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Light Naturally
for future generations

NSW Energy Savings Scheme: Review of Commercial Lighting

Final Report

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TABLE OF CONTENTS

Chapter 1. Introduction 5

Chapter 2. Compliance with Lighting Design Standards 7
2.1. Background 7
2.2. Introduction to AS/NZS 1680 7
2.3. Current ESS Approach to Compliance 8
2.4. Development of an Improved Approach 9
2.4.1. Multi-Tiered Approach 9
2.4.2. Requirements for Medium and Large Projects 11
2.4.3. Requirements for Small Projects 13
2.5. Applications not Covered Adequately by AS/NZS 1680 14
2.5.1. Specialised Applications with Design Standard other than AS/NZS 1680 14
2.5.2. Interior Applications for which there is not a Clear Design Standard 15
2.5.3. Applications that do not Fit any of the Previous Categories 15
2.6. Summary of Recommendations from this Chapter 16

Chapter 3. Appropriately Qualified Persons 17
3.1. Lighting Courses 17
3.2. Lighting Qualifications and Professional Ethics 19
3.3. Summary of Recommendations from this Chapter 20

Chapter 4. Performance of Lighting Technologies 21
4.1. Introduction 21
4.2. Current Approach 21
4.3. Introduction to "Solution Elements" 23
4.4. Solution Element – Eliminate the Emerging Technologies Category 23
4.5. Solution Element – Installation Permanence 24
4.6. Solution Element – Technology Specifications 25
4.6.1. Conventional Technologies 26
4.6.2. Downlights 27
4.6.3. Emerging Technologies 29
4.6.4. Summary of Recommendations – Technology Specifications 32
4.7. Solution Element – Laboratory Testing to Prove Claimed Performance 33
4.7.1. Discussion and Recommendations 33
4.7.2. Test Methods 34
4.7.3. Laboratory Testing of Lamp Circuit Power 35
4.7.4. Sample Sizes 36
4.7.5. Recognised Laboratories 37
4.7.6. Credibility of Test Reports 37
4.7.7. Check Testing 37
4.7.8. Leveraging from Existing Certification Schemes 37
4.8. Solution Element - Proof of MEPS Registration 38
4.9. Solution Element - Warrantee and Compatibility Requirements 38
4.10. Solution Element - Approval per Model Rather than per ACP 39
4.11. Solution Element - Outsource Design Approval and Product Approval 40
4.12. Solution Element - Prove Emerging Technology Performance Post-Installation 41
4.13. Summary of Recommendations from this Chapter 42

Chapter 5. Safety and EMC Requirements 43
5.1. Introduction 43
5.2. Background Information 43
5.2.1. NSW - Electrical Safety Legislation – Appliances and Equipment 43
5.2.2. Victoria - Electrical Safety Legislation – Appliances and Equipment 46
5.2.3. NSW - Electrical Safety of Installation 46

5.2.4. Victoria - Electrical Safety of Installation ... 46
5.2.5. ERAC ... 47
5.2.6. Report - Review of Electrical Safety Issues for Lighting Technologies ... 49
5.2.7. EMC ... 50
5.3. Discussion ... 51
5.4. Summary of Recommendations from this Chapter ... 51

Chapter 6. Other Issues ... 52
6.1. Extended Operating Hours ... 52
6.2. Application of the BCA in NSW ... 52
6.3. Calculation of Energy Savings ... 53
6.4. Summary of Recommendations from this Chapter ... 53

Appendix A – Introduction to Lighting Design Software ... 54
A.1. Introduction ... 54
A.2. Example of Software: Relux ... 59
A.2.1. Room Characteristics ... 59
A.2.2. Luminaire Characteristics ... 60
A.2.3. Light Calculation ... 61
A.2.4. Software Output and First Approximation of Compliance ... 62

List of Figures

Figure 1 – lighting design and verification for medium and large projects (optional for small projects) ... 12
Figure 2 – typical efficacies of conventional lamp technologies (source: testing commissioned by Beletich Associates) ... 24
Figure 3 – Room characteristics ... 59
Figure 4 - Surface characteristics ... 60
Figure 5 - Thorn luminaires placed on the office plan ... 60
Figure 6 - Light calculation settings ... 61
Figure 7 - Manual setting of maintenance factor ... 61
Figure 8 - Iso lux assessment ... 62
Figure 9 – Technical report ... 62
Figure 10 - Positioning of an observer for UGR control ... 63
Figure 11 - UGR in the observer's field of view ... 64

List of Tables

Table 1 – project tiers and requirements for lighting design/verification ... 10
Table 2 – IESANZ accredited courses ... 17
Table 3 – other IESANZ courses (Enlightenment) ... 17
Table 4 – Other lighting courses ... 18
Table 5 – downlight specifications ... 28
Table 6 – linear LED lamp specifications (4-foot lamps) ... 29
Table 7 – linear panel troffer specifications ... 30
Table 8 – LED highbay specifications ... 30
Table 9 – numbers of registered Designlights models ... 32
Table 10 – recommended sample sizes and compliance criteria ... 36
Table 11 – analysis of recommendations ... 42
Table 12 – Summary of software packages ... 56

GLOSSARY AND ABBREVIATIONS

ACMA:	Australian Communications and Media Authority
ACP:	Accredited certificate provider
AEMO :	Australian Energy Market Operator
Ballast:	Device connected between the power supply and one or more discharge lamps primarily to limit the current of the lamp(s)
BaU :	Business-as-usual
BCA:	Building Code of Australia
cd	Candela = luminous intensity = power emitted by a light source in a particular direction
CFL:	Compact fluorescent lamp
CFLi:	Compact fluorescent lamp with integrated ballast
CFLn:	Compact fluorescent lamp with non-integrated ballast
CLF:	Commercial lighting formula - lighting upgrades from which ESCs are generated using the ESS commercial lighting formula
Control gear:	Lighting ballast or transformer
Conventional technology:	Lighting technology that appears in Table 9 of the ESS Rule
CPD:	Continuing professional development
CRI:	Colour rendering index
DSF:	Default savings factor (clause 9.3 of the ESS Rule)
DTIRIS:	NSW Department of Trade and Investment, Regional Infrastructure and Services
EMC:	Electromagnetic compatibility
Emerging technology:	LED, T5 adaptor, induction lamp, VRU or technology not in Table 9 of ESS Rule
EOH:	Extended operating hours
ESC:	Energy savings certificate
ESS:	NSW Energy Savings Scheme
ESV:	Energy Safe Victoria
HID:	High intensity discharge lamp
IES or IESANZ:	Illuminating Engineering Society of Australia and New Zealand
IPART:	NSW Independent Pricing and Regulatory Tribunal – scheme administrator of the ESS
kcd:	kilo-candelas – see cd above
Lamp:	Source of artificial optical radiation
LCP:	Lamp circuit power - the power drawn by a single lamp and its associated control gear
LED:	Light emitting diode
Lm:	Lumen, the international measure of light output (luminous flux)
Luminaire:	Apparatus which distributes, filters or transforms the light transmitted from a light source, including lamp(s), control gear and all components necessary for fixing and protecting the lamps
Lux:	The international measure of illuminance, or light falling on a surface (lm/m^2)
L_{70}:	Operating hours at which light output depreciates to 70% of initial
MIES:	Member of IES The Lighting Society
MWh:	Mega-watt hour
Nominal:	The manufacturer's rated value for a lighting product
OEH:	NSW Office of Environment and Heritage
RLP:	Registered Lighting Practitioner of the IESANZ
SME:	Small-medium sized enterprise
SSL:	Solid state lighting
T5 adaptor:	Kit (including lamp) that will modify a T8 or T12 luminaire to suit a T5 lamp
VEET	Victorian Energy Efficiency Target scheme
VESC	Victorian Essential Services Commission
VRU:	Voltage Reduction Unit
W:	Watt

Chapter 1. INTRODUCTION

In recent months, commercial lighting formula (CLF) projects have begun to dominate Energy Savings Certificate (ESC) creation activities in NSW. This indicates that CLF projects are economically viable and relatively straightforward to implement. It is in this context that IPART have concluded that a review of CLF certificate creation is timely, in order to ensure that CLF projects continue to lead to high quality, safe lighting outcomes. Achieving these aims is considered to be in the best interests of all ESS CLF participants – in order to ensure the economic viability and longevity of the CLF activity in NSW.

The key issue currently confronting IPART is a lack of certainty that CLF projects are resulting in appropriate lighting outcomes. Inclusive in this issues are the following:

- IPART analysts and ESS auditors may not be technically qualified to check the compliance of projects with the Rule requirements (i.e. absolute compliance with all parts of AS/NZS 1680).
- IPART receives large quantities of requests for emerging technologies and extended operating hours.
- ACPs may lack lighting design capability.

Beletich Associates and Light Naturally were commissioned by IPART to produce a public report whose recommendations were targeted primarily at the NSW Energy Savings Scheme (ESS). The Victorian Essential Services Commission (VESC), the NSW Office of Environment and Heritage (OEH) and the NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) are also partners in the project. As a result of VESC involvement, certain aspects of this report may be relevant to the commercial lighting component of the Victorian Energy Efficiency Target (VEET).

The objective of this report is to recommend solutions aimed at ensuring that ESS CLF projects adhere to the following principles:

1. Installed lighting meets or exceeds the key requirements of AS/NZS 1680 and/or other standards as appropriate. Examination of this principle should include:
   a. A review of the current 'minimum illuminance' approach to satisfying the requirements of AS/NZS 1680.
   b. Consideration of the Rule requirement that energy savings must 'have no negative effect on production or service levels' as this relates to overall lighting characteristics such as CRI, lamp lifetime, lumen maintenance, electrical safety and other lighting characteristics as appropriate.
   c. Guidance for applications where AS/NZS 1680 does not apply and where task requirements are at odds with standards (e.g. restaurant ambient lighting versus cleaning tasks).
   d. Development of a methodology for assessing lighting design, for use by ACPs and ESS auditors, which is sufficient to ensure that the key requirements of AS/NZS 1680 (and/or other standard/criteria as appropriate) are consistently met.
   e. Requirements for training and qualifications.
2. Lighting upgrades are carried out by appropriately trained and qualified persons.

3. An appropriate process is in place for assessment and acceptance of conventional and emerging lighting technologies. Examination of this principle should include advice related to:
    a. The information required and processes used by IPART for acceptance of lighting technologies.
    b. The current use of laboratory testing to determine Lamp Circuit Power, as it relates to real world use of lighting technologies.
    c. Further requirements relating to lamp lifetime and other equipment characteristics to ensure good lighting outcomes.
    d. The potential for streamlining approvals based on a product approval list.
    e. Incorporation of safety requirements into the delivery of commercial lighting activities.
    f. How technologies fit within current and emerging regulatory requirements.

Chapter 2. Compliance with Lighting Design Standards

2.1. Background

Clause 9.4 (a) (iii) of the current ESS Rule states that ESCs can be generated from *Building Lighting, provided that the Scheme Administrator is satisfied that the lighting characteristics of each space, after implementation of the Lighting Upgrade, exceed the relevant recommendations of AS/NZS 1680, or another benchmark approved by the Scheme Administrator*.

The purpose of this chapter to explain the key requirements of AS/NZS 1680 and propose a methodology for ensuring compliance with these key requirements (and/or other requirements if required).

2.2. Introduction to AS/NZS 1680

The majority of commercial lighting projects will occur within buildings and for applications covered adequately by AS/NZS 1680, such as offices, factories, warehouses, etc. Applications that might fall outside of this scope are dealt with in section 2.5 of this report. At the time of writing, the AS/NZS 1680 series of standards comprised the following parts:

- 1680.0:2009 Interior lighting - safe movement. This part of the standard is mandatory as required by the Building Code of Australia (BCA).
- 1680.1:2006 Interior and workplace lighting - general principles and recommendations.
- 1680.2 series:
    - 1680.2.1:2008 Interior and workplace lighting - circulation spaces and other general areas.
    - 1680.2.2:2008 Interior and workplace lighting - office and screen-based tasks.
    - 1680.2.3:2008 Interior and workplace lighting - educational and training facilities.
    - 1680.2.4:1997 Interior lighting - industrial tasks and processes.
    - 1680.2.5:1997 Interior lighting - hospital and medical tasks.
- 1680.3-1991 Interior lighting - measurement, calculation and presentation of photometric data.
- 1680.4:2001 Interior lighting - maintenance of electric lighting systems.
- 1680.5:2012 Interior and workplace lighting - outdoor workplace lighting.

The requirements of AS/NZS 1680 can be summarised qualitatively as follows:

- Recommended working plane maintained illuminance - the defined level below which the <u>average illuminance</u> on any surface is not allowed to fall. The recommended level set is dependent on the task to be performed on the working plane.
- Recommended <u>uniformity of illuminance</u> – the ratio of the minimum illuminance to the average illuminance of the working plane within the calculation area.
- Recommended cut-off angle for partially enclosed luminaires (control of <u>disability glare</u>).
- Recommended typical maximum glare index values (control of <u>discomfort glare</u>).
- Recommended <u>colour temperature</u> of light sources (control of colour appearance).
- Recommended <u>colour rendering</u> properties of light sources (control of colour quality).

Of the above requirements, the aspects that should be considered as key requirements in the CLF are as follows:

- Average maintained illuminance.
- Uniformity of illuminance.
- Disability glare (cut-off angle for luminaires).

However it is also recommended that all CLF lighting designs should be cognizant of all the requirements of AS/NZS 1680.

2.3. Current ESS Approach to Compliance

The current ESS approach to demonstrating compliance with AS/NZS 1680 can be summarised as follows:

- Lux levels must exceed the relevant recommendations of AS/NZS 1680 or other benchmark approved by IPART. Lux levels refer to average maintained illuminance as described in AS/NZS 1680.
- Lux level measurements should be carried out in accordance with AS/NZS 1680.1 Appendix B.
- Post-installation lux measurement is required, however software modeling of 'as installed' configurations may be accepted on a case by case basis.
- The site operator (Original Energy Saver) may be required to sign a statement declaring that they are satisfied with the new lux levels (e.g. particularly for non-AS/NZS 1680 applications). This may require post-installation lux levels to be compared to previous lux levels.
- Equipment-specific information shall also be addressed, including:
    - Colour Temperature.
    - Colour Rendering Index.
    - Glare.
    - Reflectance from surfaces.
    - Uniformity.
    - Daylight interaction and effects.

Some shortfalls of this approach are considered to be as follows:

- Complexity of AS/NZS 1680 – the following of all aspects of this standard is difficult for non-lighting professionals.
- Lux level measurements:
    - Lack of competence of the person undertaking the measurements.
    - Pre-installation measurements will include an unknown level of lumen depreciation due to dirtying of the luminaire and room, and the unknown age of existing lamps.
    - Exclusion of external sources of light (including daylight).
    - Calibration of light meter.

- The following aspects are mentioned generally with no specific requirements:
    - Colour Temperature.
    - Colour Rendering Index.
    - Glare.
    - Reflectance from surfaces.
    - Uniformity.
    - Daylight effects.

An improved approach to compliance with AS/NZS 1680 is discussed in the following section.

2.4. Development of an Improved Approach

An improved approach to ESS commercial lighting has been developed, with the primary objective of providing increased likelihood of compliance with AS/NZS 1680. The key to the approach recommended is twofold:

- Use of qualified lighting design personnel.
- Use of lighting design software, which has been widely adopted by the lighting industry for planning of lighting installations and for ensuring compliance with relevant lighting standards.

2.4.1. Multi-Tiered Approach

It is considered that larger CLF projects should be subject to more stringent lighting design principles. With this in mind, a multi-tiered approach has been developed, involving the following three tiers of lighting projects:

1. **Small Projects**
    - These are projects for which a sophisticated lighting design and verification process is not considered economically justified.
    - A very basic lighting design and verification for a small site, performed by a lighting professional, is estimated to cost in the order of $750 (this estimate includes economies of scale for undertaking multiple projects/sites).
    - If we set 25% as a notional maximum proportion that lighting design/verification should represent as a proportion of ESC revenue, then projects with ESC revenue of $3000 or less would not economically justify lighting design/verification.
    - This $3000 threshold translates to 100 ESCs (at a nominal value of $30 per ESC) therefore:
    - <u>If the project (site) generates less than 100 ESCs, then lighting design/verification is not required and a simplified approach can be taken</u>.
    - Approached from an alternate perspective, 100 ESCs equates to a continuous lighting power saving of around 3300W (assuming the default ESS project lifetime of 30,000 hours). If the lighting power saving achieved was 12 W/m^2 (which is considered typical) then the site would be around 275 m^2 in size, which is considered an appropriate SME site.
    - Other requirements for small projects are outlined in section 2.4.3. Note that small projects (where no design and verification process is undertaken) should also be

constrained in that they involve only "like-for-like" replacement of technologies (see section 2.4.3). Small projects can however choose to undertake a design and verification process if they do not wish to adhere to like-for-like replacement requirements.

