Associates, 2013).

Case 1 - Replace twin 1200mm T12 with single 1150mm T5

	Lamp type	Ballast type	Lamp Power (W)	No. lamps in each fitting	Total fitting Power (W)	No. of Fittings	Total lighting power (W)	Power density (W/m2)	Energy cost p.a.	CapEx per Fitting
Existing Installation:	Fluorescent T12	Magnetic - class D	40	2	104	23	2,407	24.1	$809	
New Installation:	Fluorescent T5	Electronic - class A2	28	1	32	23	735	7.3	$247	$125

Results (over 20 years):	Energy cost saving p.a.	Gross CapEx:	Value of white certificates	Net CapEx	Simple payback (years)	Return on investment	Internal rate of return
	$562	$2,894	$1,004	$1,890	3.4	495%	30%

Case 2 - Replace twin 1500mm T12 with single 1450mm T5

	Lamp type	Ballast type	Lamp Power (W)	No. lamps in each fitting	Total fitting Power (W)	No. of Fittings	Total lighting power (W)	Power density (W/m2)	Energy cost p.a.	CapEx per Fitting
Existing Installation:	Fluorescent T12	Magnetic - class D	65	2	154	23	3,565	35.6	$1,198	
New Installation:	Fluorescent T5	Electronic - class A2	35	1	39	23	910	9.1	$306	$150

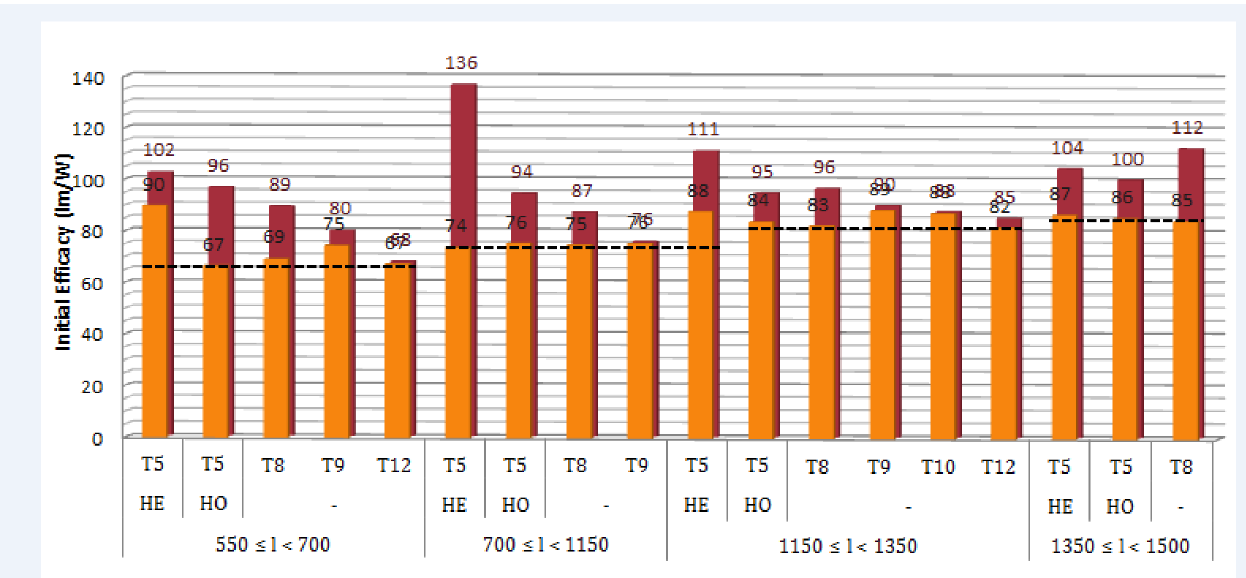
Results (over 20 years):	Energy cost saving p.a.	Gross CapEx:	Value of white certificates	Net CapEx	Simple payback (years)	Return on investment	Internal rate of return
	$892	$3,472	$1,593	$1,879	2.1	849%	48%

Thus in all cases, a phase-out of the remaining T12 lamps in Australia would lead to significant savings over a short payback period. This would be further enhanced in states with an energy certificate scheme.

Initial efficacy

In Figure 27, initial minimum (orange column) and maximum (red column) efficacy performances of E3-registered linear fluorescent lamps are shown, with lamps categorised by their length (L1–L4 represent the current length categories in AS/NZS 4782.2) and tube diameter/type (T5HE, T5HO, T8, T12).

Figure 27. Minimum (orange column) and maximum (red column) rated initial efficacy of E3-registered linear fluorescent lamps, categorised by lamp length in mm as per AS/NZS 4782.2 (550 ≤ L1 < 700; 700 ≤ L2 < 1150; 1150 ≤L3 < 1350; 1350 ≤ L4 ≤ 1500) and tube diameter (2014). Corresponding MEPS levels applied across each length.



Evidently, the efficacy range of T5-HE lamps in each of the length categories is most broad, in particular with L2 and L3 lengths, showing that a large variation in quality is available in Australia and New Zealand. This pattern is also evident with T5-HO models, in particular L1, where lower efficacy is 67 lm/W and upper quality is at 96 lm/W. There are T5-HE products that exceed 100 lm/W and T5-HO products that exceed 90 lm/W in all length categories. The efficacy range for most of the T8 lamps of all lengths is also quite broad, showing that significant improvement in product performance has been achieved in the eleven years since the MEPS was put in place. Upper efficacy levels are reasonably high in the T5 and T8 lamp types, which is indicative that MEPS could be increased.

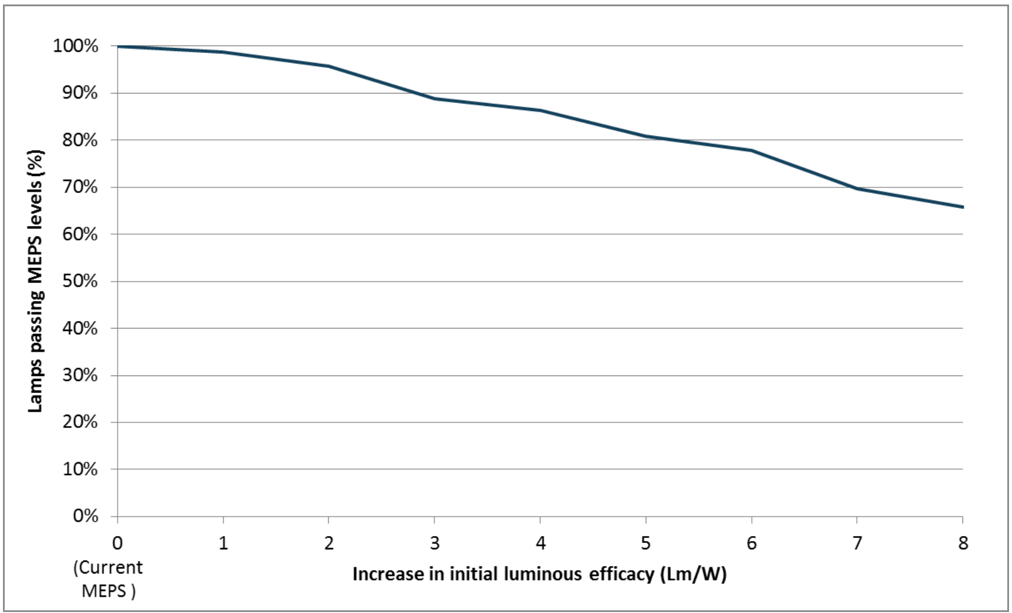
Consideration of increasing the initial efficacy MEPS level for current lamp length categories within the scope of AS/NZS 4782.2 would depend on the energy savings being targeted. Eight Steps are shown in Table 18, where the Step number represents an increase of that step number in lumens per watt (i.e. Step 4 for L1 lamps would be an initial efficacy of 4 lumens per watt: 66 + 4 = 70 lm/W).

Table 18. Initial efficacy requirements for incremental 1 lm/W stepped increase in MEPS for linear fluorescent lamps.

		L1	L2	L3	L4
		$550 \le l < 700$	$700 \le l < 1150$	$1150 \le l < 1350$	$1350 \le l \le 1500$
	Current MEPS	66	74	80	85
	Step 1	67	75	81	86
	Step 2	68	76	82	87
	Step 3	69	77	83	88
	Step 4	70	78	84	89
	Step 5	71	79	85	90
	Step 6	72	80	86	91
	Step 7	73	81	87	92
Initial efficacy (lm/W)	Step 8	74	82	88	93

E3 registration lamp data has informed the potential for an increase in the initial efficacy MEPS requirement by allowing calculations of the percentage of models in the Australian and New Zealand market which would pass the requirements of the proposed stepped increase in lm/W (Table 18). If the aim of a revised initial efficacy MEPS was to remove the lowest 10% of the market by energy performance, Step 4 (i.e. an increase of initial efficacy by 4 lm/W) would achieve this objective by retaining approximately 87% of the lamps currently registered (Figure 28). If the aim was to remove the lowest 20% of the market by energy performance, then increasing the initial efficacy MEPS by 6 lm/W (Step 6) would retain about 78% of the lamps currently registered. Ideally the volume of products removed from the market should also be taken into account, however specific product sales data is not available.

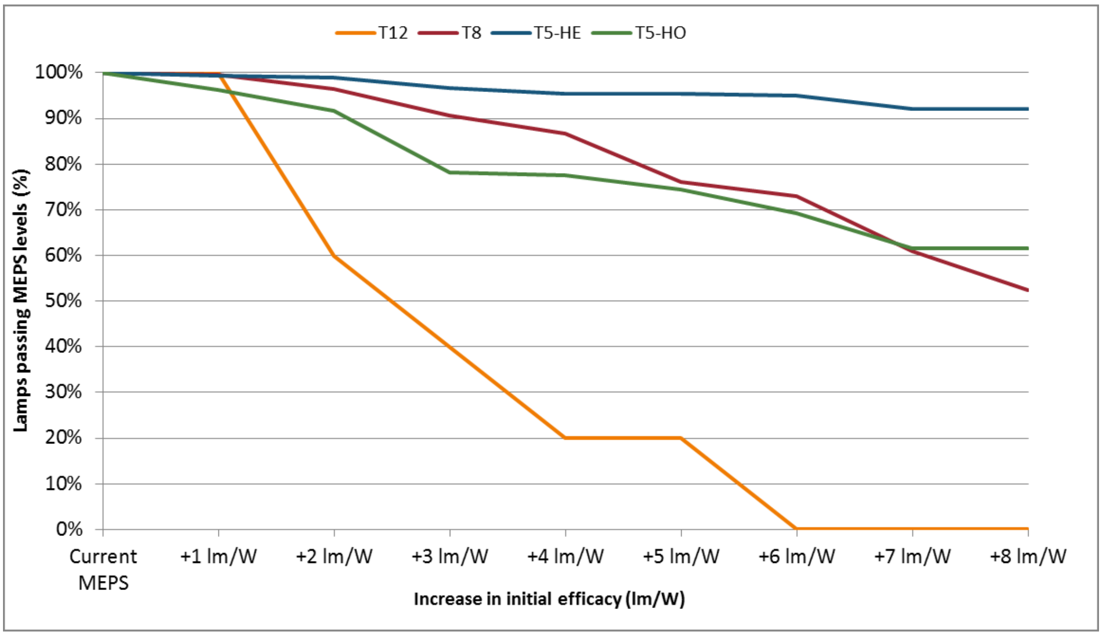
Figure 28. Percentage of all lamps incremental increases in initial efficacy levels of 1 lm/W steps, according to Table 18 (E3 registered and approved lamps).



Based on tube diameter, the percentage of lamps registered in Australia and New Zealand which would not meet an increase of initial efficacy is shown in Figure 29). When graphed this way, it shows that T5-HE and T8 lamps are more robust against an increase in initial efficacy MEPS requirements – only approximately 5% and 12% (respectively) of registered lamps would be phased-out with Step 4, while approximately 21% of T5-HO and 80% of T12 lamps would be phased-out with this increase. If the initial efficacy was increased by 5 lm/W, 5% of T5-HE, 25% of T5-HO, 23% of T8 and 80% of T12 registered lamps would be removed from the market.

Option 3a: Increase the current initial efficacy MEPS requirement for linear fluorescent lamps of length 550–1500 mm by at least 4 lm/W.

Figure 29. Percentage of Australian and New Zealand registered linear fluorescent lamps that would be retained if initial efficacy requirements were increased, according to Table 18.



Maintained Efficacy

In contrast to other prominent overseas standards (e.g. EU and China), Australia and New Zealand specify nominal values for maintained efficacy in the MEPS. This is a carryover from AS/NZS 4782 inception which integrated New Zealand standard NZHB 4782.2:2001; the NZ standard included provision for lamps to fall into alternative MEPS levels. Other overseas standards stipulate maintained efficacy based on a percentage of the initial efficacy, which allows for an equitable amount of lumen depreciation over time for all lamps regardless of lamp category grouping.

The ratio between initial and maintained efficacy values in AS/NZS 4782.2 is not consistent between the length categories. There is no technical reason why these ratios should not be the same.

Option 3b: Increase the maintained efficacy MEPS requirement for linear fluorescent lamps of length 550–1500 mm using a similar approach to Table 18.

Option 3c: Revise the maintained efficacy MEPS so it is based on a percentage of the initial efficacy.

Increasing the Scope of Lamp Length

Market survey data show that lamps of length greater than 1500 mm (T8 and T12) currently not included in the scope of MEPS have some variation in efficacy. In Australia in 2014 the estimated penetration rate of 1800 mm lamps was at a maximum 2%. It is questionable whether there would be significant overall energy savings achieved by introducing MEPS for lamps with a length greater than 1500 mm (however savings for premises with these lamps installed could be significant).

Aligning with overseas requirements

Lamp characteristics aside from length also impact on a lamp's maximum potential light output:

- tube diameter (higher efficacy in smaller diameters);
- power consumption (watts);
- colour temperature (higher efficacy in warmer CCT lamps); or
- colour rendering (very high CRI requires concessions on efficacy).

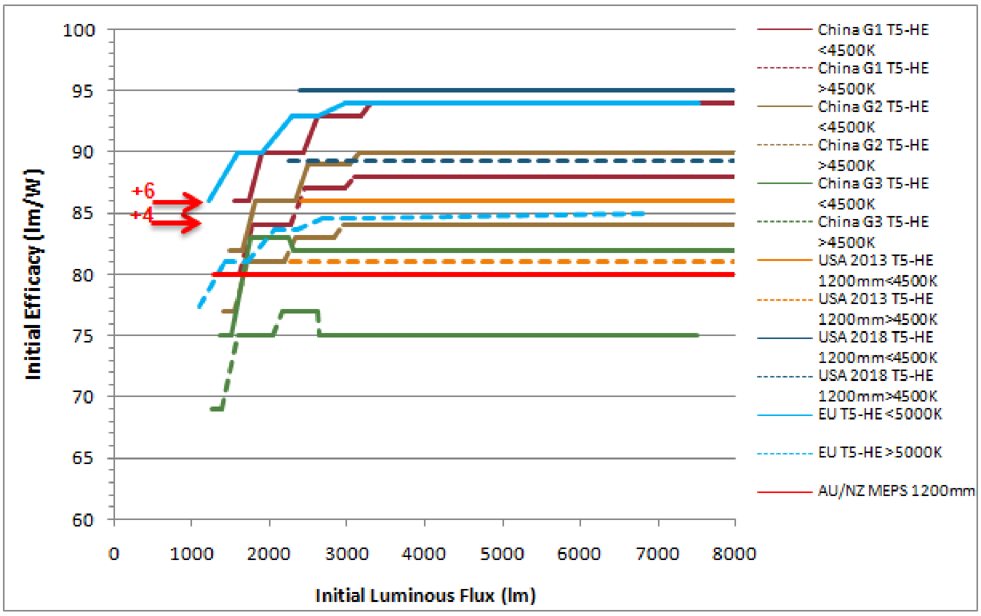
Many overseas standards do not primarily categorise lamp efficacy requirements on length. However there is no international consensus on categorisation. For example, the EU categorises lamps by diameter (T5, T8 and T12) and differentiates T5 lamps as HE and HO, then lamps are categorised by wattage. They provide a 10% allowance for lamps with CCT over 5000K. USA categorise lamps primarily by tube diameter and then have secondary categorisations of length and CCT. Similarly, Hong Kong has primary categorisation by tube diameter and secondary categorisation based on CCT and length (for some lamps – see Appendix B Table 37). China is similar to the EU, categorising lamps by tube diameter then wattage, but they have individually laid out separate minimum efficacy requirements based on CCT rather than stating an allowance based on a percentage.

Most international standards have concessions for lamps of higher colour temperature in their efficiency policies. Canada, China and the USA explicitly tabulate different MEPS levels for lamps ≤ 4500 K and greater than 4500 K, while Hong Kong and Korea have the differentiation as ≤ 6000 K and greater than 6000 K. In contrast, the EU has an overall MEPS level with deduction percentages for rated minimum efficacy values are allowed for lamps with a CCT ≥ 5000 K (see Appendix B Table 24).