2. **Medium Projects**
   - These are projects for which a lighting design and verification process is considered justified, however for these projects ACPs would not be required to use an IES-qualified lighting designer[1] for design and verification.
   - The notional upper threshold for such projects is considered to be a site which is 500m^2 in size and operates 12 hours each day of the year (equivalent to a 750m^2 site operating for default CLF hours of 3000 p.a.)
   - Assuming a lighting power saving of 12 W/m^2, this translates to just over 250 ESCs, therefore:
   - <u>If the project (site) generates 100-250 ESCs (inclusive) then lighting design and verification is required however ACPs would not be required to use an IES-qualified lighting designer (although this is desirable and encouraged for the larger projects in this tier).</u>
   - Requirements for medium projects are outlined in section 2.4.2.
3. **Large Projects**
   - These are projects for which lighting design/verification is considered justified, and for which ACPs would be required to use an IES-qualified lighting designer.
   - <u>If the project (site) generates more than 250 ESCs, then lighting design/verification is required and ACPs would be required to use an IES-qualified lighting designer.</u>
   - Requirements for large projects are outlined in section 2.4.2.

These project tiers and corresponding requirements are summarised in Table 1. The detailed requirements for medium and large projects are also outlined in section 2.4.2 and for small projects in section 2.4.3.

Table 1 – project tiers and requirements for lighting design/verification

Project Size	Project Size (ESCs)	Lighting Design / Verification Required ?	Required to Use IES-Qualified Lighting Designer ?	For Detail Refer to Section
Large	>250	Yes	Yes	Section 2.4.2
Medium	100-250	Yes	Optional	Section 2.4.2
Small	<100	Optional	Optional	Section 2.4.3

In order to prevent gaming of this threshold system, projects should not be able to be subdivided into smaller projects. This may be implemented, for example, by requiring that only one CLF project shall be allowed to be submitted each year by a tenant or building owner for any single level of a single building.

[1] IES = Illuminating Engineers Society of Australia and New Zealand – discussed in sections below

2.4.2. Requirements for Medium and Large Projects

Medium and large projects (defined in section 2.4.1) would be subject to lighting design and verification requirements. The key principles employed in these requirements are as follows:

- Take advantage of lighting design software. These software packages (many available free of charge) undertake complex lighting calculations but are relatively straightforward to operate with enhanced graphical interfaces. See an introduction to software packages in Appendix A – Introduction to Lighting Design Software.
- Provide clear guidance to ACPs and ESS auditors regarding good practice in lighting design and compliance verification.
- Involve skilled personnel in lighting design.
- Reduce audit requirements where skilled personnel are employed.
- Undertake appropriate checks at a number of stages in the lighting design and verification process.

The proposed approach to medium and large CLF projects is described in Figure 1, which outlines a process for design and verification as well as technical audit of medium and large CLF projects (optional for small CLF projects – i.e. where like-for-like option is not employed).

Figure 1 – lighting design and verification for medium and large projects (optional for small projects)

Process Step	Description	Personnel Used	Audit[2]
Design	Use approved software[3]		Simple check that approved software was used
Approval	Design[4] approved as compliant with key aspects of AS/NZS 1680	MIES/RLP[5]	Simple check that design is MIES/RLP approved
		or	
		Trained person[6] Medium projects only	Detailed audit of design compliance
Installation			
Verification	On-site check – "installed as designed" [7] Only if Approval (above) was done by MIES/RLP	MIES/RLP	Simple check that on-site check was done by MIES/RLP
		or	
		Trained person Medium projects only	Detailed audit of on-site check
			or
			Auditor performs an on-site check
			or
			Auditor performs a light level survey
	or		
	On site light level survey[8]	MIES/RLP	Simple check that light level survey was done by MIES/RLP
		or	
		Trained person Medium projects only	Detailed audit of the light level survey
			or
			Auditor performs a light level survey

2 Audit = technical audit by member of ESS audit panel

3 See Appendix A – Introduction to Lighting Design Software

4 A Design Guide would be provided as part of training (see Chapter 3) including required outputs such as average maintained illuminance, uniformity of illuminance and disability glare

5 MIES = Member of IES The Lighting Society, RLP = IES Registered Lighting Practitioner - these are described in section 3.2

6 Trained Person is the nominated ACP employee who has completed the introductory lighting course (discussed in section 3.1)

7 Key output is a checklist and photographic evidence that all luminaires are installed and operating as per design

8 Key output is a spreadsheet of all light levels measurements for the measurement grid, together with calculations for average maintained illuminance and uniformity of illuminance

For large projects, ACPs would be required to use an IES-qualified lighting designer (MIES or RLP – see section 3.2) at the approval and verification stages – the option of using a "trained person" (see section 3.1) would not be available.

The approach described in Figure 1 is problematic for medium and large projects which are "pre-existing" – i.e. where the lighting upgrade has already been installed. For such projects, the design and approval stages could be reverse engineered – that is software modeling and design approval could be produced from the set of installed luminaires, etc. Whilst this may seem to be an inefficient requirement, it is considered necessary to close a loophole that will be created if the design/approval phases are allowed to be omitted for pre-existing projects. i.e. ACPs may tend to treat all projects as pre-existing (upgrade then create ESCs afterwards). This is contrary to the one of the aims of this chapter, which is to upskill ACPs and ingrain in them high quality lighting design and verification practices.

2.4.3. Requirements for Small Projects

Small projects are defined in section 2.4.1 as generating less than 100 ESCs for each site. For these projects, sophisticated lighting design and verification (including light level surveys) would not be not be mandatory. In order to avoid design and verification requirements, small projects should only involve "like-for-like" replacement of technologies, as follows:

- Halogen downlight:
  - Replaced by **LED downlight** (recommended for general, task or feature lighting)
    - Comply with the specification outlined in section 4.6.2.
  - Replaced by **CFL downlight** (recommended for general lighting only).
    - Comply with the specification outlined in section 4.6.2.
- Fluorescent luminaire:
  - Replaced by **LED linear panel troffer luminaire**:
    - Comply with the specification outlined in section 4.6.3.
    - Intensity distribution shall result in "zonal lumens" that are ±20% of the incumbent luminaire, for all zones (can be extracted from manufacturer-provided IES file using free photometric software) and the total (summed) light output of the luminaire is equal to or greater than the incumbent luminaire.
    - Does not include fluorescent luminaire converted to suit LED linear "tube" light source.
  - Replaced by **fluorescent luminaire**:
    - Intensity distribution shall result in "zonal lumens" that are ±20% of the incumbent luminaire, for all zones (can be extracted from manufacturer-provided IES file using free photometric software) and the total (summed) light output of the luminaire is equal to or greater than the incumbent luminaire.

- T8/T12 linear fluorescent lamp:
  - Replaced by **T5 adaptor** (if retained in the ESS[9]):
    - Comply with any requirements outlined in section 4.6.3.
  - Replaced by **LED linear "tube" replacement lamp** (if retained in the ESS[9]):
    - Comply with the specification outlined in section 4.6.3.
    - Lamp shall emit at least the same quantity of light (ie total lumens) as a typical linear fluorescent tube in a 360° axial intensity distribution, or the intensity distribution of the retrofitted luminaire shall result in "zonal lumens" that are ±20% of the incumbent luminaire, for all zones (can be extracted from manufacturer-provided IES file using free photometric software) and the total (summed) light output of the luminaire is equal to or greater than the incumbent luminaire.

The final installation should be signed off by the site operator (Original Energy Saver) including a statement to the effect that the installation is accepted as "like-for-like".

Note that ACPs would be free to follow a design process for small projects (Figure 1) if they do not wish to follow the "like-for-like" requirements listed above.

2.5. Applications not Covered Adequately by AS/NZS 1680

This section deals with applications not adequately covered by AS/NZS 1680. Such applications are likely to fall into the categories in the following sub-sections.

2.5.1. Specialised Applications with Design Standard other than AS/NZS 1680

These applications include the following (with corresponding recommendations for design standards):

- Roads and public spaces (including outdoor lighting and car parks): require adherence to AS/NZS 1158 *Lighting for Roads and Public Spaces*. Note that outdoor lighting design should also give consideration to AS 4282 *Control of the Obtrusive Effects of Outdoor Lighting*.
- Traffic signals: require adherence to AS/NZS 2144 *Traffic Signal Lanterns*.
- Sports lighting: require adherence to AS 2560 *Sports Lighting*. For those sports where no Australian Standard applies, an appropriate set of lighting performance criteria as set out by the sport's governing body should be adhered to. For example, Cricket Queensland has set out its own requirements due to the absence of an Australian Standard or a Cricket Australia requirement.
- Access and mobility: require adherence to AS1428 *Design for Access and Mobility* which provides design requirements for dedicated buildings designed for people with disabilities. It includes application-specific recommended maintained illuminance levels as well as light switch requirements. Note that Part 2 of this standard is often required by Commonwealth Government agencies for various areas of Government buildings.

For these applications (for which there is a clear design standard other than AS/NZS 1680) the ESS should require adherence to the above standards, along with adherence to the process outlined in Figure 1, with design approval and verification to be undertaken only by an MIES/RLP.

[9] Note the recommendations in section 4.5 regarding installation permanence

Note that it is not recommended that emergency and exit lighting be included in the CLF at this time, due to the inherent safety aspects of this type of lighting.

2.5.2. Interior Applications for which there is not a Clear Design Standard

These applications may include such premises as restaurants and clubs, retail applications, etc. For these applications (and indeed for all applications) the ESS should require adherence to AS/NZS 1680.0:2009 *Interior lighting - Safe Movement*, as required by the BCA. This standard requires:

- Minimum illuminance of 20 lux (throughout the space).
- Glare: luminance of the light from the luminaire shall not exceed 25 kcd/m^2 from angles 70° to 90° (from the downward vertical axis through luminaire)

In addition, for these premises IPART approval should be sought in advance for the applicable task and associated target lighting as outlined in Table 3.1 of AS/NZS 1680.1 - Recommended Maintained Illuminances for Various Types of Tasks, Activities or Interiors. Note that this likely to be a very small number of applications. In such cases the tasks to be carried out at the facility should be mapped against Table 3.1 which includes classes of tasks ranging from “movement and orientation” to “exceptionally difficult”. These classes are well described in the table.

Verification of compliance should also be carried out in accordance with Figure 1, with design approval and verification undertaken only by an MIES/RLP. The final installation should also be signed off by the site operator (Original Energy Saver).

2.5.3. Applications that do not Fit any of the Previous Categories

For such applications (likely to be a very small number of projects) the ACP should apply to IPART in advance for approval of the design and verification approach. The approach should embrace the basic structure and principles as outlined previously for conventional applications. The final installation should also be signed off by the site operator (Original Energy Saver).

2.6. Summary of Recommendations from this Chapter

The key aspects of recommendations from this chapter can be summarised as follows (please refer to the body of the chapter for more detail):

Key Requirements of AS/NZS 1680:

The aspects of AS/NZS 1680 that should be considered as key requirements in the CLF are as follows:

- Average maintained illuminance.
- Uniformity of illuminance.
- Disability glare (cut-off angle for luminaires).

Applications falling under AS/NZS 1680:

Projects should be tiered, as outlined in the table below:

Project Size	Project Size (ESCs)	Lighting Design / Verification Required ?	Required to Use IES-Qualified Lighting Designer ?	For Detail Refer to Section
Large	>250	Yes	Yes	Section 2.4.2
Medium	100-250	Yes	Optional	Section 2.4.2
Small	<100	Optional	Optional	Section 2.4.3

Medium and large projects should be subject to the design and verification process outlined in Figure 1. Small projects can adhere to a "like-for-like" technology replacement regime (see section 2.4.3). However <u>all</u> projects should be cognizant of <u>all</u> the requirements of all parts of AS/NZS 1680.

Specialised applications for which there is a clear design standard other than AS/NZS 1680:

These projects should adhere to the applicable design standard (listed in section 2.5.1) and the process outlined in Figure 1 is required, with the additional requirement that the design approval and verification shall only be undertaken by an MIES/RLP.

Interior Applications for Which There is Not a Clear Design Standard:

Interior projects should adhere to 1680.0:2009 Interior Lighting - Safe Movement. IPART approval should be sought <u>in advance</u> for the applicable task and associated target lighting as outlined in Table 3.1 of AS/NZS 1680.1. The process outlined in Figure 1 is required, with the additional requirement that the design approval and verification shall only be undertaken by an MIES/RLP.

Applications that do Not Fit Any of the Previous Categories:

For projects which do not fit any of the above categories, the ACP should apply to IPART in advance for approval of the design and verification approach, which should embrace the basic structure and principles as outlined in Figure 1.

All projects:

All interior projects should adhere to 1680.0:2009 Interior lighting - Safe Movement. All installations should be signed off by the site operator (Original Energy Saver).

Chapter 3. Appropriately Qualified Persons

The purpose of this section is to summarise relevant lighting courses and qualifications, and to make appropriate recommendations for the training and qualification requirements of a "trained person" (see section 2.4.2).

3.1. Lighting Courses

Table 2 lists the courses accredited by the IESANZ which are suitable to achieve the qualification of MIES (see section 3.2).

Table 2 – IESANZ accredited courses

Title	Qualification Level	Institution	Duration	Cost (2012)	Links (accessed June 2012)
Lighting	Master	QUT	1.5 years FT/ 3 years PT	$23,400	www.qut.edu.au/study/courses/master-of-lighting-on-shore
Lighting	Grad Dip	QUT	1 years FT/ 2 years PT	$15,600	www.qut.edu.au/study/courses/graduate-diploma-in-lighting-on-shore
Lighting	Grad Cert (plus 2 additional units from Grad Dip)	QUT	1 years FT/ 1.5 years PT	$19,500	www.qut.edu.au/study/courses/graduate-diploma-in-lighting-on-shore
Design Science (Illumination Design)	Master	University of Sydney	1.5 years FT/ 3 years PT	$26,280	www.sydney.edu.au/architecture/programs_of_study/postgraduate/illumination_design.shtml
Design Science (Illumination Design)	Grad Dip	University of Sydney	1 year FT/ 2 years PT	$17,520	www.sydney.edu.au/architecture/programs_of_study/postgraduate/illumination_design.shtml
Design (Lighting Design Studio)	Master	University of Technology Sydney	1.5 years FT/ 3 years PT	$26,460	www.datasearch.uts.edu.au/dab/courses/design-details.cfm?spk_cd=C04243&spk_ver_no=1
Science & Technology (Lighting)	Grad Cert	Massey University of New Zealand	6 months FT/ 1 year PT	$3,400	http://www.massey.ac.nz/massey/learning/programme-course-paper/programme.cfm?prog_id=93287&major_code=
Lighting Engineering & Design	Non-award	RMIT	2 years PT	$2,100	www.rmit.edu.au/engineeringtafe/lightingdesign

The IESANZ also offers an introductory lighting course, Enlightenment, outlined in Table 3.

Table 3 – other IESANZ courses (Enlightenment)

Title	Qualification Level	Institution	Duration	Cost (2012)	Links (accessed June 2012)
Enlightenment	N/A	IESANZ	3 days	$1,100 members/ $1,210 non-members	www.iesanz.org/education/education-seminar/the-basics-of-efficient-lighting

The IESANZ Enlightenment course provides fundamental lighting knowledge and basic lighting principles that people who operate within the lighting industry should be familiar with. It operates well as an induction program to lighting for those who require no specialist lighting training. This program allows the participant to be suitably informed of the basic lighting concepts to enable them to understand and communicate these concepts to others.

Topics include:

- An introduction into the function of lighting.
- Fundamentals of light and photometry.
- Lamp choices.
- Control gear.
- Selling efficiency and replacement technologies.
- Sustainability.
- Health considerations.
- Public misconceptions.
- Compliance with Australian standards, codes and regulations.

Note that lighting design (including design calculations) was deliberately excluded from the course so as not to give attendees the false impression that, on completion of the course, they would be knowledgeable in all aspects of lighting design. Courses are run in Adelaide, Brisbane, Canberra, Melbourne, Perth and Sydney subject to minimum enrolments.

Non-IES certified courses are summarised in Table 4.

Table 4 – Other lighting courses

Title	Qualification Level	Institution	Duration	Cost (2012)	Links (accessed June 2012)
Lighting	Grad Cert	QUT	6 months FT/ 1 year PT	$7,800	www.qut.edu.au/study/courses/graduate-certificate-in-lighting-on-shore
Design Science (Illumination Design)	Grad Cert	University of Sydney	6 months FT/ 1 year PT	$8,760	sydney.edu.au/architecture/programs_of_study/postgraduate/illumination_design.shtml
Lighting Principles	TAFE Statement	Sydney Institute Petersham College	1 year PT	$1,600	www.sit.nsw.edu.au/courses/search.php?cid=14467&area=courses&Media_Index_ID=111
Interior Decoration Design Series: Creative Lighting Applications	Short Course	RMIT	6 months PT	$595	www.shortcourses.rmit.edu.au/keysearch.php?show_public_course=1&select_course_type_code=S320125&cbs=032a4fe0012bad57abe86490155b9264
Lighting Design	Professional Certificate	The Design Ecademy	Online learning	€ 1,195	www.thedesignecademy.com/our-courses/lighting-design-course
Lighting for Interior Design	Short Course	Australian Institute of Interior Design	9 hours	$250	www.interior-design-academy.com/lighting-for-interior-design-course.php
Lighting for Living (for NECA members only)	N/A	National Electrical & Communications Association (NECA)	2 days	free	www.vic.neca.asn.au/index.php/education_training/training_calendar/lighting_for_living

These courses outlined in Table 4 do not meet the full syllabus requirements to achieve MIES from the IESANZ, however they do provide an excellent grounding in various aspects of lighting and lighting design concepts.

It is recommended that the Enlightenment course be used as the basis for training and qualification of a "trained person" (see section 2.4.2) along with basic lighting design and CLF-specific training elements. The "trained person" course would involve training an employee of the ACP in the following:

- Enlightenment: ~18 hours.
- Appreciation of basics of fundamentals of lighting design: ~ 6 hours.
- IPART administrative requirements: ~3 hours.

This course could be developed and run relatively quickly with the support and engagement of the IESANZ. It is recommended that the IESANZ be approached by IPART to seek collaborative engagement to develop the syllabus and teaching materials, and then to deliver the required training component for the express purpose of meeting the needs of the ESS CLF.

3.2. Lighting Qualifications and Professional Ethics

In Australia, there is only one organisation with recognised professional lighting qualifications - the Illuminating Engineering Society of Australia and New Zealand. It has two qualifications relevant to the ESS:

- MIES – Member of IES The Lighting Society: A member who has successfully completed a lighting course accredited by IES The Lighting Society and who has a minimum of four years of approved lighting practice or equivalent practice in an allied field. Post-nominals allowed: MIES
- RLP – Registered Lighting Practitioner: RLP is an additional qualification for those members of the Society who regularly practice lighting design at a high level of performance and who wish to maintain those high standards in the future by undertaking Continual Professional Development activities. Post-nominals allowed: RLP.

Members of the IESANZ are encouraged to participate in continuing professional development (CPD). This is defined as the continuous involvement in planned activities aimed at the maintenance, improvement and broadening of a member's knowledge and skill in carrying out his/her lighting employment. The IESANZ provides a system for members for documenting, weighting and certifying such activities and provides guidance on a minimum amount of CPD on an ongoing basis.

In order to preserve the confidence of the community in the integrity and judgment of the Society, members must agree to conform in their personal, business and professional activities with the letter and the spirit of the Society's Code of Ethics. Clause extracts pertinent to the ESS are as follows:

- Maintain high standards of objectivity and integrity in their professional work.
- Exercise scientific caution and regard for the limits of present knowledge in their professional reporting avoiding exaggeration, sensationalism and superficiality.
- Strive to keep up to date in their knowledge and application of this knowledge in the areas of lighting in which they practice

- In any situation where a conflict may arise ensure that they have defined the nature and direction of their loyalties and informed all parties of them.
- Refer people to competent colleagues for services that fall outside their own competence.
- Not lay false claim to professional qualifications, affiliations, characteristics or capabilities for themselves or for their organisations.
- Not allow their names to be used in connection with their services in such a way as to misrepresent the nature and efficiency of these services.

3.3. Summary of Recommendations from this Chapter

As outlined in section 2.4, it is recommended that MIES or RLP qualified persons be taken advantage of in the CLF design and verification process. Alternatively ACPs can (for certain projects) nominate a "trained person". This person shall be an employee of the ACP and shall have completed an introductory lighting course that covers the following:

- IESANZ Enlightenment: The Basics of Efficient Lighting Seminar: ~18 hours.
- Appreciation of basics and fundamentals of lighting design: ~ 6 hours.
- IPART administrative requirements: ~3 hours.

Chapter 4. PERFORMANCE OF LIGHTING TECHNOLOGIES

4.1. Introduction

The objective of this chapter is to outline a number of potential solutions aimed at ensuring that CLF lighting upgrades are fitted with lighting technologies that are fit for purpose. This includes recommending an appropriate process for assessment and acceptance of conventional and emerging lighting technologies, including:

- The information required and processes used by IPART for acceptance of lighting technologies.
- The current use of laboratory testing to determine Lamp Circuit Power, as it relates to real world use of lighting technologies.
- Further requirements relating to lamp lifetime and other equipment characteristics to ensure good lighting outcomes.
- The potential for streamlining approvals based on a product approval list.

Sections 4.4 onwards outline a number of "solution elements" that may be applied in whole or in part, as elements of the final solution package to be implemented by IPART.

4.2. Current Approach

Under the current ESS Rule, emerging technologies are defined as follows:

- T5 adaptors.
- LEDs.
- Voltage reduction units (VRUs).
- Induction lamps.
- Other technologies not listed in table 9 of the ESS Rule, for example cold cathode CFLs.

In order to install lighting products that fall into these categories, an ACP must currently apply to IPART in advance for approval of each model. To date, the following approximate numbers of requests for approval of emerging technologies have been received (note that these are numbers of ACP applications which may contain requests for multiple models):

- LED: 400.
- T5 adaptor: 75.
- VRU: 13.
- Induction lamp: 12.

Currently, IPART require that the following items are supplied as part of the application for each emerging technology model:

- Lamp Circuit Power (LCP): independent testing from a NATA accredited laboratory (or equivalent) or an LCP listed on the Lighting Council of Australia's website of registered products as part of its SSL Quality Scheme (requires product marking traceable to website registration).
- Electrical safety: (required for connection to mains power) evidence to demonstrate that equipment meets the electrical safety requirements of the Electrical (Consumer Safety) Act 2004, either:

- an Australian Certificate of Approval[10] (if it is a Declared Article[11]) or
- a Certificate of Suitability issued by NSW Fair Trading (if it is a Non-Declared Article[12]) or
- Documentation showing the Regulatory Compliance Mark (RCM[13]).

- Electromagnetic Compatibility (EMC): evidence to demonstrate that equipment meets the EMC requirements of the Radio Communications Act 1992 (administered by ACMA). Information accepted as evidence of compliance with electrical safety and EMC regulatory arrangements includes: Evidence of the RCM and verifiable regulatory approval number, or supplier code issued by ACMA and ACMA declaration of conformity.
- Nominal Lamp Lifetime (necessary for lamp-only replacements and T5 adaptor kits): evidence of the Nominal Lamp Lifetime - generally manufacturers' specifications will suffice, however lamps utilising traditional 5mm LEDs must supply an independent test report showing Nominal Lamp Lifetime.
- For Voltage Reduction Units: output voltage and installation details.
- For linear LED tubes: Certificate of Suitability from NSW Fair Trading, or equivalent.

Emerging technologies are also required to demonstrate that they reduce energy consumption without reducing lighting characteristics, however details of this requirement are not currently explicit.

It is considered timely to review this approach to emerging technologies, as the lighting market has evolved in recent years and the volume of ACP applications for emerging technology approval has increased substantially. IPART have also described two competing issues that require resolution:

A. The large quantity of "approval in advance" applications for emerging technologies is straining internal resources. Inherent in this issue is the requirement that approvals are performed on an ACP basis, rather than on a product basis, which has the potential to result in task duplication and inconsistency between applications for an identical model.

B. Uncertainty regarding the performance of emerging technologies.

At this time, the opportunity should also be taken to review the approach to all lighting technologies including conventional technologies.

In order to approach the large quantity of inter-related issues, a number of potential "solution elements" have been developed for this report. These are described in the following sections.

Note that safety and EMC issues for lighting technologies are dealt with separately in this report, in Chapter 5.

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[10] An Australian Certificate of Approval may be issued by NSW Fair Trading, or an equivalent body in another state, or by an independent certifier

[11] Declared Articles include T5 adaptor kits and power supplies

[12] Non-Declared Articles include voltage reduction units, LED tubes, and induction lamps

[13] An RCM covers both electrical safety and EMC requirements

4.3. Introduction to "Solution Elements"

The sections below outline a number of discrete "solution elements". These may be regarded as a menu, from which elements can be chosen to form the final solution package to be implemented for the ESS CLF. Many of these elements will involve inter-dependence with other elements. That is, implementation of one element may influence the need to implement other elements. For example, allowing emerging technologies to prove performance post-installation would serve to heighten the focus on product quality requirements.

For these reasons, not all of the solution elements outlined below include firm recommendations. Some will require further discussion and refinement. Note also that these solution elements have largely been developed <u>in isolation of each other</u>. Section 4.13 seeks to bring together recommendations from all the solution elements described in this chapter.

4.4. Solution Element - Eliminate the Emerging Technologies Category

In order to streamline the approvals process, one potential solution is to remove technologies from the emerging technologies list entirely, such that they no longer require any form of approval, and are simply dealt with in the same manner as conventional lighting technologies.

Advantages

- Would significantly reduce approvals processing for IPART.

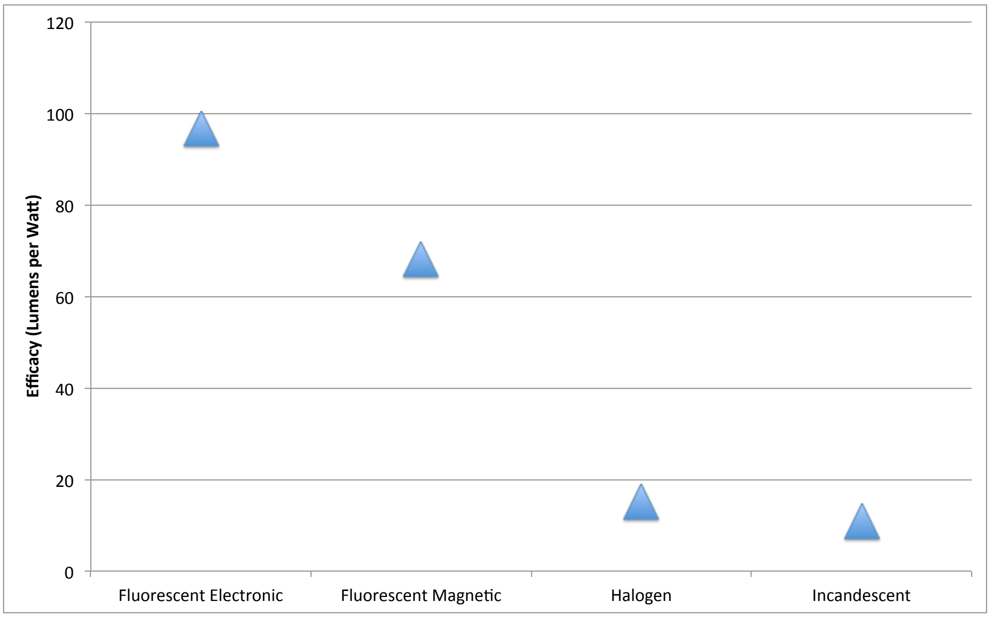
Disadvantages

- Immature lamp technologies such as LED should be viewed from the perspective that commercial lighting continues to be dominated by efficient fluorescent lighting, which is subject to MEPS and is considered a well proven technology. As demonstrated in Figure 2, in order to compete with modern fluorescent lighting, LEDs must exhibit very high efficacy. To avoid misleading the reader, LED efficacy is not graphed on this figure - there is a very wide range of LED efficacy available in the market, in the order of 10 to 100 lm/W.
- It is considered that a significant number of LEDs, T5 adaptors, VRUs and induction lamps continue to suffer from inaccurate performance claims.

Recommendation

- Continue to require emerging technologies to prove their performance, i.e. not be treated as conventional technologies.
- There have been relatively low numbers of requests for approval of VRUs, and problems exist for this technology in relation to achievable energy savings (e.g. when fitted to electronic and constant wattage ballasts) and also in relation to lamp dimming which might cause AS/NZS 1680 compliance problems. For these reasons, it is considered pertinent to **remove VRUs from the ESS Rule** by implementation of a sunset clause. Note that voltage optimisation devices differ from VRUs in that they typically optimise voltage for an entire site, thus should be treated elsewhere in the ESS Rule.

Figure 2 – typical efficacies of conventional lamp technologies (source: testing commissioned by Beletich Associates)



4.5. Solution Element - Installation Permanence

Given the maturity of the ESS commercial lighting market, and the underlying economics of CLF projects (as evidenced by their popularity) it may be timely to require that all (or at least the majority of) CLF lighting upgrades be required to be "permanent". e.g. using dedicated luminaires which are dedicated to an efficient light source technology, rather than lamp-only replacement solutions (or potentially even luminaire retrofits). Such upgrades would not be able to easily revert to the incumbent or a less efficient technology.

On example is the installation of a CFLn lamp (CFL lamp with separate ballast) which requires the installation of a dedicated compact fluorescent luminaire which has an inbuilt ballast and will physically accept only a CFLn. By contrast, the installation of a conventional CFLi lamp (integral ballast with bayonet/Edison cap) can be easily reverted to an incandescent or halogen lamp.

Note that ACPs may currently, in order to demonstrate permanence, make modifications to facilitate retrofitting the existing luminaire (e.g. control gear removal) such that the lamp cannot revert to its incumbent technology.

In the current ESS Rule "Asset Lifetime" is used in the CLF to represent the lifetime (in years) over which energy savings are accrued. For commercial buildings this is currently 10 years, and for road/public/traffic lights this is 12 years. ACPs are required to demonstrate the permanence of their proposed upgrades in line with these Asset Lifetimes. In certain situations, where the permanence of the upgrade is in question, these Asset Lifetimes may be considered optimistic, especially where the business-as-usual baseline for lighting technology is improving rapidly.

Advantages

- Significantly reduced risk of reverting to a less efficient technology, e.g. with a dedicated luminaire, when the lamp fails it can only be replaced with an identical lamp (no reversion is possible) and thus the energy savings should accrue over the time horizon of the CLF, which is currently 10 years for commercial buildings.

- Would effectively disallow, or limit the use of, T5 adaptors and LED linear replacement lamps. These technologies are also subject to safety risks as outlined in Chapter 5.
- Would halt the use of lamp lifetime as an input variable to the calculation of energy savings (although proof of lamp lifetime using test reports may still be required in order to prove product quality where appropriate – see section 4.7.2 for recommended test methods). Allowing for different lamp models to achieve different energy savings based on the rated lamp lifetime creates an incentive to claim very long lamp life. This has lead to problems for both the ESS and VEET in the past, due to the difficulty in verifying claims of long lamp lifetime. A further difficulty relating to lamp lifetime is that it is typically quoted as the median lamp life, however it is the mean lamp life that should be used to accurately calculate energy savings. The difference between median and mean lamp life is not well understood, and would potentially need to be studied for each lamp technology or each lamp model.

Disadvantages

- Removing lamp-only replacements (including LED) from the ESS CLF (and potentially from the DSF if desired) would limit the number of small projects which make up a significant volume of ESCs.
- May disadvantage projects involving a combination of new luminaires and lamp replacements.

Recommendation

- **Require all lighting upgrades to be permanent (would disallow or limit the use of T5 adaptors and LED linear replacement lamps) or alternatively allow non-permanent upgrades only for small projects** (defined in section 2.4.3) with a limit on the energy savings horizon of X hours (X = the minimum lifetimes recommended in section 4.7.1 which are demonstrated by providing test reports with test methods recommended in section 4.7.2).