This overview shows that unfortunately there is no one international approach to the categorisation of linear fluorescent lamps, but that many overseas MEPS primarily categorise lamps on diameter rather than the Australian and New Zealand approach of categorising by length. Alignment with a diameter categorisation system used by one of the major markets (e.g. EU, China, US) may have advantages in terms of simplifying entry to the Australian and New Zealand markets for a broader range of products. The following analysis demonstrates some of the implications of applying the EU and China MEPS systems to the range of products currently registered in Australia and New Zealand.

In Figure 30 the Australia/New Zealand initial efficacy MEPS for 1200mm linear fluorescent lamps is compared to three international requirements – USA (2013 and 2018), China (2013 'G3', 2016 target 'G2', and upper target 'G1'), Europe (2009 Stage 2). MEPS lines for other AU/NZ lengths are not included here so as to avoid unnecessary visual obscuration and the '+4' and '+6' arrows represent where the level would be if the Australia and New Zealand MEPS were increased by 4 lm/W and 6 lm/W, respectively. All countries categorise their lamps slightly differently, making it difficult to compare requirements. In general, however, Australian and New Zealand MEPS are below the EU requirements for T5-HE and T8 lamps, also below China's G1 requirements, and those of the USA.

Figure 30. International MEPS for T8 linear fluorescent lamps. Australia/New Zealand MEPS for 1200mm linear fluorescent lamps included (most common length sold).



The current MEPS level in China is 'G3' level, or grade 3; these are the two lines shown lowest on Figure 30 with the <4500K as a solid line and >4500K the dotted line (this pattern was used for each of the international MEPS). China have indicated in their standard that in 2016 they will move their MEPS to 'G2', grade 2, which for the warmer CCTs is marginally better than current AU/NZ 1200mm linear MEPS, but for higher CCTs it is equivalent or slightly lower than local levels (depending on wattage or lumen package). EU T8 MEPS for >5000K is approximately equivalent to the AU/NZ level shown, however requirements for <5000K are significantly higher. Overall China's Grade 1 target level 'G1', the USA's 2013 and 2018 levels and the EU <5000K are at comparable levels, which would affect the content of products available in the AU/NZ markets if any of these were to be adopted. The extent of potential impacts will be explored later.

This overview shows that unfortunately there is no one international approach to the categorisation of linear fluorescent lamps, but that many overseas MEPS primarily categorise lamps on diameter rather than the Australian and New Zealand approach of categorising by length. Alignment with a diameter categorisation system used by one of the major markets (e.g. EU, China, US) may have advantages in terms of simplifying entry to the Australian and New Zealand markets for a broader range of products. The following analysis demonstrates some of the implications of applying the EU and China MEPS systems to the range of products currently registered in Australia and New Zealand.

A further point of difference is that for lamps with lumen output between 1000 lumens and 2500-3000 lumens, the international standards have either lower MEPS thresholds (EU and China) or simply exempt lamps below this point (USA), whereas Australia/New Zealand impose the fixed MEPS level for lamps with lumens approximately 1200 lumens. The reason other regions graduate MEPS through this lumen/wattage range is because at lower outputs fluorescent lamps are not able to create light as efficiently.

Figure 31 shows requirements from the same three international regions as above, for T5-HE linear fluorescent lamps. The Australia/New Zealand initial efficacy MEPS for 1200mm linear fluorescent lamps is included for comparison, and the '+4' and '+6' arrows represent where the level would be if MEPS were increased by 4 lm/W and 6 lm/W, respectively. It can be viewed from the chart that international MEPS and future target levels predominantly exceed current local MEPS. Ultimately, the levels that will be applied in USA by 2018, EU in 2016 and China's G1 target are close to equivalent at 94-95 lm/W. For high CCT, the MEPS is most stringent for USA, at ~ 89 lm/W; as opposed to 88 lm/W in China's target; and approximately 85 lm/W in EU. Conversely, if the current MEPS in Australia/New Zealand were increased by 4 lm/W, this would bring us in line with the EU level for high CCT lamps; if local MEPS were increased by 6 lm/W, this corresponds with the USA level for low CCT lamps.

Figure 31. International MEPS for T5-HE (High efficacy) linear fluorescent lamps. Australia/New Zealand MEPS for 1200mm linear fluorescent lamps included (most common length sold).

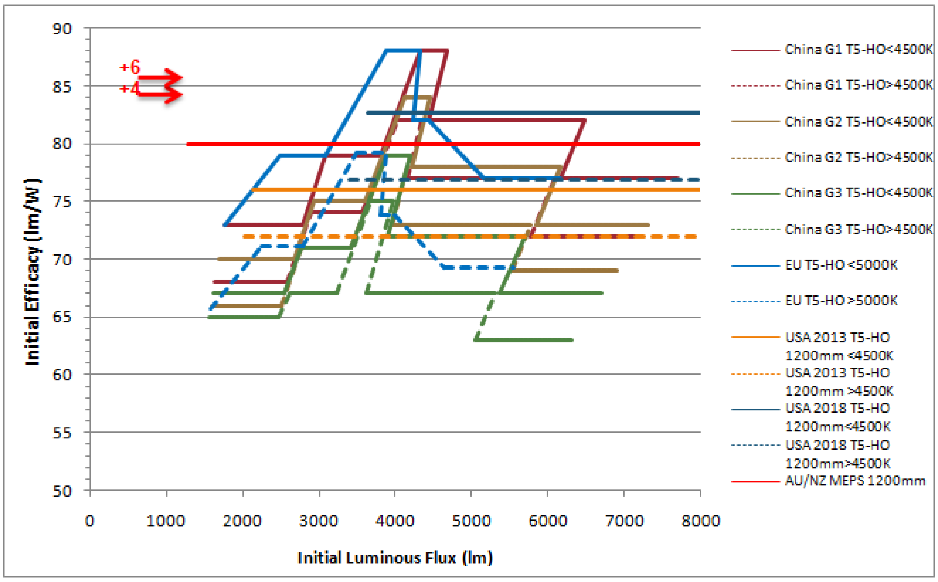
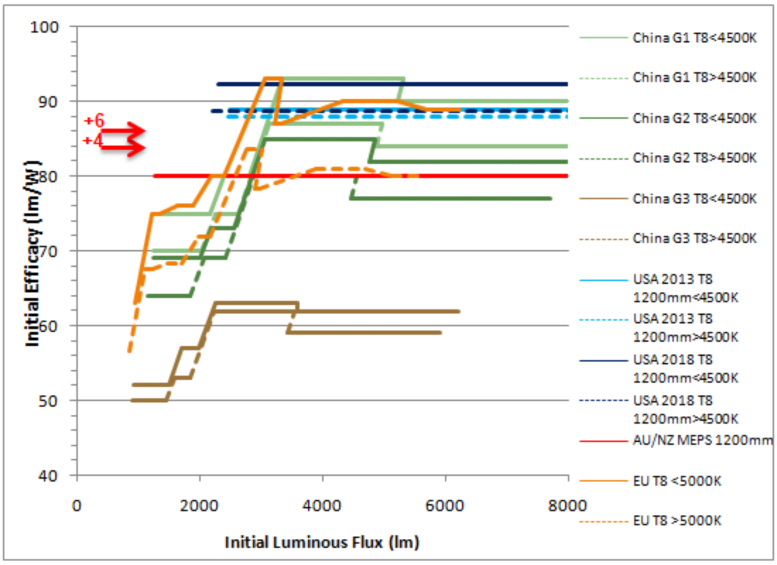


Figure 32 shows international requirements for T5-HO linear fluorescent lamps, with Australia/New Zealand initial efficacy MEPS for 1200mm linear fluorescent lamps, with the '+4' and '+6' arrows represent where the level would be if MEPS were increased by 4 lm/W and 6 lm/W, respectively. EU levels are most stringent for this lamp diameter, particularly for lower lumen output models, though for the 49-53W model (approximately 4000lm) the China G1 target levels are the same.

Figure 32. International MEPS for T5-HO (High output) linear fluorescent lamps. Australia/New Zealand MEPS for 1200mm linear fluorescent lamps included (most common length sold).



To more easily compare with the EU requirements, the average, maximum and minimum initial efficacy of Australia/New Zealand registered lamp models is plotted by EC No 245/2009 wattage categories (T8 lamps – Figure 33 and T5 lamps – Figure 34). The current EU requirement is also indicated in each figure. The average T8 lamp initial efficacy in Australia and New Zealand is almost the same as the EU requirement for each wattage category (Figure 33), indicating that there are a number of T8 lamps on the Australian/New Zealand market which do not meet the European MEPS. Similarly, average T5-HE lamp efficacy in the Australia/New Zealand is comparable to the EU requirements (Figure 34). In contrast, Australia/New Zealand average T5-HO lamp efficacy is generally above the EU requirements (Figure 34) but near to the average performance level for the 54W HO lamp models.

Figure 33. Efficacy range and average of T8 linear fluorescent lamp models registered in Australia and New Zealand based on wattage, and the EU efficacy requirement.

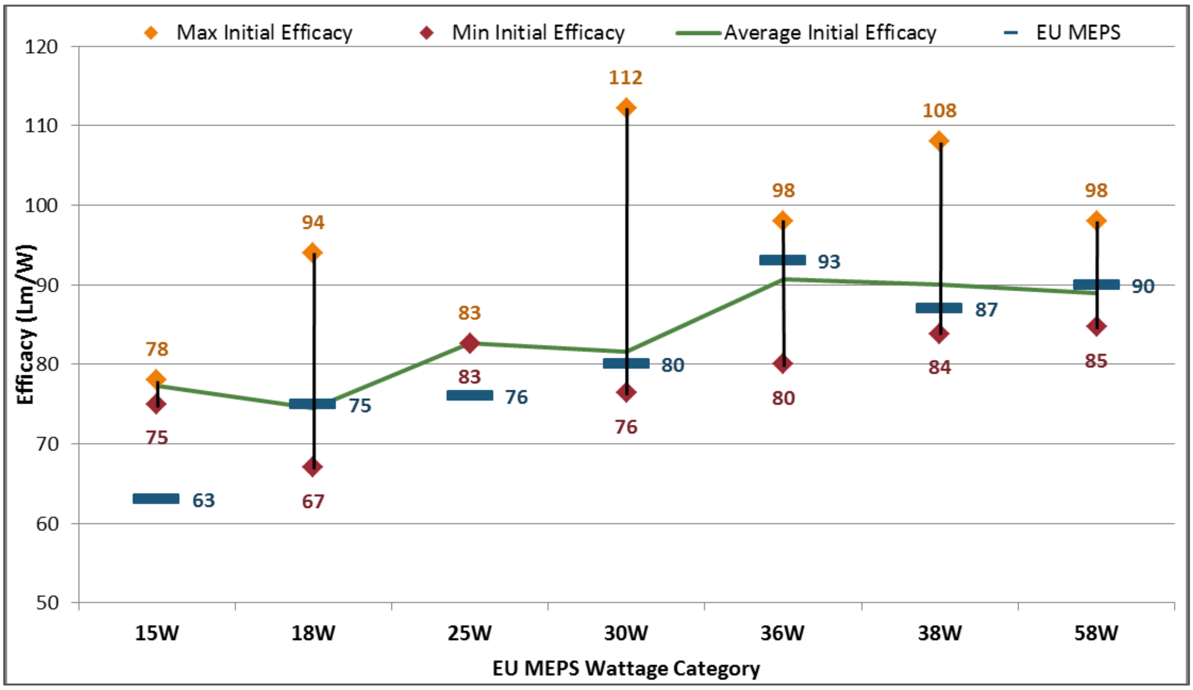
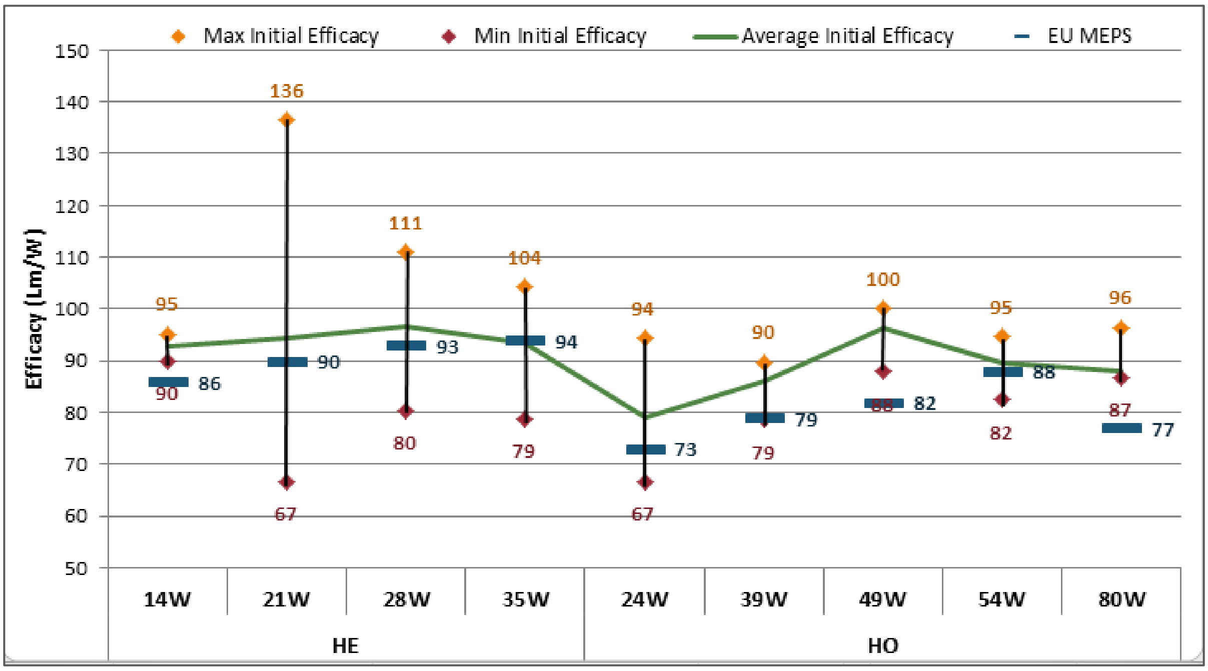
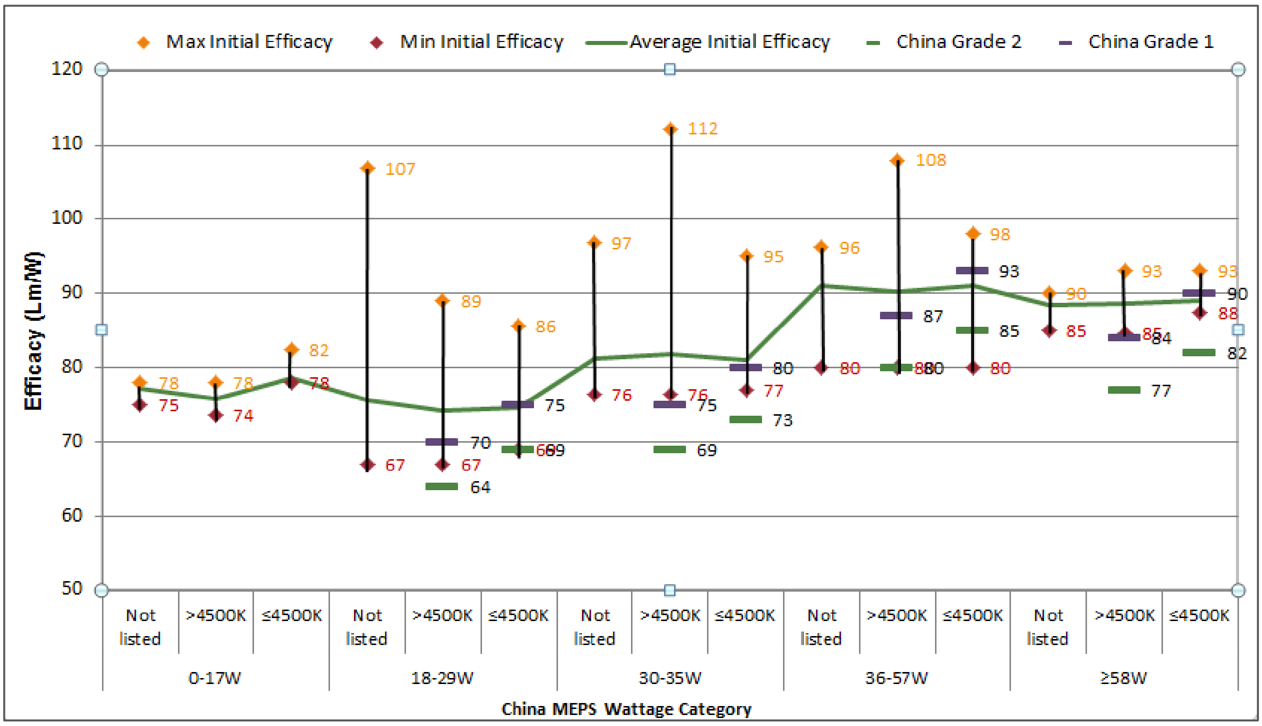


Figure 34. Efficacy range and average of T5 linear fluorescent lamp models registered in Australia and New Zealand based on wattage, and the EU efficacy requirement for HE (left) and HO (right).