4.6. Solution Element - Technology Specifications

This solution element would require that certain technologies meet a minimum specification which contains absolute limits on key performance parameters. For example, LEDs might be required to meet a specification identical to or similar to US Energy Star[14] or Designlights[15]. Compliance with technology specifications could be demonstrated by siting certification with these programs or by siting independent test reports.

Advantages

- Creates a level playing field for technologies, which must all meet the same specification.
- May reduce IPART processing requirements for products with existing certification such as Energy Star.
- Encourages ACPs to use products with existing certification.

[14] http://www.energystar.gov/

[15] http://www.designlights.org/

Disadvantages

- Additional IPART processing (evaluation of test reports) is required for products not already certified by a certification scheme such as Energy Star or Designlights – this may be a significant number of products.
- The stringency and rigidity of technology specifications may limit project flexibility and increase project costs by excluding non-complying (but relatively efficient and inexpensive) products.

In order to assess which lighting technologies might be suited to the use of technology specifications, the technologies are broken down into the following categories and examined separately:

- Conventional technologies.
- Downlights.
- Emerging technologies.

These categories are examined in the following sub-sections, and separate recommendations have been developed for each.

4.6.1. Conventional Technologies

This section describes technology specifications as they might apply to conventional technologies (i.e. non-emerging technologies). These technologies are further broken down into various commercial lighting technology sub-categories, as follows.

Fluorescent Lamps (Linear and CFLn)

A technology specification for efficacy and CRI is not considered necessary as linear fluorescent lamps are subject to MEPS for these attributes, and this technology is mature.

Recommendation

- **Do not require a technology specification for fluorescent lamps**.

CFLi Lamps

A technology specification is not considered necessary as CFLi lamps are subject to MEPS including a minimum lamp life of 6000 hours. Note that minimum light output and minimum lifetime requirements for CFL downlights are dealt with separately in section 4.6.2.

Recommendation

- **Do not require a technology specification for CFLi lamps**.

Fluorescent Ballasts

An absolute specification is not considered necessary as many (linear) fluorescent ballasts are subject to MEPS and this technology is mature.

Recommendation

- **Do not require a technology specification for fluorescent ballasts**.

Fluorescent/CFLn/CFLi Luminaires

An absolute specification could be applied to the light output ratio for fluorescent luminaires, although this aspect should be taken account of in the lighting design and AS/NZS 1680 compliance process. Note that luminaires are not currently subject to MEPS.

Recommendation

- **Do not require a technology specification for fluorescent/CFLi luminaires**.

Incandescent/Halogen Lamps, Transformers and Luminaires:

An absolute specification is not considered necessary as many of these lamps and transformers are subject to MEPS, and this technology is mature. Note that an incandescent/halogen luminaire does not typically have a significant impact on efficacy in a commercial lighting context.

Recommendation

- **Do not require a technology specification for incandescent/halogen lamps, transformers and luminaires**.

HID Lamps, Ballasts and Luminaires

HID lamps, ballasts and luminaires are not currently subject to MEPS. An absolute specification for these items is not considered necessary, as their performance should be taken account of in the lighting design and AS/NZS 1680 compliance process.

Recommendation

- **Do not require a technology specification for HID lamps, ballasts, and luminaires**.

4.6.2. Downlights

Downlights are considered a special case, as these are likely to be installed in situations where a sophisticated design process is unlikely to occur or is unwarranted. Thus replacement downlights for 50W halogen units might benefit from adherence to an absolute specification. Currently, the ESS Rule, drafted in 2009, includes a Default Savings Factor (DSF) for downlights (note that this is separate from the CLF) – see ESS Rule clause 9.3(b)(i). This clause includes a simple specification as follows:

- Downward light output ≥ 500 lm.
- Lumen maintenance ≥ 80%.

A revised downlight specification has been developed for this report, and is outlined in Table 5 (see right-hand columns). It effectively updates the current DSF downlight specification to take into account the recent emergence of sophisticated test methods for LEDs and the introduction of MEPS for reflector CFLs. The table also lists the key requirements of other LED specification programs for comparison. Proof of certification by these other programs may reduce compliance costs, particularly where program requirements are at least as stringent as those required by IPART. Note that the IEA initiative does not currently include a certification aspect.

Table 5 – downlight specifications

Parameter	Energy Savings Trust LED Luminaire Requirements V3.0	Energy Star Luminaires V1.1	IEA Downlights (tiers 1-3)	IEA Directional Lamps (MR16) (tiers 1-3)	Recommended (LED Downlight)	Recommended (CFL Downlight)
Require proof of MEPS registration	-	-	-	-	-	Yes (CFL lamp)
Minimum initial luminous flux (lm)	N/A – uses centre beam intensity	345-575	N/A – uses centre beam intensity	780	500	500
Minimum efficacy (lm/W)	N/A – uses centre beam intensity	42	40, 55, 70 lm/W (tiers 1-3)	40, 50, 60 lm/W (tiers 1-3)	No – the LCP in the CLF will encourage efficacy (low power)	No - covered by MEPS (lamp)
Power (W)	-	-	-	-	Laboratory test to prove LCP	Laboratory test to prove LCP
Minimum lumen maintenance L_{70} (hours)[16]	35khrs	25khrs	30khrs, 35khrs, 40khrs (tiers 1-3)	15khrs, 15khrs, 25khrs (tiers 1-3)	35khrs (fixture) 25khrs (lamp-only)	No - covered by MEPS
Minimum life (hours)	35khrs	Various	30khrs, 35khrs, 40khrs (tiers 1-3)	15khrs, 15khrs, 25khrs (tiers 1-3)	35khrs (fixture) 25khrs (lamp-only)	10khrs
Minimum CRI	80	80	70, 80, 80 (tiers 1-3)	70, 80, 80 (tiers 1-3)	80	80
Color temperature target (K) and tolerances	2700 3000 3500 4000 5000 6500 No tolerance	2700 3000 3500 4000 5000 7-step tolerance (ANSI C78.377)	2700 3000 3500 4000 5000 5700 6500 Various tolerances[17]	2700 3000 3500 4000 5000 5700 6500 Various tolerances	Harmonise with IEA	Covered by MEPS
Harmonics		FCC requirements	FCC requirements	FCC requirements	IEC 61000.3.2	Covered by MEPS

Recommendation

- **Require a technology specification for LED/CFL downlights as shown in Table 5 (RH columns).**

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[16] L_{70} = operating hours at which light output depreciates to 70% of initial
[17] Available from http://ssl.iea-4e.org/task-1---quality-assurance

4.6.3. Emerging Technologies

The most common LED upgrade is likely to be for downlights, and these are covered in the previous section. Other emerging technology categories are covered in the following sub-sections.

LED linear replacement lamps

It is considered that LED linear replacement lamps (if retained in the ESS[18]) should be subject to a relatively stringent absolute specification, reflecting the fact that the fluorescent lamps they replace are efficient and well proven. The key aspects of DesignLights[19] and the draft IEA specifications[20] are shown in Table 6 (4-foot lamps) along with Australian MEPS for linear fluorescent lamps. The table also includes a recommendation for the ESS (see right-hand column). Note that Energy Star does not currently cover LED linear replacement lamps.

Table 6 – linear LED lamp specifications (4-foot lamps)

Parameter	Designlights (4-foot lamps)	(Draft) IEA (tiers 1-3) (4-foot lamps)	MEPS for linear fluorescent lamps (4-foot lamps)	Recommended
Minimum luminous flux (lumens)	Bare Lamp: 2200 lm. 2 lamps tested in fixture: 3750 lm	3000	N/A	Either Designlights or IEA can be used by the ACP
Minimum efficacy (lm/W)	Bare Lamp: 96 lm/W In fixture: 75 lm/W	Bare lamp: 80, 96, 120 lm/W (tiers 1-3)	Bare lamp: 80 lm/W	Either Designlights or IEA (any tier) can be used by the ACP
Power (W)	-	-	-	Laboratory test to prove LCP in typical luminaire
Minimum lumen maintenance L_{70} (hours)[21]	50khrs	30khrs, 35khrs, 50khrs (tiers 1-3)	N/A	30khrs
Minimum life (hours)	-	30khrs, 35khrs, 50khrs (tiers 1-3)	-	30khrs
Minimum CRI	80	80	79	80
Color temperature target (K) and tolerances	≤ 5000	2700 3000 3500 4000 5000 5700 6500 Various tolerances[22]	-	Either Designlights or IEA can be used by the ACP
Harmonics		THD ≤ 20% FCC requirements		Complies IEC 61000.3.2 when fitted to luminaire

Recommendation

- **Require a technology specification for LED linear replacement lamps, as shown in Table 6 (right-hand column).**

[18] Note the recommendations in section 4.5 regarding installation permanence

[19] http://www.designlights.org/

[20] Final specifications are imminent

[21] L_{70} = operating hours at which light output depreciates to 70% of initial

[22] Available from http://ssl.iea-4e.org/task-1---quality-assurance

LED linear panel troffer luminaires

LED linear panel troffer luminaires could be subject to an absolute specification. The key aspects of the DesignLights[23] specification are shown in Table 7 along with a recommendation (see right-hand column). Note that Energy Star does not currently cover LED linear panel troffers.

Table 7 – linear panel troffer specifications

Parameter	Designlights (2 x 2' troffer)	Designlights (1 x 4' troffer)	Designlights (2 x 4' troffer)	Recommended
Minimum luminous flux (lumens)	3000	2000	4000	Use Designlights
Minimum efficacy (lm/W)	60 lm/W	65 lm/W	65 lm/W	Use Designlights
Power (W)	-	-	-	Laboratory test to prove LCP
Minimum lumen maintenance L_{70} (hours)[24]	35 khrs	35 khrs	35 khrs	Use Designlights
Minimum life (hours)	-	-	-	-
Minimum CRI	80	80	80	Use Designlights
Color temperature target (K) and tolerances	≤ 5000	≤ 5000	≤ 5000	Use Designlights
Harmonics	-	-	-	Luminaire complies IEC 61000.3.2

Recommendation

- **Require a technology specification for LED linear panel troffers, as shown in Table 7 (right-hand column).**

LED highbay luminaires

LED highbay luminaires could be subject to an absolute specification. The key aspects of the DesignLights specification are shown in Table 8 along with a recommendation (right-hand column). Note that Energy Star does not currently cover LED highbay luminaires.

Table 8 – LED highbay specifications

Parameter	Designlights (High-bay and Low-bay fixtures for Commercial and Industrial buildings)	Designlights (High-bay-Aisle Lighting)	Recommended
Minimum luminous flux (lumens)	10,000	10,000	Use Designlights
Minimum efficacy (lm/W)	70 lm/W	60 lm/W	Use Designlights
Power (W)	-	-	Laboratory test to prove LCP
Minimum lumen maintenance L_{70} (hours)	35 khrs	35 khrs	Use Designlights
Minimum life (hours)	-	-	-

[23] http://www.designlights.org/

[24] L_{70} = operating hours at which light output depreciates to 70% of initial

Parameter	Designlights (High-bay and Low-bay fixtures for Commercial and Industrial buildings)	Designlights (High-bay-Aisle Lighting)	Recommended
Minimum CRI	70	70	Use Designlights
Color temperature target (K) and tolerances	≤ 5700	≤ 5700	Use Designlights
Harmonics	-	-	Luminaire complies IEC 61000.3.2

Recommendation

- **Require a technology specification for LED highbay luminaires, as shown in Table 8 (right-hand column).**

T5 adaptors and VRUs

If retained in the ESS, an absolute specification for T5 adaptors and VRUs would require significant development, as there is no known credible specification for these technologies.

Recommendation

- **In the absence of technology specifications for T5 adaptors and VRUs (if retained in the ESS) these should be required to be tested in order to prove the performance claimed by the supplier.**

Induction lamps

An absolute specification for induction lamps would also require significant development, as there is no known credible specification for this technology. Given the nature of projects that induction lamps would be installed into (large industrial applications) their performance should be taken account of in the lighting design and AS/NZS 1680 compliance process.

Recommendation

- **In the absence of a technology specification for induction lamps, these should be required to be tested in order to prove the performance claimed by the supplier.**

4.6.4. Summary of Recommendations - Technology Specifications

In summary, technology specifications for the following technologies are recommended:

- **LED/CFL downlights as shown in Table 5 (right-hand columns).**
- **LED linear replacement lamps, as shown in Table 6 (right-hand column).**
- **LED linear panel troffers, as shown in Table 7 (right-hand column).**
- **LED highbay luminaires, as shown in Table 8 (right-hand column).**

As they do not currently exist, development of technology specifications for T5 adaptors (if retained in the ESS[25]), VRUs and induction lamps would require significant development time. **In the absence of technology specifications for T5 adaptors, VRUs (if retained in the ESS) and induction lamps, these should be required to be tested in order to prove the performance claimed by the supplier.**

Note that these recommendations have been developed in isolation of other sections of this report. Section 4.13 brings together recommendations from all sections of this chapter.

For reference, the numbers of models currently certified by the US Designlights program are shown in Table 9.

Table 9 – numbers of registered Designlights models

Bollards	15
Display Case Lighting	14
Four-foot Linear Replacement Lamps	**4**
Fuel Pump Canopy	421
High-bay Aisle Lighting	**36**
High-bay and Low-bay Fixtures for Commercial and Industrial Buildings	**292**
Horizontal Refrigerated Case Lighting	191
Linear Panels (1x4 Troffer)	**54**
Linear Panels (2x2 Troffer)	**158**
Linear Panels (2x4 Troffer)	**58**
Outdoor Pole/Arm-mounted Area and Roadway Luminaires	6249
Outdoor Pole/Arm-Mounted Decorative Luminaires	1488
Outdoor Wall-Mounted Area Luminaire	3304
Parking Garage Luminaires	826
Refrigerated Case Lighting	391
Retrofit Kits for Outdoor Pole/Arm-mounted Area and Roadway Luminaires	560
Retrofit Kits for Outdoor Pole/Arm-mounted Decorative Luminaires	73
Track or Mono-point Directional Lighting Fixtures	356
Vertical Refrigerated Case Lighting	226

[25] Note the recommendations in section 4.5 regarding installation permanence

4.7. Solution Element - Laboratory Testing to Prove Claimed Performance

4.7.1. Discussion and Recommendations

This solution element is based on requiring some technologies to be laboratory tested in order to prove their claimed performance. It is effectively a less stringent option to requiring adherence to a technology specification as discussed in section 4.6. That is, products would only be required to prove performance against the performance values nominated by the supplier, rather than against an absolute value chosen by the ESS.

Note however that many of the recommendations in this section (e.g. test methods, sample sizes, laboratories, etc.) will also be relevant if technology specifications are adopted (section 4.6) – i.e. they are useful for proving compliance with the technology specification.

The analysis of which technologies should be subject to a requirement to prove claimed performance is similar to that carried out in section 4.6 and the technology choice conclusions are the same – i.e. that downlights and LEDs should be required to prove claimed performance.

However in section 4.6, it was recommended that T5 adaptors, VRUs and induction lamps, in the absence of technology specifications for these products, be required to prove their claimed performance.

In addition, the quality of CLF upgrades would benefit from requiring all projects to prove a minimum lamp/luminaire lifetime (by siting test reports) regardless of whether the upgrade is lamp-only or permanent. This should apply regardless of whether technology specifications are chosen as the preferred option for the ESS (section 4.6). The recommended minimum lifetimes are as follows:

- CFLi, CFLn, fluorescent and induction lamps: 10,000 hours. Lifetime testing to minimum of 10,000 hours. See section 4.7.2 below for recommended test methods.
- LED lamps and fixtures: lifetimes as recommended in Table 5 to Table 8. See section 4.7.2 below for recommended test methods.

The advantages and disadvantages of laboratory testing to prove claimed performance are as follows.

Advantages

- Provides certainty of performance against supplier-claimed parameters.
- Allows a high degree of design flexibility (products do not have to meet a stringent "absolute" specification) whilst ensuring that products perform as they claim to perform.

Disadvantages

- Potentially may require a higher degree of processing.