China uses a combination of wattage and CCT to specify minimum efficacy requirements. Figure 35 illustrates the efficacy range of T8 lamp models available in the local market in their wattage groups, with China's 2016 MEPS level 'Grade 2' and target level 'Grade 1' indicated with green and purple bars (respectively). The market average for the wattage groups is also indicated by the green trendline. This chart illustrates that for the lamp models that registered their CCT on the E3 website, and those that were included in the data set through market research, China's MEPS levels are universally achieved across all wattage and CCT groups. As registration of lamp CCT on E3 products was not compulsory, a broad range of lamps cannot be put into the Chinese efficacy groupings. It is clear from the chart that the majority of T8 lamp models would pass China's target MEPS levels, other than in the category for lamps with wattage 36-57W, where a significant portion would not pass China's requirements.

Figure 35. Efficacy range of T8 fluorescent lamp models, displayed with China's MEPS levels.



Of the T5 HE lamps on the Australian market, the average efficacy level in each wattage and colour temperature category is well above China's Grade 2 (Figure 36). However, a reasonable number of lamp models would be cut from the market if China's Grade 1 were applied to Australia and New Zealand.

Figure 36. Efficacy range of High Efficiency (HE) T5 fluorescent lamp models, displayed with China's MEPS levels.

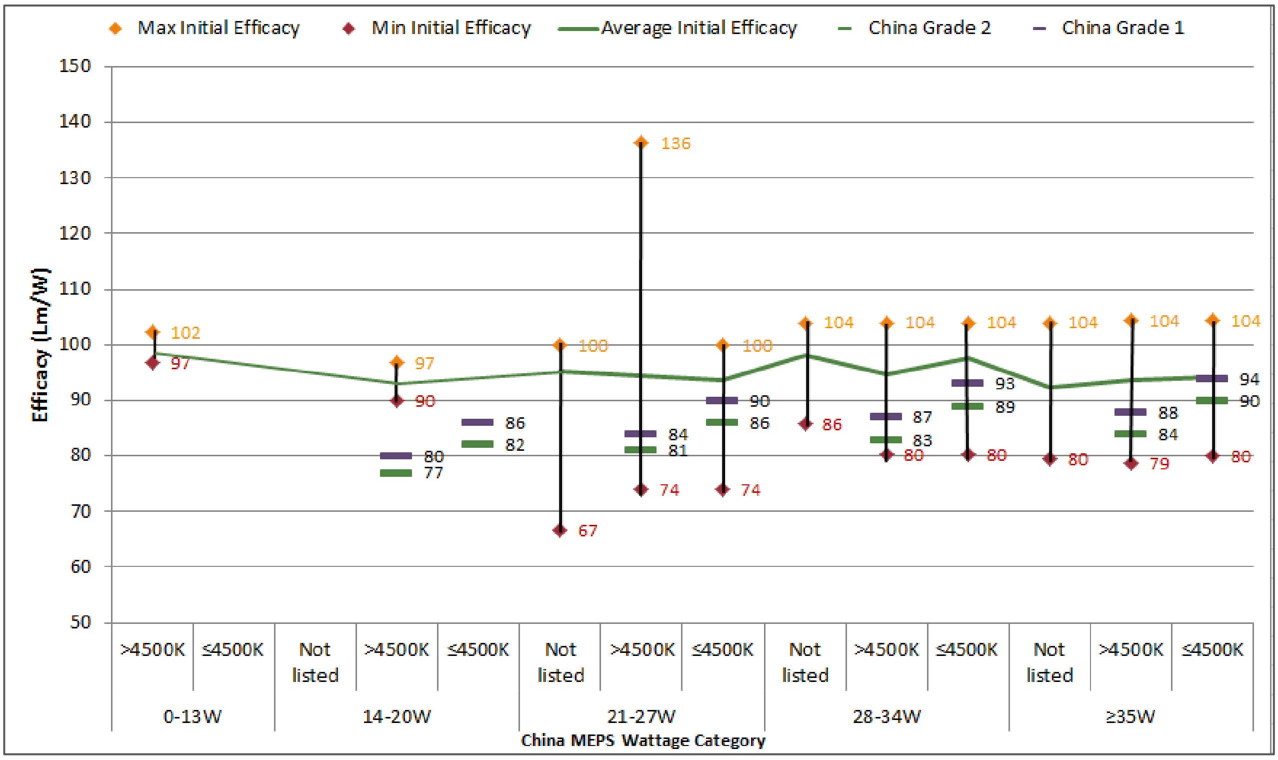


Figure 37 shows how the Australian market fit with the China's MEPS categories for HO T5 linear fluorescent lamps. It appears that HO lamp models in the local market predominantly perform well above both target grades, and there would only be a minor impact if the levels were put in place.

Figure 37. Efficacy range of High Output (HO) T5 fluorescent lamp models, displayed with China's MEPS levels.

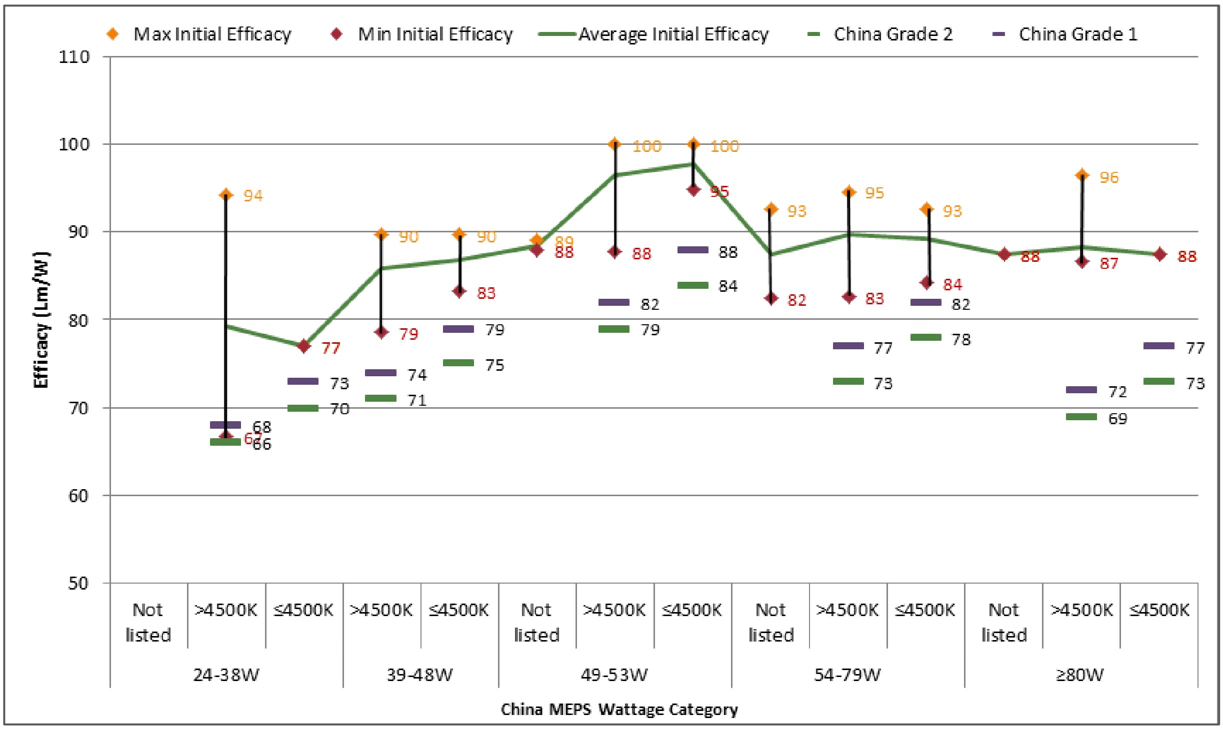
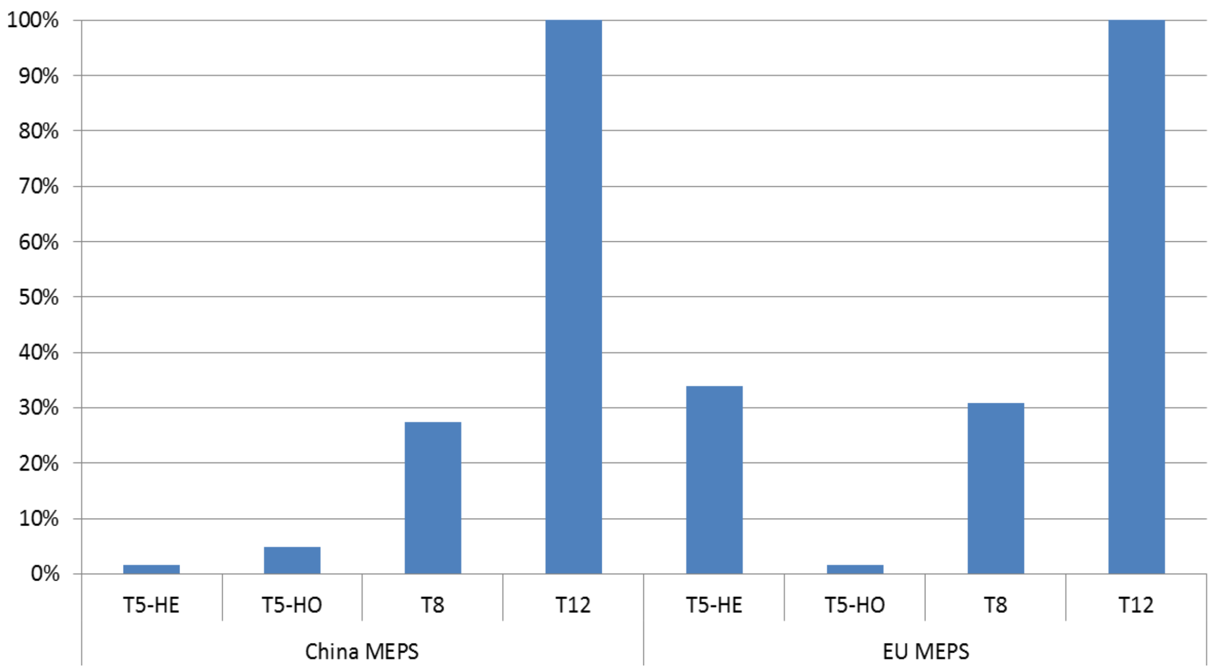


Figure 38 provides a summary of the previous figures by showing the percentage of the Australian/New Zealand approved registered linear fluorescent lamp models that would be removed from the market if the Chinese or European MEPS were adopted. All T12 lamp models would be phased out, and both MEPS schemes would remove approximately 30% of T8 lamp models from the market, while T5-HO lamp models would only be affected by 2-5% in either scheme. However, the MEPS levels for T5-HE lamps are significantly different, with China's MEPS more lenient on the market and would remove only 2-3% of lamp models, whereas the European MEPS would remove more than 30% of these lamp models from the Australian market.

Figure 38. Percentage of E3 registered linear fluorescent lamp models that would be removed from the market if the Chinese or European MEPS were adopted in Australia.



The above analysis suggests that in consideration of setting appropriate performance standards, the European and Chinese schemes represent MEPS levels and product categories that could be implemented in Australia and New Zealand. For linear fluorescent lamps the most stringent MEPS levels are those used in Europe (EU), though China has comparative levels (not entirely the same) in their target performance standard (published within the MEPS document). Alternately, taking into consideration that the volume of linear fluorescent lamps may diminish in the medium term, significant savings could still be easily made by increasing the efficacy requirements within the current MEPS system (see option above).

Option 4: Change the linear fluorescent lamp categorisation from length to tube diameter –

a) *and update the general minimum requirements of the current MEPS as per by at least 4 lm/W; or*

b) *harmonise with the EU or China MEPS levels, effectively increasing MEPS requirements in Australia and New Zealand.*

7.4 Introduce MEPS for circular fluorescent lamps in 2-3 years

To determine general achievable levels of performance of circular fluorescent lamps, rated efficacy levels of more than 100 different models across five major manufacturing brands available on the Australian and New Zealand markets were collated and plotted against the current Australia/New Zealand linear fluorescent MEPS, the EU requirement for circular lamps, and the Hong Kong requirement for T5 circular lamps (Figure 17).

T9 circular fluorescent lamps initial efficacy is broad, although over 50% of models meet the EU requirement. Nearly all of the T5 circular fluorescent lamps meet the EU and Hong Kong requirements. Therefore, it would appear that there is an opportunity to create energy savings by introducing circular fluorescent MEPS, in particular to address the lower performances of T9 lamps.

The relevant test method for determining the performance of circular fluorescent lamps is outlined in AS/NZS 60901:2003 – Single-capped fluorescent lamps – Performance specifications, which is a reproduction, with normative adjustments, of IEC 60901:2001 – Single-capped fluorescent lamps – Performance specifications. MEPS levels could be aligned with EU requirements which would remove a range of less efficient T9 products from the market.

Option 5: Develop a MEPS requirement for T9 circular fluorescent lamps, potentially based on EU requirements.

7.5 Reduce mercury content in lamps to meet international requirements

The current maximum permissible limit for mercury in linear fluorescent lamps in Australian and New Zealand is set at 15 mg. The intention was that this mercury content level would eventually harmonise with the EU No 95/2002 on restrictions of the use of hazardous substances (RoHS) in electrical and electronic equipment.

The RoHS Directive currently sets the following limits for mercury in lamps within scope of this Product Profile:

- Modern linear T5 fluorescent lamps with 'normal' lifetime (triphosphor, < 25,000 hours) – 3 mg
- Modern linear T5 fluorescent lamps with 'long' lifetime (triphosphor, ≥ 25,0000 hours) – 5 mg
- Modern linear T8 or T12 fluorescent lamps with 'normal' lifetime (triphosphor, < 25,000 hours) – 3.5 mg
- Modern linear T8 or T12 fluorescent lamps with 'long' lifetime (triphosphor, ≥ 25,0000 hours) – 5 mg
- Modern non-linear fluorescent lamps > 17 mm (triphosphor) – 15 mg

The Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury. This includes the banning of manufacture, import or export of certain lamps containing mercury from 2020 – relevant to this Product Profile are linear fluorescent lamps for general lighting purposes:

- triphosphor less than 60 watts with a mercury content not exceeding 5 mg per lamp; and
- halophosphate phosphor of 40 watts or less with a mercury content not exceeding 10 mg per lamp.

Australia and New Zealand have signed the Minamata Convention in October 2013 are now considering ratifying the Convention to become a full Party to it. Ratification of the Convention would legally bind Australia to the Convention's obligations and would therefore require that both countries adopt the mercury limits outlined above for the relevant linear fluorescent lamps.

Option 6: Reduce the maximum mercury limit for linear fluorescent lamps to harmonise with the EU or at minimum meet the Minamata Convention requirements.

7.6 Harmonise Australia and New Zealand MEPS for ballasts by increasing Australian MEPS requirements

Australia and New Zealand currently have different minimum EEI requirements for ballasts – New Zealand requires a minimum of B1 while Australia only requires ballasts to meet a minimum EEI of B2 (discussed in Section 5). EECA's sales data survey for the year ending March 2010 found that only 10 of the magnetic ballasts sold in New Zealand complied with the B1 standard (however, EECA noted that there was a high level of unregistered product in this category). Most ballasts were at a B2 standard, which New Zealand accepts under the Trans-Tasman Mutual Recognition Agreement (TTMRA).

The current MEPS standard financially disadvantages smaller, New Zealand-based suppliers who directly import products into New Zealand because they must supply the New Zealand market with B1 ballasts instead of the cheaper B2 stock (which is permissible via the TTMRA for products registered in Australia).

The majority of MEPS-registered ballasts now have an EEI of A2 (Figure 18) and all ballast (with the exception of 28 W B1) can be replaced with a more efficient model. If the minimum EEI classification was increased to A3 for Australia and New Zealand, approximately 14% of the registered ballast models would be removed. If increased to A2, about 28% of the registered ballast models would be removed. This would, however, remove magnetic ballasts from the market. Some magnetic ballasts are still manufactured in Australia by CMP, although production has been decreasing over recent years (see Section 3).

Another discrepancy between Australia and New Zealand is that in New Zealand the MEPS for fluorescent lamp ballasts also applies to those intended for use with compact 2-tube and 4-tube flat fluorescent lamps (the Australian MEPS only applies to linear fluorescent lamps).

Option 7: Align the Australian and New Zealand MEPS requirements

a) *Increase the Australian minimum EEI requirement for fluorescent lamp ballasts to B1.*

b) *Expand the scope of ballasts subject to MEPS in Australia to include those intended for use with compact 2-tube and 4-tube flat fluorescent lamps (ILCOS lamp codes FSD or FSS type T, TC-L or TC-F).*

7.7 Align with European stage 3 requirements for ballasts in 2-3 years

An alternative approach to upgrading the Australian MEPS levels would be to move to EU MEPS levels. A large portion of AS/NZS 4783.2 was based upon the European Standard EN 50294, including the declaration of EEI. However, the current EU requirements as per EC No 245/2009 have altered since the publication of AS/NZS 4783.2. The differences between the Australia/New Zealand regulations and EU requirements for fluorescent lamp ballasts are outlined below, along with possible policy options for consideration.