Recommendations

- **For downlights and LEDs, the key decision to be made is between technology specifications (section 4.6) and proving claimed performance (this section).** If the latter option is chosen, the same performance parameters recommended for technology specifications (see section 4.6) should be required to be proven.
- **In the absence of a technology specification, require T5 adaptors to prove claimed performance –** light output, LCP and lamp life.
- **In the absence of a technology specification, require VRUs to prove claimed performance.**

- **In the absence of a technology specification, require induction lamps to prove claimed performance**: light output, LCP, lamp life, colour temperature, CRI and harmonics.
- **Require all projects to prove a minimum lifetime as follows**:
    - CFLi, CFLn, fluorescent and induction lamps: 10,000 hours. Lifetime testing to minimum of 10,000 hours. See section 4.7.2 below for recommended test methods.
    - LED lamps and fixtures: lifetimes as recommended in Table 5 to Table 8. See section 4.7.2 below for recommended test methods.

The following sections provide more detail as to how performance would be proven using laboratory testing. This detail has relevance to technology specifications (section 4.6) and proving claimed performance (this section). They include detail related to test methods, sample sizes, laboratories, check testing and leveraging from existing certification schemes.

4.7.2. Test Methods

Recommended test methods for the various technologies and parameters are listed below. Note that not all of these methods will be required, but they are provided here for reference:

- All technologies:
    - Colour temperature: CIE 15.
    - CRI: CIE 13.3.
    - Luminaire photometry: AS/NZS 1680.3.
- Conventional technology – fluorescent lamp:
    - Light output, lumen maintenance, power, efficacy and life: AS/NZS 4782.1 or IEC 60081
- Conventional technology – CFLi lamp:
    - All parameters: AS/NZS 4847.1.
- Conventional technology – fluorescent ballast:
    - All parameters: AS/NZS 4783.1 or EN50294.
- Conventional technology – incandescent/halogen lamp:
    - Light output, lumen maintenance, power, efficacy and life: AS/NZS 4934.1.
- Conventional technology – halogen transformer:
    - All parameters: AS/NZS 4879.1.
- Conventional technology – HID lamp:
    - All parameters (metal halide) - IEC 61167.
- Conventional technology – HID ballast:
    - All parameters: IEC 62442-2.
- Emerging technology – LED:
    - Light output, power and efficacy: LM79.

    - Lumen maintenance: IESNA LM80 together with TM-21 (and LM-82 in order to take advantage of component-level testing being transferred to lamp/luminaire performance using in-situ temperature testing).

- Emerging technology – T5 adaptors:
    - Test methods for T5 adaptors would require significant development, but are likely to include proving of photometric and energy performance when installed into a reference luminaire.
- Emerging technology – VRUs:
    - Test methods for VRUs would require significant development.
- Emerging technology – induction lamps:
    - Light output, lumen maintenance, power, efficacy and life: IEC 62639.

Notes on LED lifetime: The typical failure mode for LEDs is gradual loss of light output, and this parameter is referred to as lumen maintenance. Hence lumen maintenance is commonly used as a proxy for LED lifetime. For many overseas LED schemes, the time at which light output drops to 70% of the initial light output (referred to as the L_{70} life) is when the LED is considered to have reached the end of its life. Overseas LED certification schemes typically require minimum L_{70} values of between 15000 and 35000 hours.

4.7.3. Laboratory Testing of Lamp Circuit Power

Lamp circuit power (LCP) is the total circuit power of the luminaire, including any control gear, but expressed per lamp. Nominal lamp power (NLP) is the manufacturer's rated power for a lamp (although in some cases IPART require that this is supported by test report).

Laboratory testing of LCP (and potentially lamp power) is required for emerging technologies, as the power draw of these technologies is not as predictable as for conventional technologies (for which there are considerable data and long standing international standards). For emerging technologies there are other performance parameters that are equally as important for the CLF, and these are discussed elsewhere in this chapter.

Testing of LCP is recommended to be undertaken by a recognised laboratory, for the following reasons:

- Performance claims for emerging technologies are frequently exaggerated by suppliers, and this may include power draw.
- Recognised laboratories have a degree of independence.
- Testing is performed under controlled conditions of supply voltage, ambient temperature, etc.
- Testing of power is very straightforward and thus can be performed alongside other photometric and performance testing.

It is possible that laboratory LCP tests results will differ slightly from real-world installations, due to reasons such as supply voltage. However, this disadvantage is mitigated by the following factors:

- Both the incumbent technology (via the standards that underpin the CLF) and the upgrade technology are subject to the same (or very similar) laboratory test conditions. It is the difference in power between the incumbent and upgrade technology that determines energy saving. This difference is likely to be similar when examining either laboratory results or real-world results, so long as only one of these conditions is chosen (i.e. an apples-with-apples comparison).

- LEDs and T5 adaptors use electronic circuitry to control current. Thus slight differences in voltage are unlikely to significantly alter current flow.
- Any uncertainty inherent in real-world power, versus laboratory power, should be viewed in the context of uncertainty inherent in other variables in the CLF equation, for example asset lifetime, operating hours, etc.

Thus it is not recommended to alter the laboratory test requirement for LCP, unless accurate real-world power data for both incumbent and upgrade technologies can be established. This is likely to require considerable resources and would still be subject to significant uncertainty.

Note that, for non-integral-ballast fluorescent lamps, lamp power testing is performed using a reference ballast.

In addition, ideally LCP testing should be performed for each discrete combination of lamp (including LED) and control gear that might be encountered in the market or is proposed for use in the CLF.

4.7.4. Sample Sizes

Recommended minimum sample sizes and compliance criteria to be applied to test methods are listed in Table 10**.** These would apply to any tests or test reports (e.g. to prove compliance against an absolute specification or to prove claimed performance). Note that the test methods recommended in 4.7.2 do not all contain sample size requirements, and that the sample size recommendations in Table 10 should take precedence.

Table 10 – recommended sample sizes and compliance criteria

Parameter	Minimum Sample Size	Compliance Criteria
Light output, lamp/circuit power and efficacy	10	Mean ≥ required value
Lumen maintenance (LED)	See TM21	
Lumen maintenance (other)	10	Mean ≥ required value
Colour temperature and SDCM	10	All samples ≤ required SDCM value
Colour CRI	10	Mean ≥ required value
Other CFLi parameters	See AS/NZS 4847.2	
Lamp lifetime	10	Life of the median lamp (or 6th of sample size of 10) shall be ≥ required value
Transformer / ballast energy performance	1	Mean ≥ required value
Luminaire photometry	1	Mean ≥ required value
Harmonics	1	Must comply with standard

4.7.5. Recognised Laboratories

In addition to the specification and testing issues discussed in previous sections, it is considered worthwhile to include some requirements with respect to approved test laboratories. **It is recommended that testing be undertaken only by Energy Star or NATA-recognised laboratories.**

Currently there will be very few, if any, laboratories in Australia familiar with LED testing to LM-79, LM-80, TM-21 and LM-82. Thus, for all tests involving these methods, it is recommended that testing be undertaken only by an Energy Star certified laboratory[26]. Other testing (e.g. AS/NZS 4847.1) can be undertaken by either an Energy Star certified laboratory or an independent laboratory with NATA accreditation or NATA-recognised accreditation (see Mutual Recognition Agreements within APLAC[27] and ILAC[28]).

4.7.6. Credibility of Test Reports

The most credible method for checking whether a test report is credible (e.g. not a forgery) is to investigate the laboratory whose name appears on the report, as follows:

- Does the laboratory exist?
  - Check laboratory's website.
  - Call the laboratory - check if the test report in question was carried out by that laboratory.
- Check that the laboratory is accredited by an APLAC or ILAC signatory - check the laboratory accreditation number.

4.7.7. Check Testing

It is recommend that the ESS scheme embark on a check testing regime in order to verify product claims, or at least have the ability to undertake this testing if required. The advantages of a check testing regime are the ability to independently sample products from the field, as well as to test products at a laboratory of IPART's choice.

4.7.8. Leveraging from Existing Certification Schemes

Key aspects of existing certification schemes for LEDs are covered in section 4.6.3. Where aligned with ESS requirements, these can be used to add weight to product performance claims. For example, if a product (or parameter of a product) is certified by Energy Star, the test report does not require close scrutiny. **Hence it is recommended that IPART leverage from existing certification schemes** in order to add weight to product claims.

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[26] List available from http://www.energystar.gov/index.cfm?c=news.nr_news&news_id=http://www.energystar.gov/cms/default/index.cfm/news-and-announcements/hidden-articles/epa-recognized-bodies-for-lighting-products/epa-recognized-laboratories-for-integral-led-lamps/

[27] Asia Pacific Laboratory Accreditation Cooperation: www.aplac.org/aplac_mra.html

[28] International Laboratory Accreditation Cooperation: www.ilac.org/ilacarrangement.html

4.8. Solution Element - Proof of MEPS Registration

For all technologies that are required to meet MEPS (including conventional technologies) **it is recommended that product applications (for emerging technologies) and lighting design records (for conventional technologies) include a screen shot of the MEPS registration** from the energyrating.gov.au website (note the registration number is not available from the website and links to individual products are not possible). Technologies that are required to meet MEPS currently include:

- Linear fluorescent ballasts (excluding LED drivers and ballasts intended to drive T5 lamps).
- Linear fluorescent lamps.
- ELV halogen transformers.
- CFLi lamps.
- Incandescent / halogen lamps.

The purpose of the requirement to demonstrate MEPS registration this is to address the fact that ACPs may not be aware that some products are subject to mandatory MEPS and may inadvertently import products that are not MEPS registered.

4.9. Solution Element - Warrantee and Compatibility Requirements

It is not uncommon in the commercial lighting market for suppliers to offer a warrantee of 2 years on lamps and ballasts, and 5 years on luminaires. These warrantees are often however project-specific and depend on details such as operating environment and lighting operating hours. In order to further improve CLF project quality, it may be prudent to require that ACPs or suppliers offer warrantees of the above durations. Note that the Energy Star integral lamps specification requires a minimum warrantee of 3 years.

Additionally, all equipment installed should be certified by the supplier/ACP as compatible with any incumbent dimmers, control gear or other incumbent control equipment.

Recommendation

- **Consider requiring a minimum warrantee on installed lighting equipment**.
- It is recommended that all **installed lighting equipment should be certified as compatible** by the equipment manufacturer with any incumbent dimmers, control gear or other incumbent control equipment.

4.10. Solution Element - Approval per Model Rather than per ACP

This solution element centres on application and approval of products on the basis of each make/model, rather than by the ACP. Approved models would then be placed on a central list/register (which may or may not be public) and may be available for use by other ACPs.

One example of this is the AEMO process for approval of road lighting luminaires[29]. This process involves the following steps:

- Applications from product suppliers must be sponsored by a local authority - e.g. local council who may which wish to install those products.
- The supporting documentation (test reports, etc.) are published on the AEMO website for comment and approval by industry. The period for comments on the proposed product will be 20 business days.
- In the absence of any comments that dispute the proposal, AEMO will accept the product.
- The new product will be approved and published in the AEMO load table and may only be used exactly as tested, i.e. the combination of luminaire, control equipment, and lamp shall be as tested.

This example may translate to the CLF whereby ACPs sponsor a supplier's product and, once approved, that product is able to be used in ESS, VEET, etc.

Advantages

- Would relieve duplication by IPART.
- Would potentially reduce inconsistencies between ACPs accredited for the same product.
- A public register (or accessible only by ACPs) would assist with self-regulation of performance claims for products.

Disadvantages

- Some ACPs may want to keep their product and its performance information confidential.

Recommendation

- **Implement approval per model rather than per ACP**. Include appropriate grandfathering and/or sunset clauses on existing approvals - e.g. existing product approvals will be placed on the public register within 12 months, unless the ACP requests that the product is removed from the list and no longer used. No products shall remain outside the public register system at the end of the sunset period.

[29] http://www.aemo.com.au/en/Electricity/Retail-and-Metering/Metrology-Procedures/Update-to-NEM-Load-Table-Unmetered-Loads_Current-Proposals

4.11. Solution Element - Outsource Design Approval and Product Approval

One potential solution to alleviate IPART resource constraints is to outsource both CLF lighting design and product approval tasks (as currently undertaken by IPART) to an independent technical body. This model is employed by overseas energy programs such as Energy Star who use 3rd party certifiers[30].

In such a model, the technical tasks of assessing both lighting design and product performance (either against technology specifications or against supplier claims) would be undertaken by an external body with the following attributes:

- Commercial independence.
- Possess appropriate technical personnel.
- High level of understanding of lighting design.
- High level of understanding of lighting product performance issues including test methods, etc.
- Centralised (i.e. one central body).
- Preferably, contracted directly to the Scheme Administrator rather than to ACPs. ACPs could however pay fees to the Scheme Administrator as part of a cost-recovery model.

In order to investigate such an approach, a pilot project could be considered – this would aid in identifying the scope, boundaries and costs, as well as ironing out the practical and technical issues.

Advantages

- Significantly reduce workload for IPART.
- The organisation engaged would have significant expertise in lighting design, lighting products and their critical assessment.

Disadvantages

- Ensuring that the organisation engaged retains ongoing competency.
- Cost – estimated in the order of several hundred dollars per product (for product approval).

Recommendation

- **Consider outsourcing of design approval and product approval**.

[30] See http://www.energystar.gov/index.cfm?c=third_party_certification.tpc_index

4.12. Solution Element - Prove Emerging Technology Performance Post-Installation

An alternative method for relieving resource constraints is to remove the requirement for emerging technologies to prove their performance in advance. Proof of model performance could occur post-installation, requiring approval or scrutiny by a third party such as IPART, an auditor or other independent body.

Advantages

- Significantly reduce workload for IPART.

Disadvantages

- Rectification of installations post-installation, if equipment is found to fail in proving its performance.

Recommendation

- This is not highly recommended, and should only be considered if a strong contractual obligation can be put in place, to rectify any installations fitted with non-complying products.

4.13. Summary of Recommendations from this Chapter

All recommendations from this chapter are brought together in Table 11. The strength of each primary recommendation is identified using a series of tick marks, along with an alternate recommendation if the primary recommendation is not taken up.

Table 11 – analysis of recommendations

Primary Recommendation	Strength of Recommendation	Discussion / Notes	Alternate Recommendation (Strongly recommended if Primary Recommendation is not taken up)
Remove VRUs	✔✔✔		
All upgrades must be permanent (would disallow or limit the use of T5 adaptors and LED linear replacement lamps)	✔✔		Non-permanent upgrades allowed only for small projects (energy saving limit of X hours – see section 4.5)
Technology specs for downlights	✔✔		Laboratory testing to prove performance
Technology specs for LED linear replacement lamps	✔✔		Laboratory testing to prove performance
Technology specs for LED linear panel troffers	✔		Laboratory testing to prove performance
Technology specs for LED highbay luminaires	✔		Laboratory testing to prove performance
T5 adaptors to prove performance – light output, LCP and lamp life (if retained in the ESS)	✔✔✔	If all upgrades required to be permanent, T5 adaptors will be less prevalent. Note that some further development of test methods is required.	
Induction lamps to prove performance: light output, LCP, lamp life, colour temperature, CRI and harmonics	✔✔✔		
VRUs to prove performance	Remove from CLF – see above		
All projects to prove a minimum lamp/fixture lifetime of X hours (see section 4.7.1)	✔✔	Consider allowing in-house manufacturer laboratories (who may already have conducted tests)	
Require Energy Star or NATA-recognised lab testing	✔✔✔		
Undertake check testing	✔✔✔		
Leverage from existing certification schemes	✔✔✔		
Proof of MEPS registration	✔✔		
Equipment certified as compatible with incumbent dimmers, etc.	✔✔		
Minimum warrantee for equipment	✔✔		
Approval per model	✔✔✔		
Outsource project and product approval	✔✔		

Once the final recommendations have been settled on, details of each can be finalised for inclusion in a public document. **As this point it is recommended that a further iteration of these details be undertaken**, particularly as details may be influenced by other recommendations.

Chapter 5. Safety and EMC Requirements

5.1. Introduction

This chapter covers electrical safety and EMC issues. The objectives of this chapter are to investigate:

- The incorporation of safety requirements into CLF requirements.
- How technologies fit within current and emerging regulatory requirements.

This report is not a complete review of all possible safety issues. It seeks however to highlight safety issues as they arise and intersect with the objectives of this report. It is possible that further specialised work may be required, for example by an OH&S / risk specialist or electrocution expert, in order to fully canvass all safety aspects of ESS commercial lighting projects.