The EEI categorisation in AS/NZS 4783.2 was fully harmonised (with a minor exception) with the EU when it was first implemented. However, the calculation factors for the EU categorisation have since changed. A comparison between the EEI values quoted in AS/NZS 4783.2 and the current EU requirements in EC No 245/2009 has revealed that there is a discrepancy between the efficiency levels required of a ballast to be classified into the given EEI categories. Ballasts sold in Australia and New Zealand must have a greater efficiency (lamp power/input power) than for the same product to be sold in the EU. For example, A2 ballast for use with the T8 lamp FD-15-E-G13-26/450 is required to have a 94% efficiency to be sold in Australia and New Zealand, compared to 84% in the EU.

Ballast 'apparent' differences between Australia/New Zealand and Europe are contained within the definitions. AS/NZS 4783.2 states that:

$$Ballast\ efficiency = \frac{P_{lamp}}{P_{input}}$$

where P_{lamp} is the rated lamp power and P_{input} is the rated input of the ballast.

For the A class electronic ballasts within scope of EC No 245/2009, "values are specifically calculated using P_{lampHF}, which is the 'rated/typical' lamp wattage for high frequency operation as listed in column 5, Table 26 (in Appendix B) for HF ballasts, as opposed to the lamp wattage when operated at low frequency of 50Hz (column 4) of the lamp."

$$Ballast\ efficiency = \frac{P_{lampHF}}{P_{input}}$$

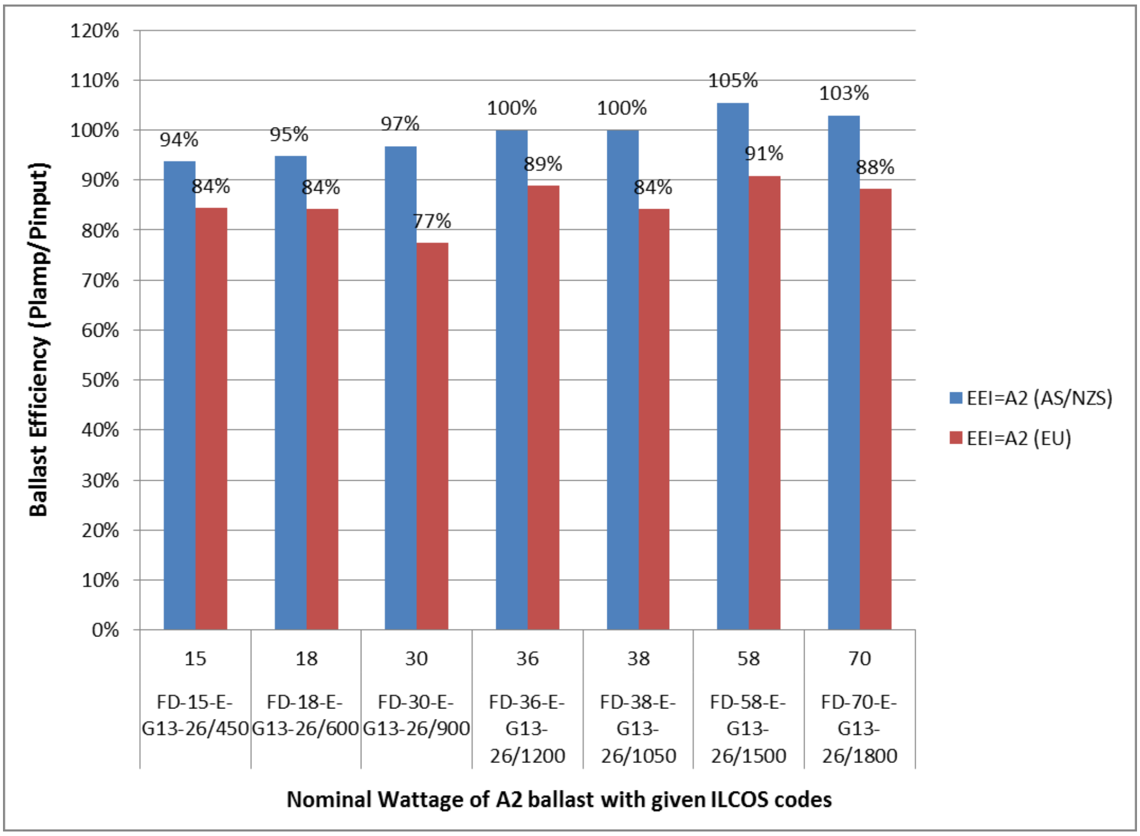
For example, for B class ferromagnetic ballasts in Australia/New Zealand, there have been adjustments for performance of the lamp/ballast due to voltage differences. At the time of establishing AS/NZS 4783.2 voltage was assumed to be 240 V (while Europe uses 230 V) and therefore a correction factor of 0.95 was applied. For example, a T8 36 W linear fluorescent lamp with a B2 ballast:

$$Ballast\ efficiency\ (AS/NZS) = \frac{P_{lamp}}{P_{input}} = \frac{36}{43} = 83.7\%$$

and applying the voltage correction factor

0.95 x 83.7% = 79.5% (same as the EU requirement; see Appendix B Table 26).

Figure 39. Comparison of ballast efficiency requirements in Australia/New Zealand (blue) and Europe (red) for ballasts with EEI classification A2.



These equate to the same operating efficiency of the ballast, however the representation 'on paper' in the standard is somewhat obscured. Many ballasts manufactured for the European market and labelled accordingly may be sold in Australia and New Zealand. Without an alternative marker in place to indicate the Australia/New Zealand version of EEI, there is the potential that many of the ballasts sold here may not meet the AS/NZS specifications. The simplest method of solving this problem would be to adopt the calculation methods as performed in the EU standard.

Europe also specifies two additional categories which serve as higher energy performance standards within these EEI category bands – A2 BAT and A3 BAT. These categories encourage industry to continue to improve their product. Furthermore, from 13 April 2017 Europe will increase the requirements of ballasts to be of minimum EEI classification A2 or A2 BAT (non-dimmable) and A1 BAT (dimmable) (see Section 6).

For B class ferromagnetic ballasts in Australia/New Zealand, there have been adjustments for performance of the lamp/ballast due to voltage differences. At the time of establishing AS/NZS 4783.2 voltage was assumed to be 240 V (while Europe uses 230 V) and therefore a correction factor of 0.95 was applied. For example, a T8 36 W linear fluorescent lamp with a B2 ballast:

$$Ballast\ efficiency\ (AS/NZS) = \frac{P_{lamp}}{P_{input}} = \frac{36}{43} = 83.7\%$$

and applying the voltage correction factor

0.95 x 83.7% = 79.5% (same as the EU requirement; see Appendix B Table 26).

Option 8: Harmonise with EU methodology for determining the EEI and introduce the additional EEI ballast categories A2 BAT and A3 BAT.

Option 9: Increase the MEPS to align with the EU Stage 3 requirements (to be applied from April 2017) of EEI = A2 or A2 BAT for non-dimmable ballasts and A1 BAT for dimmable ballasts.

7.8 Introduce a voluntary or mandatory MEPS level for commercial luminaires

When selecting a luminaire, a number of factors need to be considered including lighting requirements, in particular illuminance levels at the task, luminous intensity distribution, luminous flux of each fitting, and luminaire efficiency. An assessment of luminaire suitability on the basis of only one of these properties can be misleading, e.g. if only glare reduction is taken into account the minimum light intensity may not be achieved (Pohl and Zimmerman 2003). The selection of an efficient luminaire requires the weighting of factors such as efficacy, light quality and light output, to achieve the desired light effect (Green Seal 2000a).

There are various terms and calculations for defining the photometric efficiency or lighting performance specifications of luminaires. The most commonly used are Light Output Ratio (LOR) and Luminaire Efficacy Rating (LER). The LOR is the ratio of the total flux of the luminaire or ratio of light emitted from the luminaire to the light emitted from the light source (Van Tichelen 2007 and see IEC 50 (845/CIE 17.4)). The calculation for LER, however, differs between sources –

- *LER = LOR × ballast efficiency × lamp efficacy*, where ballast efficiency is the ratio between the nominal lamp power and the total input power of the ballast-lamp circuit (Van Tichelen 2007).
- *LER = (LOR × total rated lamp lumens × BF) / input watts*, where ballast factor (BF) is the light output of a fluorescent lamp(s) operated on a ballast as a percentage of the light output when operated on a standard "reference" ballast (Green Seal 2000b).
- *LER = (number lamps per luminaire × rated lamp light output × BF × LOR) / Luminaire input power*, where BF is the fraction of rated lamp lumens that a particular lamp-ballast combination will produce (Myer et al. 2009).
- *LER = BLE × lamp efficacy × LOR*, where ballast luminous efficacy (BLE) is the lamp power divided by the ballast power (Beletich, Page and Brocklehurst 2014).

Testing of system efficacy on a lensed 'wrap-around' surface mount luminaire was undertaken by Beletich, Page and Brocklehurst (2014) and it was found that theoretical LER equation (which is the same as that proposed by Van Tichelen 2007) was a good predictor of actual luminaire efficacy. However, it was noted that this method of determining system efficacy would only be useful where efficiency is a key driver and aesthetics is of minimal concern (Beletich, Page and Brocklehurst 2014).

Of the countries discussed in this report, only the EU and Japan have mandatory requirements for fluorescent lamp luminaires energy efficiency / power consumption. The USA has mandatory efficiency requirements for federal government purchasing, and a voluntary ENERGY STAR specification. The USA specifications both use the LER as given by Green Seal (2000b). The EU and Japan use very different requirements to those listed above:

- EU – the power consumption of luminaires for fluorescent lamps without integrated ballasts must not exceed the sum of the power consumption of the incorporated ballasts, excluding other components inside the luminaire which may use power. This requirement does not address overall luminaire efficacy as it does not take into account light output.
- Japan – total luminous flux of the fluorescent lamp mounted on the fluorescent luminaire by the power consumption of the florescent luminaire, where *total luminous flux = (rated total luminous flux value of lamp) × (ballast light output coefficient) × (temperature compensation coefficient).*

Beletich, Page and Brocklehurst (2014) note that one constraint for the development of MEPS for luminaires has been the absence of an agreed international standard which includes photometric and electrical characteristics.

A holistic measure of luminaire efficiency should incorporate the (maintained) efficacy of the light source, the electrical losses of the control gear and the (maintained) photometric efficiency of the light fitting. However, simple efficiency measures such as 'downward efficacy' (the amount of downward flux emitted, divided by the total power consumed by the lamp and control gear) often fail to take into account:

- the light levels required by the application to be lit;
- the characteristics of the room, including its height, shape and reflective properties of the internal surfaces including the ceiling;
- glare;
- uniformity of light; and
- the ability of the luminaire to control the light source based on time of day, movement, daylight levels, etc.

A more sophisticated measure may be System Efficacy which is defined as:

System Efficacy = useful lumens/total wattage

where

useful lumens = UF × maintained lamp lumens

UF = Utilisation Factor for a luminaire in room with fixed room index and reflectances

total wattage = total circuit power of lamps and control gear.

A consideration for luminaire ratings is the inclusion of in-built control systems. The BCA Section J6 already allows greater watts per square metre for installed lighting if control systems such as Digital Addressable Lighting Interface (DALI) dimmability are installed (see Section 5). Any inclusion of in-built control systems in a luminaire rating would need to consider the compatibility and overlap with the current BCA provisions.

Option 10: Determine a suitable energy efficiency test method for commercial luminaires and implement voluntary or mandatory MEPS.

7.9 Product labelling and education initiatives

7.9.1 Linear fluorescent lamps

Currently, linear fluorescent lamps have voluntary energy efficiency labelling as outlined in Appendix C of AS/NZS 4782.2, based on the European 'A-G' label on household lamps. AS/NZS 4782.2 states "…State governments will consider a mandatory approach should the proportion of household lamps that carry the label not increase substantially." The current European-style voluntary label could be made mandatory, or an adaptation of the Australia/New Zealand Energy Rating Label (using a star rating) could be applied on a voluntary or mandatory basis to linear fluorescent lamps.

Mark Ellis & Associates (2003) discussed a number of pros and cons relating to mandatory energy efficiency labelling of linear fluorescent lamps, and included:

- improved and simplified energy efficiency information flow to the end user, although in the commercial sector linear fluorescent lamps are usually not specified by the end user so may have a less than optimal impact on the sale of efficient lamps; and
- the need to support labelling with informational programs to educate consumers, or in the case of the commercial sector, target lighting designers.

In 2003 labelling was not considered an effective option for reducing energy consumption of linear fluorescent lamps in Australia and New Zealand, due to the minimal impact mandatory labelling has on removing inefficient lighting products from the market and far-removed end users in the commercial market where linear fluorescent lamps are predominant (Mark Ellis & Associates 2003).

Little has changed since 2003 in terms of the way that linear fluorescent lamps are provided to the market in Australia and New Zealand. The audience for such a label is limited and to some extent can be considered more informed than the general population. Therefore it is not proposed to change the current optional arrangements for labelling.

7.9.2 Ballasts

In Australia, fluorescent lamps ballasts subject to MEPS must be labelled with the EEI classification while ballasts outside the scope of MEPS but within the scope of AS/NZS 4783.2 can be voluntarily labelled with the EEI classification. In New Zealand labelling ballasts with the EEI classification is voluntary. For both countries labelling with the EEI must be in the form, for example, “EEI = A3”.

The AS/NZS 4783.2 EEI labelling scheme was fully harmonised (with a minor exception) with the EU when it was first implemented. However, the labelling requirements in Europe will change 13 April 2017 with shortening the ballast labelling requirements by removing the need to include “EEI =”.

Option 11: introduce mandatory labelling of fluorescent lamp ballasts within the scope of MEPS for products sold in New Zealand, to align with the Australian requirements.

Option 12: Remove the requirement to label “EEI =” before the EEI classification to align Australia and New Zealand with the EU.

7.10 Voluntary labelling

An alternative or addition to mandatory energy labelling would be voluntary energy labelling and/or the use of endorsement labelling such as ENERGY STAR.

The main disadvantage of any voluntary or endorsement labelling scheme is that it is generally only the high efficiency products which are labelled and, while it would make it easier for consumers to identify these products, they would not be able to compare the performance and benefits with the lower efficiency products. Also this may only motivate a limited proportion of suppliers to improve the efficiency of their products. Endorsement schemes need to be supported by a robust compliance regime and considerable marketing and promotion if consumers are going to use and have confidence in endorsement labels.

The New Zealand government runs an active ENERGY STAR scheme for a number of electrical appliances, including residential and directional commercial grade luminaires (not linear fluorescent luminaires). An active promotion, compliance and enforcement regime is required to ensure the ENERGY STAR endorsement is used correctly, to maintain the relationship with the US program. The program relies on industry partners actively promoting the endorsement mark and using it in the correct manner.

Voluntary and endorsement labelling schemes also suffer from the same limitations as a mandatory labelling scheme – in that a large part of the commercial lighting market is covered by a split incentive (where the appliance is purchased by someone who isn’t the end-user and bill payer). Consequently, it is difficult to see how a voluntary labelling scheme or expanding the ENERGY STAR endorsement scheme to Australia would benefit the commercial lighting market.

7.10.1 Luminaires

There is currently no energy efficiency labelling requirement for commercial luminaires (within the scope of this Product Profile) sold in Australia or New Zealand. Energy star endorsement labelling is currently proposed for a range of commercial luminaires in New Zealand, this is voluntary labelling for high efficiency products. Policy options which may be considered are voluntary labelling or mandatory labelling. However, no international energy efficiency programs include mandatory labelling of luminaires.

Option 13: A mandatory or voluntary energy rating labelling scheme applied to commercial luminaires.

7.11 Information, education, behaviour and controls

Opportunities exist to educate commercial lighting designers, building managers and occupants regarding the efficient design, maintenance and use of commercial lighting installations. To maximise energy efficiency of commercial lighting, building managers need to establish and implement a scheduled cleaning and re-lamping program for luminaires to reduce depreciation of illumination levels from dirty luminaires and prevent lamps from being run until total failure.

The total energy consumption of commercial lighting is also influenced by the occupant’s usage and controls. Configuring lighting design to the specific requirements of the user will reduce over-illumination; however, this can be a costly task for both building owners and tenants. The types of controls installed will depend on how the commercial space is used. Strategies can include occupancy sensing, scheduling, lumen maintenance, dimming (i.e. DALI), daylight linking and load shedding. It is important to educate building occupants how to use the lighting system to ensure maximum efficiency is achieved.

Work in this area would need to take into account building code requirements. To have a significant effect would require the development and implementation of a commercial lighting education strategy that aligned with other initiatives in this area. Information could include education programs for designers, specifiers and installers of lighting systems, and sales training at both the retail and wholesale level (EECA, LCNZ and EC). While such initiatives could lead to improved commercial lighting outcomes in terms of both efficient and quality, they would not serve as a replacement for the savings that have and can be achieved through regulation of minimum performance.

7.12 Summary of options

No action (business as usual)

Option 1: Existing MEPS for linear fluorescent lamps and fluorescent lamp ballasts remain unchanged, and no new policy is adopted for other products within the scope of this Product Profile.

Update Australian and New Zealand test standards for fluorescent lamps and ballasts

Option 2: Update Australian and New Zealand test standards for fluorescent lamps and ballasts to recent International Electrotechnical Commission standards.

Revise local MEPS levels for linear fluorescent lamps in 2-3 years

Option 3a: Increase the current initial efficacy MEPS requirement for linear fluorescent lamps of length 550–1500 mm by at least 4 lm/W.

Option 3b: Increase the maintained efficacy MEPS requirement for linear fluorescent lamps of length 550–1500 mm using a similar approach to Table 18.

Option 3c: Revise the maintained efficacy MEPS so it is based on a percentage of the initial efficacy.

Harmonise with international requirements for linear fluorescent lamps

Option 4: Change the linear fluorescent lamp categorisation from length to tube diameter –

a) *and update the general minimum requirements of the current MEPS as per by at least 4 lm/W; or*
b) *harmonise with the EU or China MEPS levels, effectively increasing MEPS requirements in Australia and New Zealand.*

Introduce a MEPS requirement for circular fluorescent lamps in 2-3 years

Option 5: Develop a MEPS requirement for T9 circular fluorescent lamps, potentially based on EU requirements.

Reduce mercury content in lamps to meet international requirements

Option 6: Reduce the maximum mercury limit for linear fluorescent lamps to harmonise with the EU or at minimum meet the Minamata Convention requirements.

Harmonise Australia and New Zealand MEPS for ballasts by increasing Australian MEPS requirements

Option 7: Align the Australian and New Zealand MEPS requirements –

a) *Increase the Australian minimum EEI requirement for fluorescent lamp ballasts to B1.*
b) *Expand the scope of ballasts subject to MEPS in Australia to include those intended for use with compact 2-tube and 4-tube flat fluorescent lamps (ILCOS lamp codes FSD or FSS type T, TC-L or TC-F).*

Align with European stage 3 requirements for ballasts in 2-3 years

Option 8: Harmonise with EU methodology for determining the EEI and introduce the additional EEI ballast categories A2 BAT and A3 BAT.

Option 9: Increase the MEPS to align with the EU Stage 3 requirements (to be applied from April 2017) of EEI = A2 or A2 BAT for non-dimmable ballasts and A1 BAT for dimmable ballasts.

Voluntary or mandatory MEPS for commercial luminaires

Option 10: Determine a suitable energy efficiency test method for commercial luminaires and implement voluntary or mandatory MEPS.

Product labelling and education initiatives

Option 11: introduce mandatory labelling of fluorescent lamp ballasts within the scope of MEPS for products sold in New Zealand, to align with the Australian requirements.

Option 12: Remove the requirement to label "EEI =" before the EEI classification to align Australia and New Zealand with the EU.

Option 13: A mandatory or voluntary energy rating labelling scheme applied to commercial luminaires.

Other options which were investigated but were not preferred options can be found in Appendix C.

7.13 Potential Energy Benefits

Energy savings and greenhouse gas emission reductions for a linear fluorescent lamp MEPS revision have been estimated below. A MEPS revision for linear fluorescent lamps where the MEPS levels were increased in stringency by 4 lm/W would save a further 1% of the electricity used. While there is a lack of data for cost benefit analysis of other options at this stage, the preferred options would be analysed thoroughly in a RIS.

Table 19. Estimated energy savings from revised linear fluorescent lamp MEPS in Australia.

Policy options, Australia	Energy savings p.a. compared to BAU (GWh p.a.)	Savings GHG emissions (kt CO2-e)
LFL (BAU)	-	-
LFL (MEPS+4)	36.7	32.2
LFL (MEPS+6)	47.5	41.7
LFL (EU)	11.1	9.7
LFL (China G2)	3.7	3.2
LFL (China G1)	29.4	25.8

Table 19a. Estimated energy savings from revised linear fluorescent lamp MEPS in New Zealand.

Policy options, New Zealand	Energy savings p.a. compared to BAU (GWh p.a.)	Savings GHG emissions (kt CO2-e)
LFL (BAU)	-	-
LFL (MEPS+4)	7.0	1.1
LFL (MEPS+6)	9.0	1.5
LFL (EU)	2.1	0.4
LFL (China G2)	0.7	0.1
LFL (China G1)	5.6	0.9

8 References

ABCB (2010) *Energy Efficiency Provisions for BCA 2010 Volume One: Information Handbook*. Australian Building Codes Board.

AFR (22/01/2015) *AMP, Mirvac see the light on LED*. Australian Financial Review, pg. 5.

Beletich Associates (unpublished) *Scope of Work: Development of MEPS and Labelling Regime for Commercial Linear Fluorescent and HID Highbay Luminaires*. For the Australian Greenhouse Office.

Beletich S, Page E and Brocklehurst F (2014) *Mapping & Benchmarking of Linear Fluorescent Lighting*. *Draft*. CLASP.

CELMA (2007) *Comments on the Commission's Working document on possible ecodesign requirements or fluorescent lamps without integrated ballast, for ballasts and luminaires used with these lamps, and on the conditions for the indication of suitability of lighting products for office lighting*. CELMA.

EECA *Energy savings from improved product energy efficiency. Lighting*. Energy Efficiency and Conservation Authority, New Zealand.

EECA (2015) Linear fluorescent lamps - total sales and efficiency data *(*www.eeca.govt.nz/resource/linear-fluorescent-lamps-total-sales-and-efficiency-data). Energy Efficiency and Conservation Authority, New Zealand.

EECA, LCNZ and EC *New Zealand Efficient Lighting Strategy 2008 to 2010*. Energy Efficiency and Conservation Authority, Lighting Council New Zealand, and Electricity Commission.

E3 (2012) *2010 Residential Lighting Report*. Prepared for E3 by Energy Efficient Strategies.

E3 (2014) *Impacts of the E3 program: Projected energy, cost and emission savings*. Prepared for E3 by George Wilkenfeld Associates.

E3 (2015) *Internal commercial lighting stock model (draft)*. Prepared for E3 by Light Naturally.

Energetics Pty Ltd and George Wilkenfeld & Associates (1994) *Energy Performance Standards and Energy Labelling for Industrial and Commercial Equipment*.

George Wilkenfeld and Associates (2001) *Draft for Public Comment. Regulatory Impact Statement: Minimum Energy Performance Standards and Alternative Strategies for Fluorescent Lamp Ballasts*. Prepared for the Australian Greenhouse Office.

GWA (2001) *Final Regulatory Impact Statement: Minimum Energy Performance Standards and Alternative Strategies for Fluorescent Lamp Ballasts*. Prepared for the Australian Greenhouse Office by George Wilkenfeld and Associates Pty Ltd, Killara, Australia.

Green Seal (2000a) Green Seals Choose Green Report: Energy-Efficient CFL Downlight Luminaires (www.wbdg.org/ccb/browse_cat.php?c=193).

Green Seal (2000b) Gr*een Seal's Choose Green Report: Linear Fluorescent Luminaires* (www.wbdg.org/ccb/browse_cat.php?c=193).

International Energy Agency (2012), *World Energy Outlook*

Julien Freed Consulting (2012) *Energy Saver Energy Efficient Lighting Technology Report*. Office of Environment and Heritage, Sydney, Australia.

KEMA (2007) *New Zealand Electric Energy-Efficiency Potential Study, Volume 1*. Electricity Commission of New Zealand.

Lewis A and Gomer S (2008) *An Australian Cost Curve for Greenhouse Gas Reduction*. McKinsey & Company, Australia.

Lighting Council Australia (*Retrofitting Fluorescent Luminaires to Improve Energy Performance*) Lighting Council Australia Official News No. 15.

MEA (2001) *Analysis of Potential for Minimum Energy Performance Standards for Lamps*. Prepared for the Australian Greenhouse Office by Mark Ellis & Associates, Wagstaffe, Australia.

Mark Ellis & Associates (2003) *Regulatory Impact Statement: Minimum Energy Performance Standards and Alternative Strategies for Linear Fluorescent Lamps – Final*. Mark Ellis & Associates, Wagstaffe, NSW.

Myer MA, Paget ML and Lingard RD (2009) *Performance of T12 and T8 Fluorescent Lamps and Troffers and LED Linear Replacement Lamps: CALiPER Benchmark Report*. PNNL-18076, Pacific Northwest National Laboratory, Richland WA, USA.

NAEEEC (2002) *Minimum Energy Performance Standards: Lamps*. National Appliance and Equipment Energy Efficiency Committee.

NAEEEP *Fact Sheet 01, MEPS for fluorescent lamp ballasts*. National Appliance and Equipment Energy Efficiency Program.

NAEEEP (2004) *Greenlight Australia – A strategy for improving the efficiency of lighting in Australia 2005-2015*. Report No 2004/18, Department of the Environment and Heritage, Australian Greenhouse Office, Australia.

Newell G, MacFarlane J and Kok N (2011) *'Building Better Returns'. A Study of the Financial Performance of Green Office Buildings in Australia*. Australian Property Institute Inc., Sydney.

NFEE (2009) *The Basics of Efficient Lighting: A Reference Manual for Training in Efficient Lighting Principles*. National Framework for Energy Efficiency.

pitt&sherry (2012) *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia – Part 1 – Report*. Department of Climate Change and Energy Efficiency.

Pohl W and Zimmermann A (2003) 'Chapter 3: Artificial Lighting' in Tsangrassoulis A, Synnefa A, Jacobs A, Wilson M, Solomon J, Fontoynont M, Pohl W and Zimmermann A (eds), *SynthLight Handbook*, European Commission.

Regulations.gov *2011-08-04 Energy Efficiency Program: Test Procedure for Lighting Systems (Luminaires); Request for Information*. US Government (http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-TP-0041-0003).

Siddiqi T and Lim B (2013) *Data Project for the FluoroCycle Scheme: National Environment Protection Council*. Prepared for the Department of Sustainability, Environment, Water, Populations and Communities by Net Balance, Australia.

Stewardship Solutions (2008) *New Zealand Lighting Industry Product Stewardship Scheme – Phase 1 Assessment and Review*. Prepared for Lighting Council New Zealand and The Electricity Commission.

Unknown (2006) 'The Stern Review on the Economic Effects of Climate Change', *Population and Development Review*, 32:793-798.

Van Tichelen P, Jansen B, Geerken T, Vanden Bosch M, VanHoof V, Vanhooydonck L and Vercalsteren A (2007) *Preparatory Studies for Eco-design Requirements of EuPs, Lot 8: Office lighting, Final Report April 2007*. Study for the European Commission DGTREN unit D3, Contract – TREN/D1/40-2005/LOT8/S07.56452. VITO, Belgium.

Waide P (2011) *Opportunities for Success and CO_2 Savings from Appliance Energy Efficiency Harmonisation: Part 2: An Assessment of Test Procedures and Efficiency Metrics*. Navigant Consulting in partnership with CLASP, the Collaborative Labeling & Appliance Standards Program, London.

Appendix A – Fluorescent Lamp Energy Consumption Modelling and Assumptions

Note that the wattage and subsequent lumen and energy consumption values are based around a weighted average of lamps currently used in Australia; Table 20 and Table 21 do not inform a like-for-like retrofit scenario since the replacement lumens do not necessarily match.

Table 20. Comparison of lamp characteristics and cost benefits.

Weighted Average	T12	T8	T5-HE	T5-HO	Non-integrated CFL	Circular
Lamp wattage (W)	35.0	31.8	22.9	43.7	22.8	33
Circuit wattage (W)	43.0	39.8	26.6	47.4	29.8	39
Output per lamp (lm)	3000	2700	2100	3500	1400	2400
Lamp efficacy (lm/W)	74	83	91	79	61	73
Average lamp lifetime (hrs)	11000	20000	22000	24000	10000	10000
Lamp run time p.a. (hrs)	3650	3650	3650	3650	3650	3650
Lamp lifetime (years)	3.0	5.5	6.0	6.6	2.7	2.7
Lamp+Ballast energy consumption (kWh p.a.)	157	145	97	173	109	142
Indirect energy consumption (kWh p.a.)	55	51	34	61	38	50
Total energy consumption (kWh p.a.)	212	196	131	234	147	192
Lamp import price ($)	$2.82	$1.52	$1.98	$1.52	$4.24	$5.29
Lamp trade price ($)	$7.05	$3.79	$4.96	$3.79	$10.61	$13.22
Lamp end-user price ($)	$9.30	$5.00	$6.55	$5.00	$14.00	$17.45
Lamp replacement labour cost ($)	$2.67	$2.67	$2.67	$2.67	$2.67	$2.67
Incremental electronic ballast trade price (T5)	-	-	$33.00	$33.00	-	-
Annualised lamp capital cost (enduser) ($ p.a.)	$3.97	$1.40	$1.53	$1.17	$6.08	$7.34
Annualised lamp capital cost (national imports) ($ p.a.)	$1.82	$0.76	$0.77	$0.64	$2.52	$2.90
Annual lamp energy cost (enduser) ($ p.a.)	$40.82	$37.75	$25.23	$45.00	$28.28	$37.01
Total annual cost (enduser) ($ p.a.)	$44.79	$39.15	$26.76	$46.17	$34.36	$44.35
Total annual cost per lumen (enduser) ($ p.a.)	$0.0149	$0.0145	$0.0127	$0.0132	$0.0245	$0.0185

The following fundamentals were assumed in producing the information provided in Table 20:

- Lamp run time per annum is 10 hours per day (i.e. 8am – 6pm), 365 days per year.
- Weighted average lamp trade price obtained from supplier catalogues ($5.11) and weighted average import price obtained from ABS statistics ($1.47).

— The margin on import prices to obtain the trade price was calculated to be 250%.
— Margin of 10% for electrical contractor and 20% for electrical wholesaler applied to quoted trade price in order to reflect end-user price.

- Indirect energy consumption due to removal of additional lamp heat load in air-conditioned buildings was given a weighted cross-sectoral average allowance of 35% of the quoted lamp energy consumption (GWA 2001).
- Labour cost of replacing each lamp was calculated at a rate of 30 lamps replaced per hour @ $80 per hour labour charge, equating to $2.67 per lamp.
- An additional cost of fitting an electronic ballast was applied to T5 lamps (as per previous discussions with ballast manufacturers; MEA 2001).
- Energy costs for the end user were obtained from Origin Energy (www.originenergy.com.au) for small business at a national average of 26c/kWh. This does not include the additional daily electricity supply price.
- Energy costs and lamp run times are assumed to remain constant in real terms over the life of the evaluation.

Table 21. Cost benefit analysis of swapping to high efficiency T5-HE from less efficient T12 and T8 lamp models (see Table 8).

	T5-HE	T12	Numerical Difference	% Difference	T8	Numerical Difference	% Difference
Lamp wattage (W)	28.0	40.0	-12.0	-30.0%	36.0	-8.0	-22.2%
Circuit wattage (W)	31.7	48.0	-16.3	-34.0%	44.0	-12.3	-28.0%
Output per lamp (lm)	2700	3000	-300.0	-10.0%	3000	-300.0	-10.0%
Lamp efficacy (lm/W)	96	75	21.0	28.0%	90	6.0	6.7%
Average lamp lifetime (hrs)	22000	11000	11000.0	100.0%	20000	2000.0	10.0%
Lamp run time p.a. (hrs)	3650	3650	0.0	0.0%	3650	0.0	0.0%
Lamp lifetime (years)	6.0	3.0	3.0	100.0%	5.5	0.5	10.0%
No units required for 10 year period	2.0	4.0	-2.0	-50.0%	2.0	0.0	0.0%
Lamp+Ballast energy consumption (kWh) over 10 years	1157	1752	-595.0	-34.0%	1606	-449.0	-28.0%
Indirect energy consumption (kWh) 10 years	405	613	-208.2	-34.0%	562	-157.1	-28.0%
Total energy consumption (kWh.) over 10 years	1562	2365	-803.2	-34.0%	2168	-606.1	-28.0%
Lamp import price ($)	$1.98	$2.82	-0.8	-29.6%	$1.52	0.5	31.0%
Lamp trade price ($)	$4.96	$7.05	-2.1	-29.6%	$3.79	1.2	31.0%
Lamp end-user price ($)	$6.55	$9.30	-2.8	-29.6%	$5.00	1.6	31.0%
Lamp end-user price ($) over 10 years	$13.10	$37.20	-24.1	-64.8%	$10.00	3.1	31.0%
Replacement labour cost ($) over 10 years	$5.33	$10.67	-5.3	-50.0%	$5.33	0.0	0.0%
Incremental electronic ballast trade price (T5)	$16.50						
Energy cost (enduser) ($ over 10 years)	$105.29	$159.43	-54.1	-34.0%	$146.15	-40.9	-28.0%
Total annual cost (enduser) ($ over 10 years)	$140.22	$207.30	-67.1	-32.4%	$161.48	-21.3	-13.2%

Appendix B – Overseas Programs and Specifications

Efficiency Programs

Fluorescent lamps

Canada

The Energy Efficiency Act contains regulations which prescribe the energy efficiency standard for each regulated product under the Act. CAN/CSA-C819-11 – Performance of general service fluorescent lamps is a mandatory standard which specifies performance requirements (including lamp efficacy – see Appendix B

Table 32) based on length categories. The standard applies to:

- rapid-start straight-shaped fluorescent lamps with a nominal overall length of 1200 mm, a medium bi-pin base and a rated wattage ≥ 28 W;
- rapid-start straight-shaped fluorescent lamps with a nominal overall length of 2400 mm, a recessed double-contact base, a nominal power of not less than 95 W and a nominal current of 0.8 amps;
- rapid-start U-shaped fluorescent lamps with a nominal overall length of 560-635 mm, a medium bi-pin base and a rated wattage ≥ 28 W;
- instant-start straight-shaped fluorescent lamps with a nominal overall length of 2400 mm, a single-pin base and a rated wattage ≥ 52 W; and
- any fluorescent lamp that is a physical and electrical equivalent of a lamp described above.