Currently, IPART require that the following items are supplied as part of the application for each emerging technology model:

- Electrical safety: (required for connection to mains power) evidence to demonstrate that equipment meets the electrical safety requirements of the NSW Electrical (Consumer Safety) Act 2004, either:
  - an Australian Certificate of Approval[31] (if it is a Declared Article[32]) or
  - a Certificate of Suitability issued by NSW Fair Trading (if it is a Non-Declared Article[33]) or
  - Documentation showing the Regulatory Compliance Mark (RCM[34]).
- Electromagnetic Compatibility (EMC): evidence to demonstrate that equipment meets the EMC requirements of the Radio Communications Act 1992 (administered by ACMA). Information accepted as evidence of compliance with electrical safety and EMC regulatory arrangements includes: Evidence of the RCM and verifiable regulatory approval number, or supplier code issued by ACMA and ACMA declaration of conformity.

5.2. Background Information

5.2.1. NSW - Electrical Safety Legislation - Appliances and Equipment

In New South Wales, NSW Fair Trading administers the Electricity (Consumer Safety) Act 2004 and the Electricity (Consumer Safety) Regulation 2006. These cover the sale of mains supplied electrical appliances and equipment. Certain appliances and equipment (known as declared articles) must be approved by the Commissioner for Fair Trading or by an approved equivalent.

All approved declared articles must carry the appropriate approval mark and comply with the relevant safety standard to enable the product to be sold. The remaining appliances and equipment (known as non-declared articles) must comply with minimum safety requirements contained in Australian Standard AS/NZS 3820:2009 (as amended).

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[31] An Australian Certificate of Approval may be issued by NSW Fair Trading, or an equivalent body in another state, or by an independent certifier.

[32] Declared Articles include T5 adaptor kits and power supplies.

[33] Non-Declared Articles include voltage reduction units, LED tubes, and induction lamps.

[34] An RCM covers both electrical safety and EMC requirements.

Reciprocal agreements are in place between the State regulators to allow a declared article approved initially by the approval authority in one jurisdiction to be sold in all other jurisdictions without any further formality. NSW Fair Trading has also given authority to a number of Recognised External Approval Schemes (REAS) to certify electrical appliances and equipment. The REAS that have been given authority are: SAI Global Certification Services, TUV Rheinland Australia, SGS Systems and Services Certification, the Australian Gas Association, SAA Approvals and UL International NZ.

The Electricity (Consumer Safety) Act 2004 provides for the prohibition of any article that is, or is likely to become, unsafe and may compel such remedial action (including recall) necessary for public safety. It is an offence to sell a declared article if:

- Not approved by NSW Fair Trading or the relevant Authority or REAS.
- Not marked with the approval mark allocated by the approval or certification agency or the Regulatory Compliance Mark (if appropriate).
- It does not comply with the relevant class and, if applicable, model specifications or other prescribed requirements for that article.

Approval must be sought for declared articles. Declared articles (relevant to lighting) are as follows:

- Bayonet and Edison screw lamp holder / adaptor.
- Decorative lighting outfit:
  - For decorative, display or illumination purposes.
  - Portable.
  - Consists of:
    - Lamps including LED or lamp holders interconnected by flexible cord of less than 2.5mm^2 cross-sectional area.
    - Lamps including LED within a flexible enclosure.
  - May be integral with a frame or similar support and includes any integral power supply or control device.
- Fluorescent lamp ballast:
  - For controlling current flowing through fluorescent lamp.
  - Independent or built-in type intended for use with luminaires (portable or fixed).
  - Integral type, rated at 60 watts or less, such that it forms a non-replaceable part of a fluorescent lamp/ballast combination.
  - Adaptor type such that it allows the insertion of a fluorescent lamp into the ballast.
- Fluorescent lamp starter.
- Inspection handlamp:
  - For inspection purposes using illumination.
  - Holds incandescent or discharge lamp
  - Hand held.

  - Not including handlamp with magnification facility.
- Luminaire – portable type:
  - Household type.
  - Provides illumination or for decorative purposes.
  - Fitted with flexible cord, appliance inlet socket or a power supply with integral pins for insertion into a socket outlet.
  - For standing on a table or floor or is fitted with a clamp or similar for attachment to vertical or horizontal surfaces.
  - For use with tungsten filament, tubular fluorescent or other discharge lamps.
  - Constructed to represent a model, person or animal and by its design and materials is likely to be treated by a child as a toy.
  - Has metal parts which are required to be earthed or double insulated from live parts (excluding live parts of an all insulated lampholder).
- Power supply or charger:
  - Output not exceeding 50 volts a.c. or 120 volts ripple free d.c.
  - Provide supply to separate luminaires.
  - For charging batteries or to supply equipment.
  - Includes LED and other lighting power supplies.

Non-declared articles can voluntarily seek approval, which may be granted where it is shown that the article complies with the relevant Australian Standard as determined by NSW Fair Trading.

The majority of the Australian Standards applied to electrical articles are based on IEC and European (EN) Standards. Test reports to these standards may be accepted provided any deviations included in the applicable Australian Standard are suitably addressed. Fair Trading will generally accept test reports from laboratories accredited by (but not limited to):

- NATA.
- The Certifying Body (CB) scheme.
- Organisations with a reciprocal arrangement with NATA.
- Recognised or certified within their own country by an appropriate national body or internationally by similar bodies and which can establish that they meet standards not inferior to those above.

5.2.2. Victoria - Electrical Safety Legislation - Appliances and Equipment

In Victoria, Energy Safe Victoria (ESV) administers the Electricity Safety Act 1998 and the Electricity (Equipment) Regulations 2009. These cover the sale of legally "prescribed" electrical appliances and equipment, and the list of appliance types is harmonised with NSW – see section 5.2.1 for lighting appliances. ESV approves prescribed electrical equipment by way of a "certificate of approval" which remains in force for up to 5 years. Similar to NSW, non-prescribed appliances in Victoria can voluntarily apply for a "certificate of compliance".

Test reports, from approved laboratories, must accompany approvals and these can use IEC standards where appropriate (addressing any Australian national variations in an addendum report). Approved laboratories must be recognised by NATA or IANZ (New Zealand).

5.2.3. NSW - Electrical Safety of Installation

The NSW Electrical (Consumer Safety) Act 2004 and the Electrical (Consumer Safety) Regulation 2006 include requirements for notification of electrical work to electricity network providers and to NSW Fair Trading. A Certificate of Compliance Electrical Work (Compliance Certificate) is a uniquely numbered form which is required to be completed by an electrical contractor every time the contractor adds, alters, disconnects, reconnects or replaces an electrical installation.

Consumers should be given a copy of the Compliance Certificate at the completion of the job and advised to retain it. The Compliance Certificate is the consumer's assurance that a licensed contractor has completed and tested the work to ensure it is effective and compliant with the Australia/New Zealand wiring rules for electrical installation work.

Electrical contractors must submit a copy of the Compliance Certificate to the electrical network provider if the work involves: a new installation, work which require the network provider to do extra work for the network connection or for metering arrangements, work on electrical switchboards or associated equipment that effects the electrical loading, method of electrical protection, system of earthing or the physical location of the switchboard.

For the ESS, **it is recommended that, where a Compliance Certificate is required to be generated, that a photocopy of the Compliance Certificate be held by the ACP as part of the records for each project**.

Currently, the ESS Rule requires that Default Abatement Activities be performed by an electrician, if the activity involves the modification or replacement of electrical wiring. **It is recommended that IPART consider extending a licensed electrician to all ESS activities involving electrical wiring**, subject to a thorough assessment of the legal and safety aspects of ESS activities.

5.2.4. Victoria - Electrical Safety of Installation

Similar to NSW, the Victorian Electricity Safety Act 1998 and Electricity Safety (Installations) Regulations 2009 require a certificate of electrical safety (COES) to be issued for all electrical installation work. Failure to comply with these requirements is a criminal offence and licensed workers who do so may be subject to disciplinary action. ESV has introduced an online system enabling electricity professionals to purchase and lodge COES electronically.

5.2.5. ERAC

The Electrical Regulatory Authorities Council (ERAC) is the peak body of electrical safety regulators in Australia and New Zealand. ERAC acts to ensure electrical safety regulatory systems are contemporary and harmonised wherever possible. The mission of ERAC is to provide benefits to Australian and New Zealand Governments, industry and the public by striving for a uniform regulatory environment for electrical activities, for the purpose of achieving acceptable levels of electrical safety, supply quality and energy use efficiency. Its principal objectives are as follows:

- Development of a policy framework that encourages and provides for coordinated regulatory development in each jurisdiction.
- Coordination of individual State/Territory/NZ program objectives and activities, to ensure uniformity wherever possible.
- Representation of ERAC's agreed policies at the national level for the purpose of securing support from Governments, industry and the public.
- Active participation in policy and technical committees of organisations such as Standards Australia and Standards New Zealand to ensure that the content of national technical standards is consistent with regulatory directions and requirements.

In November 2011 ERAC released an information bulletin in relation to T5 adaptors and LED linear replacement lamps[35]. This bulletin is summarised as follows:

- ERAC has serious concerns with electrical safety issues of both the LED linear replacement lamps and T5 adaptors, including with the products themselves and with the modifications to existing luminaires.
- Recent enforcement actions for these products by Safety Regulators in Australia, New Zealand, and Europe have shown instances where these products do not comply with essential safety requirements, such as protection against electric shock. In Australia and New Zealand these safety principles are specified in AS/NZS 3820 Essential Safety Requirements for Low Voltage Electrical Equipment.
- The following reports of failures have been made:
    - Failure of insulation causing the metal enclosure body of such devices to become live and present an electric shock risk.
    - Access to live parts.
    - While being installed, with one end of the tube inserted in the luminaire, the other end may become live and presents a possible accessible electric shock hazard.
- Currently there is no specific electrical safety standard for these products that could be used to cover all electrical risks. Therefore designers, manufactures, importers and suppliers would need to apply requirements from several electrical safety standards and engage in good engineering design principles to ensure the products are made in a manner that is electrically safe.
- These issues, and development of standards, are under discussion by ERAC and the Australian and New Zealand electrical safety standards committee for lighting products (EL-041). During these discussions concern has been raised that some manufacturers,

[35] Available from http://erac.gov.au/images/Downloads/0001%20-%20T8-T5%20flourescent%20lamp%20adaptor%20retrofits.pdf

importers, distributors, installers and retailers may not be fully aware of the potential safety risks relevant to the replacement tubes they supply.

In the bulletin, the following recommendations were suggested by ERAC as general guidance information:

- LED linear replacement lamps and T5 adaptors: Suppliers are responsible for ensuring that these products are safe and comply with electrical safety requirements.
- Modified luminaires: For a modified luminaire, the manufacturer of the original luminaire will no longer be responsible for compliance of the modified product. Any modifications made to the original luminaire may alter the characteristics of the original product, for example the safety aspects of the original luminaire, hence compliance assessments of the original luminaire may no longer be applicable to the modified luminaire. In this case, the modified luminaire will be considered to be a new luminaire. Persons placing on the market modification kits for incorporation into an existing luminaire must ensure that the modified luminaire is safe when the kit is installed in accordance with their supplied instructions. When placing a modified luminaire on the market or modifying a luminaire on site, the modified product should comply with the requirements outlined below for new luminaires. Those responsible for placing such product on the market have the full responsibility for ensuring its safety and compliance with all applicable electrical product safety standards.
- New luminaires (including modified luminaires):
    - Must be safe and comply with AS/NZS 60598.1 and any applicable part 2 of that series of safety standards.
    - Should be marked with a warning label that is visible whilst replacing lamps. This warning label should be legible and indelible and show the intent of: 'Warning - not for use with any fluorescent lamps, use only <Brand> <Model Number> <Type> Lamp'.
    - Should have a fuse to protect against short circuits.
    - The luminaire must continue to be safe if a fluorescent lamp is re-installed, although it does not have to function.
- Retrofit luminaires:
    - No modification of the original luminaire is allowed. It is assumed that the original luminaire will have been fully compliant with safety standard AS/NZS 60598.1 and any applicable part 2 of that series of safety standards.
    - The replacement of a glow starter with other devices does not constitute a modification of the luminaire itself. However the use of such devices should not compromise safety when used in luminaires.
- LED linear replacement lamps:
    - LED linear replacement lamp shall comply with the requirements of safety standards AS/NZS 61347.1, IEC 61347.2.13 and relevant requirements of AS/NZS 60598.1. Note that IEC 62031 may be used in lieu of IEC 61347.2.13.
    - Irrespective of the standards mentioned above, where the product has unique characteristics, assessments of safety must have adequately covered all risks of the product. This may involve the use of several other Australia and New Zealand

standards and/or international standards and other assessments to ensure the product is electrically safe.

  - The LED linear replacement lamp should be assessed to ensure no access to live parts can be achieved during installation.
  - Full installation instructions and diagrams shall be provided.
  - LED linear replacement lamp shall be capable of being fitted into an un-modified luminaires without causing a safety hazard, although it does not have to function.

- T5 adaptors:
  - Adaptor is a prescribed/declared article and shall have an Australian or New Zealand Certificate of Approval as a 'Fluorescent lamp ballast'.
  - Adaptor assembly shall comply with safety standards AS/NZS 61347.1, AS/NZS 61347.2.3 and the relevant requirements of AS/NZS 60598.1.
  - Irrespective of the standards mentioned above, where the product has unique characteristics, assessments of safety must have adequately covered all risks of the product. This may involve the use of several other Australia and New Zealand standards and/or international standards and other assessments to ensure the product is electrically safe.
  - The adaptor should be assessed to ensure no access to live parts can be achieved during installation.
  - Full installation instructions and diagrams shall be provided.
  - T8/T5 fluorescent lamp adaptor assemblies shall be capable of being fitted into an un-modified luminaires without causing a safety hazard, although it does not have to function.

5.2.6. Report - Review of Electrical Safety Issues for Lighting Technologies

IPART recently commissioned a report *Review of Electrical Safety Issues for Lighting Technologies under the NSW Energy Savings Scheme*. The key conclusions and recommendations of this report are summarised as follows:

- Seek a legal opinion about IPART's legal responsibility for safety.
- Commission a safety review of the ESS to be undertaken by a specialist risk consultant.
- Impose an additional condition of accreditation that requires ACPs to maintain public liability insurance and insurance cover for product replacement and rectification of works.
- Consider amending the ESS Rule to specifically include electrical safety requirements.
- Include in the ACP audit scope: the activities of ACPs comply with safety requirements, records are available to demonstrate products meet relevant safety standards, and records are available to demonstrate that rewiring was undertaken by a licensed electrician.
- Include in the ACP annual report: report on how they are meeting the revised Conditions of Accreditation regarding safety, what safety training has been undertaken, that any electrical wiring was undertaken by a licensed electrician.
- Update Fact Sheet 3 "Minimum Requirements for Installer Conduct" to include addressing safety of installation and products.

- Maintain and strengthen the relationship with NSW Fair Trading, including process to follow if electrical safety issues arise.

It is recommended that these recommendations be taken up by IPART.

5.2.7. EMC

ACMA enforces EMC regulatory arrangements under the Radiocommunications Act 1992. All products that fall within the scope of the regulation are subject to compliance with the arrangements and must be appropriately labeled with the compliance mark (C-tick).

The purpose of the regulation is to minimise electromagnetic interference between electronic products which may diminish the performance of electrical products or disrupt essential communications. The EMC regulatory arrangements introduce technical limits for emissions from electrical/electronic products and communications services. To establish compliance with the regulatory arrangements, suppliers must demonstrate that products meet relevant standards before such products are supplied into Australia.

ACMA recognises a number of European and international EMC standards. Also under the Trans-Tasman Mutual Recognition Arrangement (TTMRA), the ACMA has harmonised the EMC regulatory arrangements with New Zealand.

Electric lighting products, such as incandescent lamps, luminaires, magnetic and electronic ballasts fall within the scope of CISPR 15. ACMA has limited the level of radiofrequency emissions (radiated and conducted) from all lighting equipment with a primary function of generating or distributing light intended for illumination purposes.

Depending on the risk of interference from the product, compliance level 1 or 2 will apply. Most electrical and electronic products are covered by the EMC regulatory arrangements. Most lighting equipment will be under medium risk (compliance level 2) with the exception of incandescent lights and battery powered lighting which are low risk (compliance level 1).

While compliance with the applicable standard is mandatory, there are no requirements to hold a test report, label or maintain a Supplier's declaration of conformity (DoC) for low risk (compliance level 1) devices such as incandescent lamps.