CAN/CSA-C819-11 does not apply to fluorescent lamps with a CRI of 82 or greater, or a range of other fluorescent lamps designed for specific purposes– see Natural Resources Canada (www.nrcan.gc.ca/energy/regulations-codes-standards/products/6939) for the list of excluded lamps.

Hong Kong

The Hong Kong *Code of Practice for Energy Efficiency of Lighting Installations (2007), Addendum 1* sets minimum energy efficiency requirements for indoor lighting, including linear, circular, U-shaped and non-integrated compact fluorescent lamps. The Code of Practice applies to offices, schools, car parks, places of public entertainment and recreation, places of public assembly, hotels, shops, department stores, restaurants and communal areas of residential buildings.

Luminous efficacy requirements for linear fluorescent lamps are specified by lamp diameter, wattage and colour temperature categories (Appendix B Table 37). The Code of Practice defers to the *Hong Kong Voluntary Energy Efficiency Labelling Scheme for Non-integrated Type Compact Fluorescent Lamps* (September 2012) for luminous efficacy requirements for non-integrated CFLs (Table 37). Prescribed initial operating hours for tubular fluorescent lamps is 2000 hours, and for non-integrated CFLs is 100 hours. Maximum allowable power density (W/m^2) for various indoor spaces is also specified in the Code of Practice.

Korea

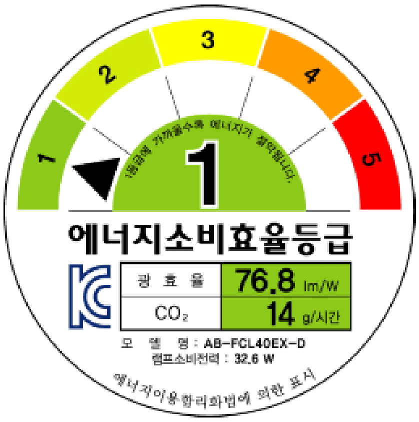
The standard *KS C 7601:2004 Fluorescent lamps for general lighting service* sets mandatory performance standards for linear (categorised by wattage; 20 W, 28 W, 32 W and 40 W), circular (32 W and 40 W) and non-integrated compact (FPX 13 W, FDX 26 W, FPL 27 W, FPL 32 W, FPL 36 W, FPL 45 W, and FPL 55 W) fluorescent lamps.

Note: FPL is equivalent to the EU standard category 'Long single parallel tube, lamp cap 2G11 (4 pin)'; FPX is equivalent to the EU standard category 'Small single parallel tube, lamp cap G23 (2 pin) or 2G7 (4 pin)'; and FDX is equivalent to the EU standard category 'Double parallel tubes, lamp cap G24d (2 pin) or G24q (4 pin)'.

There are five performance levels, with Level 5 the minimum requirement and Levels 1-4 target energy performance standards (TEPS). Efficacy requirements for each lamp category are also dependent on colour temperature – less than 6000 K, or 6000 K or greater (Appendix B Table 39).

Korea has a mandatory labelling program which indicates the efficacy level (1–5), the efficacy in lumens per watt to the first decimal place, CO_2 emissions as g/hour and power consumption in watts.

Figure 40. The mandatory label for fluorescent lamps sold in Korea.



Other countries

The **Thailand** standards *TIS 2309-2549 (2006) Double-Capped Fluorescent Lamps: Energy Efficiency Requirements* and *TIS 2334-2550 (2007) Single-Capped Fluorescent Lamps: Energy Efficiency Requirements* are administered under a collaboration between the Energy Policy and Planning Office (EPPO) and the Thai Industrial Standards Institute (TISI).

Performance of linear fluorescent lamps is based on initial luminous efficacy, maintained efficacy at 5000 hours and incorporates a minimum CRI (Appendix B Table 40). Lamps are separated into four length categories which are the same as those for Australian and New Zealand. Energy efficiency requirements under TIS 2334-2550 were not available at the time of publication of this Product Profile.

India has a mandatory performance standard *IS 2418 (Part II):1977 – Indian Standard Specification for Tubular Fluorescent Lamps for General lighting services: Part 2 Standard lamp data sheets (first revision)* for 1200 mm length tubular fluorescent lamps of wattages up to 40 W. Halophosphate lamps with a colour temperature of 6500 K and triphosphor lamps with a colour temperature of 6500 K, 4000 K or 2700 K are within scope of the standard.

The Indian Bureau of Energy Efficiency (BEE) has developed a star label which is mandatory to display on all linear fluorescent lamp packages, and this label displays the performance requirements for linear fluorescent lamps. A star marking must also be stamped on the lamp.

Figure 41. Star rating label and performance measures for linear fluorescent lamps in India.

BEE STAR RATING PLAN					
STAR RATING	*	**	***	****	*****
Lumens per Watt at 0100 hrs of use	<61	>=61 & <67	>=67 & <86	>=86 & <92	>=92
Lumens per Watt at 2000 hrs of use	<52	>=52 & <57	>=57 & <77	>=77 & <83	>=83
Lumens per Watt at 3500 hrs of use	<49	>=49 & <54	>=54 & <73	>=73 & <78	>=78

Vietnam's mandatory standard *TCVN 8249:2013 Edition 2 Linear fluorescent lamps – Energy efficiency* applies to tubular fluorescent lamps of 4–65 W, used with 50 Hz ballasts and high frequency ballasts for use on 220 V electric grid. A minimum and high energy efficiency level (lm/W) is given, categorised by lamp wattage range

(≤ 20 W; > 20 W and ≤ 40 W; > 40 W and ≤ 65 W) and CCT (less than or greater than 4400 K). Mercury content is limited to 15 mg.

Ballasts

Canada

In Canada, ballasts must comply with the *Energy Efficiency Regulations Technical Requirements for Energy-Using Products Fluorescent Lamp Ballasts*, last updated in 2010. Within scope of the requirements are fluorescent lamp ballasts designed for input of 120, 277 or 347 V, and designed to operate with an F32T8, F34T12, F40T10 or F40T12 rapid-start fluorescent lamp or an F96T12IS, F96T12ES, F96T12HO or F96T12HO ES fluorescent lamp.

The efficiency measure is termed the ballast efficacy factor (BEF; Appendix B Table 33) and is calculated as follows:

- Rapid-start lamps BEF = relative light output / power input (watts)
- Instant-start lamps BEF = relative lamp power / power input (watts)
- Instant-start lamps with high frequency ballasts BEF = relative light output / power input (watts)

All ballasts must have a power factor of at least 0.9. The exception is ballasts designed for 120 V and to operate F32T8 rapid-start fluorescent lamps that have a colour rendering index greater than 75 where the power factor must be at least 0.5.

Other countries

A number of other countries have mandatory performance standards and/or labelling for ballasts (see Van Tichelen et al. (2007) for a full list), but the requirements of these standards were not available at the time of preparing this Product Profile. Brief information about the standards for some of these countries is provided below.

- **Hong Kong:** electromagnetic and electronic ballasts for tubular fluorescent and non-integrated compact fluorescent lamps including circular and square CFL are within the scope of the *Code of Practice for Energy Efficiency of Lighting Installations (2007) Addendum 1*. The Code specifies the maximum allowable power consumption of a given ballast is variable according to the power consumption of the lamp it is operating (Appendix B Table 38).
- **Israel:** *SI 5485 - Ballasts for fluorescent lamps - Energy efficiency requirements and labelling*, is published by the Standards Institute of Israel. The scope of the standard was not available at the time of publication of this Product Profile.
- **Korea:** MEPS for fluorescent lamp ballasts are detailed in *KS C 8100: AC supplied electronic ballasts for fluorescent lamps* and *KS C 8102: Magnetic ballasts for fluorescent lamps*. These standards apply to ballasts for use with linear, circular and compact fluorescent lamps within the scope of *KS C 7601:2004 Fluorescent lamps for general lighting service* (discussed previously). Korea also has a mandatory labelling program which includes ballasts for fluorescent lamps. The products are graded as 1 to 5, and those closest to the 1st grade are the most energy efficient products.
- **Thailand:** mandatory MEPS are in place for magnetic and electronic ballasts with the specifications given in *Magnetic Ballasts for Fluorescent Lamps - Thailand - Minimum Energy Performance Standard (2004)* and *Electronic Ballasts for Fluorescent Lamps - Thailand - Minimum Energy Performance Standard (2004)*.
- **Brazil:** mandatory certification of ballasts is conducted by a Certification Body for Products (Organismo Certificador de Produtos or OCP) accredited by the National Institute of Metrology, Standardisation and Industrial Quality (Instituto Nacional de Metrologia, Normalização e Qualidade Industria or INMETRO). The INMETRO mark is mandatory for ballasts and voluntary for luminaires. Ballasts must comply with *ABNT NBR 14418-2011 A.C. supplied electronic ballasts for tubular fluorescent lamps - Performance requirements*.
- **Vietnam:** MEPs for fluorescent lamp ballasts are given in *TCVN 7897:2013 Edition 2 Electronic ballasts for fluorescent lamps – Energy efficiency* and *TCVN 8248: 2013 Edition 2 Electromagnetic ballasts for fluorescent lamps – Energy efficiency*. Ballasts within scope are for use with 4–65 W fluorescent lamps. TCVN 7897 does not apply to electronic ballasts integrated into lamps. A minimum and high level efficiency coefficient is given in each standard which ballasts must comply with.

Labelling

Brazil

Granted by the Ministry of Mines and Energy, the National Award of Conservation and Rational Use of Energy Selo Procel de Economia de Energya (Brazilian Energy Conservation Program Energy Efficiency Stamp) seeks to motivate the development of projects towards the adequate and efficient use of energy. Those products selected gain the right to use the Procel seal. The *National Awards for Energy Conservation and its Rational Use* on industrial projects are divided into classes; the relevant class being for Energy. The Energy class awards industries that achieve a proven reduction in specific consumption and/or a reduction in the demand for energy at times of peak demand. Selection of award winners takes into account qualitative and quantitative criteria, including:

- percentage of the reduction obtained in specific energy consumption;
- total energy savings;
- cost/benefit ratio;
- ratio between the average amount of energy saved and average total consumption in the period just before the actions were implanted;
- reduction of operating and/or maintenance costs;
- environmental benefits;
- potential for application in other activities or industries; and
- other benefits not related to energy.

Hong Kong

The Electrical and Mechanical Services Department in Hong Kong runs the voluntary Energy Efficiency Labelling Scheme, which provide information on energy consumption and efficiency to help consumers make better purchasing decisions. There are two types of labels – 'grading-type' and 'recognition-type'. Electronic ballasts are issued with the recognition-type label, which informs the consumer that the product has been certified to meet the minimum energy efficiency and performance requirements.

Figure 42. An example of the 'recognition-type' energy efficiency label which can be issued for electronic ballasts in Hong Kong.

Hong Kong also has the Green Label Scheme – an independent and voluntary scheme which identifies more environmentally preferable products based on the life cycle analysis. *GL-007-009 Product Environmental Criteria for Electronic Ballasts* sets out the environmental criteria and product performance requirements, with the aim to promote the energy efficiency, energy saving, improved lighting performance and longevity features of the product. The product criteria include:

- minimum service life of 50,000 hours;
- mortality ≤ 2.5% per 1000 hours for the first 50,000 hours when tested;
- operating frequency > 25 kHz;
- maximum power consumption of the system (ballast and lamp) ≤ limits given in the energy efficiency labelling scheme; and
- ballast-lumen factor (BLF) of 1.00 ≥ BLF ≥ 0.95.

Other countries

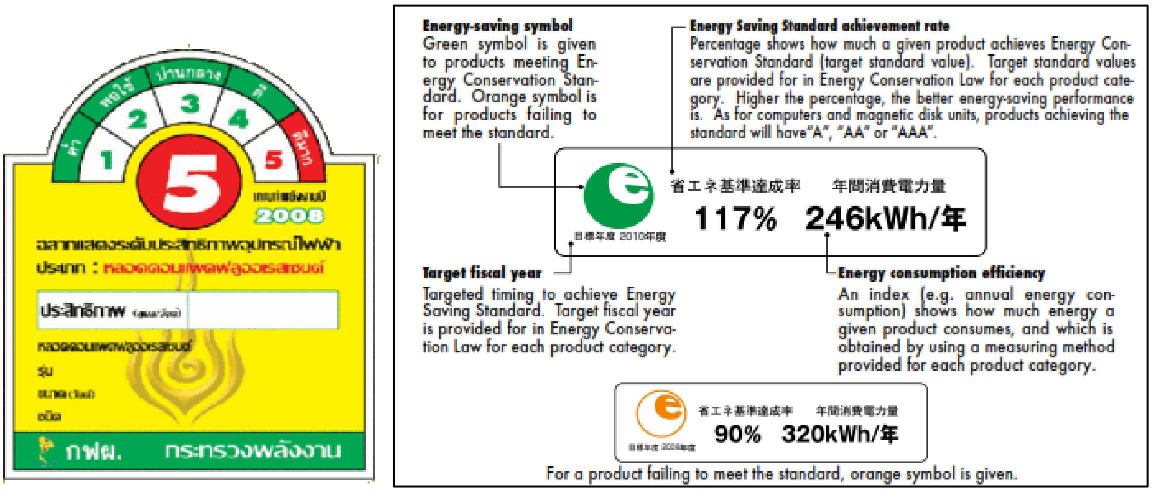
A number of other countries have voluntary labelling programs for commercial lighting products within the scope of this Product Profile, including:

- **Canada:** the voluntary labelling scheme Environmental Choice Program (ECP) was established by Environment Canada in 1998. ECP has over 300 categories of products, including magnetic and electronic ballasts, to help consumers identify services and products which are less harmful to the environment.
- **China:** the Energy Conservation Product Certification program includes ballasts for tubular fluorescent lamps, double-capped fluorescent lamps for general lighting service (must meet Tier 2 requirements of the mandatory MEPS); and single-capped fluorescent lamps.
- **Singapore:** modular CFLs which meet the following criteria are eligible for the Green Labelling Scheme:

  — separate ballast and adaptor;
  — at least 50 lm/W if amp is < 10 W, or
  — at least 60 lm/W if lamp is ≥ 10 W and ≤ 30 W, or
  — at least 75 lm/W if lamp > 30 W;
  — lamp must not contain more than 10 mg of mercury; and
  — cadmium and arsenic must not be used in the manufacturing.

- **Thailand:** the Energy Efficiency Labelling No. 5 Programme applies to CFLs, ballasts for fluorescent lamps, T5 fluorescent lamps and luminaires. The Energy Efficiency No.5 Label indicates the electrical energy efficiency performance of products in home appliances. Number 1 refers to the lowest efficiency and number 5 to the highest efficiency. Thailand also has the Thai Green Label for CFLs, fluorescent lamp ballasts and fluorescent lamps. The label is similar to the Hong Kong Green Label, in that it is based on life cycle analysis of products. Thailand also has HEPS for electronic and magnetic ballasts and double-capped fluorescent lamps.
- **Japan:** the Energy Saving Labeling Program applies to fluorescent lamps. The label typically consists of the energy conservation logo in combination with information on the target year, achievement rate of energy efficiency standards, and energy consumption efficiency. The energy conservation logo is coloured orange for a product which doesn't achieve the target energy efficiency standard, and is coloured green for a product which achieves over 100 per cent of the target standard.
- **Israel:** *SI 520 – Tubular fluorescent lamps for general lighting service* (April 1964) and its 7 amendments (final 2007) was mandatory until it was declared voluntary in November 2011 (effective from February 2012) in response to perceived barriers in trade.
- **India:** tubular fluorescent lamps are eligible for voluntary HEPS under the BEE star rating plan – the minimum rating is 1-star and products can be voluntarily manufactured to attain up to a 5-star rating. The label must include information on the type of ballast, ballast efficiency percentage and the star rating based on energy efficiency performance. The star rating is also printed on the name plate of the ballast.
- **Korea:** voluntary target energy performance standards for linear, circular and non-integrated compact fluorescent lamps are within the scope of KS c 7601:2004 (discussed previously). There are four target levels above the MEPS, with TEPS Level 1 having the highest luminous efficacy. TEPS aim to encourage manufacturers to increase the energy efficiency of their product up to a technically feasible and economically suitable level.
- **Sri Lanka:** there is currently a voluntary 5-star labelling scheme for magnetic ballasts. Legislation is being prepared to make it a mandatory standard.
- **Vietnam:** Linear fluorescent lamps and magnetic and electronic ballasts that meet the high efficiency level in the performance standards are eligible to display an endorsement label.

Figure 43. An example of the voluntary Thailand Energy Efficiency Label No. 5 (left) and the Japanese Energy Saving Label (right).



Specifications

Europe

Table 22. Linear and circular fluorescent lamp efficacy requirements as per EC No 245/2009.

Lamp type	Nominal wattage (W)	Rated luminous efficacy (lm/W) 100 h initial value
T8 (26 mm diameter) and all other double capped tube diameters, including T12 (38 mm Ø)	15	63
	18	75
	25	76
	30	80
	36	93
	38	87
	58	90
	70	89
T5 (16 mm diameter) High Efficiency	≤ 13	Exempt
	14	86
	21	90
	28	93
	35	94
	> 80	Exempt
T5 (16 mm diameter) High Output	≤ 13	Exempt
	24	73
	39	79
	49	88
	54	82
	80	77
	> 80	Exempt
T9 (29 mm diameter) circular, base G10q	22	52
	32	64
	40	70
	60	60
T5 (16 mm diameter) circular, base 2GX13	22	77
	40	78
	55	75

Lamp type	Nominal wattage (W)	Rated luminous efficacy (lm/W) 100 h initial value
	60	80

Note: where nominal wattages are different from those listed here, lamps must reach the luminous efficacy of the nearest equivalent in terms of wattage, and if equidistant between two wattages must conform to the higher efficacy of the two.

Note: deductions to energy efficiency requirements are granted for fluorescent lamps with high colour temperature, high colour rendering and/or second lamp envelope, as per Table 24.

Table 23. Single-capped fluorescent lamp efficacy requirements as per EC No 347/2010 amendment to EC No 245/2009. Refer to the Directive for example images of each lamp type.

Lamp type	Nominal wattage (W)	Rated luminous efficacy (lm/W) 100 h initial value
Small single parallel tube, lamp cap G23 (2 pin) or 2G7 (4 pin) – work with magnetic and electronic ballasts	5	48
	7	57
	9	67
	11	76
Double parallel tubes, lamp cap G24d (2 pin) or G24q (4 pin) – work with magnetic and electronic ballasts	10	60
	13	69
	18	67
	26	66
Triple parallel tubes, lamp cap GX24d (2 pin) or GX24q (4 pin) – work with magnetic and electronic ballasts	13	62
	18	67
	26	66
4 legs in one plane, lamp cap 2G10 (4 pin) – work with magnetic and electronic ballasts	18	61
	24	71
	36	78
Long single parallel tube, lamp cap 2G11 (4 pin) – work with magnetic and electronic ballasts	18	67
	24	75
	34	82
	36	81
Triple parallel tubes, lamp cap GX24q (4 pin) – work with electronic ballast only	32	75
	42	74
	57	75
	70	74
Four parallel tubes, lamp cap GX24q (4 pin) – work with electronic ballasts only	57	75
	70	74
Long single parallel tube, lamp cap 2G11 (4 pin) – work with electronic ballasts only	40	83
	55	82
	80	75
Single flat plane tube, lamp cap GR8 (2 pin), GR10q (4 pin) or GRY10q3 (4 pin) – square shape or (very) high output	10	65
	16	66
	21	64
	28	73
	38	71
	55	71
Four/three parallel T5 tubes, lamp cap 2G8 (4 pin) – square shape or (very) high output	60	67
	82	75
	85	71
	120	75

Table 24. Deduction percentages for rated minimum efficacy values for fluorescent lamps with high CCT, high colour rendering (Ra) and/or second envelope. Indicated deductions are cumulative.

Lamp parameter	Deduction from luminous efficacy at 25ºC
CCT ≥ 5000 K	-10%
95 ≥ Ra > 90	-20%
Ra > 95	-30%
Second lamp envelope	-10%
Lamp survival factor ≥ 0.50 after 40,000 burning hours	-5%

Table 25. Lamp lumen maintenance factors and lamp survival factors for double-capped fluorescent lamps.

Lamp lumen maintenance factor	Lamp lumen maintenance factor – burning hours				Lamp survival factor – burning hours			
Lamp types	**2000**	**4000**	**8000**	**16,000**	**2000**	**4000**	**8000**	**16,000**
Double-capped fluorescent lamps operating on non-high frequency ballasts	0.95	0.92	0.90	-	0.99	0.97	0.90	-
Double-capped fluorescent lamps on high frequency ballast with warmstart	0.97	0.95	0.92	0.90	0.99	0.97	0.92	0.90
Single-capped fluorescent lamps operating on non-high frequency ballasts	0.95	0.90	0.80	-	0.95	0.92	0.50	-
Single-capped fluorescent lamps operating on high frequency ballast with warmstart	0.97	0.90	0.80	-	0.95	0.90	0.87	-

Table 26. EEI requirements for non-dimmable ballasts for fluorescent lamps, EC No 347/2010 (continued overleaf).

Lamp Data					BALLAST EFFICIENCY (Plamp/Pinput) Non-dimmable				
Lamp type	**Nominal Wattage (W)**	**ILCOS CODE**	**Rated/typical wattage (W) 50 Hz**	**Rated/typical wattage (W) HF**	**A2 BAT**	**A2**	**A3**	**B1**	**B2**
T8	15	FD-15-E-G13-26/450	15	13.5	87.8%	84.4%	75.0%	67.9%	62.0%
T8	18	FD-18-E-G13-26/600	18	16	87.7%	84.2%	76.2%	71.3%	65.8%
T8	30	FD-30-E-G13-26/900	30	24	82.1%	77.4%	72.7%	79.2%	75.0%
T8	36	FD-36-E-G13-26/1200	36	32	91.4%	88.9%	84.2%	83.4%	79.5%
T8	38	FD-38-E-G13-26/1050	38.5	32	87.7%	84.2%	80.0%	84.1%	80.4%
T8	58	FD-58-E-G13-26/1500	58	50	93.0%	90.9%	84.7%	86.1%	82.2%
T8	70	FD-70-E-G13-26/1800	69.5	60	90.9%	88.2%	83.3%	86.3%	83.1%
TC-L	18	FSD-18-E-2G11	18	16	87.7%	84.2%	76.2%	71.3%	65.8%
TC-L	24	FSD-24-E-2G11	24	22	90.7%	88.0%	81.5%	76.0%	71.3%
TC-L	36	FSD-36-E-2G11	36	32	91.4%	88.9%	84.2%	83.4%	79.5%
TCF	18	FSS-18-E-2G10	18	16	87.7%	84.2%	76.2%	71.3%	65.8%
TCF	24	FSS-24-E-2G10	24	22	90.7%	88.0%	81.5%	76.0%	71.3%
TCF	36	FSS-36-E-2G10	36	32	91.4%	88.9%	84.2%	83.4%	79.5%
TC-D/DE	10	FSQ-10-E-G24q=1 FSQ-10-I-G24d=1	10	9.5	89.4%	86.4%	73.1%	67.9%	59.4%
TC-D/DE	13	FSQ-13-E-G24q=1 FSQ-13-I-G24d=1	13	12.5	91.7%	89.3%	78.1%	72.6%	65.0%
TC-D/DE	18	FSQ-18-E-G24q=2 FSQ-18-I-G24d=2	18	16.5	89.8%	86.8%	78.6%	71.3%	65.8%
TC-D/DE	26	FSQ-26-E-G24q=1	26	24	91.4%	88.9%	82.8%	77.2%	72.6%

Lamp Data					BALLAST EFFICIENCY (Plamp/Pinput) Non-dimmable				
Lamp type	Nominal Wattage (W)	ILCOS CODE	Rated/typical wattage (W)		A2 BAT	A2	A3	B1	B2
			50 Hz	HF					
		FSQ-26-I-G24d=1							
TC-T/TE	13	FSM-13-E-GX24q=1	13	12.5	91.7%	89.3%	78.1%	72.6%	65.0%
		FSM-13-I-GX24d=1							
TC-T/TE	18	FSM-18-E-GX24q=2	18	16.5	89.8%	86.8%	78.6%	71.3%	65.8%
		FSM-18-I-GX24d=2							
TC-T/TC-TE	26	FSM-26-E-GX24q=3	26.5	24	91.4%	88.9%	82.8%	77.5%	73.0%
		FSM-26-I-GX24d=3							
TC-DD/DDE	10	FSS-10-E-GR10q	10.5	9.5	86.4%	82.6%	70.4%	68.8%	60.5%
		FSS-10-L/P/H-GR10q							
TC-DD/DDE	16	FSS-16-E-GR10q	16	15	87.0%	83.3%	75.0%	72.4%	66.1%
		FSS-16-I-GR8							
		FSS-16-L/P/H-GR10q							
TC-DD/DDE	21	FSS-21-E-GR10q	21	19	89.4%	86.4%	79.2%	73.9%	68.8%
		FSS-21-I-GR10q							
		FSS-21-L/P/H-GR10q							
TC-DD/DDE	28	FSS-28-E-GR10q	28	26	89.7%	86.7%	81.3%	78.2%	73.9%
		FSS-28-I-GR10q							
		FSS-28-L/P/H-GR10q							
TC-DD/DDE	38	FSS-38-E-GR10q	38.5	36	92.3%	90.0%	85.7%	84.1%	80.4%
		FSS-38-L/P/H-GR10q							
TC	5	FSD-5-I-G23	5.4	5	72.7%	66.7%	58.8%	49.3%	41.4%
		FSD-5-E-2G7							
TC	7	FSD-7-I-G23	7.1	6.5	77.6%	72.2%	65.0%	55.7%	47.8%
		FSD-7-E-2G7							
TC	9	FSD-9-I-G23	8.7	8	78.0%	72.7%	66.7%	60.3%	52.6%
		FSD-9-E-2G7							
TC	11	FSD-11-I-G23	11.8	11	83.0%	78.6%	73.3%	66.7%	59.6%
		FSD-11-E-2G7							
T5	4	FD-4-E-G5-16/150	4.5	3.6	64.9%	58.1%	50.0%	45.0%	37.2%
T5	6	FD-6-E-G5-16/225	6	5.4	71.3%	65.1%	58.1%	51.8%	43.8%
T5	8	FD-8-E-G5-16/300	7.1	7.5	69.9%	63.6%	58.6%	48.9%	42.7%
T5	13	FD-13-E-G5-16/525	13	12.8	84.2%	80.0%	75.3%	72.6%	65.0%
T9-C	22	FSC-22-E-G10q-29/200	22	19	89.4%	86.4%	79.2%	74.6%	69.7%
T9-C	32	FSC-32-E-G10q-29/300	32	30	88.9%	85.7%	81.1%	80.0%	76.0%
T9-C	40	FSC-40-E-G10q-29/400	40	32	89.5%	86.5%	82.1%	82.6%	79.2%
T2	6	FDH-6-L/P-W4.3x8.5d-7/220		5	72.7%	66.7%	58.8%		
T2	8	FDH-8-L/P-W4.3x8.5d-7/320		7.8	76.5%	70.9%	65.0%		
T2	11	FDH-11-L/P-W4.3x8.5d-7/420		10.8	81.8%	77.1%	72.0%		
T2	13	FDH-13-L/P-W4.3x8.5d-7/520		13.3	84.7%	80.6%	76.0%		
T2	21	FDH-21-L/P-W4.3x8.5d-7/		21	88.9%	85.7%	79.2%		
T2	23	FDH-23-L/P-W4.3x8.5d-7/		23	89.8%	86.8%	80.7%		
T5-E	14	FDH-14-G5-L/P-16/550		13.7	84.7%	80.6%	72.1%		
T5-E	21	FDH-21-G5-L/P-16/850		20.7	89.3%	86.3%	79.6%		
T5-E	24	FDH-24-G5-L/P-16/550		22.5	89.6%	86.5%	80.4%		

Lamp Data					BALLAST EFFICIENCY (Plamp/Pinput) Non-dimmable				
Lamp type	**Nominal Wattage (W)**	**ILCOS CODE**	**Rated/typical wattage (W)**		**A2 BAT**	**A2**	**A3**	**B1**	**B2**
			50 Hz	**HF**					
T5-E	28	FDH-28-G5-L/P-16/1150		27.8	89.8%	86.9%	81.8%		
T5-E	35	FDH-35-G5-L/P-16/1450		34.7	91.5%	89.0%	82.6%		
T5-E	39	FDH-39-G5-L/P-16/850		38	91.0%	88.4%	82.6%		
T5-E	49	FDH-49-G5-L/P-16/1450		49.3	91.6%	89.2%	84.6%		
T5-E	54	FDH-54-G5-L/P-16/1150		53.8	92.0%	89.7%	85.4%		
T5-E	80	FDH-80-G5-L/P-16/1150		80	93.0%	90.9%	87.0%		
T5-E	95	FDH-95-G5-L/P-16/1150		95	92.7%	90.5%	84.1%		
T5-E	120	FDH-120-G5-L/P-16/1450		120	92.5%	90.2%	84.5%		
T5-C	22	FSCH-22-L/P-2GX13-16/225		22.3	88.1%	84.8%	78.8%		
T5-C	40	FSCH-40-L/P-2GX13-16/300		39.9	91.4%	88.9%	83.3%		
T5-C	55	FSCH-55-L/P-2GX13-16/300		55	92.4%	90.2%	84.6%		
T5-C	60	FSCH-60-L/P-2GX13-16/375		60	93.0%	90.9%	85.7%		
TC-LE	40	FSDH-40-L/P-2G11		40	91.4%	88.9%	83.3%		
TC-LE	55	FSDH-55-L/P-2G11		55	92.4%	90.2%	84.6%		
TC-LE	80	FSDH-80-L/P-2G11		80	93.0%	90.9%	87.0%		
TC-TE	32	FSMH-32-L/P-2GX24q=3		32	91.4%	88.9%	82.1%		
TC-TE	42	FSMH-42-L/P-2GX24q=4		43	93.5%	91.5%	86.0%		
TC-TE	57	FSM6H-57-L/P-2GX24q=5 FSM8H-57-L/P-2GX24q=5		56	91.4%	88.9%	83.6%		
TC-TE	70	FSM6H-70-L/P-2GX24q=6 FSM8H-70-L/P-2GX24q=6		70	93.0%	90.9%	85.4%		
TC-TE	60	FSM6H-60-L/P-2G8=1		63	92.3%	90.0%	84.0%		
TC-TE	62	FSM8H-62-L/P-2G8=2		62	92.2%	89.9%	83.8%		
TC-TE	82	FSM8H-82-L/P-2G8=2		82	92.4%	90.1%	83.7%		
TC-TE	85	FSM6H-85-L/P-2G8=1		87	92.8%	90.6%	84.5%		
TC-TE	120	FSM6H-120-L/P-2G8=1 FSM8H-120-L/P-2G8=1		122	92.6%	90.4%	84.7%		
TC-DD	55	FSSH-55-L/P-GR10q		55	92.4%	90.2%	84.6%		

Table 27. EEI requirements for non-dimmable ballasts for fluorescent lamps not included in Table 26.

$\eta_{ballast}$	Energy Efficiency Index
$\geq 0.94 * EBb_{FL}$	A3
$\geq EBb_{FL}$	A2
$\geq 1-0.75*(1-EBb_{FL})$	A2 BAT

Table 28. EEI requirements for dimmable ballasts for fluorescent lamps, as per EC No 245/2009.

Complied class at 100% lumen output	EEI of dimmable ballast
A3	A1
A2	A1 BAT (Best Available Technology)

USA

Table 29. Minimum efficacy requirements for fluorescent lamps (manufactured after 14 July 2012) in the USA.

Requirements		Linear fluorescent lamp type					U-shaped fluorescent lamp
		T8	T5-High Efficiency		T5-High Output		
		4 ft (1220 mm)	4 ft miniature bipin (1220mm)	8 ft slimline (2440 mm)	4 ft miniature bipin (1220mm)	8 ft (2440 mm)	2 ft (610 mm)
Minimum average lamp efficacy (lm/W)	CCT ≤ 4500K	89	86	97	76	92	84
	4500K < CCT ≤ 7000K	88	81	93	72	88	81

Table 30. Minimum efficacy requirements for fluorescent lamps in the USA to take effect from 2018.

Requirements		Linear fluorescent lamp type					U-shaped fluorescent lamp
		T8	T5-High Efficiency		T5-High Output		
		4 ft medium bipin (1220 mm) ≥ 25 W	4 ft miniature bipin (1220 mm) ≥ 25 W	8 ft slimline (2440 mm) ≥ 49 W	4 ft miniature bipin (1220 mm) ≥ 44 W	8 ft recessed double contact (2440 mm) All wattages	2 ft (610 mm) ≥ 25 W
Minimum average lamp efficacy (lm/W)	CCT ≤ 4500K	92.4	95	97	82.7	92	85
	4500K < CCT ≤ 7000K	88.7	89.3	93	76.9	88	83.3

Table 31. The ballast luminous efficiency and applicable fluorescent lamp ballasts subject to energy efficiency requirements in the United States as per 10 CFR 430.