ACMA states that some changes made to an existing luminaire will affect the radiofrequency signature of the original device and will result in what is effectively a new product. The most critical of these changes include:

- Removal of power factor correction capacitor.
- Inclusion of a blocking inductor into the luminaire circuit.
- Introduction of an electronic ballast.
- Re-configuration of the luminaire wiring layout.
- Introduction of an emergency conversion pack.

Note that CISPR 15 was recently updated such that testing above 30 MHz will be mandatory[36] from 9 Feb 2013. Note also that ACMA may allow some grandfathering of product approvals.

[36] See http://www.acma.gov.au/WEB/STANDARD/pc=PC_310707

5.3. Discussion

Given the issues outlined in the previous sections, the current requirements imposed by IPART for safety and EMC compliance of emerging technologies (i.e. proof of regulatory compliance or voluntary safety compliance if product is not regulated) are considered appropriate.

However, the effect of T5 adaptors and LED linear replacement lamps when fitted to existing luminaires raises further issues for both safety and EMC. These products can create electrical safety and EMC compliance issues, when installed into existing luminaires with control gear, that may not be apparent to the product suppliers or installers.

There are three potential responses to these issues:

- Eliminate T5 adaptors and LED linear replacement lamps from the CLF. This is aligned with other benefits, such as installation permanence, that have been raised elsewhere in this report.
- Implement procedures to ensure that any as-modified/retrofitted luminaires are safe and EMC compliant. Currently, IPART have informed ACPs that they are responsible for the as-modified/retrofitted luminaire. However, it may be necessary to implement procedures to ensure that ACPs are checking and ensuring compliance of installed products in existing luminaires. This raises difficulties as these products are likely to be installed into many different types of luminaires, and checking of safety and EMC compliance for each luminaire / control gear type is likely to be expensive and complex. It would require a safety and EMC test (to relevant safety and CISPR standards) to be performed for each permutation of T5 adaptor / LED lamp when combined with each model of luminaire. This is likely to be impractical and prohibitively expensive.
- Similar to the current practice of IPART and ERAC, provide information to ACPs, informing them of their responsibilities with regard to safety and EMC. However the efficacy of this approach is unclear (i.e. ACPs may simply choose to ignore this advice and implement unsafe practices).

The safest approach would be to eliminate T5 adaptors and LED linear replacement lamps from the CLF (including modified and retrofit luminaires[37]). If this is not considered feasible, it is recommended that a detailed safety investigation of these devices be undertaken.

5.4. Summary of Recommendations from this Chapter

The recommendations form this chapter can be summarised as follows:

- Where an electrical wiring Compliance Certificate is required to be generated for an installation, a photocopy of the Compliance Certificate should be held by the ACP as part of the records for each project.
- Consider extending a licensed electrician requirement to all ESS CLF activities involving wiring, subject to a thorough assessment of the legal and safety aspects of ESS activities.
- Take up the safety recommendations from the report *Review of Electrical Safety Issues for Lighting Technologies under the NSW Energy Savings Scheme*.
- Consider eliminating T5 adaptors and LED linear tubes and from the Rule. If this is not feasible, undertake a detailed safety investigation of these devices.

[37] Modified and retrofit luminaires can be considered luminaires which have had their light source technology altered (e.g. from T8 to LED or T5).

Chapter 6. OTHER ISSUES

A number of issues have also been raised by IPART. These are discussed in this chapter.

6.1. Extended Operating Hours

Currently, IPART are experiencing large quantities of applications (required in advance) for extended operating hours (EOH). IPART have recently proposed the following for approval of extended operating hours:

- ACPs must develop a procedure for managing EOH, including identification and collation of supporting documentation and calculation of the hours to be claimed.
- ACPs shall submit their EOH procedure for approval by the Scheme Administrator.
- Once the EOH procedure is accepted, ACPs would then be able to claim EOH at relevant sites and be able to input those hours into a generic Commercial Lighting Tool.
- Note that, to meet the requirements of the ESS Rule, the EOH procedure developed by the ACP must include a step seeking Scheme Administrator approval to claim EOH. IPART envisages that this step would involve an email advising IPART of the proposed EOH and a declaration that the approved EOH procedure has been implemented and appropriate records obtained. The Scheme Administrator would respond approving the EOH, with the proviso that this will be subject to audit.

The interpretation of the above is that approval-after-the-fact will be allowed for EOH each site, once a pre-approved process has been put in place by the ACP. This solution appears appropriate, provided that appropriate audit procedures are in place. **Other potential solutions include**:

- **Require time-of-use metering data, where such meters are installed.**
- **Outsource approval of EOH applications, as discussed in section 4.11.**
- **Require approval-in-advance for EOH projects above a certain ESC quantity threshold** (e.g. large projects as defined in section 2.4.1)**.**

These solutions can be considered alongside the current IPART treatment of EOH.

6.2. Application of the BCA in NSW

The CLF includes a calculation for lighting projects where the upgrade is subject to Section J of the Building Code. Regulation 94 of the NSW Environmental Planning and Assessment Regulation 2000 states the following:

> *Consent authority [e.g. Council] may require buildings to be upgraded*
>
> *(cf clause 66B of EP&A Regulation 1994)*
>
> *(1) This clause applies to a development application for development involving the rebuilding, alteration, enlargement or extension of an existing building where:*
>
> > *(a) the proposed building work, together with any other building work completed or authorised within the previous 3 years, represents more than half the total volume of the building, as it was before any such work was commenced, measured over its roof and external walls, or*
> >
> > *(b) the measures contained in the building are inadequate:*

(i) to protect persons using the building, and to facilitate their egress from the building, in the event of fire, or

(ii) to restrict the spread of fire from the building to other buildings nearby.

(2) In determining a development application to which this clause applies, a consent authority is to take into consideration whether it would be appropriate to require the existing building to be brought into total or partial conformity with the Building Code of Australia.

(3) The matters prescribed by this clause are prescribed for the purposes of section 79C (1) (a) (iv) of the Act.

This effectively means that the Council has discretion to require the building to comply with the Building Code. Presumably, this also means that the Councils have discretion over which sections of the Building Code shall be complied with. Energy efficiency may however represent a low priority for some councils in this context, i.e. relative to the safety aspects mentioned in section 94 of the Regulation. The implication of this is that Councils may infrequently require commercial building renovations to comply with Section J. This conclusion may need to be tested with a selection of Councils.

6.3. Calculation of Energy Savings

Currently the business-as-usual (BaU) baseline for commercial lighting upgrades does not take into account any future improvement in BaU lighting efficiency. Regulatory schemes which might affect baseline assumptions for the activities are effectively the Building Code and product MEPS. As discussed in the previous section, building codes are not likely to have a significant impact on the energy efficiency of the existing building stock. MEPS is likely to significantly effect only the ELV halogen activities, which involves the phase-out of 50W ELV reflector lamps in favour of 35W. **The effect of lamp MEPS can be modeled if required –** for example modeling of a 2 year sunset period for 50W lamps, followed by 8 years of 35W lamps (over a total 10 year time horizon).

6.4. Summary of Recommendations from this Chapter

The recommendations from this chapter are as follows:

- Extended operating hours (for consideration):
    - Require time-of-use metering data, where such meters are installed.
    - Outsource approval of EOH applications.
    - Require approval-in-advance for EOH projects above a certain ESC quantity threshold (e.g. large projects as defined in section 2.4.1).
- Model the effect of ELV lamp MEPS if required.

Appendix A - Introduction to Lighting Design Software

A.1. Introduction

Lighting design and analysis software can calculate lighting levels and other parameters for interior and exterior environments, taking into account:

- Electric lighting from lamp/luminaire data files.
- Dimensions and surface properties (such as reflectance) of the architectural environment as specified by building plans.
- Light contributions from daylight (some software packages).

For electric lighting, data for the luminaire is provided in the form of measured luminous intensity distributions ("photometric data" in an ASCII delimited text file). This information is typically provided by the lamp/luminaire manufacturer and can either be integrated into the software package via linked or add-on catalogues or by importing individual lamp files. Importable lamp data file formats include:

- IES – a standard file format created by the Illuminating Engineering Society (IES) for the electronic transfer of photometric data quantities of luminous flux and luminous intensity distribution at any designated angle as tested using a gonio-photometer.
- CIE – similar to IES format, this data file was developed by the International Commission on Illumination (CIE); luminous intensity distribution is provided for over a specific range of angles.
- LDT – Eulumdat, an industry standard photometric data file commonly used in Europe, which additionally contains lines specifying correlated colour temperature (CCT) and colour rendering index (CRI)

For natural daylight, there are several "sky models" that accurately predict the distribution and intensity of direct sunlight and diffuse daylight, based on time and date, geographic location, and weather conditions. Historical weather data at most locations can also be integrated for prediction of annual, daily and hourly conditions. The software package will generally contain an integrated sky model and will offer input options to choose between these parameters as required.

To create the model of the architectural environment, there is the option to manually create the rooms using the software editor or simply import two- or three-dimensional computer-aided design (2D/3D CAD) drawings. CAD file formats include:

- DWG – Drawing file, a binary file format for storing 2D and 3D design data and metadata and is the native format for CAD packages such as AutoCAD
- DXF – Drawing Interchange Format, developed by Autodesk for enabling data interoperability between AutoCAD and other programs
- 3DS – a 3D vector file in binary format, originally the native format for the old Autodesk 3D Studio DOS
- STF – Setup Information File, similar to DWG which exports room geometry, room designations, window and door positions, reflectance and also lamp positions
- WRL – a file extension for a Virtual Reality Modeling Language (VRML) file format, often used by browser plug-ins to display virtual reality environments. VRML files are known as "worlds", this is what WRL stands for.

- JPG, PNG, BMP, HDR, WMF – image files composed of digital data, these have varying degrees of compression (fidelity loss)
- XLS – Excel spreadsheet format which holds data in worksheets, charts and macros

Outputs provided by lighting design packages include:

- Illuminance, E (lux) – as point calculations, isolux contour lines and pseudo colours
- Luminance, L (cd/m^2) – in rendered pseudo colour
- UGR – Unified Glare Rating, an international index presented by CIE publication 117 which is used to evaluate and limit the psychological direct glare (known as discomfort glare) from luminaires
- STV – Small Target Visibility, usually used in street lighting – is a weighted average of the visibility level of an array of targets on a roadway considering (a) luminance of the targets, (b) luminance of the immediate background, (c) adaptation level of the adjacent surroundings, (d) disability glare.
- DF – Daylight Factor, the ratio of internal light level to external light level used to indicate whether artificial lighting is required in the space.
- U_0 – Overall Luminance Uniformity, L_{min}/L_{avg}
- UG – Uniformity Gradient, the highest rate of change of values between adjacent measuring points, E_{max}/E_{min}

A summary of popular software packages is provided in Table 12.

Table 12 – Summary of software packages

Software	Minimum release date and version	Developed by	Mainly Used For	Cost	Links	Inputs	Outputs	Level of Complexity
DIALux	6 July 2012, V 4.10	DIAL GmbH	Indoor & outdoor lighting, road lighting, sports complex lighting, emergency lighting	Free	www.dial.com	DXF, DWG, 3DS, STF, WRL, manufacturer lamp data	Complete project reports, Luminance diagrams, tabulated photometric data (intensity), PDF, WMF images, DWG, DXF, STF for architectural elements, UGR for observers, Energy evaluation report,	Simple
Relux	Feb 2012, V 2012.2	Relux Informatik AG	Light simulation in 2D/3D; generation of isolines, pseudo colours and 3D light distributions (lux). Includes cost-efficiency analysis of luminaires, analysis of daylight influence on iso-lux diagrams, quotation module.	Free	www.relux.com	DXF, DWG, 3DS, WRL, JPG, PNG, manufacturer lamp data	Lux isolines, pseudo colours, 3D light distribution diagrams, Lux uniformity; DXF, DWG for scenes; HDR for simulations; XLS for lists; UGR for several observers; Luminance	Simple
AGi32	24 Jan 2012, V2.3	Lighting Analysts	Popular architectural lighting analysis tool which provides comprehensive lighting calculations; high-quality rendering for interior and exterior environments, including daylighting. Computes illuminance in any situation; assists in luminaire placement and aiming, validates adherence to various lighting criterion. Point-by-point lighting, photometrically correct colour-rendered visualisations. Uses radiosity simulation engine.	USD 895	www.agi32.com		E (lux) - horizontal, vertical, variable meter aiming, lighting power density (W/m²) UGR, L (cd/m²) in rendered pseudo colour, pavement L, veiling L UG, aiming diagrams STV, DF	Advanced

Software	Minimum release date and version	Developed by	Mainly Used For	Cost	Links	Inputs	Outputs	Level of Complexity
Elum Tools	9 July 2012, V 2013 R1	Lighting Analysts	Fully integrated add-in for Autodesk Revit, designed to calculate point by point illuminance on any work plane or surface utilising lighting fixture families and surface geometry already present in the Revit model. Radiosity based.	USD 549	www.elumtools.com	IES photometric files	Luminance point by point, Lux point by point and pseudo colour, mesh overlay of radiosity	Advanced
Optis	N/A	Optis	Analysis and prediction of stray light, hot spots, uniformity, intensity, irradiance and illuminance. Simulation of ambient lighting conditions including daylighting. Efficiency analysis with active 3D ray tracing. Compliance checks with legislation and standards	EUR 30,000	www.optis-world.com	LDT/IES photometric files, manufacturer plugin data, CAD files	Lux, Luminance, Intensity calculations. Photometry maps, cross-sections, point measurements, colourimetry,	Intermediate
OptiWin	29 Sept 2009, V 2008.3	Glamox International	Light calculation of complete projects	Free	www.glamox-international.com	DXF, DWG 2D files DXF, 3DS, for 3D Manufacturer photometric files	glare calculations UGR, lighting power density (W/m²) point illuminance calculations (lux) isolux curves economic calculations	Simple
Radiance	1 Nov 2011, V 4.1	Lawrence Berkeley Laboratory	Predicts illumination, visual quality and appearance of lighting and daylighting design using ray tracing techniques. Advantage in that there are no limitation on the geometry or materials that may be simulated.	Free	radsite.lbl.gov	DXF, IES photometric files, material/object/ model libraries available		Advanced

Software	Minimum release date and version	Developed by	Mainly Used For	Cost	Links	Inputs	Outputs	Level of Complexity
Visual 2.6	2 July 2012, V 2.6.0224	Acuity Brands Lighting	3D lighting analysis including Area tool to calculate pole spacing; Floodlight tool to calculate required number of luminaires for given lux criteria; Interior tool determines illuminance achieved by specified lighting power density; Template tool views iso-lux contours and point-by-point lux; Economic tool to compare products, calculate retrofit projects, life cycle analysis, reporting.	USD 100 OR free basic edition	www.acuitybrandslighting.com	DWG/DXF files, IES/CIE/LDT photometric data files	Illuminance point by point, Isolines, filled contour, pseudo colour, and grey scale render, economic reports, U_0, Intensity distributions,	Intermediate

A.2. Example of Software: Relux

This example has been made with the software Relux but it would be approximately the same process with the other software mentioned in the previous section

A.2.1. Room Characteristics

When starting a new project on Relux these parameters can be set:

- room dimensions
- height of the reference plan
- offset to the wall
- Surface reflectance, texture and colour.

An existing plan can also be imported.

Figure 3 – Room characteristics

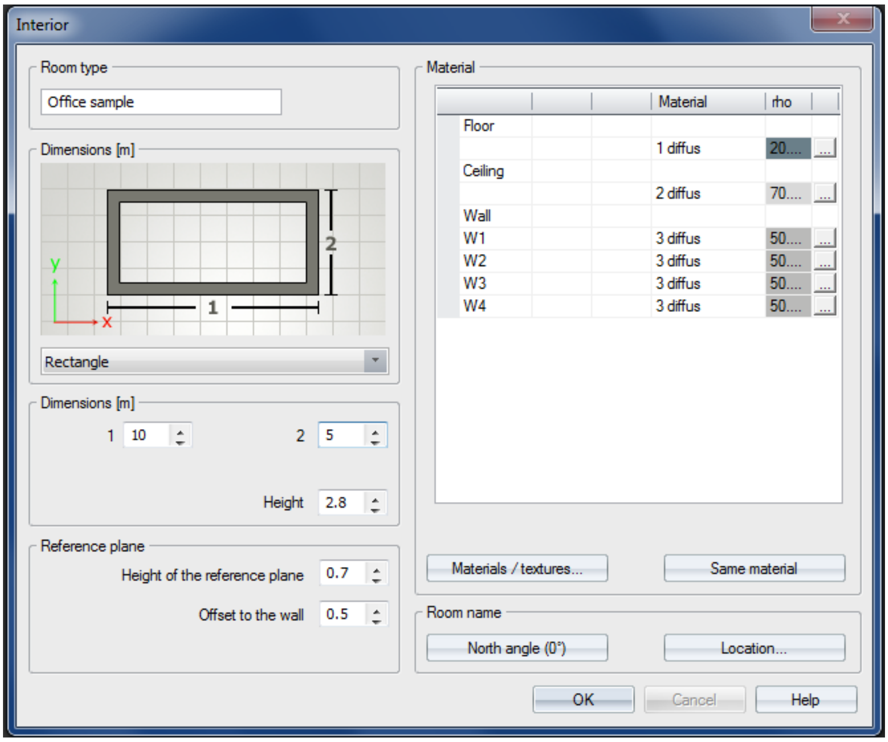
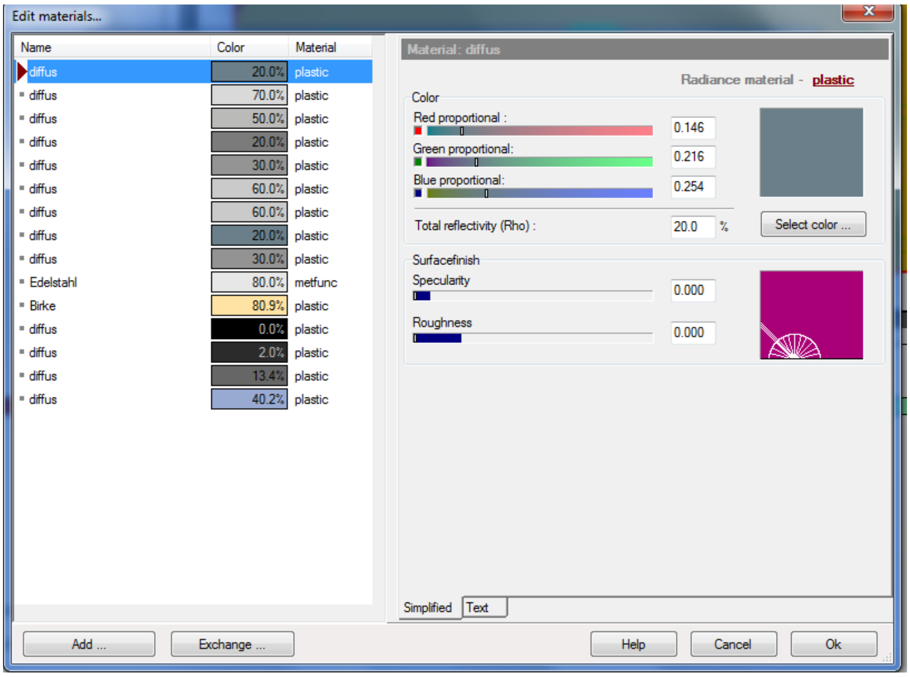


Figure 4 - Surface characteristics



Note: the characteristics used for the purpose of this example are displayed in Figure 3 and Figure 4 and the reflectance and the working plan height chosen are in the range of recommended values in AS/NZS 1680.1.

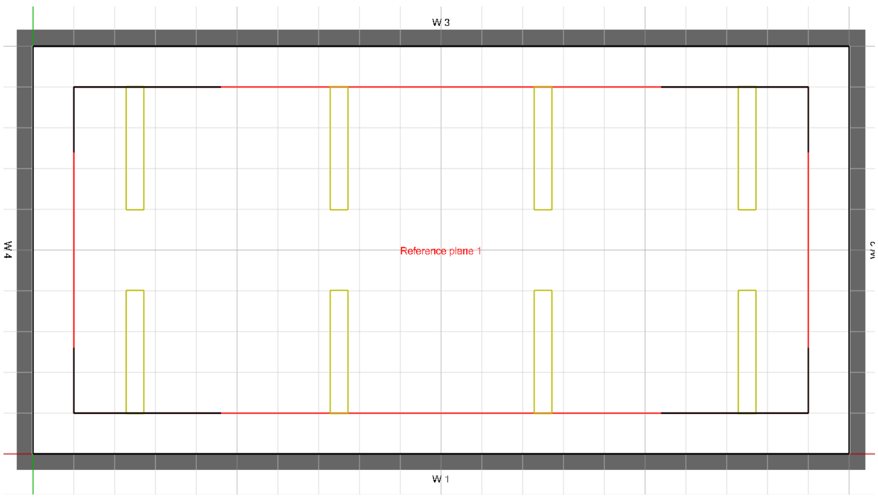
A.2.2. Luminaire Characteristics

To use a specific luminaire in a Relux project, the photometric data can be obtained by uploading the IES file into the software.

In this example, the luminaire used is Thorn DIFFUSALUX II G 1X49W HF PS OP [STD] and the photometric data come from the IES file provided by Thorn.

Once the luminaires data have been uploaded in the software, they can be placed on the plan.

Figure 5 - Thorn luminaires placed on the office plan



A.2.3. Light Calculation

The following parameters can be set:

- Prevailing type of luminaires (direct/indirect).
- Raster spacing.
- Maintenance factor: it is set by defaut at 0.8 for a very clean room, with low yearly usage, according to the standardised data from CIE document *Maintenance of indoor electric lighting systems, 2005*. Nevertheless this value needs to be manually changed depending on the type of room, of luminaires and of lamps (Refer to Figure 7).

Figure 6 - Light calculation settings

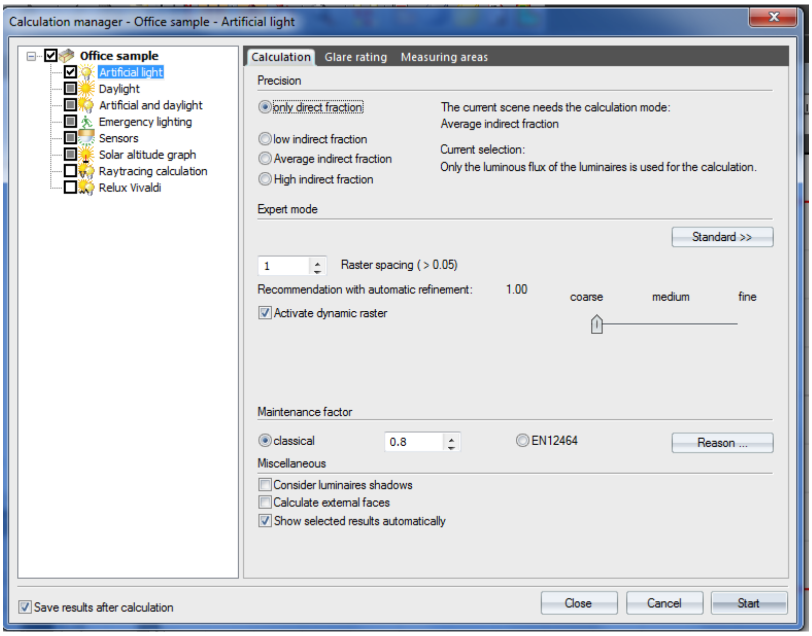
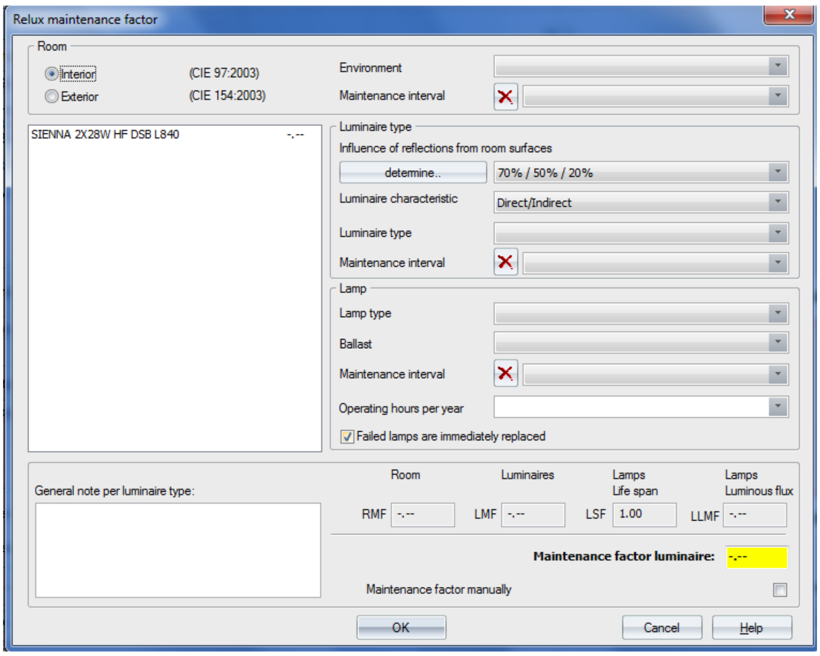


Figure 7 - Manual setting of maintenance factor



A.2.4. Software Output and First Approximation of Compliance

Once the parameters are set, Relux can populate an Iso lux assessment and a technical report, as dispayed on Figure 8 and Figure 9.

This kind of software modelling is a way of obtaining theorical and rough values of average maintained illuminance,uniformity, power density and glare index, in a first approach, and to control the compliance with the current regulations.

Figure 8 - Iso lux assessment

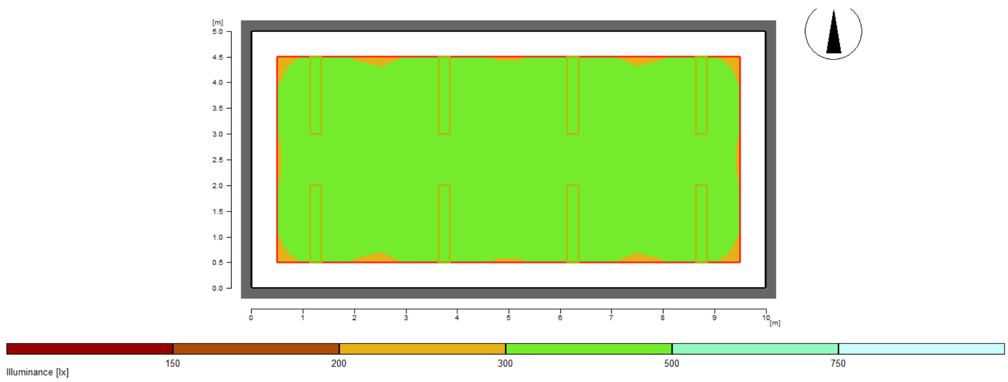


Figure 9 – Technical report

General

Calculation algorithm used		Average indirect fraction
Height of evaluation surface		0.70 m
Height of luminaire plane		2.30 m
Maintenance factor		0.80
Total luminous flux of all lamps		34400 lm
Total power		418.4 W
Total power per area (50.00 m²)		8.37 W/m² (2.27 W/m²/100lx)

Illuminance

Average illuminance	Eav	369 lx
Minimum illuminance	Emin	300 lx
Maximum illuminance	Emax	448 lx
Uniformity g1	Emin/Em	1:1.23 (0.81)
Uniformity g2	Emin/Emax	1:1.49 (0.67)

Type No.\Make

Type	No.	Make	
		Thorn	
1	8	Order No.	: 96 202 394
		Luminaire name	: DIFFUSALUX II G 1X49W HF PS OP [STD]
		Equipment	: 1 x T16 49 W / 4300 lm

In this example, only the general lighting is taken into account. Therefore, this lighting treatment must:

- Reach an average maintained illuminance of 320 lux, the recommanded maintained illuminance value for routine office tasks in AS/NZS 1680.1.
- Reach the threshold of 0.5 for the uniformity of illuminance g1 over the space (Minimum Illuminance to Average illuminance), threshold given in AS/NZS 1680.1.
- Not exceed an illumination power density of 9W/m^2, the maximum illumination power density allowed by the Building Code of Australia 2012 for an office artificially lit to an ambient level of 200 lux or more.

According to the report displayed in Figure 9, this lighting treatment complies with AS/NZS 1680.1 recommendations concerning maintained illuminance and uniformity, with a maintained illuminance of 369 lux, and a uniformity of 0.81 over the space, as well as with the Building Code of Australia, with a power density of 8.37 W/m^2.

With Relux, an approximation of the Unified Glare Rating (UGR) can also be obtained. By setting the position of an observer and the orientation of his view as shown in Figure 10, Relux will populate an evaluation of the UGR in the field of view of this observer (refer to Figure 11).

Figure 10 - Positioning of an observer for UGR control

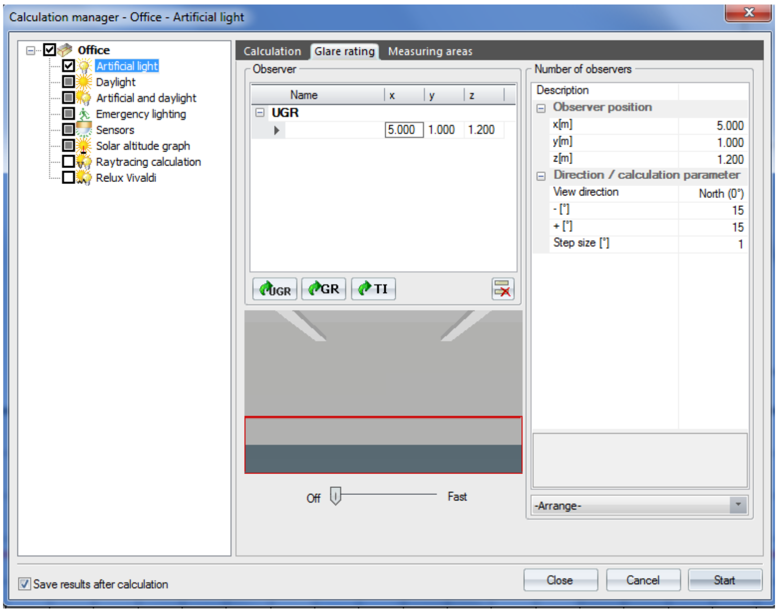
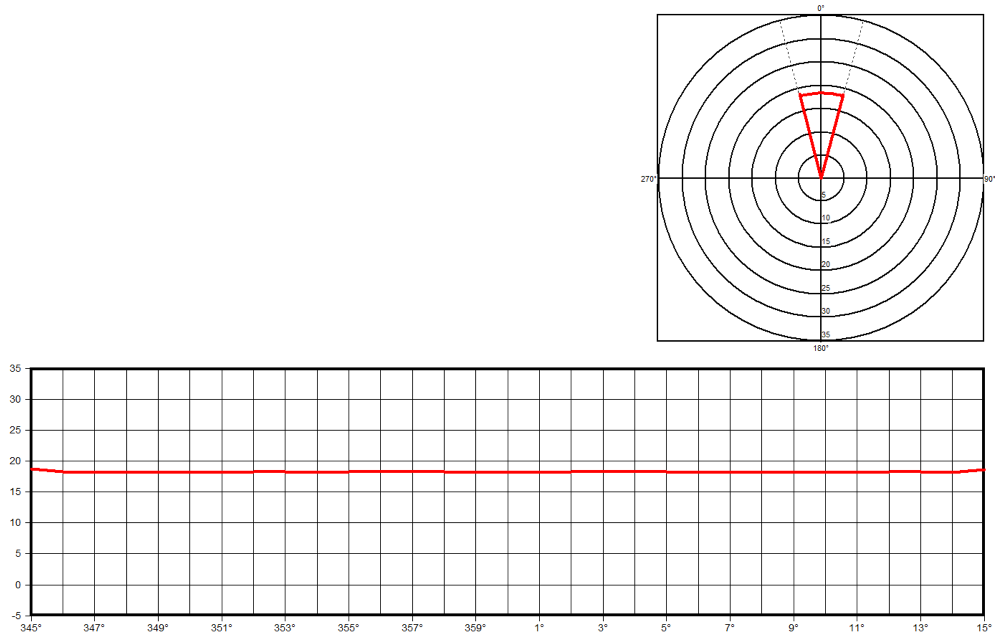


Figure 11 - UGR in the observer's field of view



Typical maximum values of glare index (UGR) are given in AS/NZS 1680. In this example (Normal range of office tasks, only general lighting), the UGR must be inferior to 19 to comply with this standard. With a UGR of around 18, this lighting treatment complies with AS/NZS 1680.1 recommendations in first approximation, and from this work station.