Product class	Fluorescent lamp ballasts shall have a ballast luminous efficiency (BLE) no less than A/(1+B*total lamp arc power ^-C) where A, B and C are as follows:		
	A	B	C
Instant start and rapid start ballasts (not classified as residential) that are designed to operate: 4-foot medium bipin lamps 2-foot U-shaped lamps 8-foot slimline lamps	0.993	0.27	0.25
Programmed start ballasts (not classified as residential) that are designed to operate: 4-foot medium bipin lamps 2-foot U-shaped lamps 4-foot miniature bipin standard output lamps 4-foot miniature bipin high output lamps	0.993	0.51	0.37
Instant start and rapid start ballasts (not classified as sign ballasts) that are designed to operate 8-foot high output lamps	0.993	0.38	0.25
Programmed start ballasts (not classified as sign ballasts) that are designed to operate 8-foot high output lamps	0.973	0.70	0.37
Sign ballasts that operate 8-foot high output lamps	0.993	0.47	0.25
Instant start and rapid start residential ballasts that operate: 4-foot medium bipin lamps 2-foot U-shaped lamps 8-foot slimline lamps	0.993	0.41	0.25
Programmed start residential ballasts that are designed to operate: 4-foot medium bipin lamps 2-foot U-shaped lamps	0.973	0.71	0.37

Canada

Table 32. Minimum efficacy of fluorescent lamps as per CAN/CSA-C819-11.

	Medium bi-pin base, rapid-start		U-shaped, rapid-start		High output, rapid-start, recessed double contact		Slimline, instant-start, single-pin	
Length (mm)	1200		560–635		2400		2400	
Nominal wattage (W)	> 35	≤ 35	> 35	≤ 35	> 100	≤ 100	> 65	≤ 65
Average CRI	69	45	69	45	69	45	69	45
Rated luminous efficacy (lm/W)	75	75	68	64	80	80	80	80

Table 33. Minimum efficiency requirements for ballasts in Canada.

Application for Operation of	Ballast Input Voltage (V)	Total Nominal Lamp Wattage (W)	Minimum Ballast Efficacy Factor (BEF)
One F40T12 lamp Also for use on 40W/48T10/RS lamps	120	40	2.29
	277	40	2.29
	347	40	2.22
One F34T12 lamp	120	34	2.61
	277	34	2.61
	347	34	2.53
Two F40T12 lamps Also for use on 40W/48T10/RS lamps	120	80	1.17
	277	80	1.17
	347	80	1.12
Two F34T12 lamps	120	68	1.35
	277	68	1.35
	347	68	1.29
Two F96T12(IS) lamps Also for use on 60W/96T12/IS lamps	120	150	0.63
	277	150	0.63
	347	150	0.62
Two F96T12(ES) lamps	120	120	0.77
	277	120	0.77
	347	120	0.76
Two 110W F96T12HO lamps	120	220	0.390
	277	220	0.390
	347	220	0.380
Two F96T12HO(ES) lamps	120	190	0.42
	277	190	0.42
	347	190	0.41
Two F32T8 lamps	120	64	1.250
	277	64	1.230
	347	64	1.200

All ballasts must have a power factor of at least 0.9 except for ballasts designed for 120 V input and to operate F32T8 rapid-start fluorescent lamps that have a CRI > 75 where the power factor must be at least 0.5.

China

Table 34. Minimum efficacy requirements for linear fluorescent lamps in China, as per GB 19043-2013.

Lamp type	Additional information	Diameter (mm)	Nominal wattage (W)	Initial Luminous Efficacy (lm/W)					
				Colour temperature: 6500 K, 5000 K			Colour temperature: 4000 K, 3500 K, 3000 K, 2700K		
				Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3
Cathode preheating lamp which equips with starter and works on AC frequency circuits		26 (T8)	18	70	64	50	75	69	52
			30	75	69	53	80	73	57
			36	87	80	62	93	85	63
			58	84	77	59	90	82	62
Cathode preheating lamp which works on high frequency circuits	High luminous efficacy series	16 (T5)	14	80	77	69	86	82	75
			21	84	81	75	90	86	83
	High lumen series		24	68	66	65	73	70	67
	High luminous efficacy series		28	87	83	77	93	89	82
			35	88	84	75	94	90	82
	High lumen series		39	74	71	69	79	75	71
			49	82	79	75	88	84	79
			54	77	73	67	82	78	72
			80	72	69	63	77	73	67
		26 (T8)	16	81	75	66	87	80	75
			23	84	77	76	89	86	85
			32	97	89	78	104	95	84
			45	101	93	85	108	99	90

Table 35. Minimum efficacy requirements for circular and non-integrated compact (single-capped) fluorescent lamps in China, as per GB 19415-2003.

Lamp type	Nominal wattage (W)	Initial Luminous Efficacy (lm/W)			
		Energy efficiency grades (Colour: F6500, F5000)		Energy efficiency grades (Colour: F4000, F3500, F3000, F2700)	
		Target	Minimum	Target	Minimum
Circular	22	58	44	62	51
	≥ 32	68	48	72	57
CFL – double-tube, quad-tube, multi-tube, square	5-7	51	41	54	44
	9, 10, 13	60	50	64	54
	11 (double-tube)	74	67	80	72
	16-26	62	56	66	60
CFL – double-tube, square	≥ 28	69	62	73	66
CFL – multi-tube	≥ 28	64	54	68	58

Table 36. Energy efficiency requirements for linear fluorescent lamp ballasts in China, as per GB17896-2012.

Linear lamp type	Nominal power (W)	International code	Electronic ballasts: Rated Power (W)	Electronic ballasts: Ballast efficiency (%) Tier 1	Tier 2	Tier 3	Magnetic ballasts: Rated power (W)	Magnetic ballasts: Ballast efficiency (%)
T8	15	FD-15-E-G13-26/450	13.5	87.7	84.4	75.0	15	62
	18	FD-18-E-G13-26/600	16	87.7	84.2	76.2	18	65.8
	30	FD-30-E-G13-26/900	24	82.1	77.4	72.7	30	75
	36	FD-36-E-G13-26/1200	32	91.4	88.9	84.2	36	79.5
	38	FD-38-E-G13-26/1050	32	87.7	84.2	80.0	38.5	80.4
	58	FD-58-E-G13-26/1500	50	93.0	90.9	84.7	58	82.2
	70	FD-70-E-G13-26/1800	60	90.9	88.2	83.3	69.5	83.1
T5	4	FD-4-E-G5-16/150	3.6	64.9	58.1	50.0	4.5	37.2
	6	FD-6-E-G5-16/225	5.4	71.3	65.1	58.1	6	43.8
	8	FD-8-E-G5-16/300	7.5	69.9	63.6	58.6	7.1	42.7
	13	FD-13-E-G5-16/525	12.8	84.2	80.0	75.3	13	65
T2	6	FDH-6-L/P-W4.3x8.5d-7/220	5	72.7	66.7	58.8		
	8	FDH-8-L/P-W4.3x8.5d-7/320	7.8	76.5	70.9	65.0		
	11	FDH-11-L/P-W4.3x8.5d-7/420	10.8	81.8	77.1	72.0		
	13	FDH-13-L/P-W4.3x8.5d-7/520	13.3	84.7	80.6	76.0		
T5-E	14	FDH-14-G5-L/P-16/550	13.7	84.7	80.6	72.1		
	21	FDH-21-G5-L/P-16/850	20.7	89.3	86.3	79.6		
	24	FDH-24-G5-L/P-16/550	22.5	89.6	86.5	80.4		
	28	FDH-28-G5-L/P-16/1150	27.8	89.8	86.9	81.8		
	35	FDH-35-G5-L/P-16/1450	34.7	91.5	89.0	82.6		
	39	FDH-39-G5-L/P-16/850	38	91.0	88.4	82.6		
	49	FDH-49-G5-L/P-16/1450	49.3	91.6	89.2	84.6		
	54	FDH-54-G5-L/P-16/1150	53.8	92.0	89.7	85.4		
	80	FDH-80-G5-L/P-16/1150	80	93.0	90.9	87.0		
T8	16	FDH-16-L/P-G13-26/600	16	87.4	83.2	78.3		
	23	FDH-23-L/P-G13-26/600	23	89.2	85.6	80.4		
	32	FDH-32-L/P-G13-26/1200	32	90.5	87.3	82.0		
	45	FDH-45-L/P-G13-26/1200	45	91.5	88.7	83.4		

Hong Kong

Table 37. Minimum efficacy requirements for linear, U-shaped and circular fluorescent lamps in Hong Kong.

<table>
<tr><th colspan="3">Lamp type</th><th>Lamp code</th><th>Nominal lamp wattage (W)</th><th colspan="2">Minimum allowable luminous efficacy (lm/W)</th></tr>
<tr><td colspan="3" rowspan="2">Fluorescent tube</td><td rowspan="19">MCF</td><td rowspan="2"></td><td colspan="2">Colour temperature</td></tr>
<tr><td>< 6000 K</td><td>≥ 6000 K</td></tr>
<tr><td rowspan="11">T5
Luminous efficacy referenced at 35°C operating temperature</td><td rowspan="9">Tubular and U-shaped</td><td rowspan="4">High efficiency type with lumen per unit tube length < 2700 lumen/m</td><td>14</td><td>87</td><td>80</td></tr>
<tr><td>21</td><td>90</td><td>84</td></tr>
<tr><td>28</td><td>93</td><td>87</td></tr>
<tr><td>35</td><td>94</td><td>87</td></tr>
<tr><td rowspan="5">High output type with lumen per unit tube length ≥ 2700 lumen/m</td><td>24</td><td>75</td><td>71</td></tr>
<tr><td>39</td><td>81</td><td>76</td></tr>
<tr><td>49</td><td>90</td><td>85</td></tr>
<tr><td>54</td><td>83</td><td>79</td></tr>
<tr><td>80</td><td>79</td><td>75</td></tr>
<tr><td colspan="2" rowspan="2">Circular</td><td>40-60</td><td>70</td><td>65</td></tr>
<tr><td>< 40</td><td>75</td><td>70</td></tr>
<tr><td colspan="3" rowspan="6">T8 and non-T5
Luminous efficacy referenced at 25°C operating temperature</td><td>< 15</td><td>49</td><td>45</td></tr>
<tr><td>15</td><td>63</td><td>59</td></tr>
<tr><td>18</td><td>71</td><td>69</td></tr>
<tr><td>30</td><td>76</td><td>73</td></tr>
<tr><td>36</td><td>88</td><td>86</td></tr>
<tr><td>≥ 58</td><td>85</td><td>82</td></tr>
<tr><td colspan="7">For fluorescent tubes of the same type having a wattage falling between two indicated values, the nominal lamp wattage can be calculated by linear interpolation between the two luminous efficacy values of the two closest wattage values indicated.</td></tr>
<tr><td colspan="3" rowspan="3">Compact fluorescent
Non-integrated type with no built-in control gear, up to 60 W</td><td rowspan="3">CFN</td><td>≤ 10</td><td colspan="2">50 at 100 h</td></tr>
<tr><td>11-30</td><td colspan="2">65at 100 h</td></tr>
<tr><td>≥ 31</td><td colspan="2">75 at 100 h</td></tr>
</table>

Table 38. Maximum allowable values of lamp control gear loss, as per the Hong Kong Code of Practice for Energy Efficiency of Lighting Installations.

Lamp type	Lamp code	Nominal lamp wattage (L_w)	Maximum allowable lamp control gear loss (W)
Lamp controlled by electromagnetic ballast			
Tubular fluorescent	MCF	$L_w \leq 18$ W	7
		18 W < L_w < 58 W	10
		58 W ≤ L_w < 85 W	12
		$L_w \geq 85$ W	16
Compact fluorescent (non-integrated type without built-in control gear)	CFN	$L_w < 18$ W	6
		$L_w \geq 18$ W	9
Lamp controlled by electronic ballast			
All types	All types	Complies with Table 1 of The Hong Kong Voluntary Energy Efficiency Labelling Scheme for Electronic Ballasts, Electrical and Mechanical Services Department (www.emsd.gov.hk/emsd/eng/pee/eels_sch_doc.shtml).	

Korea

Table 39. Performance levels for fluorescent lamps in Korea as per KSC 7601.

Nominal wattage (W)	Colour Temp	Target Luminous Efficacy (lm/W) (Level 1)	Target Luminous Efficacy (lm/W) (Level 2)	Target Luminous Efficacy (lm/W) (Level 3)	Target Luminous Efficacy (lm/W) (Level 4)	MEPS (lm/W) (Level 5)
Linear fluorescent lamp						
20	< 6000 K	78.6	72.8	67.8	63.4	59.6
	≥ 6000 K	75.9	70.3	65.4	61.2	57.5
28	< 6000 K	97	88.2	84.3	80.8	77.6
	≥ 6000 K	95	86.4	82.6	79.2	76
32	< 6000 K	97	88.2	84.3	80.8	77.6
	≥ 6000 K	95	86.4	82.6	79.2	76
40	< 6000 K	102.5	93.2	89.1	85.4	82
	≥ 6000 K	100	90.9	87.0	83.3	80
Circular fluorescent lamp						
32	< 6000 K	69.6	66.9	64.4	62.1	60.0
	≥ 6000 K	67.2	64.6	62.2	60.0	58.0
40	< 6000 K	76.5	73.6	70.8	68.3	66.0
	≥ 6000 K	74.2	71.3	68.7	66.3	64.0
Non-integrated compact fluorescent lamp						
FPX 13 W FDX 26 W	< 6000 K	66.2	60.2	57.6	55.2	53.0
	≥ 6000 K	63.7	57.9	55.4	53.1	51.0
FPL 27 W	< 6000 K	73.7	67.0	64.1	61.4	59.0
	≥ 6000 K	71.2	64.7	61.9	59.3	57.0
FPL 32/36/45/55 W	< 6000 K	85	77.3	73.9	70.8	68.0
	≥ 6000 K	82.5	75.0	71.7	68.8	66.0

Thailand

Table 40. Minimum performance requirements for linear fluorescent lamps in Thailand.

Lamp nominal length 'l' (mm) (mandatory)	550 ≤ l < 700	700 ≤ l < 1150	1150 ≤ l <1350	1350 ≤ l ≤1500
Lamp typical power (watts) (informative)	**16–24**	**17–40**	**28–50**	**35–80**
Initial efficacy (F_{100})	66.0	74.0	80.0	83.0
Maintained efficacy (F_{5000})	59.5	66.5	72.0	74.5
Minimum colour rendering index (CRI)	80	80	80	80

Japan

Table 41. Japan's Top Runner Program minimum requirements for fluorescent lamp luminaires.

Category	Application	Lamp shape	Lamp size	Target standard (lm/W)
I	For facilities	Double-capped type or compact double tube type	Equipment with the lamp size of 86 or larger	100.8
II			Equipment with the lamp size less than 86	100.5
III		Compact type other than the double lamp type		61.6
IV	Home use	Ring type or double-capped type	Equipment with the total sum of the lamp size of 70 or more (excluding the double-capped fluorescent lamp with the size of 20)	91.6
V			Equipment with the total sum of the lamp size less than 70 and equipment with the total sum of the lamp size of 70 or more using double-capped fluorescent lamps with the size of 20	78.1

"Lamp size" refers to the "value of size category" of fluorescent lamps specified in Japanese Industrial Standard C7601 Fluorescent lamps for general lighting service *or in J*apan Electric Lamp Manufacturers Association Standard 211 Fluorescent lamps (general lighting service) for high frequency illumination. *Where fluorescent lamps do not specify the "value of size category", the value of the "rated lamp power" specified in* Japanese Industrial Standard C7617-2 Double-capped fluorescent lamps – Part 2: Performance specifications *shall be used for double-capped fluorescent lamps and the value of the "rated lamp power" specified in* Japanese Industrial Standard C7618-2 Single - capped fluorescent lamps - Part 2: Performance specifications *shall be used for ring type and compact fluorescent lamps.*

Appendix C – Other options considered

The following options were investigated but were not preferred options.

U-shaped and non-integrated compact fluorescent lamps

A number of economies have minimum efficacy requirements for U-shaped fluorescent lamps (Hong Kong, Canada, USA) and non-integrated CFLs (EU, China, Hong Kong, Korea). The majority of non-integrated CFLs available in Australia and New Zealand have a rated initial efficacy equivalent to or just exceeding the relevant EU requirements (Figure 16). There is no international test method for determining the performance of U-shaped or non-integrated compact fluorescent lamps. Furthermore, the test method used with overseas performance standards for these lamps is generally not clear. No policy options for non-integrated CFLs are proposed in this Product Profile due to given that current data indicates that these lamps are at least meeting the EU requirements and the lack of information about the Australian and New Zealand market size.

No policy options for U-shaped fluorescent lamps are proposed in this Product Profile due to the lack of information about the current Australian and New Zealand market.

T8-T5 adapters

Recent testing undertaken by the Australian Government (see Section 4) indicates that although overall energy use is reduced when using the T8-T5 adapters with lamp replacement, the efficacy of the whole unit (total light output per watt consumed) did not achieve the MEPS for the lamp it was replacing (Figure 19). Illumination levels, as well as glare and task specific lighting requirements, may not meet the minimum requirements of AS 1680.

One option to address this issue would be to include T8-T5 adapters within scope of AS/NZS 4782.2 so at minimum the adapters should meet the MEPS of the lamp that it being replaced. This would require the development of some specific provisions and correction factors. However given the prediction that the installation of T8-T5 adapters may reduce within the next few years due to cyclical new fit-outs with T5 luminaires and/or projected change to linear LED lamps, a MEPS on these products is not recommended.

Product Profile – Commercial Lighting

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